MODELING JUVENILE TRAUMATA AND TAPHONOMY:
PATTERNS AND IMPLICATIONS FOR
THE ENDANGERED CHILD

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by
Jessica L. Hotaling
Spring 2021
MODELING JUVENILE TRAUMATA AND TAPHONOMY:
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ABSTRACT

MODELING JUVENILE TRAUMATA AND TAPHONOMY:
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by
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Master of Arts in Anthropology
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Though global problems of children have recently gained heightened attention, there is a troublesome lack of depth in exploring children on their own terms in the field of biological anthropology. This issue translates directly into the analysis of juvenile remains for signs of trauma and possible child abuse. Misunderstanding skeletal markers imposes numerous challenges onto accurate interpretations of the lived experiences of children, and trauma may be easily confused in cases where remains are damaged postmortem. In a pilot study, this thesis investigated patterns of taphonomic processes and trauma in two juvenile skeletal samples.

It was hypothesized that in juvenile (<17 years) human remains: (1) taphonomic processes and abusive trauma will manifest in unique and distinguishable patterns, and (2) these modeled patterns can be widely applicable in skeletal analyses regardless of temporal context. A total of 100 juvenile skeletons from the Center for American Archeology’s skeletal collection...
and 101 infants and children sampled from the Harris County Forensic Institute’s Infant Injury Database were analyzed. Data were collected on age-at-death, taphonomic processes, fracture location and morphology, and fracture timing to establish clear patterns of involvement for both postmortem processes and trauma.

The results suggest that taphonomic processes and traumatic injury do affect the skeleton in distinguishable and predictable ways. Results also highlight the issue of taphonomic bias. Overlap between skeletal regions vulnerable to postmortem processes and those vulnerable to traumatic injury may skew skeletal interpretations. This project calls attention to the inherent difficulties in accurately assessing child abuse and the limitations incurred by both the biomechanical properties of the juvenile skeleton and observer inexperience. This thesis demonstrates the need for improved and standardized modeling of both taphonomic damage and trauma in order to reach accurate and ethical interpretations of the juvenile skeleton.
CHAPTER I

INTRODUCTION

Research Utility

Anthropology has a long-standing, albeit uneven, relationship with studying children. Historically, anthropologists have assigned children passive roles as objects acted upon by adults, they have been marginalized, and largely they have been misunderstood. However, in more recent years, anthropologists have grown increasingly curious about the lived experiences of children and this is directly represented in the modern bioarchaeological literature. The anthropological interest in children is a direct outcome of feminist studies, such as those conducted by Sofaer Derevenski (1994), Lillehammer (1989), and Moore and Scott (1997) (Lewis 2007, 3). Its rising prominence in the field is in part due to elevated attention to certain global problems of children, including those of war, abuse, poverty, and sexual exploitation (Bluebond-Langner and Korbin 2007). These issues, paired with the acknowledgement that children make up large portions of any population, have resulted in anthropologists from all subfields investigating children and their role in society.

Biological anthropology has an incomplete understanding of children and the juvenile skeleton. Many collections lack juvenile remains due to issues of differential preservation of children and the erroneous notion that only adult skeletons hold importance (Beauchesne and Agarwal 2018). Bioarchaeologists study children in the past and their social roles, health, and regarding acts of violence inflicted upon them. Forensic anthropologists observing juvenile
remains in medicolegal contexts are responsible for recreating past life events, often tied to trauma and child abuse that have direct and serious consequences in medicolegal cases. However, research specific to the juvenile skeleton is underdeveloped and often neglected. Too often are cases of juvenile trauma, pathology, and taphonomy approached through a lens developed for adult skeletons and the realities of biological and social differences put aside. Thus, with increasing awareness into the biocultural differences of children comes a growing need to develop more nuanced research on the juvenile skeleton.

Information loss is one of the more serious issues in anthropological studies involving children and the juvenile skeleton. There is an inherent invisibility of children in the archaeological record due to differential burial practices and preservation, and in more contemporary contexts they also suffer from issues of taphonomic processes. Distinguishing between trauma and postmortem damage proves to be an ongoing analytical struggle. Acts of violence may be confused with or obscured by taphonomic processes, resulting in misinterpretation. This project approaches this issue with an attempt to codify trauma, pathology, and taphonomic patterns and establish a model of prediction to differentiate between ante- or perimortem acts of violence and postmortem damage.

Children hold important and unique roles in societies both past and present, and ultimately their prescribed liminal position as non-adults means that any study concerning children must be cognizant of their vulnerability, variability, and their once lived experiences of hardship. By developing a model that can aid in differentiating abuse from postmortem damage, harmful, speculative, and significant misinterpretations may be avoided, and the lives of children more accurately and holistically understood. A model for future use is needed to improve studies
of children in both bioarchaeological and medicolegal contexts. In bioarchaeological contexts, children buried over decades and millennia will inevitably sustain postmortem damage, making conclusions about violence challenging and treacherous. In addition, the need to differentiate between postmortem damage and abuse is of the utmost importance in medicolegal contexts. Children are unfortunately not spared from violent acts. They are often victims in cases of domestic violence and also fall victim to larger, more systemic issues of human rights abuses, including those that result in genocide. Analytical issues in establishing the accuracy of ante- and perimortem events can cause problems for medicolegal specialists in important decisions of cause and manner of death. Thus, this thesis helps fill the gap of child-focused research, and acts as a pilot study in modeling pattern-focused methodology of both taphonomic processes and trauma. The ultimate goal is to contribute to the body of research working to demystify child abuse analysis and implement ethical standards by which to do so.

Research Design and Hypotheses

This thesis utilizes data collected from two samples: The Center for American Archeology (CAA) skeletal collection and the Harris County Institute of Forensic Sciences (HCIFS) Infant Injury Database (IID). In total, data were collected from 201 individuals. Data collection for the CAA sample required creation of an entirely new protocol outlined in subsequent chapters, which included the following: recording burial context, constructing age-at-death estimations, and morphological analysis of taphonomic processes, all fractures (traumatic and non-traumatic), and select pathological processes. Data collection for the IID consisted of recoding existing collected data by the HCIFS forensic anthropology team and maintaining
consistency with the methodology used for the CAA collection. The purpose of this methodology was to collect data that would be useful in constructing comparative patterns of taphonomic damage and trauma.

Data analysis was carried out in SPSS v. 27 and focused primarily on frequency calculations for pattern development within and between the CAA and IID samples. This included but was not limited to addressing questions concerning regions of the skeleton most vulnerable to postmortem damage, trauma, and frequencies of trauma type. When possible, chi-square tests were performed to evaluate any relationships between factors such as age and preservation, age and trauma type, and sample and fracture location. Further details on the numerous variables considered in this study are outlined in Chapters IV and V.

**Hypotheses**

The primary hypothesis addressed in this thesis focuses on whether taphonomic processes and trauma are patterned in different ways in the juvenile skeleton. It is predicted 1) that distinct patterns can be modeled for these skeletal markers, and 2) that these patterns can be used to demystify analyses where children and violence coincide. The ability to develop widely applicable patterns regardless of temporal context is another concept considered here. It is expected that patterns of abuse modeled on modern data can indeed be applied in archaeological and historic contexts with the caveat of taphonomic bias. Fragmentation and degradation due to postmortem processes may eliminate portions of bone where trauma may have been inflicted, and they may eliminate entire regions of a skeleton. It is expected that this taphonomic bias may ultimately prevent accurate trauma analysis and therefore accurate interpretations of violence, child abuse, and all other circumstances surrounding a death event.
Organization of Thesis

This thesis continues through seven chapters. Chapter II posits a multifaceted theoretical framework for data collection and interpretation. This chapter presents key terms and definitions, including but not limited to defining age categories, “childhood,” “violence,” and “child abuse.” Chapter II also includes the establishment of a biocultural framework and finally situates this thesis within an ethical framework. Chapter III progresses through a literature review, detailing the diagnostic criteria for child abuse, issues with postmortem damage, and the biomechanical properties of juvenile bone. Chapter III also introduces a more thorough problematization of the current project, presents the main hypotheses, and concludes with objectives and general expectations.

Materials and methods are presented in Chapter IV. The archaeological and forensic samples used in this study are discussed in detail, as are methods of data collection and analysis. Chapter V presents the results of data analysis. Finally, Chapters VI and VII of this thesis constitute the discussion of results and conclusions, limitations, and ways to move forward, respectively.
CHAPTER II

THEORETICAL FRAMEWORK

Introduction

The research design and hypotheses posited by this thesis are situated within a complex theoretical framework in which biology and sociocultural systems are linked. This chapter discusses these intricacies in detail, laying a foundation for interpreting skeletal markers in the context of violence. This chapter begins by discussing definitions of childhood to highlight its complexities and establish standard terminology for this thesis. The next section focuses on conceptualizing violence and child abuse based on these foundations. A biocultural framework is then established to situate this thesis more specifically in its two dominant realms. Lastly, this chapter establishes an ethical framework from which to view the work carried out by this thesis.

Defining Childhood

Any study concerning children must first begin by defining “childhood” and understanding it as an academic subject. The study of children in archaeology emerged from gender theory in the 1990s, contemporaneous with recent stages of third-wave feminist theorizing and often in the same studies undertaken concerning women (Sofaer Derevenski 1994; Lewis 2007; Lillehammer 1989; Moore and Scott 1997). Since then, investigations have been moved out of the realm of adults, with studies focused specifically on children’s own, active social role. This emergence occurred more recently in bioarchaeology; however, studies of childhood in a
broader anthropological sense have existed for decades, and they provide appropriate foundations for which relevant terminology has been defined.

Though they are complex and fluid concepts, establishing definitions of the terms “child” and “childhood” are important before entering a more nuanced discussion on violence and abuse. Currently, neither term has a universally accepted definition. Panter-Brick (1998) notes that UNICEF defines a child as any individual between the ages of 0-15 years, though others consider the beginning and end points to be weaning and seven years of age, or age at earliest possible independence (Bogin 1997). Mary Lewis, a prominent childhood bioarchaeologist, further defines juvenility into more specific stages, wherein children occupy the 1-14.6 year range, preceded by infants (birth to one year) and succeeded by adolescents (14.6-17 years). Lewis considers those full birth to 17 years to be “nonadults.” This study will consider all under the age of 17 years, following Lewis’ terminology, with the sole substitution of “juveniles” for “nonadults.” Many workers use the catchall terms “subadult” or “nonadult” to refer to those under the age of 17. To avoid defining these individuals based on what they are not, this study uses the term “juveniles.” Hopefully in the future there will be consensus reached on a term that more adequately identifies this diverse age group on their own terms.

The lack of standardization for the term “child” directly translates into ambiguity surrounding the concept of childhood. A universal definition is thus difficult to establish, and according to some scholars, to do so would be irrelevant and even meaningless, as the concept of childhood varies broadly not only temporally but also cross-culturally (Hardman 2001). At any point in time, it appears there can be any number of “childhoods.” Despite this lack of fixedness, it is important to note that childhood is universalized in the sense that it is delineated by
biological or cultural events marking transitionary periods in an individual’s life from one phase to another, and it is accompanied by unique behavior and social roles (Hardman 2001). These social roles take on a myriad of forms, though their flexibility and characteristic vulnerability make childhood distinctly experienced from any other phase of life.

Ethnographic studies on childhood originated with Margaret Mead’s 1929 examination of child thought in Samoa, though they did not gain much traction until French philosopher Philippe Ariès (1962) published his seminal work, *Centuries of Childhood: A Social History of Family Life* (Lewis 2007). Ariès proposes a strictly cultural, Western construction of childhood based largely on Medieval art, which he argues did not display childhood or real children until the sixteenth century. The depiction of children as small adults led Ariès to argue that Europeans must not have had any concept of childhood, at least nothing culturally significant enough to occupy an entire phase of life, as it is often conceptualized today. However, Ariès also posits the notion that this lack of realistic painting may have been a coping mechanism of artists to the very real threat of infant mortality in Medieval times (Lewis 2007). After the 1500s, Ariès proposes the establishment of a Western childhood, one corroborated by evidence in specialized toys, clothing, and literature for children. Ariès’ claims have since been challenged by many researchers refuting the notion of a recently developed, essentialized childhood arising in Europe. Bluebond-Langner and Korbin (2007), Waller (2005), Lewis (2007), Panter-Brick (1998), and Beauchesne and Agarwal (2018) all advocate for a culturally subjective reality of childhood, one that has existed for millennia and been transformed both temporally and cross-culturally. Thus, moving forward, a Westernized framing of childhood presents inherent limitations and is argued to be avoided if research is to be conducted accurately and ethically.
Following this establishment of childhood as a subjective experience defined by transitionary stages, it is necessary to conceptualize a tripartite model of age. Childhood is often defined by numerical years but can also be defined by cultural events marking the end of one phase and the beginning of another. Both sets of factors contribute to the perception of the child and to the treatment of children in society. In the tripartite model of age, there are three components: biological age, chronological age, and social age (Inglis and Halcrow 2017). Biological age corresponds to the physiological reality of growth, development, and degeneration. Chronological age is typically a prescribed age in numerical units based on the state of biological age. Lastly, social age is the age of an individual determined by societal norms and values and can vary according to time, location, culture, and language (Inglis and Halcrow 2017). While social age significantly influences how an individual is treated, it is foundationally structured by biological age, which connects the individual to their external environment in physical, individualized ways. The contemplation of all three components of age is imperative in an accurate interpretation of the experiences of childhood and the treatment of children by others.

Violence and Child Abuse Conceptualized

A discussion on the maltreatment of children requires conceptual understanding of violence. Like definitions for “child” and “childhood,” there are no universally accepted definitions of violence (Redfern 2017a). Meaning varies between cultures and languages, time, and space; it is not fixed and unchanging but rather fluid and subjective, despite appearing deceptively simple. Since the 1970s when studies emerged on the topic of violence,
conceptualizations have changed, moving away from a term that solely encapsulates physical injury to that which includes psychological, emotional, and even economic harm (Redfern 2017a, 3). According to Redfern, the etymology of violence can be traced back to the Latin “violentus” and refers to an act of physical force used to harm or abuse, with the explicit element of intent (Redfern 2017a, 4). In 2002, the World Health Organization provided a more detailed definition, regarding violence as “the intentional use of physical force or power, threatened or actual, against oneself, another person, or against a group or community, that either results in or has a high likelihood of resulting in injury, death, psychological harm, maldevelopment, or deprivation” (World Health Organization 2002, 4).

Though violence is often equated with aggression, the latter lacks the central component of culture. Martin and Harrod (2015) advocate for violence to be seen as a culturally constructed social behavior deeply embedded into every human group. Like other aspects of society that are “culturally mediated,” such as religion or politics, violence is accompanied by a specific logic instilled by societal norms and expectations (Martin and Harrod 2015, 117). This is not to say all forms of violence are socially acceptable, and what is considered socially acceptable violence (e.g. certain forms of child abuse) may change over time and differ cross-culturally. Because attempts to qualify violence are riddled with these complexities, there is a corresponding ambiguity in interpreting violence, both in the past and the present. Anthropologists should then acknowledge that aside from requiring the key components of motivation and intentionality, violence is perhaps best understood as a culturally embedded practice that cannot be divorced from social norms.
Anthropologists do not study violence for one sole purpose, nor do they approach the topic through a myopic lens. Bioarchaeologists may study traumatic injuries to understand the meaning of violence itself at specific times or in specific groups. Forensic anthropologists, on the other hand, use evidence of skeletal injury to interpret the circumstances of a death event in contemporary medicolegal contexts. Martin and Harrod argue that all anthropologists interested in violence interpret the social behavior through three main avenues: 1) evidence from skeletal remains, 2) analysis of contextual data, and 3) the use of various social theories developed from ethnographic work (Martin and Harrod 2015, 119). This study focuses on child abuse as a manifestation of violence. Martin and Harrod’s three main avenues hold true in any study of child abuse, given its complicated nature. Especially in bioarchaeological analyses that may only have observational access to physical manifestations of abuse, it is important to instill recognition of difficult-to-detect forms of child abuse and acknowledge that child abuse may come in many forms departing from the more visible, physical reality of maltreatment.

Rebecca Redfern’s (2017b) discussion on domestic violence (DV) sets up a more nuanced consideration of child abuse. Redfern defines domestic violence beyond the expectation that it occurs solely between two intimate partners. Instead, Redfern’s discussion includes all family members as potential perpetrators and victims. Many have critiqued the attempt to develop an accurate clinical model of domestic violence, but Redfern advocates for such models, so long as they consider the social implications and cultural underpinnings of DV (Redfern 2017b, 19). Domestic violence, and thus child abuse as a direct extension, does not occur in isolation from other violent circumstances. There is a strong concurrence of DV with warfare, poverty, structural violence, and socioeconomic inequality, showing that domestic violence
cannot be separated from its social context. Redfern describes these complexities of social connectedness as different “threads” making up an intricate “web of violence” (Redfern 2017b, 26). Untangling the complexities of violence in any form is only possible with an understanding of the extrinsic and intrinsic factors contributing to its existence.

Like violence, child abuse is defined in ambiguous terms, reflecting a thematic lack of standardization in conceptualization. As of June 8, 2020, the World Health Organization had defined child maltreatment as “the abuse and neglect that occurs to children under 18 years of age. It includes all types of physical and emotional ill-treatment, sexual abuse, neglect, negligence and commercial or other exploitation, which results in actual or potential harm to the child’s health, survival, development or dignity in the context of a relationship of responsibility, trust or power” (World Health Organization 2020). Thus, child abuse cannot be limited to physical harm, though it may be easiest to detect in the archaeological record and in modern contexts in this form. The literature explored below shows that it is possible to detect forms of child abuse that depart from the direct and the physical, including those of neglect, exploitation, and deprivation of resources. Thus, child abuse is established as a socially constructed concept with very real consequences.

It is important to recognize the underlying subjective nature of abuse. What is considered maltreatment in one society may not be considered maltreatment in another. In fact, the Western norm of leaving infants and children alone to sleep is regarded as a heinous, abusive action in many other cultures (Redfern 2017a, 130). It is also important to note that social age categories of children may differ cross-culturally, resulting in very different lived experiences of children and potentially mystifying interpretations of abuse. For example, adolescents
(previously defined as individuals aged 14.6-17 years) may suffer trauma from involvement in social behavior accompanying older age, such as warfare or violent status-related rites. In these cases, a diagnosis of child abuse would be inaccurate and negligent of social context. Moving forward, it will be imperative to remain conscious of the transformative nature of child abuse as recognized in the present and often transposed onto the past.

Establishing a Biocultural Framework

The concepts of childhood and abuse are established as complex and variable entities. This study addresses these topics in relationship to age, childcare, and violence none of which fall under the sole purview of biological anthropologists. Therefore, it is important to establish a cross-disciplinary theoretical framework, one that can accommodate merging differing views with a direct aim toward holism and accuracy in interpretation. For the purpose of this study, children do not just end up abused without contextualizing sociocultural factors. These factors must be understood and approached seriously in studies of biological alterations to the human skeleton.

As stated by biological anthropologist James Calcagno, “humanity itself is a biocultural product” (Calcagno 2003, 14). While recognizing social, biological, and cultural diversity is at the core of biological anthropology, conducting research without welcoming intellectual diversity risks producing narrowed and unrepresentative interpretations. This project establishes a biocultural framework to account for these underlying complexities and attempt more accurate interpretations of the deceased. Though definitions are not standardized, “biocultural” is defined here as the confluence of sociocultural aspects with an individual’s
biology (Wiley and Cullin 2016). Culture influences biology and biology is directly tied to sociocultural treatment and perception. Individuals and entire groups may be denied the comfort and good health that come from a safe environment, resulting in decreased health and differential morbidity and mortality patterns; or in the reality of malnutrition and onset of metabolic disease due to structural violence in a dangerously stratified society (Goodman and Leatherman 1999, 4).

Because this study aims to improve analyses wherein the culturally constructed concept of violence may be a factor, it is vital to integrate biological and cultural perspectives into one holistic framework. This study establishes the biological underpinnings of differential bone preservation, biomechanics, and stress and ties these intrinsic factors to intent, an inherently social concept. In addition, it is important to note that any discussion of children cannot ignore the separation in their social realm from that of adults. The difference in social standing and cultural expectations of children naturally factor into their biological processes, and their visible biology often shapes the former. With a biocultural framework, biological anthropology is well-suited to address the topic of child abuse and propose ways to move forward with accurate interpretations of such acts of violence. The underlying goal is to minimize bias, increase accuracy in interpretations, and account for variability.

Ethical Framework

As anthropologists, it is imperative to consider the ethical treatment of humans as it pertains to stewardship, research, and the dissemination of knowledge. Bioarchaeology and forensic anthropology are particularly charged with ethical quandaries as their focus is on human remains, a voiceless group vulnerable to insensitivity and callousness in ways unique to that of
the living. This section addresses the intricacies of ethically studying human remains by means of a scientific agenda, and it establishes an ethical framework within which this study is situated.

Anthropology has a foundation deeply rooted in colonialism and racism, and it is only in recent decades that ethics have entered the discourse. With a longstanding history of insensitivity toward Black, Indigenous, and People of Color (BIPOC), it is crucial to persistently and critically evaluate the ethical sphere of anthropological studies, and establish ethical frameworks centered on inclusivity, sensitivity, and decolonizing principles. Recent decades have shed light on the inherently subjective nature of scientific research, drawing attention to unethical practices engaged in by primarily Western, white researchers. Ethical guidelines have emerged that now lay the groundwork for current and future work. These guidelines now exist due to the hard work and activism of those marginalized groups directly affected by insensitive and myopic anthropological work. To ensure this work was not done in vain and to secure an ethical future for anthropological practice, anthropologists must work within ethical frameworks that recognize and respect cultural and temporal subjectivities.

What is considered valuable research is not ubiquitously agreed upon. Especially when considering the study of human remains, the value of research and analysis of skeletal collections is inherently subjective; what is valued by Western, white scholars may not be in line with the values of those from other cultures (Zuckerman et al. 2014). Research in general is often deeply rooted in colonial action, and it is important to note that colonial structures and systems cannot be reformed; rather, they must be dismantled. While the colonialisit structure to modern anthropology has yet to be abolished, strides have been made in ensuring proper treatment of
human remains. Justifying research using skeletal collections remains complicated, though it is most often rooted in recognition and respect for the agency that individuals hold even after death.

Forensic anthropology and bioarchaeology exist as specialized subfields of anthropology, occurring at the confluence of many fields, such as medicine, forensic science, cultural anthropology, sociology, and archaeology (Passalacqua and Pilloud 2018). Due to the focus on human remains in medicolegal and archaeological contexts, this thesis establishes an ethical framework using principles applicable to both contexts.

The ethics of modern medicine are largely founded on two principles, those of beneficence and nonmalfeasance (Passalacqua and Pilloud 2018, 28). The former refers to doing work that is beneficial to others, whereas the latter embodies a “do no harm” sentiment. While these hold relevance to forensic anthropological work, Appelbaum (1997) illustrates the necessity of amending these standards for forensic science. Here, truth-telling, or more generally, transparency, and respect for persons are more directly applicable ethical principles, as the goal of forensic practitioners is not to benefit health as much as it is to seek justice. Ideally, all anthropological work would rely on informed consent to ensure best ethical practices. However, this is not typically feasible in forensic anthropology or bioarchaeology, and anthropologists must find other ways to enforce respect.

Bioarchaeological ethics are perhaps best rooted in a relational framework focused on deriving meaning from and by skeletal remains (Zuckerman et al. 2014). There is a need to move beyond empirical knowledge derision and toward a practice better suited to connect modern subjectivities to those of the past. Ethical bioarchaeological practices aim to establish an interpretive space in which the deceased can recount their histories, but this is not enough to root
ethical bioarchaeological work. Anthropologists working in this realm must consider stewardship and question for whom they work. This thesis denounces the practice of science for science’s sake, in favor of scientific work situated within pertinent sociocultural issues. Without respecting cultural subjectivity and prioritizing the values and methodologies of those marginalized groups often studied, it becomes easy for the harm of science to outweigh its benefits. Nystrom (2014) argues that the use of unclaimed bodies can all too easily represent structural violence against the derived marginalized populations. However, it is important to note that not all postmortem evaluation will constitute structural violence and it is possible to conduct ethical studies on the deceased.

The samples used in this study include the Center for American Archeology’s (CAA) skeletal collection and the Harris County Institute of Forensic Science’s (HCIFS) Infant Injury Database (IID). The CAA collection is composed of pre-Columbian indigenous remains, which situates its use firmly within the Native American Graves Protection and Repatriation Act of 1990 (NAGPRA). NAGPRA mandates “all US Government agencies, non-Smithsonian Institution museums, and other institutions receiving federal funding to inventory Native American human remains, assess ancestral associations (‘cultural affiliation’), communicate with federally recognized tribes, and return remains if requested by these tribes” (Larsen 1997, 341). This act, brought about by indigenous activism, is one step toward stopping invasive studies by insensitive researchers. It is not perfect, and “federal recognition” is an issue in and of itself rooted in gatekeeping. However, since its inception, NAGPRA has introduced a new, beneficial climate requiring communication between all researchers and indigenous groups. Generally, remains believed to be Native American are repatriated to the appropriate Native American tribal
nation. The housing of the CAA collection and use of these remains in this study exist strictly in compliance with NAGPRA. No requests have been made for repatriation, and research planned for publication is circulated to Native American tribes by the CAA (Jane Buikstra, personal communication, March 22, 2021). In addition, the principle of nonmalfeasance is enforced here; no destructive practices were involved in data collection and all remains were handled with extreme care and caution.

Contrasting the CAA archaeological collection, the HCIFS IID is a modern forensic sample. The IID was constructed using data from all deceased infants and children autopsied at the Harris County Medical Examiner’s Office (Soto Martinez et al. 2019). As Passalacqua and Pilloud (2018) state is the case for most forensic analyses, informed consent was impossible to obtain for the individuals comprising this database. Especially when informed consent is not attainable and decedents are identified, the benefits of the research must outweigh any harm to the dignity of the decedent, any possible living relatives, and the skeletal remains themselves (Pilloud and Passalacqua 2018). In addition, data must be presented anonymously. The benefits of the IID are established in its creation as an aid to improve the accuracy of child abuse research and case analysis, a much-needed tool in a field with large gaps in child-focused research. The IID presents data anonymously as well, and it is protected behind a formal application process for access. Despite the obvious hindrance in lack of informed consent, as is the theme for forensic and bioarchaeological research, the use of the IID remains aligned with the ethical principles adhered to in this study.

Transparency in anthropological work is fundamental to professional and ethical research. Anthropologists have a social responsibility to respect the dead and do all that is
possible to accommodate the fact that informed consent is, more often than not, impossible to obtain. Though complicated and subjective, reflecting upon the ethical boundaries of working with skeletal remains is imperative to carrying out meaningful research. The individuals comprising the samples used in this study did not consent to be studied. In the case of the CAA collection, these are children whose death circumstances remain largely unknown due to their archaeological context. The infants and children comprising the IID sample all suffered untimely ends at the hands of abuse and violence. Though my identity as a non-indigenous researcher means that it is ultimately not my place to determine whether the benefits of this work using the CAA collection outweigh any potential harm to descendant communities, I justify the use of these remains through the potential benefits that child-focused research such as this pilot study may have. The goals of this thesis and the use of these skeletal remains are twofold: to help educate forensic and archaeological practitioners, and to ensure the improved ethical treatment of and justice for children in the future through increased accuracy in child abuse research.

It is expected that ethical standards will develop in a positive trajectory streamlined by the centering of marginalized voices, and the standard for research using human remains is likely to shift toward body donation via informed consent. It is important to note that this does not necessarily mean future collections will be more holistically representative of populations, because body donation remains the most inexpensive method of body disposal (Passalacqua and Pilloud 2018; Zuckerman et al. 2014). Therefore, these collections will likely be mostly composed of lower income, marginalized individuals, which has its own implications for anthropological research. However, obtaining informed consent via body donation ultimately presents the most ethical practice. As it stands, the Uniform Anatomical Gift Act (UAGA)
“allows an individual to donate their body for transplantation, research, education, or therapy in advance of their death,” with the next-of-kin also able to donate a relative’s body “if it does not contradict the decedent’s wishes for treatment after death” (Passalacqua and Pilloud 2018, 55).

Hopefully, anthropology sees positive forward progress with the establishment of ethical frameworks with enforceable standards. Knowledge of how to properly handle, analyze, and store remains without physical detriment or disrespect must also be a part of these standards.

Though anthropology at the current moment suffers from the infancy of ethical practice, this study ultimately justifies the use of human remains to establish criteria that will benefit further interpretations of children, help bring closure to families, and bring about justice when needed.

Summary

This thesis is situated within themes of childhood, violence, and ethical practice. The sections above demonstrate the necessity of defining terms, unpacking social complexities, and rethinking Western norms if anthropology is to engage in meaningful and constructive research. It is established that children occupy a vastly different societal role than adults, and that “childhood” is as subjective as concepts of violence. What remains consistent is the need to understand children on their own terms because of their uniqueness regarding biology, social roles, and the circumstances of their oppression.

For the purposes of this study, there are three categories of juveniles: infants, children, and adolescents. It has been crucial to establish these categories, as infants, children, and adolescents will experience violence in different ways. Understanding the intricacies of childhood itself and actively denouncing the practice of homogenizing juveniles is crucial in
taking steps toward helping and better understanding these vulnerable groups. Moving forward, the term “violence” and all discussions of abuse are specifically referring to acts of aggression enmeshed with intent and social context. What has hopefully been made clear in this chapter is that children deserve to be understood on their own terms, and as victims, understood in the context of abuse of power typically patterned and directed by adults.

Lastly, an ethical framework has been established from which to view this thesis. This chapter has highlighted the fact that nothing is simple in studies involving human remains or marginalized demographics. Western notions of value must be critically evaluated when conducting research and situated within discussions of stewardship. This thesis operates primarily on the principles of transparency, respect for persons, and beneficence. Studies on children are inherently complicated to ethically substantiate, as children are so often stripped of their agency in life. With this in mind, the work conducted here is ultimately justified in the recognition that their agency can be restored even after death, and their inclusion used to help others moving forward.
CHAPTER III

BACKGROUND AND LITERATURE REVIEW

Introduction

This chapter introduces the diagnostic criteria for child abuse in the juvenile skeleton, discusses the confounding effects of taphonomic damage, and details this project’s research design as contextualized within the existing body of literature and anthropological practice. The purpose of this chapter is to highlight expected patterning of abuse and postmortem damage across the different age categories of children. This chapter begins with a literature review on trauma patterns in the juvenile skeleton derived from medical and bioarchaeological sources. Taphonomic processes, namely postmortem damage, and the juvenile skeleton are then discussed. This section also presents information on the bone biomechanics of the juvenile skeleton, as compared to their adult counterpart to establish a foundation for research expectations. Lastly, this chapter puts forth this project’s research design, including contextual problematization that leads into questions and hypotheses, and ultimately the expectations of this work.

Diagnosing Child Abuse

Most knowledge about child abuse in archaeological contexts is ascertained using the modern clinical and forensic diagnostic criteria. Recent documented, comparative samples are especially useful with their associated medical records, family histories, soft-tissue injuries, and
radiographs that are commonly inaccessible in the archaeological record. The primary source for child abuse in any context is the children themselves; however, scientists are often left to deduce such intentional violence from secondary sources, such as those listed above. Thus, this information is needed to provide a more realistic foundation with which to assess both archaeological and more recent remains.

The clinical literature acknowledges that inflicted skeletal trauma in the child can involve virtually all skeletal elements (Cooperman and Merten 2001). However, there are noticeable patterns to child abuse that aid in the initial recognition of maltreatment. Age proves to be the single-most important risk factor in modern cases of child abuse, with 55-70% of all inflicted skeletal trauma in infants younger than one year old (Cooperman and Merten 2001, 123). In these known cases of abuse, over one half of the children sustained multiple fractures in a chronic context. Cooperman and Merten also note that child abuse can be affected in frequency and severity by socioeconomic factors, though ultimately abuse transcends social and economic delineations. It is particularly important to note that disability and prematurity may also leave a child more vulnerable to maltreatment, and this factor should be considered in all cases of suspected child abuse.

Anthropological studies of child abuse rely on clinical pattern recognition within previously mentioned social contexts, though they depend largely on skeletal evidence. The first documentation of child abuse came from French physician Ambrose Tardieu who, in 1860 described skeletal evidence of maltreatment in a quantifiable manner (Lewis 2007). However, child abuse remained largely ignored in the clinical literature until Kempe et al. coined the phrase “battered baby syndrome” in 1962, drawing attention to a widespread phenomenon and
ultimately gaining traction in the medical community. Since then, noticeable patterns of child abuse have been reported and upheld through retesting and contextualization.

The most common markers of child abuse are fractures of the extremities, followed by cranial fractures (Cooperman and Merten 2001). Common cranial injuries associated with abuse include “pond lesions,” which are characterized by depressed fractures and are common in juvenile bone with greater pliability. The parietal, occipital, frontal, and temporal bones are the most commonly fractured cranial bones both accidentally and in cases of abuse (Love et al. 2011). Skeletal markers more suggestive of abuse include complex fractures of the cranial base, depressed fracture margins, stellate configurations, multiple intersecting fractures, and fractures crossing sutures (Love et al. 2011). It is important to note that facial fractures are not included in common cranial injuries indicative of maltreatment, possibly indicating a desire of the perpetrator to hide evidence of abuse (Cooperman and Merten 2001). In addition, Lewis (2007) notes that survivors of child abuse may exhibit ossified subdural hematomas in the form of endocranial lesions or “hair-on-end” bone projections from such brutal force on a fragile body.

Postcranial elements affected by abuse include the ribs and clavicles, as well as any element that may be vulnerable during shaking or grabbing (Cooperman and Merten 2001). Distinguishable trauma to the extremities includes the classic metaphyseal lesion, widely acknowledged to be strongly indicative of infant abuse (Thackeray 2016). The classic metaphyseal lesion (CML) was first introduced as a term by John Caffey in 1953 and investigated further by Paul Kleinman and colleagues in 1986. The CML manifests as a number of microfractures in the most immature portions of the metaphyses of long bones (Kleinman et al. 2011). Resulting in a distinctly “disc-shaped” fracture of bone and cartilage, the CML may be
described as a “corner” or “bucket-handle” fracture. The CML is considered such a strong indicator of abuse because it almost always corresponds with other traumatic injuries. A study by Thackeray (2016) shows most infants (95.8% of those studied) with a CML have at least one additional, non-CML fracture and approximately one-third of those studied had traumatic brain injury. Other associated injuries include cutaneous, oropharyngeal, and abdominal or thoracic injuries. Identification of a CML should prompt immediate investigation into physical child abuse.

Ultimately, many of these skeletal indicators may be diagnosed morphologically by anthropologists, although they are enhanced by the use of histological and radiographic analysis that may reveal greater detail in fractures and new bone formation (Cooperman and Merten 2001; Lewis 2007). Lastly, while there exists a number of recognizable skeletal patterns useful to anthropologists, not all child abuse will manifest as physical trauma. As previously mentioned, abuse can take many forms, including mental and emotional trauma, malnutrition, starvation, poor hygiene, and a lack of medical care or attention (Piercecchi-Marti et al. 2006). Some of these frequently neglected forms of abuse can cause specific skeletal lesions such as Harris lines, delays in bone maturation, dental caries, linear enamel hypoplasias, porotic hyperostosis, and cribra orbitalia (Cook and Buikstra 1979; Piercecchi-Marti et al. 2016). Evaluation of these indicators, alongside isotopic analysis into diet and malnutrition, provides useful supplementary information (Lewis 2007).

It is important to note that when not associated with physical trauma, these non-traumatic skeletal markers do not immediately signify abuse (Redfern 2017a). Non-specific indicators such as growth delays and dental and metabolic disease may also be reflective of other
social circumstances, including class struggle, structural violence, religious practices, or lack of access to appropriate resources. Due to this broad applicability, their presence may simply provide supplementary information into maltreatment. What can ultimately be diagnosed as abuse is only manifested physically in most if not all archaeological and medicolegal contexts. Biological anthropologists may be able to unpack elements of physical abuse more clearly than other forms of maltreatment. However, a serious hindrance is the lack of ability to recognize the traumatizing effects of emotional and psychological harm toward children, which often manifest as a detriment to their physical health.

Postmortem Damage and the Juvenile Skeleton

The ability to accurately interpret ante- and perimortem events such as violent encounters of abuse is often obscured by taphonomic processes. For the purposes of this study, taphonomy is defined as the study of alterations to an organism from the time of death until its recovery (Pokines and Symes 2013). The term was coined by Efremov in 1940, who used it to describe the “science of burial” (Pokines and Symes 2013, 3). Initially studied by paleontologists and geologists, taphonomy has become increasingly researched by anthropologists from the 1970s and into the present. At its core is interpreting past life events in conjunction with understanding contemporary and past natural processes. Poorly quantified in anthropology and not standardized, taphonomic processes often present as insurmountable analytical hurdles. It is not uncommon for anthropologists to confuse postmortem damage with trauma and vice versa. In their Manual of Forensic Taphonomy (2013), Pokines and Symes note that one problem is a lack
of comparison of common taphonomic observations and a dearth of research regarding common skeletal regions of confusion.

Reconstructing ante- and perimortem events are made more difficult by taphonomic processes including fragmentation, general erosion of cortical bone, and loss of skeletal elements, and further complicated by uncertainty and variability surrounding the length of the perimortem interval. Bone biophysical properties change after death, and the length of time needed to pass before bone no longer reacts in a “living” manner remains poorly understood (Pokines and Symes 2013, 10). These complications mean taphonomic processes may add confounding information to a case, and there is also the possibility of information loss (via bone loss or degradation). Surface changes, cracking, and carnivore scavenging can all be mistaken for bone alterations that occurred during an individual’s life. Especially vulnerable to taphonomic processes are the epiphyses and metaphyses of long bones, sternal rib ends, and characteristics of the midfacial and pubic areas (Pokines and Symes 2013). General erosion of the surface of many elements and the loss of smaller, informative elements such as teeth also present challenges. It is also important to note that elements damaged in the perimortem time frame, such as areas surrounding a high-velocity impact like a gunshot wound, are more vulnerable to postmortem damage and significant information loss.

Research about specific taphonomic processes acting on juvenile remains is scarce and underdeveloped. While the bone biomechanics of children are well understood, the ways in which juvenile bone is affected by postmortem change are not. Manifold (2012) and Guy et al. (1997) provide two unique instances of child-focused research, an anomaly when considering the trend toward adult-centered research in the field. The literature also shows that survival of
human remains is dependent on many intrinsic and extrinsic factors, including but not limited to bone type and size, age, soil type, and soil pH (Manifold 2012). Elements with more trabecular bone (e.g. vertebrae, ribs, sterna, and long bone epiphyses) are more vulnerable to destruction, as are bones with lower mineral density. Juvenile bone is characterized both by a greater trabecular constituent and lower bone mineral density, making age an especially important factor in its preservation.

The Biomechanical Properties of Juvenile Bone

Before unpacking the specifics of differential preservation, it is important to understand the biomechanical properties of juvenile bone. Most literature on the topic addresses juvenile bone biomechanics in the context of traumatic injury, though scant literature addresses differential preservation. Understanding how juvenile bone reacts to stress is significant in a discussion on taphonomy, as the primary concern is distinguishing perimortem from postmortem processes. Juvenile bone reacts to stress uniquely compared to adult bone. It fails and fractures differently primarily because the bones are in the process of forming, with osteon systems rapidly remodeling (Ogden 2000). These unique biomechanical properties are strongly correlated with age, and they are additionally affected by factors such as height, weight, and bone measurements (Hymel and Spivack 2001). Ultimately, an understanding of bone biomechanics lends increased credibility and objectivity to case analyses of child abuse, including those in which taphonomic processes are a factor.

Bone mass, bone mineral density (BMD), and bone mineral content are key components of understanding differences in bone biomechanics. Bone mineral content is known to change as a function of age, regressing at the onset of the postnatal period and then developing
with growth and age (Guy et al. 1997). Properties of compact and trabecular bone depend on this mineral content and the mineral density of bone, in addition to being dependent on the proportion of secondary to primary osteons. Higher BMD results in stronger bone, as does a higher proportion of primary osteons (Hymel and Spivack 2001). Juvenile bone is more resistant to injury compared to adult bone in part due to the higher number primary osteons present during early growth and development. The lower mineral (inorganic) content and higher collagen (organic) content of juvenile bone also means that it has increased plasticity and an enhanced ability to store energy prior to failure compared to adult bone, yielding a greater frequency of greenstick, or splintering fractures, and incomplete fractures (Hymel and Spivack 2001). It is important to note that musculature lends support to the skeletal system, balancing out tensile stress during injury and lowering the risk of fracture. However, not all children have comparably healthy musculoskeletal systems. Children with conditions resulting in lesser muscle mass and lower muscle functionality, such as cerebral palsy, may experience a greater vulnerability to fracture compared to their peers (Hymel and Spivack 2001). While there are reliable generalizations about juvenile bone biomechanics, it is important to keep in mind the different factors that may affect a stress response.

Other biomechanical properties that may affect response to stress and the manifestation of taphonomic processes include peak bone mass, cortical thickness, and bone healing rate (Ogden 2000; Hymel and Spivack 2001; Manifold 2014). Manifold (2014) explains that peak bone mass (PBM) for trabecular bone is reached toward the end of the second year of life. Thus, the trabecular bone of individuals below the age of two may suffer from poorer preservation compared to that of older individuals. In addition, Manifold notes no significant sex
differences in bone mass prior to puberty. Afterward, there tends to be an increase in the cortical thickness of males (Manifold 2014, 119). An increase in cortical thickness with age, regardless of sex, results in increased bone mass and BMD and consequently a greater likelihood of preservation after burial (Manifold 2014). However, nutrition can have an adverse effect on BMD. Malnutrition, specifically in the form of vitamins C and vitamin D deficiencies, can directly result in cortical thinning (Manifold 2014). Bone healing rate is also important to consider in a discussion on juvenile bone biomechanics. Juvenile bone heals more rapidly than adult bone due to the unique nature of its periosteum and increased blood supply to osseous regions (Ogden 2000). Healing occurs faster the younger an individual is, adding another confounding factor in detecting inflicted injury in the juvenile skeleton, especially one affected by taphonomic processes.

Bone mineral density increases with age, with strength increasing contemporaneously, due to the development of the skeletal crystalline structure. Thus, greater tensile and compressive strength and the concordant resistance to taphonomic processes increases with age as well (Guy et al. 1997). In general, juvenile bone is brittle due to this low density, low strength, and poorly mineralized structure, resulting in its vulnerability to the more crushing and abrading taphonomic processes (Guy et al. 1997). It is important to note that there is a threshold sometime before the age of three in which juvenile bone crosses over from the “infant” type (higher moisture content) to an “adult” type (harder and denser) (Guy et al. 1997). Therefore, not all juvenile bone reacts to stress in the same way, and certain expectations must be established for different age categories.
The juvenile skeleton continues to present other unique taphonomic challenges. Due to its developing nature, the juvenile skeleton is easier to disarticulate and be scavenged by animals and dispersed or removed entirely from the initial burial site (Manifold 2012). In addition, trauma and pathological conditions may accelerate the process of decomposition, ensuring easier passage of microorganisms and further loss of information (Manifold 2012). Those pathological conditions resulting from nutrient deficiency, such as rickets or scurvy, result in more porous bone, and in turn a greater vulnerability to taphonomic processes. Extrinsic factors are also significant in preservation of the juvenile skeleton. Soil characteristics, including soil pH, are often the main driving force behind taphonomic alterations to bone (Manifold 2012). Acidic environments cause the demineralization of bone and decomposition due to bacteria may also ensue. It is important to note that much of what is known regarding these taphonomic processes is learned via studies conducted at experimental decomposition facilities, which only focus upon mature bone. In adults, it is understood that taphonomic processes can cause skeletal elements to lose their density and entirely degrade, though this is not well-understood in cases of juvenile remains (Manifold 2012, 58).

The effects of other taphonomic processes contribute to misinterpretation of past life events. Temperature variation can cause expansion and contraction of the surrounding earth, resulting in bone fragmentation and cracking that may be misinterpreted as perimortem fractures (Manifold 2012). Plant roots can damage bone and mimic trauma, and the marks they leave on a bone’s surface may resemble certain pathological indicators. Neonate bone is shown to be more difficult to destroy in a fire context due to its higher moisture content and elasticity, though it is more fragile than adult bone post-burn event (Waterhouse 2013). Overall, juvenile bones respond
differently to taphonomic processes when compared to their adult counterparts as exhibited by the existing literature. The fact that children are smaller, have more unfused components, more trabecular bone, and a higher organic component than adults means that the literature should progress toward understanding the juvenile skeleton on its own terms.

Current Project: Problematization

Two persistent issues motivate this research project. The first is anthropology’s longstanding and uneven relationship with studying children. As mentioned above, children are often neglected in developing research and attempts at their skeletal evaluation are often conducted using adult methodology. Not only do children occupy distinct societal roles and undergo unique stressors, but it has been established that the juvenile skeleton reacts to its environment in ways distinct from their adult counterparts. As elevated interest is brought to the issues of children, there is a growing need to understand this demographic on its own terms. It is not sufficient to evaluate the juvenile skeleton based on methodology developed for adults.

Second is the issue of standardization. There is a resounding lack of comprehensive analyses of taphonomic signatures for human bone, which complicates any study of skeletal remains. Taphonomic processes manifest in specific patterning as do traumatic injuries and pathological conditions. These patterns must be understood and methods for analysis standardized to demystify the perimortem period and clarify interpretations of past life events. If anthropologists continue to use varying criteria to record taphonomic processes, traumatic injury, and pathological conditions, the general lack of ability to conduct appropriate comparative analyses will persist. Taphonomic processes provide sufficient confusion in interpreting an
individual’s life events, and future research should focus on removing the compounding issue of conflicting terminology or methodology. Currently, little literature exists for differentiating trauma from postmortem damage in the juvenile skeleton.

Hypotheses

The above literature review contextualizes this project and situates it in a realm of developing research on trauma, taphonomy, and the juvenile skeleton. Here, primary research questions are put forth and frame the core hypotheses of the current project. Accompanying each research question is an explanation of existing issues followed by research expectations based on the existing literature.

Question 1: How do skeletal patterns of child abuse manifest differently from taphonomic patterns of damage?

- **Research hypothesis:** It is expected that abusive trauma will manifest in patterns different from those of damaging taphonomic processes.
- **Null hypothesis:** Abusive trauma and postmortem damage will manifest in the same patterns in the juvenile skeleton.

Significant research is currently attempting to understand patterns of child abuse; substantially less is focused on differentiating the physical manifestations of child abuse from taphonomic damage. In both archaeological and medicolegal contexts, it is crucial to understand what events occurred during life, around the death event, and after death. Confusion of ante- or
perimortem trauma for postmortem damage, and vice versa, can result in erroneous claims about the past, and have dire circumstances in modern criminal cases.

Distinctive skeletal patterns are expected to characterize abuse and postmortem damage. Abuse is expected to manifest in fractures to long bones, the skull, ribs, and clavicles, in addition to hair-on-end projections characteristic of subdural hematomas. Non-specific pathological indicators including but not limited to linear enamel hypoplasias, porotic hyperostosis (PH), and cribra orbitalia (CO) may disproportionately accompany signs of trauma, as they may be reflective of neglect and malnutrition or be byproducts of structural violence. Specifically, active cases of PH and CO are expected in cases of fatal child abuse where physical abuse and general maltreatment coexisted up until the death event. Healed PH and CO may indicate an acute phase of malnutrition or disease unrelated to abuse. In cases of child abuse, evidence of chronic injury is also expected, as is fracture in more than one location, representing multiple injury events (i.e., recidivism). Taphonomic processes are expected to target areas with more trabecular bone, including the vertebrae, sternum, epiphyses, and metaphyses. Certain morphological features of postmortem breaks are expected to be distinctive, such as margin shape and direction.

Different categories of children are expected to react to stress and sustain damage from taphonomic processes in unique ways. Infants are expected to be more vulnerable to taphonomic processes, specifically those resulting in bone loss, than other children. Infants (those aged birth-one year) also comprise the age category most likely to experience fatal child abuse. Thus, infants are both the most likely to suffer postmortem damage and the most likely to endure inflicted trauma, presenting an expected challenge to accurately interpreting abuse in the
archaeological record. Adolescents (those aged 14.6-17 years) are expected to be most resistant to general degradation and bone loss due to higher bone mineral density, increased strength of the crystalline matrix, and thicker cortical bone. Children, or individuals falling in the 1-14.6 age range, are expected to vary in trauma patterns and in their preservation. Those on the younger end of the spectrum will most likely show evidence of greenstick fractures and well-healed fractures, and they will be more poorly preserved than their older counterparts. These expectations hold significant implications for studies of child abuse, which show that most cases of child abuse are inflicted upon infants and younger children. Thus, accurately assessing child abuse in archaeological contexts or modern contexts susceptible to more extreme taphonomic processes is expected to be more difficult than assessing child abuse in older age categories.

Question 2: Can patterns be modeled that are widely applicable regardless of temporal context?

- **Research hypothesis:** It is hypothesized that modeled patterns of taphonomic processes and abusive trauma will be widely applicable regardless of temporal context.
- **Null hypothesis:** Modeled patterns of taphonomic processes and abusive trauma will not be widely applicable.

Child abuse patterns are almost entirely discerned from the modern, clinical literature. Modern cases of child abuse are often accompanied by greater contextual information, eyewitness accounts, and confessions, leading to a greater number of known child abuse cases in the present compared to those suspected in ancient contexts. Thus, this study aims to develop a model based on this modern literature. In addition to the modern, clinical literature on child
abuse, the model will consider archaeological literature on taphonomic processes and patterning. Thus remains the question: Can trauma patterns developed from modern data be used to analyze trauma in archaeological collections, and can taphonomic patterns modeled on archaeological data be applied to modern cases?

A model based on pattern recognition drawing from modern, clinical literature is expected to be applicable to both archaeological and medicolegal cases of suspected child abuse. Expectations are based on the literature, which show no significant differences in skeletal patterns of child abuse throughout time or between location. Perpetrators of abuse typically target the same areas regardless of context, often mimicking acts of aggression, carried out by punches, kicks, and blows to the face (Redfern 2017b). Therefore, patterns of child abuse derived from modern cases are expected to translate well in an archaeological context if preservation permits. It is expected that taphonomic bias may obscure accurate analysis of trauma in the past, as juvenile remains are particularly vulnerable to postmortem damage, erosion, and fragmentation.

Manifestations of taphonomic processes in juvenile bone have not been shown to differ temporally regarding type of alteration, though the extent to which processes alter bone may grow more extreme over long periods of time. The biomechanical properties of juvenile bone remain the same in ancient and modern contexts, and taphonomic processes are expected to take the same toll on juvenile remains regardless of temporal context. Differences in susceptibility to taphonomic processes may be explained by malnutrition and disease and specific burial context, but not by temporal specificity.
Objectives and General Expectations

The purpose of this project is to establish a model that can be used in future studies involving analyses of juvenile remains in both archaeological and medicolegal contexts. A primary objective is to explore the intricacies of taphonomic damage and trauma as it correlates with the different age categories of juveniles. It is expected that patterns of taphonomic damage will differ from patterns of trauma, and that certain age categories will differentially experience both. However, accurate assessment of trauma may be complicated by the differential bone biomechanics of children compared to adults and confounding taphonomic factors. Therefore, this project occupies the role of a much-needed pilot study in the trend toward more nuanced studies of children and contextualized violence.

Summary

Undertaking a trauma- and taphonomy-focused project requires the review of a large body of literature detailing the unique qualities of the juvenile skeleton. This chapter has highlighted the need for more specific child-focused research if children are to be better served by biological anthropologists. The juvenile skeleton is compositionally different from that of adults, therefore cannot be studied based on adult methodology. It is more flexible due to having a greater organic component, has more trabecular bone, and more unfused elements, meaning its relationship to stress and trauma cannot be assessed according to the adult trauma response, nor can patterns of child abuse be based on adult domestic or other types of violence. Because of these differential biomechanical properties, juvenile remains are also affected by taphonomic processes in unique ways.
The literature review above has outlined expectations regarding patterning of abuse and postmortem damage. It has also established that the infant, child, and adolescent skeleton should be considered separately. Trauma is expected to be found primarily on the limbs and cranium, with a lower frequency of thorax injuries, whereas taphonomic processes are expected to target the thorax and regions of the skeleton where there is a greater proportion of trabecular to cortical bone (e.g., the metaphyses of long bones). Infants are expected to suffer the most from both trauma and postmortem damage, with frequencies of both decreasing as age increases.

This thesis is contextualized within scant literature addressing taphonomic processes as they affect children in addition to scant literature on child-specific trauma patterns. The goal is to assess patterns of both trauma and taphonomic processes in one discussion focused on demystifying analyses of child abuse. Differing patterns of trauma and postmortem damage are expected, as is differential vulnerability correlated with age category. Lastly, it is expected that modeled patterns of trauma and taphonomic damage will be widely applicable regardless of temporal context. Taphonomic bias obscuring trauma markers is expected to account for many of the complications that ensue when trying to accurately assess child abuse in the past, or in more modern cases affected by damaging postmortem processes.
CHAPTER IV

MATERIALS AND METHODS

Introduction

The following chapter identifies the materials and methods used for data collection and data analysis. First, the two samples used in this study are presented, each with details on composition, collection, and context. Next, this chapter introduces methods of data collection, including methods used to analyze skeletal materials and methods used to recode existing data. Lastly, methods of data analysis are discussed. This section details the creation of a digital database for use in this thesis along with methods of statistical analysis.

Materials

The sample used in this study is composed of individuals from one archaeological collection and a single forensic database. Archaeological data were collected on individuals housed in the Center for American Archeology (CAA) repository in Kampsvisle, Illinois. Forensic data were collected and recoded from the Infant Injury Database (IID), a compendium of juvenile autopsy data from Harris County, Texas.

The Center for American Archeology Skeletal Collection

The Center for American Archeology (CAA) in Kampsvisle, Illinois houses archaeological collections excavated from within the Lower Illinois River Valley (LIV). The Lower Illinois River Valley and surrounding region has been inhabited fairly continuously since approximately 9,000 BCE, according to radiocarbon dates (Styles and McMillan 2009; Wiant et
al. 2009). Burials for this study span the Middle Woodland to Mississippian periods (50 BCE-1350 CE), during which time significant cultural and societal developments occurred. In the Middle Archaic Helton Phase preceding the Middle Woodland period, mortuary practices had distinct signifiers with significant changes over time. Adolescents and older children were buried on bluff tops whereas infants and younger children were often buried in midden deposits alongside the very sick or old, perhaps reflecting a society that devalued those who could not contribute to their community at the capacity of able adults and adolescents (Buikstra 1981). By the Middle Woodland period, all individuals came to be buried in bluff edges or in mounds in the valley itself. The Middle Woodland period, dating from approximately 50 BCE to 400 CE, is typically characterized by the florescence of the Hopewell tradition, a period of rising structural complexity and during which long-distance trade or direct procurement occurred (Struever and Houart 1972). During this time, archaeologists acknowledge a male-dominated funerary tradition with an increase in grave goods and a preponderance of primary burials (Buikstra 1972). In addition, mounds were central structures in mortuary practice.

The Late Woodland period is estimated to have begun around 400 CE and continued to 1000 CE (King et al. 2011). It is frequently associated with the decline and eventual disappearance of the Hopewell tradition and a rise in population size contemporaneous with the intensification of maize cultivation and a subsequent decline in skeletal indicators of health. Females came to occupy central burials in addition to males, reflecting a change in the funerary tradition (Buikstra 1984). The Late Woodland period also witnessed the reemergence of cremation, a practice not common during the preceding Middle Woodland period (Buikstra and Goldstein 1973). Individuals in Late Woodland burials were found in flexed or semi-flexed positions and secondary burials became common alongside primary interment. Often a period of
decomposition in the crypt occurred, where bodies could be viewed, which was then followed by
the bundling of bodies for burial within the mound structure (Connor 1984). This practice has
resulted in a prevalence of disarticulated skeletons within the mound structures. The Late
Woodland period was followed by the Mississippian period (approximately 1000 CE to the point
of colonizer contact) (Connor 1984). During this time, valley peoples engaged in heightened
interaction with Cahokia, and archaeologists have deduced a period of more frequent
interpersonal violence based on antemortem trauma patterns (Connor 1984). The LIV sites used
for analysis in this project were primarily excavated in the 1970s under the direction of Jane
Buikstra in association with the Center for American Archeology.

A total of 100 juvenile individuals were selected for analysis. These individuals were
identified based on completion of skeletal remains and the potential for adequate data collection.
Of these, 40 are infants (birth–one year), 59 are children (one–14.6 years), and one is an
adolescent (14.6–17 years). The sample spans various time periods and site locations. Middle
Woodland, Late Woodland, and Mississippian burials are included in the sample from Gibson,
Helton, Ledders, and Carter sites.

The Infant Injury Database

As the CAA sample is not known for violence or violent deaths, a second sample was
needed to model abusive trauma patterns. The Infant Injury Database (IID) was created and is
managed by the Harris County Institute of Forensic Sciences (HCIFS) (Soto Martinez et al.
2019). The IID sample used here is a compilation of data collected from 101 infants and children
(0–5 years of age) who underwent autopsies at the HCIFS. The 0–5 years age range encapsulates
the age range in which most cases of fatal child maltreatment occur (Soto Martinez et al. 2019),
and the IID sample is specifically comprised of 68 infants and 33 children. Causes of death for
those in the IID include and are categorized into the following: “undetermined, sudden infant death syndrome (SIDS), co-sleeping, asphyxia/drowning, infectious, trauma, natural-other, and pending” (Soto Martinez et al. 2019). Manner of death subcategories are also conveyed, and include “natural-SIDS, natural-other, undetermined-undetermined, undetermined-co-sleeping, homicide, and accident” (Soto Martinez et al. 2019). In addition, the IID presents specific information regarding skeletal injuries, which is the focus here, but also includes data on external and internal soft tissue observations and intracranial hemorrhage (ICH) for each infant and child.

Methods

Methods of data collection differed for each sample, as the CAA collection and the Harris County IID were unique in composition and accessibility. However, all data were standardized and input into a single database to facilitate comparative data analysis. The individuals from the CAA collection were analyzed morphologically via direct observation for data on trauma and pathological and taphonomic processes. However, data on the Harris County individuals were simply recoded from the IID, after access was granted by the Harris County Medical Examiner’s Office. Methods of data collection on both samples are detailed below.

Methods of Data Collection

The Center for American Archeology Collection

Morphological observation was the primary method of data collection for all individuals in the CAA collection housed in Kampsview, Illinois. All individuals were personally assessed by the researcher in initial age-at-death construction and in evaluation of trauma and pathological condition to avoid any bias incurred from knowledge of existing skeletal reports.
Data was collected using a standard form created for this project by the researcher (see Appendix A).

**Age-at-Death Estimation.** Age-at-death estimations were conducted for all juvenile skeletons at the onset of data collection. The process integrated dental development and epiphyseal union methodology. Dental age ranges followed the London Atlas of Human Tooth Development and Eruption, put forth by AlQahtani et al. (2010). Developmental features including crown and root completion were observed morphoscopically, as were patterns of eruption. Age ranges corresponding to epiphyseal union and skeletal development followed procedures outlined in Schaefer et al. (2009) and Scheuer and Black (2004). Dental age ranges were privileged over those of epiphyseal union due to the more precise timing and patterning of dental development (Scheuer and Black 2004), and due to inherent variability in skeletal maturation and greater susceptibility of the postcranial skeleton to environmental and pathological stress.

**Trauma, Pathological Condition, and Taphonomic Processes.** A standard data collection form was constructed for use in this project. The form was created in a checklist format that includes regions of the skeleton most vulnerable to intentional violence and those most susceptible to postmortem damage. Categories and descriptors used throughout the data collection form were sourced from the literature on child abuse, skeletal trauma, and taphonomy (Cooperman and Merten 2001; Guy et al. 1997; Kleinman et al. 2011; Love et al. 2011; Manifold 2012; Ogden 2000; Pokines and Symes 2013; Redfern 2017a; Schaefer et al. 2009; Wedel and Galloway 2013). The format of the form was created with the goal of standardization in mind, and it was modeled on widely used standards forms in the field (Buikstra and Ubelaker 1994; Pathology Module of Osteoware™).
Data collection using the established form included morphoscopic observations of trauma, pathological condition, and taphonomic processes in the juvenile skeleton. As previously noted, age-at-death was recorded first. In addition, notes on burial context, derived from field notes and reports provided by the CAA, were made prior to making any skeletal observations. An inventory for each individual was also constructed by filling in a homunculus, and completeness scores were attributed to each element observed, with the categories of 0-25%, 25-75%, and 75-100%.

Skeletal observations specifically focused on those regions of the juvenile skeleton targeted most frequently in cases of abuse (the skull, ribs, clavicles, and extremities) and those most susceptible to postmortem damage (facial bones, vertebrae, and sternum). Each region was assessed for characteristics typical of taphonomic processes and trauma. In the case of paired elements, left and right sides were assessed individually. When siding was not possible, observations were considered to have involved the left side. Regarding taphonomic processes and postmortem damage, all elements were observed for postmortem bone destruction (damage to the element resulting in missing portions or fragments), surface erosion (typically characterized by trabeculae exposure), animal scavenging, and other damage. Observations that fell in the “other” category included excavation damage, such as trowel cut marks, root etching, and histology sample cuts drilled out of the distal ends of some long bones.

Any breaks to the bone, whether traumatic or taphonomic in nature, were categorized as fractures, and observed with attention to detail regarding various characteristics of breaks. Characteristics included fracture location (localized vs. diffuse), fracture morphology, and fracture timing. Making observations of fracture morphology entailed recording shape of the fracture, directionality of fracture propagation, and coloration of the fracture or break, among
others (Appendix A). The skeleton was also observed for traumatic injuries more common in abuse cases. In the skull, this included endocranial lesions characterized by bony hair-on-end projections. Long bones were observed for evidence of the classic metaphyseal lesion (CML), and along with the ribs and clavicles were observed for greenstick fractures.

Timing of fracture was marked as postmortem for breaks not observed to be traumatic in origin. For traumatic fractures, more subcategories of fracture timing were considered, as this timing should be indicative of past life events. Thus, antemortem trauma was distinguished from perimortem trauma. A fracture with no signs of healing (e.g., a fracture callus) was considered a perimortem injury, whereas that accompanied by evidence of healing will indicate an antemortem injury. In addition, observations of timing included specification of chronic versus acute injury. As chronic trauma more likely indicates abuse, the presence of multiple fractures in various stages of healing should be indicative of chronic sustained trauma, likely due to physical abuse (Cooperman and Merten 2001).

Pathological conditions characteristic of nutrient deficiency and delays in skeletal maturation were also included in the data collection procedure. Caution was taken in interpreting these skeletal changes for archaeological populations, due to the prevalence of nonspecific stress indicators in these times due to factors other than violence (Cook and Buikstra 1979). Cook and Buikstra (1979) note that children in the Late Woodland period experienced heightened physiological stress compared to previous time periods, which may result in more frequent observations of pathological conditions that reflect nutrient deficiency, physiological stress, and disease. Therefore, linear enamel hypoplasias (LEH), porotic hyperostosis, cribra orbitalia, dental caries, Harris lines, and bowing of the limbs were recorded, though primarily for use in modern contexts of analysis in industrialized nations. These indicators will be taken into
consideration if patterns of abuse are observed in the archaeological individuals, though they will be considered less substantive in archaeological populations than in modern contexts. Because these indicators can arise due to lack of proper medical care, resource deprivation, or other environmental stress, it would be inappropriate to use them as significant indicators of child abuse without other lines of evidence in ancient contexts, or in regions of the world where these issues are not uncommon. However, these pathological conditions may prove as useful supplements where there is otherwise strong indication of physical abuse.

Other notable trauma or pathological anomalies were noted. Though certain regions of the skeleton are known to be more frequently targeted in abuse cases than others, instances of trauma and pathological condition outside these principal regions were recorded as well. Congenital conditions, physical disability, and presence or absence of prematurity were also recorded. As discussed in the literature review, disabled children are shown to disproportionately suffer from abuse and this social factor must be taken into consideration when collecting and analyzing data. Lastly, all information was recorded on a homunculus to visually illustrate the patterning and distribution of any trauma, pathological conditions, and taphonomic processes. Data were collected for all 100 individuals from the CAA collection.

The Infant Injury Database

In addition to collecting data on the archaeological samples, data were collected on 101 juvenile autopsy cases of fatal child abuse, sampled from the Infant Injury Database (Soto Martinez et al. 2019). Because minimal trauma was expected to be detected in the archaeological sample given its context, data from individuals with known trauma was necessary to develop comparative patterns. It is important to note that all individuals in the IID sample were victims of fatal child abuse. Therefore, all analyses and interpretations view any observed patterns through
the lens of intentional violence, not accidental injury. It is possible some of the injuries suffered by these individuals occurred accidentally; however, without this information and for the purposes of this study, all fractures are assessed within a conceptual framework of violence.

Data collection on the IID consisted of recoding existing data collected by the HCIFS forensic anthropology team. The IID does not record taphonomic data, so data collection was limited more specifically to that of trauma. Like the individuals from the CAA collection, age categories were recorded for all individuals comprising the IID. All individuals in this sample were infants and children. To maintain consistency, the only trauma data recorded were those that aligned with the existing data collection protocol used for the CAA collection. For each individual, fracture presence, location, timing, and certain fracture types (e.g., complex fractures of the cranium and CML) were recorded. Data were collected on the same elements analyzed in the CAA collection, with the exception of the sternum, as this was not included in the IID. The IID included many more trauma variables than what are considered in this study (e.g., cause and manner of death and other types of traumatic fractures), and these were not included in data collection or analysis to ensure the scope of this project remain streamlined. As previously mentioned, no taphonomic data were available for analysis, nor were data on pathological conditions. Instead, the IID’s utility stands out as presenting a breadth of specific trauma data that help to establish contrasting patterns with the taphonomic processes observed in the CAA collection.

Methods of Data Analysis

A digital database built in SPSS v. 27 was created to facilitate data analysis. After all data were collected on the CAA collection, they were input into this database. Not all variables
were applicable to both samples. For example, the IID did not record taphonomic data, so these variables were simply coded as “Not Applicable.” Though certain variables required complex coding (e.g., specific long bone and rib locations), typical coding of variables included: 0: Absent, 1: Present, and 9: Unobservable or Not Applicable for all taphonomic processes, morphological characteristics of fractures, locations of skeletal markers, and pathological processes.

Once all data were input and appropriately recoded, data were analyzed in SPSS v. 27. To establish patterning of preservation, postmortem damage, and erosion and fracture presence, location, morphology, and timing, simple cross-tabulations were calculated to establish frequencies of prevalence. Frequencies concerning taphonomic processes were calculated from within the CAA collection data, and trauma frequencies were largely derived from the IID data. When comparative analyses were possible, chi-square and Fisher’s Exact tests were run within and between samples. These nonparametric tests have utility in analyzing the nominal and ordinal variables comprising this dataset. However, there were not many instances when these tests were possible due to small sample sizes. When 20 percent or more of the cells calculated in cross-tabulations had values less than five, and two-by-two cross-tabulations were possible, the more conservative Fisher’s Exact test was performed. Variables were considered to be significantly correlated at α=0.5. Ultimately, and due to the fact that each sample collected largely different data – the CAA focusing on taphonomic data and the IID on trauma – data analysis and interpretation rely heavily on the construction of patterns derived from frequency calculations within each respective sample.
Summary

This chapter has detailed the background and context of the CAA skeletal collection and the IID, the materials used in this study. In addition, it has outlined methods of data collection for each sample. Due to the inherent differences between samples, data collection protocols differed. Where morphological observation was the focus for data collection on the CAA collection, detailed recoding of existing data guided that on the IID. The data collection protocol relied on patterns and suggestions derived from the existing literature, and it should be reviewed and updated in future studies. Lastly, this chapter briefly outlined the methods of data analysis that were employed for this thesis. Considering the foundational differences between samples, data analysis primarily involved simple cross-tabulations for frequency patterning and chi-square or Fisher’s exact tests when possible. The following chapter presents the results of these analyses.
CHAPTER V

RESULTS AND PRELIMINARY EVALUATION

Introduction

The following chapter presents the results of data analysis, following the methodology detailed in Chapter IV. This chapter is divided into seven primary sections. First, general information on sample demographics and relevant context is provided. Second, results of comparative analyses between samples regarding fracture location and type are presented. The third and fourth sections detail specific patterns of taphonomic processes and traumatic injury, respectively. In the fifth section, patterns of pathological processes as observed in the CAA collection are given. The sixth and seventh sections confer patterns of age correlation with taphonomic processes and abusive trauma, respectively. A summary of results is provided at the conclusion of the chapter. Discussion of these results follows in Chapter VI.

Sample Information

The sample analyzed in this thesis was composed of 201 individuals. Of these 201, the CAA collection contributed 100 and the IID 101. Though all individuals under the age of 17 were included in the sampling parameters, infants (aged birth to one year) and children (1-14.6 years) comprised the entire sample, with the exception of one adolescent (14.6-17 years). Forty-one infants, 58 children, and the sole adolescent make up the CAA sample. The IID sample is comprised of 68 infants and 33 children. This reflects the literature detailing the greater
prevalence of fatal child abuse in infants compared to children. Table 1 summarizes this age distribution. More detailed demographic information accompanied the IID individuals (e.g., cause and manner of death); however, age-at-death is the only criterion pertinent to this study.

Table 1. Age Distribution of the CAA and IID Samples

<table>
<thead>
<tr>
<th>Collection</th>
<th>Infants</th>
<th>Children</th>
<th>Adolescents</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>CAA</td>
<td>41</td>
<td>41.0</td>
<td>58</td>
<td>58.0</td>
</tr>
<tr>
<td>IID</td>
<td>68</td>
<td>67.3</td>
<td>33</td>
<td>32.7</td>
</tr>
<tr>
<td>Total</td>
<td>109</td>
<td>54.23</td>
<td>91</td>
<td>45.3</td>
</tr>
</tbody>
</table>

Comparative Results Between Samples

To test the first hypothesis, which expects taphonomic processes and abusive trauma to manifest in distinct patterns, a series of analyses was conducted. The first section of results is presented here and considers general patterning of fracture location and certain fracture types between the CAA and IID samples. Due to the distinct nature of data collected for each sample – the CAA sample comprised mostly taphonomic data and IID of solely trauma data – few comparative analyses were possible. However, it is possible to establish certain comparative patterns that can aid in distinguishing these various types of skeletal markers. It is also important to restate that “fracture” applies to both postmortem breaks and traumatic fractures alike.

Therefore, when considering “fracture location” below and due to the nature of each sample’s data composition, the CAA collection may be assumed to represent postmortem breaks and the IID sample used to reflect traumatic fractures of abuse victims.
Fracture Location According to Sample

Certain skeletal elements were expected to be more vulnerable to taphonomic processes and others to trauma. To test this expectation, fracture presence according to specific location was compared between the CAA and IID samples. All crania in the CAA collection were fragmented to some degree, so these cranial elements were not compared to the IID for fracture location. However, specific cranial bones within the IID sample were compared for trauma prevalence, and those results presented in a following section. Skeletal regions pertinent for analysis of fracture location included the clavicles, ribs, and long bones. These regions were selected for analysis as they are typically analyzed with regard to specific segments of each bone (e.g., epiphysis vs. metaphysis vs. diaphysis). Vertebrae and sterna were not compared as they were not analyzed with the same degree of specificity of location.

Data were collected on individual left and right clavicles, but in the interest of developing region-specific generalizations, these data were aggregated into one score per individual for analysis. The clavicle was divided into three locations for analysis, and the lateral third, middle third, and medial third were all observed for fracture presence. Figure 1 illustrates the differences between fracture location in the CAA sample (postmortem breaks) and the IID sample (trauma).
Figure 1. Bar chart depicting clavicle fracture location in each sample.

Figure 1 suggests a stark difference in location prevalence between samples. However, it is important to note that there were only three cases of clavicle trauma in the IID sample. Therefore, due to the small sample size of clavicle trauma in the IID no significant conclusions can be drawn comparing the IID and CAA samples.

Like the clavicles, ribs were initially observed according to side, though data from the left and right sides were aggregated for fracture location analysis. The first set of results depicts a more general summary of fracture location and is illustrated in Figure 2. Here, overall fracture location is presented, and shows the prevalence of rib fractures in multiple locations compared to individuals with rib fractures in one single location. The second set of results presents specific frequencies of fractures occurring in each of the decided locations: posterior, postero-lateral, midshaft, antero-lateral, and anterior. These results are presented in Figure 3.
Figure 2. Bar chart depicting prevalence of overall fracture location.

Figure 3. Bar chart depicting specific frequencies of rib fracture locations.
Figure 2 shows the general patterning of aggregated fracture location data to be quite similar. In both samples, fractures were more likely to be present in multiple locations than one single location. Of the observable postmortem breaks in the CAA sample, 96.7 percent occurred in multiple locations. No individuals had fractures occurring in only one location, with the exception of 3.3 percent of the sample with anterior-only fractures. Regarding traumatic fractures in the IID, 71.4 percent of observable cases consisted of rib fractures in multiple locations. Anterior-only fractures were the next most frequent, followed by solely posterior, antero-lateral, and postero-lateral fractures. Data on midshaft fractures were not recorded in the IID.

Though statistical significance could not be reached regarding these aggregated location data due to small sample sizes in each collection, statistical significance could be evaluated for specific frequencies of each fracture location between samples. Figure 3 illustrates distinct patterns of fracture location for postmortem fractures (CAA) and traumatic fractures (IID). Chi-square tests reveal statistically significant results for postero-lateral, anterior, and antero-lateral fractures. There was no statistically significant difference in posterior rib fractures between samples ($\chi^2=2.850$, df=1, $p=.091$) and midshaft fractures were not compared here because these data were not recorded in the IID. A chi-square test ($\chi^2=16.494$, df=1, $p<.001$) comparing postero-lateral fractures revealed this location to be more common in the CAA sample compared to the IID sample (85.2 % vs. 48.9 %). Anterior rib fractures were found to be more common in the IID sample (85.1 % vs. 29.3 %) and this difference was statistically significant ($\chi^2=32.569$, df=1, $p<.001$). Lastly, analysis revealed a higher prevalence of antero-lateral fractures in the CAA sample (72.1 % vs. 41.7 %; $\chi^2=10.285$, df=1, $p=.001$). These data suggest postero-lateral and antero-lateral fractures may be more characteristic of postmortem damage and anterior fractures more characteristic of trauma; however, all locations were
common fracture sites, so fractures in any one of these locations cannot be considered diagnostic of solely postmortem damage or abusive trauma.

Long bone fracture location patterning was assessed similarly to that of the ribs. All data from humeri, radii, ulnae, femora, tibiae, and fibulae were aggregated to develop a more generalized pattern of fracture location. Long bone fractures were assessed for the following locations: proximal epiphysis, proximal metaphysis, diaphysis, distal metaphysis, and distal epiphysis. As with the ribs, a more general pattern based on aggregated and generalized data is presented and is summarized in Figure 4. Specific frequencies of each fracture location according to sample are illustrated in Figure 5.

![Long Bone Fx Location, Aggregated](image)

**Fig. 4.** Bar chart illustrating the prevalence of generalized long bone fracture locations.
The patterning illustrated in Figure 4 suggests that postmortem breaks and traumatic fractures are both more commonly found in multiple locations within an individual than fractures in just one location. Out of the observable CAA cases, 89.9 percent had fractures in multiple locations, with diaphysis-only fractures being the second most frequent at 7.9 percent. In the IID sample, 61.1 percent had fractures in multiple locations. These results also suggest single-location fractures may be more prevalent in cases of trauma compared to those of postmortem damage.

Figure 5 highlights more significant patterning. Neither sample had a high prevalence of epiphysis fractures, in large part due to the fact that many individuals in these samples did not have epiphyses due to their young age, and those existing epiphyses tended to be better-preserved than other areas of the long bones. Significance lies in the patterning of metaphyseal and diaphyseal fractures. More proximal metaphyseal fractures (86.4 % vs. 62.1 %) were found.
in the CAA collection compared to the IID sample ($\chi^2=8.151$, df=1, $p=.004$). There was also a statistically significant difference ($\chi^2=33.900$, df=1, $p<.001$) between prevalence of diaphyseal fractures in each collection (90 % in the CAA sample vs. 37.9 % in the IID). Lastly, distal metaphyseal fractures were also more common in the CAA sample (86 % vs. 69 %) and this difference was statistically significant ($\chi^2=4.239$, df=1, $p=.040$). Both metaphyses and the diaphysis were equally common targets of postmortem damage, and when one was fragmented, the others were likely to be as well. This contrasts the IID data, which suggest that metaphyseal fractures are more common in cases of traumatic injury in the juvenile skeleton compared to diaphyseal fractures.

**Comparing Prevalence of Fracture Type Between Samples**

The only fracture type that was statistically comparable between samples was complex fractures of the cranium. A chi-square test indicates statistical association between sample and fracture prevalence ($\chi^2=90.362$, df=1, $p<.001$) and Figure 6 illustrates these results.

![Complex Fractures of the Cranium](image)

**Fig. 6.** Bar chart depicting the prevalence of complex fractures of the cranium in each sample.
Of the observable cases in the CAA sample, 84.3 percent (70/83) had a complex fracture in at least one cranial bone, compared to 14 percent (14/100) in the IID sample. This stark difference in prevalence can be attributed to the fact that nearly all juvenile crania were highly fragmented or damaged in the CAA sample. Therefore, complex fractures may be more diagnostic of postmortem damage than traumatic injury, or more specifically child abuse. In addition, all individuals were observed for presence of the classic metaphyseal lesion (CML). There were no cases of CML in the CAA sample, and part of this absence may be due to information loss due to the high prevalence of PMD and fragmentation in long bone metaphyses. More details relating to CML are presented in the section on trauma patterning.

Further Patterning of Taphonomic Processes

Though analyses directly comparing patterns of taphonomic processes to those of trauma were limited due to the inherent differences in sample composition, it was possible to deduce specific patterns in each case that still hold clarification value. General patterns of postmortem damage (PMD) and postmortem fractures are presented in an upcoming section on age correlations and are not presented here. To address the first hypothesis, which expected taphonomic processes and abusive trauma to manifest in unique patterns, this section considers fracture morphology patterns of certain elements. To address the second hypothesis, which expects these patterns to be widely applicable regardless of context, site-specific preservation is analyzed, and erosion prevalence patterned to address the issue of taphonomic bias in trauma assessment via information loss.
Fracture Morphology

Most morphological variables included in the data collection protocol for the CAA collection (see Appendix A) were not analyzed. Due to the fact that the IID does not include data on fracture margin morphology, most of these variables hold no comparative value. However, pattern development of certain variables serves two purposes: (1) to aid the discussion on distinguishing postmortem from traumatic fractures, and (2) to address the issue of taphonomic bias in trauma assessment.

Juvenile crania in the CAA sample were generally highly fragmented, making specific and detailed assessments of fracture morphology difficult. However, it was possible to ascertain certain patterns. Figure 7 illustrates the prevalence of localized versus diffuse fractures of the parietal, occipital, and temporal bones.

**Fig. 7.** Bar chart depicting prevalence of localized vs. diffuse trauma in the cranial vault bones.
Diffuse fractures (those occurring in more than one location on the bone) were significantly more frequent than localized fractures in the CAA sample. They were most common in the parietals (left and right aggregated) at 93.5 percent prevalence compared to 6.5 percent prevalence of localized fractures. Diffuse fractures of the occipital occurred in 83.5 percent of the sample compared to localized fractures in 16.5 percent. Though still comprising the majority of the temporal sample, diffuse fractures had a lower prevalence (65%) in these elements (left and right aggregated), and localized fractures a slightly higher prevalence at 35 percent. These data suggest diffuse cranial fractures to be more characteristic of postmortem damage than isolated, localized fractures.

Certain morphological features of cranial fracture margins were also patterned. The features with the greatest ambiguity when assessing fracture timing (antemortem or perimortem vs. postmortem) were selected for analysis. These results are presented in Table 2.

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<td>7/78</td>
<td>37/79</td>
<td>51/79</td>
<td>2/79</td>
<td>18/79</td>
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<td></td>
<td>(9.0%)</td>
<td>(46.8%)</td>
<td>(64.6%)</td>
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<td></td>
<td>2/69</td>
<td>0/68</td>
<td>20/70</td>
<td>23/69</td>
<td>17/70</td>
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<tr>
<td></td>
<td>(2.9%)</td>
<td>(0.0%)</td>
<td>(28.6%)</td>
<td>(33.3%)</td>
<td>(24.3%)</td>
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These data reveal crushing fractures to be the least characteristic of postmortem breaks in the CAA archaeological collection. Complex and linear fractures and multiple intersecting fractures had the highest prevalence, explained by the high degree of fragmentation.
in nearly all juvenile crania. Plastic deformation (warping) of the cranial elements was not uncommon in the parietals and occipitals. These results reveal the need to approach these fracture types with caution. Oftentimes plastic deformation, linear fractures, and crushing fractures are associated with perimortem injury, though these results show they are not uncommon in cases of postmortem damage.

Specific fracture margin morphologies for the clavicles, ribs, and long bones are not presented or discussed in this thesis, due to time constraints and general lack of comparative value with the IID data. The only fracture type in these elements relevant for discussion is greenstick fractures of the ribs. Greenstick fractures were expected to be uncommon in cases of postmortem damage. This expectation was supported by the CAA data, which revealed only five instances of greenstick fractures in the entire observable sample. It can be concluded that greenstick fractures, although not impossible occurrences in postmortem circumstances, are not common fracture types associated with taphonomic damage.

**Site-Specific Preservation**

To assess whether completeness of remains differed significantly according to archaeological site, general frequencies of inventory scores were calculated and compared. Statistical analysis was not possible due to small sample sizes across sites. Figures 8, 9, and 10 illustrate trends in cranial completeness by site.
Fig. 8. Bar chart comparing cranium completeness between sites.

Fig. 9. Bar chart comparing thorax completeness between sites.
Cranium, thorax, and long bone preservation was not identical between all four sites, supporting the expectation that burial context and mortuary ritual may influence the effects of taphonomic processes. Here, “preservation” refers to overall completeness of each region and does not necessarily account for the quality of remains present. General trends revealed Carter to have slightly worse-preserved crania than the other sites, as 35.3 percent of the sample had an inventory score of one (0-25 % complete). Ledders was shown to have slightly more complete crania, as 35.5 percent of the sample had an inventory score of three (75-100 % complete). More noticeable differences exist in thorax scores across sites, and this was the worst preserved region of the skeleton. Ledders and Gibson had slightly more complete thorax regions than Carter and Helton. Scores of one (0-25 % complete) dominated the Carter and Helton sites at 70.6 percent and 63.2 percent prevalence, respectively. There were noticeable differences among long bone completeness as well. Gibson had the best-preserved long bones, as only 9.1 percent of the
sample had a score below two (<75 % complete), and Helton and Carter similarly had the least complete long bones out of all sites.

**Erosion**

Surface erosion prevalence by specific region and element was patterned to evaluate which regions of the skeleton were more susceptible to this taphonomic process, and thus more vulnerable to surface information loss. Figure 11 illustrates this pattern.

**Fig. 11.** Bart chart depicting erosion prevalence by element/region.

Erosion was shown to differentially affect regions of the skeleton. In the skull, the occipital bone and facial bones were the most commonly affected by this process, with erosion affecting 67.9 percent of occipitals and 69.0 percent of facial bones. The temporals were eroded in 55.3 percent and the parietals in 22.0 percent of observable cases. Clavicle erosion had a 61.7 percent prevalence. The vertebrae and sternal elements were similarly eroded in approximately 90 percent of individuals. The ribs have a slightly lower prevalence of erosion, which occurred in 74.3 percent of individuals. Lastly, the long bones are revealed to have the highest erosion
prevalence, at 96.7 percent of individuals with surface erosion on at least one long bone. As expected, erosion was a common process affecting those elements with more trabecular bone.

Further Patterning of Traumatic Fractures

The IID sample yields the possibility of analyzing traumatic fracture patterns related to child abuse in greater detail. Only four cases of trauma were found in the CAA sample, all antemortem and isolated incidents, consisting of one healed, occipital pond lesion, one vertebral fracture, one fracture on a distal ulna, and one tibial fracture. Due to this small sample size, all specific trauma analyses were carried out only within the IID sample, which reflects trauma sustained in correlation with cases of child abuse. To address the first hypothesis, this section presents traumatic fracture patterning regarding prevalence and location. To address the second hypothesis, fracture timing and quantity are analyzed to evaluate whether the current findings are congruent with the existing literature and thus able to be widely applied. General trends in overall trauma prevalence are first presented in Figure 12.

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Fig. 12. Bar chart depicting general trauma prevalence by skeletal region and sample.
Figure 12 illustrates 70.1 percent of IID fatal child abuse cases to have at least fracture. All 101 infants and children in the IID sample did not incur skeletal trauma as some died from causes that may not result in fractures, such as drowning, asphyxiation, and acute drug toxicity. Bones of the skull were aggregated for analysis, as were the ribs, clavicles, and long bones. The most common fractures were those of the ribs (53.7 % of cases), followed by those of the skull, including all cranial vault, facial, and mandibular elements (29.6 %), long bones (22.2 %), and lastly the clavicles and vertebrae each at 3.3 percent.

To better understand susceptibility of each specific region to traumatic injury, frequencies were calculated for each bone. Left and right sides were aggregated for analysis. Though more specific analyses would be useful in future work, these aggregated data revealed patterns useful for comparisons between regions of the skeleton most susceptible to postmortem damage.

Figure 13 illustrates the patterning of skull trauma prevalence by specific element. Trauma to the cranial vault was more common in cases of fatal child abuse than trauma to the facial bones or mandible, as was expected. The most frequently affected element was the parietal bone, for which 21 percent of cases had at least one documented fracture. The next most frequent was the occipital (16 %), temporal (5.1 %), and frontal (5 %), and the least frequent included facial bone and mandibular fractures, at three percent each. Figures 14 and 15 illustrate patterning in the thorax and long bones.
Fig 13. Bar chart depicting prevalence of skull trauma by element/region.

Fig. 14. Bar chart depicting prevalence of thorax trauma by specific bone/region.
Figure 14 highlights the trend in prevalence of thorax trauma by region, with ribs being the most frequently affected element in cases of fatal child abuse. There was at least one rib fracture in 53.7 percent of all cases involving skeletal trauma. Clavicles and vertebrae were uncommon targets and comprised three percent each of the skeletal trauma sample. No sternal data were recorded in the IID.

Figure 15 illustrates patterning of these long bone fracture data. Left and right long bones were aggregated for analysis of trauma prevalence. The humerus was the least targeted element in cases of trauma associated with fatal child abuse, comprising just 6.2 percent of all cases: the most frequently affected element was the tibia (15.8 %). The radius, ulna, femur, and fibula all occurred at roughly 11 percent prevalence within all cases of skeletal trauma. Though not depicted in Figure 15, it is important to note prevalence of the classic metaphyseal lesion (CML). Of 21 cases of long bone trauma, 17 had at least one observed CML. This 81 percent
prevalence supports the classification of the CML as a diagnostic indicator of abuse.

Timing and Quantity of Traumatic Fractures

The second hypothesis in this thesis posits that trauma patterns modeled on modern data can be widely applicable regardless of context. To address part of this statement, it is necessary to know whether the IID trauma patterns align with current literature expectations. Patterns of fracture prevalence, such as those above, aid in doing this; however, data on number of injuries and fracture timing will assist in developing further specificity and points of significance in trauma patterning. Fig 16 illustrates these patterns below.

![Fracture Events and Timing](image)

**Fig. 16.** Bar chart depicting general trends in fracture events and timing.

Data analysis revealed a much higher prevalence of multiple fractures compared to single fractures in cases of fatal child abuse (82.4 % vs. 17.6 %, respectively). Of 68 individuals with known skeletal trauma, 56 had multiple fractures and 12 had a single fracture. It was much more likely for a child to suffer multiple traumatic injuries than for only one bone to be involved.
It was also more common for a child to suffer antemortem and perimortem injuries than solely one or the other. Of 66 cases where timing could be ascertained, 48.5 percent suffered injuries before and around the time of death. Antemortem-only injuries comprised 22.7 percent of the sample, and perimortem-only constituted 28.2 percent. The trends in Figure 16 also reveal a greater likelihood that victims of fatal abuse will suffer trauma chronically prior to death. For the purposes of this analysis, “acute” injuries were defined as single fractures occurring in single elements, whereas multiple fractures in different stages of healing in a single element was considered to be evidence of chronic trauma. The data above revealed 11.8 percent of cases to have only sustained one single, acute fracture. The remainder of cases are evidence that abuse victims much more frequently suffer multiple injuries throughout their lives. Multiple instances of chronic trauma (in one element) without accompanying trauma in other elements comprised 8.2 percent of the sample. More prevalent were cases of multiple isolated acute fractures (41 %) and cases where both multiple acute injuries and multiple instances of chronic trauma were observed (39.3 %).

Patterns of Pathological Processes

Pathological processes are briefly considered here. They serve a purpose in evaluating the claim that certain pathological indicators may accompany cases of child abuse, but may also be common due an array of other health risks. Pathological processes were not documented in the IID, therefore all results were derived from the CAA collection. Porotic hyperostosis (PH), cribra orbitalia (CO), linear enamel hypoplasias (LEH), dental caries, and bowing of the upper and lower limbs were all analyzed for general frequencies of prevalence, and these results are presented in Figure 17.
Fig. 17. Bar chart depicting prevalence of pathological processes in the CAA Collection.

Overall, these pathological indicators were not uncommon the CAA sample. Of the observable cases, CO was the most frequent pathological process, occurring in 40.8 percent of the sample (n=71). In addition, approximately one-fifth of all observable cases showed evidence of PH (21.0% of 81), LEH (22.5% of 80), dental caries (20.5% of 83), and bowing of the lower limbs (21.0% of 62). The least commonly observed pathological process was bowing of the upper limbs, at 14.1 percent of 64 observable cases.

Associations with Age: Postmortem Damage and Fragmentation

This section presents the results of analyses regarding the association of age with certain taphonomic processes in the CAA collection. Postmortem damage (PMD) and general fracture presence – typically indicating fragmentation of remains – are the two criteria evaluated here as they are the most potentially affected by the unique biomechanical properties of differently aged juvenile bone. The sole adolescent was omitted for evaluation, therefore all
analyses compared only infants and children. Pearson’s chi-square tests were performed to evaluate significance of the association between age and general preservation, PMD, and fracture presence. Results were considered statistically significant at $\alpha=0.05$. In the case of small sample sizes ($<5$) and when two-by-two cross tabulations were possible, Fisher’s Exact tests were conducted in place of the Pearson’s chi-square.

**Age and General Preservation**

To evaluate whether age was associated with overall preservation of the remains, chi-square tests were used for three categories: 1) cranium preservation, 2) thorax preservation, and 3) long bone preservation. All regions were assessed on a scale of one to three. A score of one represented 0-25 percent present, two represented 25-75 percent present, and three represented 75-100 percent present. Scores of zero (absent) were excluded from analysis. Figures 18, 19, and 20 present the results for age and cranium, thorax, and long bone preservation, respectively.

![Cranium Completeness by Age](image)

**Fig. 18.** Bar chart depicting the relationship between cranium completeness and age.
Chi-square tests revealed a significant association between age and completeness of the cranium ($\chi^2=6.118$, df=2, $p=.047$). However, there was no statistically significant effect of age on thorax completeness ($\chi^2=1.277$, df=2, $p=.528$) or long bone completeness ($\chi^2=.822$, df=2,
As shown in Figure 18, child crania were better represented than infant crania, which tended to be highly fragmented with many missing elements. Figure 19 reveals the thorax to be the worst preserved region of the three, with most individuals assigned a score of one (0-25 % present); however, this did not differ significantly according to age. Figure 20 illustrates the lack of significant difference between long bone completeness and age.

**Age and Postmortem Damage (PMD)**

To assess specific regions’ vulnerability to PMD based on age, facial bone, clavicle, sternum, vertebrae, and long bone PMD presence was cross tabulated with age category. Crania and ribs were excluded from analysis as nearly all individuals were highly fragmented and damaged in these regions. Small sample sizes in certain categories required the use of Fisher’s Exact tests to assess significance. Figure 21 illustrates the prevalence of PMD in each relevant region according to age category.

![Postmortem Damage (PMD) and Age](image)

**Figure 21.** Bar chart depicting the relationship between age and PMD in five skeletal regions.
As illustrated in Figure 21, age rarely influenced PMD. The vertebral column was the only region where age had a statistically significant association (F.E. \( p = .023 \)). In this case, vertebrae tended to be slightly better preserved in infant burials compared to those of children. There was no statistically significant relationship between age and facial bone PMD (F.E. \( p = 1.000 \)). Nearly all observable facial bones exhibited some degree of PMD. However, it should be noted that children comprised 61.7 percent of all facial bone PMD and infants, 38.3 percent. As noted during observation, these results show that smaller elements such as the zygomatic, maxillae, and nasal bones were better preserved in infant burials compared to child burials. Scores for the left and right clavicles were aggregated for analysis, and results show no significance between age and clavicle PMD (F.E. \( p = .748 \)). Similarly, there appears to be no correlation between age and sternum PMD (F.E. \( p = .718 \)). However, it should be noted that only 39 burials contained observable sterna, and this was the most frequently missing element. Lastly, results show no statistically significant relationship between age and long bone PMD (F.E. \( p = 1.000 \)). All humeri, radii, ulnae, femora, tibiae, and fibulae were scored individually, though scores are aggregated here to assist in generalizing region-based patterns. Aggregated scores reflect at least one recorded instance of PMD among all elements, showing PMD to be common in all long bones. Of an observable 92 burials, only four (two infant and two child) did not exhibit any PMD in the long bones.

**Age and General Fracture Presence**

To assess whether age and general fracture presence (reflecting postmortem breaks and fragmentation of remains) were associated, these two variables were cross tabulated for the same regions assessed regarding PMD: facial bones, clavicles, sterna, vertebrae, and long bones.
Crania and ribs were similarly excluded due to their ubiquitously fragmented nature. Figure 22 presents the prevalence of fracture presence for each region according to age category.

![Fragmentation/Fx Presence and Age](image)

**Fig. 22.** Bar chart depicting the relationship between fracture presence and age for five regions.

The summary in Figure 22 illustrates no statistical significance between age category and fracture presence by anatomical region. All five skeletal regions were similarly vulnerable to fragmentation in infants and children. It was particularly rare for facial elements to remain intact with no fractures, though this was not influenced by age ($F.E. \ p=.289$). Though a higher percentage of infant clavicles were fractured compared to children and a higher percentage of child vertebrae fractured compared to infants, these relationships are likewise not statistically significant ($F.E. \ p=.106$ and $.335$, respectively). The sternum was the region least vulnerable to fragmentation regardless of age category ($F.E. \ p=.711$), but as with PMD, it should be noted only 39 burials contained observable sterna. Results of a Fisher’s Exact test also show no statistical significance between age and long bone fractures ($F.E. \ p=.073$), though it is important to
recognize that the only cases without any fractures were all infants, potentially suggesting better preservation of the long bones in this age category.

Associations with Age: Trauma

To test whether age influenced vulnerability to trauma, comparative analyses were run between age category and overall trauma presence, trauma by region, and presence of the classic metaphyseal lesion (CML). The CML was chosen as a particularly important fracture type given its direct correlation with child abuse and location in a region frequently damaged by postmortem processes. Due to the infrequency of trauma in the CAA collection, all analyses were conducted within the IID sample. To determine significance between the aforementioned variables, chi-square tests were conducted. In cases of small sample size, Fisher’s Exact test results are reported.

Age and Overall Trauma Presence

To assess the relationship between age and overall trauma presence, all regions of the body were aggregated, and trauma was marked as present in cases with at least one fracture. To evaluate the correlation between age and trauma according to specific regions of the body, frequencies were calculated for skull, rib, and long bone trauma. Due to the limited amount of clavicle and vertebrae fractures, these elements were excluded from analysis. An illustration comparing overall trauma and trauma by region with age category is presented in Figure 23.
Fig. 23. Bar chart illustrating the relationship between age and trauma by region of the body.

Of 201 cases, 46 infants and 22 children had at least one instance of traumatic injury, and a Fisher’s Exact test indicates there is no statistically significant relationship between age and overall trauma ($\chi^2=.216, df=1, p=.642, F.E. p=.811$). Trauma was common in the IID sample regardless of age category; 68.7 percent of infants and 73.3 percent of children had at least one traumatic injury. Age also did not have a statistically significant relationship to region-specific trauma in the skull, ribs, or long bones. Skull trauma, which aggregated trauma scores for all cranial vault bones, facial bones, and mandibles, was present in 29.2 percent of infants and 30.3 percent of children ($\chi^2=.12, df=1, p=.912$). Rib trauma was assessed after aggregating trauma scores from all left and right ribs. Despite a higher overall frequency of infants with rib trauma compared to children (59.7% vs. 39.3%), age was not a significantly influential factor ($\chi^2=3.310, df=1, p=.069$). Long bone data was also aggregated for analysis, and trauma to any element (humeri, radii, ulnae, femora, tibiae, and fibulae) was considered. Results of a chi-square test
show no greater likelihood of either age category in sustaining long bone trauma ($\chi^2=.029$, df=1, $p=.642$, F.E. $p=.864$).

**Age and Classic Metaphyseal Lesion Prevalence**

To test whether infants or children were more likely to sustain a classic metaphyseal lesion (CML), all long bone data were aggregated and cross-tabulated with age. A single CML on any of the long bones was enough to code CML as present for any individual. Out of 21 cases of long bone trauma, 17 included at least one CML. However, this prevalence did not differ between age categories. For example, 19.4 percent of infants and 12.5 percent of children with long bone trauma had at least one CML, therefore no statistically significant relationship was found between age category and CML presence ($\chi^2=.726$, df=1, $p=.394$).

**Summary**

These results have revealed numerous similarities and differences within and between the CAA and IID samples. Taphonomic processes such as PMD and postmortem fractures ubiquitously affected all regions of the skeleton. No single region was significantly less affected than the others, with the exception of the sternum. However, overall completeness of remains may be affected by age. Though age was not shown to correlate with thorax or long bone completeness, results showed infant crania to be more poorly preserved than child crania. Across all age categories, the thorax was the least complete. PMD and general fragmentation were also not shown to correlate with age category (infant vs. child), except for the vertebral column, which was better preserved in infant burials. The same results were shown regarding age and postmortem fractures/fragmentation, and specific regions of the skeleton were not significantly
influenced by age at death. Complex and diffuse cranial fractures were shown to be characteristic of postmortem damage compared to more localized, linear fractures.

In cases of abusive trauma, as evidenced by the IID, the elements most commonly fractured included the ribs, long bones, and cranial bones, most notably those of the cranial vault. Specific locations of fractures in the clavicles, ribs, and long bones were shown to differ according to sample as well, and certain locations proved to be more commonly targeted by either taphonomic damage or abusive trauma. The classic metaphyseal lesion was found to be highly prevalent in cases of fatal child abuse, which remains in line with the existing literature. Cases with multiple traumas, specifically individuals with both multiple acute fractures and instances of chronic trauma, were significantly more common in cases of fatal child abuse than were instances of single, acute injuries. As with analyses of age correlation and taphonomic processes, no statistically significant relationship was found between age category and overall trauma prevalence or region-specific trauma, though a greater frequency of infants suffered rib trauma compared to children.

These results show that specific patterns for taphonomic processes and abusive trauma can be modeled. Postmortem damage and fragmentation affect different regions of the skeleton compared to trauma inflicted in cases of abuse. Certain aspects of taphonomic damage and traumatic fractures help clarify ambiguous cases. These results also show that while specific patterns can be developed, there remains the issue of certain biases and limitations. Erosion was found to commonly affect all elements, especially those with more trabecular bone, potentially contributing to information loss on the surface of remains. In addition, many regions of postmortem damage and traumatic fracture overlap. Overall completeness of remains also depends on burial context, potentially making each case of skeletal assessment uniquely
challenging. Lastly, it was shown that certain pathological processes commonly known to affect abuse victims are also common in archaeological samples. The implications of these findings and significance of all results are discussed in the following chapter. Visual summaries of patterns of taphonomic processes and abusive trauma are presented in Figure 24.

Fig. 24. Skeletal diagram highlighting areas affected by taphonomic processes (left) and areas targeted in cases of child abuse (right).
CHAPTER VI

DISCUSSION

Introduction

This chapter considers the results presented in Chapter V. The primary hypotheses and their situation within broader research questions are reintroduced and evaluated. The first section focuses on the expectations put forth by the first hypothesis. It takes the patterns modeled on taphonomic processes and abusive trauma and considers the implications of these findings. The second section address the second hypothesis and evaluates whether these patterns can be widely applied in archaeological and modern contexts. Limitations of the current study and avenues for future research are discussed in Chapter VII.

Patterns of Significance

The first hypothesis posited in this study addresses the question of whether taphonomic processes and abusive trauma manifest in unique patterns in the juvenile skeleton. It was expected that unique patterning regarding location, morphology, quantity, and timing could be discerned for both postmortem damage and traumatic injury, and the results presented in Chapter V support this hypothesis. There was an unfortunate lack of comparative value between the CAA and IID samples, though select comparisons could be made. With this in mind, the focus shifted more toward evaluating the specific patterns that might be useful to recognize for holistic and accurate analysis of remains in any context.
Prior to entering a discussion on these specific patterns, it is important to remember that trauma patterns discerned from the IID sample were modeled on known cases of fatal child abuse. Therefore, these patterns may not be applicable in contexts of accidental trauma. It is possible some of these injuries were accidental in nature, but these patterns are modeled under the assumption that they are characteristic of abuse cases specifically. Future studies exploring patterns of accidental trauma compared to abusive trauma and ultimately compared to taphonomic patterning would be helpful in interpretations of the social role of children (e.g., regarding labor or warfare), but this study is primarily concerned with clarifying obscurities as they pertain to cases of child abuse.

Combinatively, taphonomic damage to the skeleton was more widespread than fractures sustained due to trauma. Distinctions can be made when comparing element and region vulnerability to postmortem processes and susceptibility to trauma, though there was significant overlap. Taphonomic processes including postmortem damage and fractures took a significant toll on juvenile crania, resulting in a high prevalence of fragmented cranial elements with complex fractures. The cranial vault elements were often poorly preserved and fragmented into numerous small pieces and the facial bones were often eroded and incomplete. Traumatic fractures of the cranium were also found in most cases of fatal child abuse, specifically involving the parietals, occipital, and temporals. The overlap in patterning here is not due to any singular reason. The cranium is targeted in abuse victims due to violent intent. It is vulnerable to taphonomic processes due to the relative cortical thinness of the vault bones and high frequencies of unfused elements (Manifold 2014). Results of data analysis also showed high frequencies of cranial pathological conditions, such as porotic hyperostosis and cribra orbitalia. Prevalence of these pathological processes may also have contributed to the overall poor preservation of the
CAA crania, as pathological conditions are known to accelerate cranial fragmentation and degradation (Manifold 2014).

The ribs were similarly fragmented and fractured in both samples. However, specific location of damage could be patterned according to trauma or taphonomic damage. In the CAA sample, most ribs were fragmented in multiple locations, most commonly at the midshaft and postero- and antero-lateral positions. In the IID sample, ribs were similarly more often fractured in multiple locations than not, but these fractures tended to cluster in the anterior and posterior regions. Patterning in the archaeological sample may be attributed to the combined factors of general fragility of this region given the thinness of cortical bone in the ribs of infants and children and pressure from the surrounding soil matrix on the thorax region following burial. In regard to the IID data, ribs were most likely fractured in this pattern as the thorax is susceptible to injuries sustained during grabbing and shaking, and also may be a side effect of CPR.

Like the crania and ribs, the long bones proved to be common targets of both taphonomic processes and abuse. High trabecular content and low cortical thickness in these elements leave the long bones vulnerable to postmortem damage, fragmentation, and erosion, and these factors also contribute to the high prevalence of traumatic fractures found in these elements. Long bones are easily broken in falls and in cases of grabbing and shaking. Though there was overlap in general prevalence of long bone involvement, specific location of damage and injury differed between samples. Like the rib patterning, this proves useful in distinguishing between taphonomic damage and abusive trauma. Long bones fractured due to postmortem processes were commonly affected throughout the bone, and fractures found just as frequently in the diaphysis as in the metaphyses, though the metaphyses tended to be damaged to a slightly greater extent. In cases of fatal child abuse, the metaphyses were significantly more affected than
the diaphyses, which tended to exhibit more acute, antemortem injuries. This patterning supports the expectation of high metaphyseal involvement in abuse cases, namely regarding the classic metaphyseal lesion. Though the metaphyses were commonly affected in both samples, involvement of the metaphyses without diaphyseal fracture may be more indicative of cases of abuse.

Other regions of the skeleton pertinent to discussion include the clavicles, vertebrae, and sternum. These elements hold less value due to infrequency of involvement in abuse cases and common absence in archaeological burials, though certain patterns prove useful. Overall, the thorax region was revealed to be the least complete region of the skeleton, revealing loss of these smaller elements either due to taphonomic processes or oversight in recovery. Those elements that remained were not spared in taphonomic damage. The vertebrae were commonly fractured at the neural arches and portions of the centra eroded or absent. Sternal bodies were rarely present for analyses, though when observable proved to be better preserved than other elements. The clavicles were frequently fractured at multiple locations, but primarily at the extremities. These patterns regarding the clavicles and vertebrae differ compared to the those modeled from the IID (sterna data were not included in this sample). Vertebrae were rarely affected in cases of fatal child abuse. Clavicles were similarly and unexpectedly infrequent targets. When clavicle fractures were present, they were not found in multiple regions of the bone as was the case with postmortem fractures; rather all cases of clavicle trauma occurred at isolated regions of the bone.

These general location and prevalence trends reveal overall that diffuse, widespread, indiscriminate damage is more characteristic of postmortem damage than are cases of localized, distinct fractures. This is particularly seen in the crania, suffering most commonly from diffuse and complex fractures, and the long bones, almost all of which were fractured in multiple
locations. Reasons for this widespread vulnerability to taphonomic processes is likely the confluence of multiple features, including but not limited to the biomechanical properties of juvenile bone and burial context. These patterns of taphonomic damage have implications for trauma analysis, and this will be discussed in more detail in an upcoming section.

**Associations with Age**

Though the first research question was concerned more broadly with overall patterns of abuse and taphonomic damage in the juvenile skeleton, it also sought to evaluate the unique experience of each juvenile age category. It was expected that infants, children, and adolescents would each incur fractures and postmortem damage in unique ways due to the rapidly changing biological structure of juvenile bone. The results obtained in this study do not fully support these expectations, and instead show greater similarities in the experiences of different age categories of juveniles. This study only compared infants and children, as there was only one adolescent present in the sample. The only statistically significant difference comparing age category and taphonomic processes revealed children to have better-preserved crania than those of children. Time constraints prohibited the distinct analysis of age with all taphonomic variables in every bone of the cranium, thorax, and limbs, and instead required data aggregation that homogenized bones of more general regions (e.g., long bones). More specific analyses may reveal statistically significant differences between preservation of each bone. During observation, it was noted that infant vertebrae, ribs, and smaller bones of the face tended to be more complete and less damaged than those of children, and this is worth consideration in future studies.

Comparisons of age and trauma prevalence revealed no correlations between the two. Infants and children alike were equal sufferers of multiple fractures in the same regions. More infants than children tended to sustain rib fractures, though no statistical significance was found.
An important consideration that bears repeating is that all trauma data were derived from cases of fatal child abuse. Infants are the most common victims of fatal abuse, and this is reflected in the age composition of the IID sample. However, the children included in the sample also died of fatal abuse. Patterns of abusive trauma according to age category are only truly expected to differ when considering non-fatal cases of abuse, as these will most likely occur in older children and adolescents, and it is only with development of biological age that biomechanical properties begin to change enough to affect trauma manifestation. Thus, patterns specific to age category are not deduced here to any significant degree, and the homogenous nature of infant and child patterning can be attributed to these aforementioned stipulations. Developing more specific patterning of abusive trauma according to age is a much more difficult task. It is difficult enough to come across juvenile remains for analysis (for both good and unfortunate reasons), but children who survive abuse often go unheard and untreated, thus their lived experience of trauma goes undocumented.

Model Applicability and the Issue of Taphonomic Bias

The second hypothesis expected these models of taphonomic damage and abusive trauma to be widely applicable regardless of temporal context. These expectations were based on the literature, which suggests domestic violence, including child abuse, to be patterned similarly regardless of location or temporal context. The literature also suggests differential susceptibility to taphonomic processes to differ not due to amount of time spent buried, but rather as a result of specific burial context and as an extension of individual skeletal biology. The deciding factors in evaluating whether the patterns found in this study are in fact broadly applicable are: 1)
congruence of findings with the literature, and 2) overlap in patterning to determine the possible effects of taphonomic bias.

The trauma patterns modeled on the IID data are aligned with the expectations posited by modern literature on child abuse. Fractures occurred in the expected regions – ribs, cranium, and long bones – and in expected patterning with regard to timing. The data show that most victims of fatal child abuse suffered multiple injuries throughout life and around the time of death, including both multiple counts of acute, isolated injuries and multiple instances of chronic trauma. To assess whether taphonomic processes would differ significantly according to context, overall completeness of skeletal regions was compared with archaeological sites of the CAA sample. Statistically significant results were unobtainable due to small sample sizes, but certain sites (Gibson and Ledders) were revealed to have slightly better-preserved skeletons compared to others (Helton and Carter). There were no extreme completeness differences however, and any distinctions are likely attributable to specific burial context. To more accurately assess whether taphonomic processes are patterned in the same ways regardless of context, more data on varied archaeological sites from different geographic regions and time periods are required. However, the patterns constructed in this study remain in line with expectations in the literature that suggest postmortem damage, fragmentation, and erosion will target skeletal elements with more trabecular bone, thinner cortical bone, and a higher organic component and manifest in diffuse as opposed to localized fractures.

The second hypothesis is supported in analysis of these results, with one caveat. Trauma patterns modeled on modern data should be applicable in archaeological contexts, and taphonomic patterns applicable regardless of context. When remains are well-preserved, models
of traumata and taphonomy should be useful guidelines for analysis and interpretation. However, there remains the resounding issue of taphonomic bias.

This study reveals that there is significant overlap in regions of concern between traumatic injury and postmortem damage, and that the high prevalence of erosion may result in erasure of surface information. Many of the regions most targeted in abuse victims are also the most vulnerable to taphonomic damage, which introduces the serious risk of information loss. The CML is considered to be particularly diagnostic of abuse, though this is a region commonly damaged and eroded due to taphonomic processes. Chronic rib trauma and fractures of the cranial vault, also highly associated with child abuse, may be obscured due to the incredibly high risk of fragmentation of these regions in burial contexts. It is not a coincidence that these patterns overlap. The biomechanical properties of juvenile bone inherently imply weaker resistance to stress and fracture in these regions. Though overlap exists, accurate analyses of trauma versus taphonomy are not impossible. Well-preserved remains provide the greatest ability to infer fracture context with the greatest levels of accuracy and precision. In the case of more poorly preserved remains, accurate analyses are possible, but may rely more heavily on recognition of distinct fracture margin morphology and higher levels of observer experience. It will also be important to continue evaluating the relationship of certain age categories with trauma and taphonomy patterning. Infants and young children are the most common victims of fatal child abuse, and complications derived from information loss may be a serious hindrance if these age categories are truly the most poorly preserved among burials of their peers.

A Note on Pathological Considerations

Data collected from the CAA sample revealed pathological conditions such as PH, CO, LEH, dental caries, and bowing of the limbs to be common in the juvenile demographic.
When accompanied by skeletal traumata characteristic of abuse, the presence of these conditions may further corroborate suspicions, as they may indicate purposeful malnutrition or starvation. However, on their own, these pathologies should not be associated with child abuse, as they can be reflective of many other conditions. It is common for these conditions to manifest due to structural inequalities, lack of access to health care and proper nutrition, and as a result of other primary pathological processes. For the purposes of this study, these pathological conditions were not found in association with trauma, and their prevalence serves as a reminder to consider multiple lines of evidence when assessing health and potential trauma from skeletal remains.

Summary

The results of this study showed that distinct patterns of taphonomic processes and traumatic injury associated with abuse can be constructed. Though the biomechanical properties of juvenile bone leave certain skeletal elements more susceptible to trauma and postmortem damage in similar ways, the two can be differentiated according to certain criteria, such as specific fracture location, quantity, and timing. Issues arise when one considers the masking effects of taphonomic processes such as postmortem damage, fragmentation, and erosion. These processes may obscure or entirely erase evidence of trauma in cases of poor preservation. Therefore, the utility of trauma- and taphonomy-specific patterns is at its greatest with better preservation of remains, though remains relevant in structuring analyses of more poorly preserved remains.
CHAPTER VII

CONCLUSION

Introduction

This final chapter offers thoughts on the current study and ways to proceed onward in child-centered anthropological research. Though certain hindrances were addressed in the previous chapter, research limitations are expanded upon in greater detail here. This discussion of limitations comprises the first section of this chapter. The second section proposes suggestions and possible approaches for future research. Finally, the research aims, results, and interpretations are summarized as a conclusion to this study.

Limitations of the Current Study

Trauma analysis, juvenile osteology, and interpretations of violence are all uniquely challenging on their own. When combined, these challenges are compounded. Any assessment of juvenile remains for signs of trauma or the possibility of abuse comes with inherent limitations, as violence is intricately linked to sociocultural subjectivities. This section focuses primarily on the logistics of research limitations and the implications of using generalized models to infer about violence in the juvenile skeleton.

This study is primarily limited in the manner of any novel methodology. Limited guidelines and protocols exist for analyzing the juvenile skeleton on its own terms, separate from those of adults, and none of these guidelines are standardized. The aim of this project was to
assess whether it was possible to develop such a model for use in the future, and a data collection protocol newly developed for first use in this study. Development of this protocol occurred based on a literature survey during the 2020-2021 COVID-19 lockdown, without access to physical remains. The data collection phase was therefore the trial run of this protocol. When viewed in retrospect, there are many possible methodological advancements; future research will be able to build on this pilot study.

Two datasets were used in this study. One from the physical remains of the CAA skeletal collection and the other derived from the existing Infant Injury Database. The data collection protocol used in this study was initially developed with physical observation of two archaeological collections in mind, and the intention of testing any crafted models on the digital IID. Due to constraints imposed by the COVID-19 pandemic, the focus and practicality of these objectives transformed multiple times. Intended for use but not pursued due to these constraints was a sample derived from the Phaleron Bioarchaeological Project, composed of juvenile archaeological remains from ancient Athens. To bridge the gap between the CAA and IID datasets, the next logical step is to introduce an archaeological sample expected to reflect both taphonomic alterations and trauma. As trauma is expected in the Phaleron remains, this population would work to interface between the existing CAA and IID samples, providing an avenue for addressing this current limitation in future studies.

In addition, many variables included in the data collection protocol were ultimately not observable or able to be compared. Ideally, all analyses of child abuse would consider the additional influence of disability (both physical and mental) and prematurity. These factors are known to correlate with abuse cases and could substantiate cases of ambiguity leaning toward violence. However, accurate knowledge of these factors relies on context often not available to
the observer. It is inherently difficult to accurately assess violence and abuse in the past, as analyses rely solely on skeletal evidence and material context. Evidence of physical disability is often erased with time, mental disability all but impossible to ascertain, and intent to inflict violence because of these factors indiscernible without verbal confirmation or written documentation. With intent comprising such a significant portion of what it means to be violent, these studies of child abuse are inherently limited in scope.

Other potentially substantiating factors include pathological indicators indicative of malnutrition. Porotic hyperostosis, cribra orbitalia, linear enamel hypoplasias, dental caries, bowing of the limbs, and Harris lines were observed in the CAA sample but not recorded in the IID. Modern data on these pathological conditions collected on cases of known child abuse would be useful in understanding whether or not they can be used to substantiate archaeological claims of abuse in the form of neglect or starvation when observed alongside significant trauma patterns. Regarding all analyses, it is also important to note that time constraints required aggregation of data. Better models will be developed once bone-by-bone patterns can be developed for vulnerability to taphonomic processes and traumatic injury.

The data compiled were ultimately difficult to work with – another limitation of this study. Though frequencies were calculated and certain variables contrasted, most variables included in data collection were not able to be statistically compared between samples due to small sample sizes. Therefore, there remains little comparative power between the modeled patterns of abusive trauma and postmortem damage. Lastly, the issue of intraobserver error must be addressed. Analyses of trauma are intrinsically subjective to level of observer experience. To accurately record data on fracture timing and prevalence, one must know what to look for. Though I had done substantial research on fracture morphology and had moderate experience
recognizing trauma at the onset of data collection, my analyses of the CAA material relied
entirely on my own accuracy of observation. In addition, the results of this thesis essentially
tested my own methodology, which further highlights the insulated nature of the work
conducted. The methodology developed and results presented for this thesis would have
benefitted from the eyes of a second observer, and this should be a consideration in future
development of these models.

Future Research

The inception of this project included the lofty goal of developing a cohesive
predictive model of fracture diagnosis for future use. This model would have taken the final form
of a decision tree-type structure, which an observer could use to walk through specific
taphonomic and traumatic identifiers to reach a conclusion about whether one was likely seeing
the results of postmortem damage, accidental trauma, or child abuse. Ultimately, due to the lack
of comparative samples, this goal was not reached. If this kind of standardized model is to be
constructed in the future, its development would benefit most simply from more data. Data on
archaeological collections with trauma and modern forensic cases with postmortem damage
would infinitely improve analyses and aid in the creation of more representative patterns. So too
would the inclusion of adolescents in these analyses. This study was only capable of comparing
infants and children, and data on adolescents (aged 14.6-17 years) is sorely missed. Child abuse
accompanies any power dynamic involving adults and juveniles, not to the exclusion of
adolescents. Their frequent social role as dependents means they remain vulnerable to abuse.
Though the social role of adolescents is expected to vary more significantly cross-culturally
compared to that of infants and children, these older juveniles must not be excluded from
research aimed at recognizing the agency of those occupying the “non-adult” sphere. This study ultimately opens the door to wide and varied future research possibilities. It calls attention to the need for multifaceted models of juvenile skeletal analysis. Fortunately, research in this vein can be approached in a multitude of ways; hopefully, anthropologists continue to recognize the value of child-centered research and more substantial models of prediction developed in the future.

Summary

The purpose of this study was to model patterns of taphonomic damage and child abuse to clarify areas of overlap, information loss, and assess widespread applicability. These goals were situated within three prevalent issues: 1) there is a dearth of child-centered research in the taphonomic literature, 2) children are often morphologically assessed on methodology developed from adult skeletons, and 3) there is an inherent difficulty in differentiating postmortem from perimortem fractures, and thus an inherent difficulty in accurately assessing trauma. The work conducted in this thesis revealed the possibility of future relief of these issues, and laid the initial foundations for future clarifying work.

Taphonomic processes including generalized postmortem damage, fractures, and postmortem erosion were shown to affect the juvenile skeleton in patterns unique to those of abusive trauma, though overlap was observed. While it seems obvious that intentional violence and postmortem damage would manifest differently in the skeleton, the challenges lie in ambiguity of fracture morphology and potential loss of information. The results obtained in this study reflect one of the reasons why the juvenile skeleton is more poorly understood compared to its adult counterpart. The biomechanical properties and size of juvenile bones contributes to difficulty in full skeletal recovery from burial contexts and information loss due to vulnerability
to taphonomic processes. Children remain challenging to study for this reason, but this should not preclude future research from working to explicate these complications.

Research in modeling these patterns of taphonomic processes and trauma do not only hold significance for archaeological populations that have suffered decades or centuries of postmortem damage. Studies of this nature will prove useful for any case of a recovered burial of a child, including homicide cases where children are buried and extending to cases of structural violence and genocide where children are tragically included in mass graves. Unfortunately children are not spared in acts of violence, therefore research must progress to decrease the possibility of a misdiagnosis of trauma or abuse.

As advancements are made in modeling these osteological patterns in the juvenile skeleton, researchers must be wary of the inherent challenges in diagnosing abuse. These include difficulties surrounding the central component of intent and requisite knowledge of the child’s social unique social role. Given the complicated nature of these circumstances, how can anthropologists ensure we are assessing trauma accurately since the consequences can be so severe? Incorrectly diagnosing abuse as accidental injury or postmortem damage has the potential to maintain power in the hands of an abuser. Misguided claims of child abuse in the present can unjustly punish an innocent individual, and even remove caretakers from children who need their protection. In archaeological contexts, erroneous claims of intentional violence in any form, including child abuse, is disrespectful to those deceased populations we so luckily have access to and can directly affect the way modern descendant communities are perceived. Alongside ensuring methodological rigidity, anthropologists must persistently challenge their knowledge of societal norms if holistic, accurate, and respectful analyses of the deceased are to continue. Moving forward, standardization should be the goal in modeling juvenile skeletal
patterns, and clear guidelines developed for assessing trauma and inferring abuse when remains demonstrate postmortem damage or ambiguous fractures. While nothing can ever rectify any act of intentional violence toward a child, we can continue in the pursuit of ethical, rigorous standards focused on recognizing their agency even after death.
REFERENCES
REFERENCES CITED


APPENDIX A
### TRAUMA AND TAPHONOMIC CHANGE RECORDING FORM FOR JUVENILES

**Observer:**

**Site Name (if applicable):**

**Date:**

**Current Location:**

**Burial/Skeleton ID/Case Number:**

**Burial Position (if known):**
- ☐ Head facing up
- ☐ Head on its side
- ☐ Thorax facing up
- ☐ Thorax on its side
- ☐ Limbs extended
- ☐ Limbs flexed

**Other (describe):**

**Age (check one):**
- ☐ Infant (birth-1 yr)
- ☐ Child (1-14.6 yr)
- ☐ Adolescent (14.6-17)

**Age range (in months/years):**

**Dental age range (AIQahtani et al.):**

**Epiphyseal fusion age range (Schaefer et al. 2009):**

---

**Record data for the following elements, and provide details when necessary:**

#### Skull

**Parietal (Left)**

- Completeness: ☐ 0-25% ☐ 25-75% ☐ 75-100%
- ☐ Post-mortem bone destruction
- ☐ Erosion
- ☐ Animal scavenging
- ☐ Other damage
- ☐ Fracture (☐ Unobservable)
  - Location (check one): ☐ localized ☐ diffuse
  - Morphology (check all that apply):
    - ☐ Depressed fracture/pond lesion
    - ☐ Stellate configuration
    - ☐ Diastatic
    - ☐ Multiple intersecting fractures
    - ☐ Linear fracture
    - ☐ Complex fracture

**Parietal (Right)**

- Completeness: ☐ 0-25% ☐ 25-75% ☐ 75-100%
- ☐ Post-mortem bone destruction
- ☐ Erosion
- ☐ Animal scavenging
- ☐ Other damage
- ☐ Fracture (☐ Unobservable)
  - Location (check one): ☐ localized ☐ diffuse
  - Morphology (check all that apply):
    - ☐ Depressed fracture/pond lesion
    - ☐ Stellate configuration
    - ☐ Diastatic
    - ☐ Multiple intersecting fractures
    - ☐ Linear fracture
    - ☐ Complex fracture
<table>
<thead>
<tr>
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<tr>
<td>☐ Irregular or jagged fracture edges</td>
<td>☐ Irregular or jagged fracture edges</td>
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<tr>
<td>☐ Fracture margin lighter in color than surrounding bone</td>
<td>☐ Fracture margin lighter in color than surrounding bone</td>
</tr>
<tr>
<td>☐ Endocranial lesions/hair-on-end projections</td>
<td>☐ Endocranial lesions/hair-on-end projections</td>
</tr>
</tbody>
</table>

Fracture timing (check all that apply)

☐ Antemortem (bridging/evidence of healing)  ☐ Antemortem (bridging/evidence of healing)
☐ Perimortem (no evidence of healing)  ☐ Perimortem (no evidence of healing)
☐ Postmortem  ☐ Postmortem
☐ Ambiguous  ☐ Ambiguous
☐ Chronic (multiple injury events in different stages of healing)  ☐ Chronic (multiple injury events in different stages of healing)
☐ Acute (single injuries in similar stages of healing)  ☐ Acute (single injuries in similar stages of healing)

Parietal(s) notes:
### Occipital

Completeness: ☐ 0-25%  ☐ 25-75%  ☐ 75-100%

☐ Post-mortem bone destruction  
☐ Erosion  
☐ Animal scavenging  
☐ Other damage  
☐ Fracture (☐ Unobservable)

Location (check one):  ☐ localized  ☐ diffuse

Morphology (check all that apply):

☐ Depressed fracture/pond lesion  
☐ Stellate configuration  
☐ Diastatic  
☐ Multiple intersecting fractures  
☐ Linear fracture  
☐ Complex fracture  
☐ Crushing fracture  
☐ Plastic deformation  
☐ Beveled fracture edges  
☐ Smooth or sharp fracture edges  
☐ Irregular or jagged fracture edges  
☐ Fracture margin lighter in color than surrounding bone  

☐ Endocranial lesions/hair-on-end projections

Fracture timing (check all that apply)

☐ Antemortem (bridging/evidence of healing)  
☐ Perimortem (no evidence of healing)  
☐ Postmortem  
☐ Ambiguous  
☐ Chronic (multiple injury events in different stages of healing)  
☐ Acute (single injuries in similar stages of healing)
Temporal (Left)

- Completeness:  
  - □ 0-25%  
  - □ 25-75%  
  - □ 75-100%

- □ Post-mortem bone destruction
- □ Erosion
- □ Animal scavenging
- □ Other damage
- □ Fracture (☐ Unobservable)
  - Location (check one):  
    - □ localized  
    - □ diffuse
  - Morphology (check all that apply):
    - □ Depressed fracture/pond lesion
    - □ Stellate configuration
    - □ Diastatic
    - □ Multiple intersecting fractures
    - □ Linear fracture
    - □ Complex fracture
    - □ Crushing fracture
    - □ Plastic deformation
    - □ Beveled fracture edges
    - □ Smooth or sharp fracture edges
    - □ Irregular or jagged fracture edges
    - □ Fracture margin lighter in color than surrounding bone
- □ Endocranial lesions/hair-on-end projections

Fracture timing (check all that apply)
- □ Antemortem (bridging/evidence of healing)
- □ Perimortem (no evidence of healing)
- □ Postmortem
- □ Ambiguous
- □ Chronic (multiple injury events in different stages of healing)
- □ Acute (single injuries in similar stages of healing)

Temporal (Right)

- Completeness:  
  - □ 0-25%  
  - □ 25-75%  
  - □ 75-100%

- □ Post-mortem bone destruction
- □ Erosion
- □ Animal scavenging
- □ Other damage
- □ Fracture (☐ Unobservable)
  - Location (check one):  
    - □ localized  
    - □ diffuse
  - Morphology (check all that apply):
    - □ Depressed fracture/pond lesion
    - □ Stellate configuration
    - □ Diastatic
    - □ Multiple intersecting fractures
    - □ Linear fracture
    - □ Complex fracture
    - □ Crushing fracture
    - □ Plastic deformation
    - □ Beveled fracture edges
    - □ Smooth or sharp fracture edges
    - □ Irregular or jagged fracture edges
    - □ Fracture margin lighter in color than surrounding bone
- □ Endocranial lesions/hair-on-end projections

Fracture timing (check all that apply)
- □ Antemortem (bridging/evidence of healing)
- □ Perimortem (no evidence of healing)
- □ Postmortem
- □ Ambiguous
- □ Chronic (multiple injury events in different stages of healing)
- □ Acute (single injuries in similar stages of healing)
Facial bones

☐ Post-mortem bone destruction
☐ Erosion
☐ Animal scavenging
☐ Other damage
☐ Fracture (☐ Unobservable)

Fracture timing (check all that apply)
☐ Antemortem (fracture callus/evidence of healing)
☐ Perimortem (no evidence of healing)
☐ Postmortem
☐ Ambiguous
☐ Chronic (multiple injury events in different stages of healing)
☐ Acute (single injuries in similar stages of healing)

Skull: Other (if yes, describe)

☐ Trauma to mandible

☐ Trauma to other elements
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Vertebrae notes (include vertebrae affected):

Sternum notes:
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Clavicle(s) notes:
Ribs (Left)

Completeness: □ 0-25% □ 25-75% □ 75-100%

☐ Post-mortem bone destruction
☐ Erosion
☐ Animal scavenging
☐ Other damage
☐ Fracture (☐ Unobservable)

Fracture location (check all that apply)
☐ Posterior
☐ Posterolateral
☐ Anterior
☐ Anterolateral
☐ Midshaft

Fracture morphology (check all that apply)
☐ Beveled fracture edges
☐ Smooth or sharp fracture edges
☐ Irregular or jagged fracture edges
☐ Fracture margin lighter in color than surrounding bone
☐ Splintering/greenstick fracture

Fracture timing (check all that apply)
☐ Antemortem (fracture callus/evidence of healing)
☐ Perimortem (no evidence of healing)
☐ Postmortem
☐ Ambiguous
☐ Chronic (multiple injury events in different stages of healing)
☐ Acute (single injuries in similar stages of healing)

Ribs notes:

Ribs (Right)

Completeness: □ 0-25% □ 25-75% □ 75-100%

☐ Post-mortem bone destruction
☐ Erosion
☐ Animal scavenging
☐ Other damage
☐ Fracture (☐ Unobservable)

Fracture location (check all that apply)
☐ Posterior
☐ Posterolateral
☐ Anterior
☐ Anterolateral
☐ Midshaft

Fracture morphology (check all that apply)
☐ Beveled fracture edges
☐ Smooth or sharp fracture edges
☐ Irregular or jagged fracture edges
☐ Fracture margin lighter in color than surrounding bone
☐ Splintering/greenstick fracture

Fracture timing (check all that apply)
☐ Antemortem (fracture callus/evidence of healing)
☐ Perimortem (no evidence of healing)
☐ Postmortem
☐ Ambiguous
☐ Chronic (multiple injury events in different stages of healing)
☐ Acute (single injuries in similar stages of healing)
### Long Bones

**Humerus (Left)**

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<tr>
<td>Fracture (☐ Unobservable)</td>
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</table>

**Location (check all that apply)**

- ☐ Proximal epiphysis
- ☐ Proximal metaphysis
- ☐ Diaphysis
- ☐ Distal metaphysis
- ☐ Distal epiphysis

**Fracture morphology**

- ☐ Beveled fracture edges
- ☐ Smooth or sharp fracture edges
- ☐ Irregular or jagged fracture edges
- ☐ Fracture margin lighter in color than surrounding bone
- ☐ Obtuse or acute fracture edges
- ☐ Breakage at right angle to long axis of bone
- ☐ Splintering/greenstick fracture
- ☐ Classic metaphyseal lesion (CML)

**Fracture timing (check all that apply)**

- ☐ Antemortem (fracture callus/evidence of healing)
- ☐ Perimortem (no evidence of healing)
- ☐ Postmortem
- ☐ Ambiguous
- ☐ Chronic (multiple injury events in different stages of healing)

### Humerus (Right)

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<td>Other damage</td>
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<tr>
<td>Fracture (☐ Unobservable)</td>
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**Location (check all that apply)**

- ☐ Proximal epiphysis
- ☐ Proximal metaphysis
- ☐ Diaphysis
- ☐ Distal metaphysis
- ☐ Distal epiphysis

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Fracture timing (check all that apply)

- [ ] Antemortem (fracture callus/evidence of healing)
- [ ] Perimortem (no evidence of healing)
- [ ] Postmortem
- [ ] Ambiguous
- [ ] Chronic (multiple injury events in different stages of healing)
- [ ] Acute (single injuries in similar stages of healing)

**Radius notes:**

### Ulna (Left)

Completeness:

- [ ] 0-25%
- [ ] 25-75%
- [ ] 75-100%

- [ ] Post-mortem bone destruction
  - PE
  - PM
  - D
  - DM
  - DE

- [ ] Erosion
  - PE
  - PM
  - D
  - DM
  - DE

- [ ] Scavenging
  - PE
  - PM
  - D
  - DM
  - DE

- [ ] Other damage
  - PE
  - PM
  - D
  - DM
  - DE

- [ ] Fracture (Unobservable)

Location (check all that apply)

- [ ] Proximal epiphysis
- [ ] Proximal metaphysis
- [ ] Diaphysis
- [ ] Distal metaphysis
- [ ] Distal epiphysis

### Radius (Right)

Fracture timing (check all that apply)

- [ ] Antemortem (fracture callus/evidence of healing)
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- [ ] Postmortem
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Tibia notes:

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- ☐ Other damage (☐ PE ☐ PM ☐ D ☐ DM ☐ DE)
- ☐ Fracture (☐ Unobservable)
Location (check all that apply)
- ☐ Proximal epiphysis
- ☐ Proximal metaphysis
- ☐ Diaphysis
- ☐ Distal metaphysis
- ☐ Distal epiphysis

Fibula (Right)

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Fibula notes:
Pathology (Y = yes, N = no, U = unobservable):

☐ Y □ N □ U  Linear Enamel Hypoplasias
☐ Y □ N □ U  Porotic Hyperostosis (☐ Active ☐ Healed, check one)
☐ Y □ N □ U  Cribra Orbitalia (☐ Active ☐ Healed, check one)
☐ Y □ N □ U  Dental caries (# of carious teeth: ____________)
☐ Y □ N □ U  Harris lines
☐ Y □ N □ U  Bowing of the upper limbs
☐ Y □ N □ U  Bowing of the lower limbs

Pathology notes:

Other (check if present and describe):

☐  Congenital condition (☐ Unobservable)

☐  Disability (☐ Unobservable)

☐  Premature (☐ Unobservable)
Other notes:

Record here any details of trauma/pathological condition/taphonomic change not included in the sections above:
Child skeleton, anterior view

Infant skeleton, anterolateral view

Diagrams taken from *Standards* (1994)
DENTAL PATHOLOGY RECORDING DIAGRAM

MAXILLARY

BUCCAL
OCCLUSAL
LINGUAL

51 52 53 54 55 56 57 58 59 60
70 69 68 67 66 65 64 63 62 61

MANDIBULAR

BUCCAL
OCCLUSAL
LINGUAL

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17

MANDIBULAR
INVENTORY – HOMUNCULUS

Notes: (select one of the above or insert preferred homunculus)