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To Walk About as They Pleaseth: An Exploratory Study of Limb Treatment and Positioning in Ancient Egyptian Mummies

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A thesis submitted in partial fulfillment of the requirements for the degree in Master of Arts

TO WALK ABOUT AS THEY PLEASETH: AN EXPLORATORY STUDY OF LIMB TREATMENT AND POSITIONING IN ANCIENT EGYPTIAN MUMMIES

Monograph

by

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Abstract

This study examines evidence of limb manipulation and positioning in a sample of eighty one (n=81) Egyptian human mummies archived in the IMPACT radiological database housed at The University of Western Ontario. The purpose of this research is to expand upon the existing research on the positioning of the arms and hands in Egyptian mummies (cf. Gray, 1972) to include the lower body in order to shed light on how the embalming process altered the legs and feet. The results of this study demonstrate that some aspects of lower body positioning vary across time periods in conjunction with other stylistic elements of mummification (e.g. upper body position), while others were more closely related to age and sex. These results support the hypothesis that the positioning of the lower body was a dynamic, varied process deliberately enacted to afford the deceased an appropriately reconstructed body suitable for use in the afterlife.

Keywords

Mummies, mummification, Ancient Egypt, paleoradiology, IMPACT radiological database

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Chapter 1

1. Introduction

Ancient Egyptian mummies have captivated the popular imagination for centuries. However, it was only following Smith and Carter's groundbreaking early Twentieth-century radiological study of the mummy of Tuthmosis IV that the full potential of mummy studies for use in paleopathological research became apparent (Cockburn, 1998, pp.3-5). More recently, the focus has shifted drastically from the study of mummies as curiosities to the consideration of mummified human remains as subjects of bioarchaeological research, culminating in more recent large-scale paleoradiological investigations (see Allam et al., 2009, 2011; Thompson et al., 2013, 2014).

While past studies relied upon destructive modes of examination such as autopsy, the application of radiological imaging technologies to ancient human remains has revolutionized the anthropological study of mummies. Additionally, projects such as the Internet-based Mummy Picture Archiving and Communication Technology (IMPACT) Radiological Database (Nelson & Wade, 2015) have further broadened the possibilities for large-scale population studies of mummies by incorporating data from a wide range of samples, thereby allowing for direct comparative studies.

1.1 Project context –Osteoarthritis in Egyptian mummies

This project is a preliminary investigation conducted in preparation for a large-scale radiological study of osteoarthritis (OA) in Egyptian mummies. The latter project, led by Dr. Andrew Wade (McMaster University) will involve consideration of a large sample of CT scans of anthropogenic Egyptian human mummies archived in the IMPACT (Internet Mummy Picture Archiving and Communications Technology) radiological database housed at the University of Western Ontario (Nelson & Wade, 2015).

In order to do so, however, we need to carefully examine the ways in which the mummification process altered the appearance of the limbs on CT scans in order to account for these changes in our analyses. Interestingly, while a few studies have looked at arm and hand positioning in Egyptian mummies (e.g. Gray, 1972), none specifically address the

treatment and positioning of the lower body. The research presented here aims to address this gap in the existing scholarship by exploring some of the ways in which the limbs may have been manipulated during the embalming process and to shed light on the role of the legs in the preparation of the deceased for the afterlife according to ancient Egyptian funerary customs.

To this end, this study will fulfill two main purposes: First, to provide further information on the treatment of the limbs and, in particular, the lower body in Egyptian mummies with the aim of contributing to future paleopathological research; and second, to demonstrate some of the practical applications of the IMPACT radiological database to the investigation of both cultural and bioarchaeological research questions.

1.2 Why use mummies to study limbs?

The main rationale behind using a sample of mummified individuals –as opposed to dry skeletons- in a study of this nature lies in the preservation of the soft tissues and, in particular, the maintenance of anatomical articulation of the skeleton by the connective tissues. While the soft tissues of the joints may be difficult, if not impossible, to visualize in any clinical capacity due to the extreme degree of desiccation incurred during mummification –as well as the technical limitations of the imaging equipment – other aspects of the extremities may be used for the purpose of retrospective diagnosis of limb pathologies.

Soft tissue preservation in the limbs, in combination with externally applied embalming materials, also preserves the articulation of the joints to a more consistent degree than in their dry skeletal counterparts. This allows for consideration of the limb as a whole, rather than as singular features such as articular surfaces, thereby increasing the accuracy of differential diagnosis of pathological conditions such as degenerative joint disease (see Watt, 1997; Arden, 2006).

In addition, a further advantage of using anthropogenic Egyptian mummies in paleopathological research lies in the preservation of markers of individual identity (e.g. social status, as indicated by burial accoutrements – see Meskell, 1999, 2002; Raven & Taconis, 2005) and, subsequently, the possibility for identifying potential risk factors for disease which might not be preserved in osteological remains.

Based on the existing clinical and archaeological literature, virtually all of the identified risk factors for pathological conditions affecting the limbs (e.g. mechanical/occupational stress, lifestyle, anatomical factors, endocrine status, trauma, senescence, etc.) are closely connected to the particular life histories of the affected individuals. In this respect, the unprecedented level of documentation and preservation of markers of individual identity and social status, both in the body itself and its burial context, are invaluable to our ability to understand pathological processes as they operated in the past.

1.3 Making a mummy

Despite these advantages, one major confounding factor exists in the interpretation of deliberately mummified human remains as research subjects: the material processes behind the mummification itself. Because the Egyptian method of embalming remained something of a 'trade secret' held only by the hereditary priesthood of embalmers (see Leca, 1980: pp.137; Ikram, 2003: pp.57), much of our knowledge of the mummification process relies upon the accounts of Greek historians such as Herodotus (c. 5th Century BCE) and Diodorus Siculus (c. 1st Century CE), as well as the few scanty references that can be gleaned from Egyptian sources such as the *Papyrus of Ani* (also known as the *Book of the Dead*). These accounts provide detailed descriptions of the more fundamental aspects of the embalming process (i.e. the removal of the organs, dehydration of the body using natron, and subsequent wrapping), however, they provide very little information regarding the treatment of the limbs specifically. Furthermore, the bulk of these sources describe what can be termed 'stereotyped' versions of the embalming process (see Wade, 2012) which were dictated according to cost, and thus do not adequately capture the spectrum of variability in mummification techniques that were employed at any given time, let alone across Egypt's history.

As a consequence, paleopathological studies of mummies typically rely upon the assumption that the limbs were left relatively intact during embalming, suggesting that the state of the limbs in the mummified individual is representative of their state in life. However, Egyptian funerary texts such as the *Book of the Dead* place considerable importance on the restoration of the limbs through mummification, drawing direct parallels between the embalming of the limbs of the deceased with the reassembly of the body of Osiris by Isis (see Budge, 1967[1895]: pp.xlviii-liv). Accordingly, modern mummy studies have also hinted at a much

greater extent of limb manipulation during embalming than was previously thought and have provided evidence that their careful positioning and posing likely bore significance on both pragmatic and symbolic levels.

During the embalming process, the limbs were typically coated with occlusive materials (e.g. plant oils, animal fats etc.) and tightly wrapped in a series of layers of bandages in order to further stave off the destructive effects of decomposition **(**Raven & Taconis, 2005; See Aufderheide, 2011 for a review of soft tissue taphonomy and mummies). In some cases, packing materials were also introduced under the skin of the limbs over the muscle via a series of strategically placed incisions (see Smith, 1914), however, little research has been published on the specific composition of these materials nor upon the modes by which the packing was introduced into the body (see Saleem et al., 2015).

At some point in the process, the arms and hands were posed in any one of a variety of positions which may have corresponded with the time period during which the embalming took place (see Gray, 1972). Modern experimental mummification studies have provided some insight into this process, however, it remains unclear at what point in the procedure this occurred and how exactly it was performed. During their experimental replication of a "classic" 18th Dynasty mummification, Brier and Wade (1997) found that while the limbs initially remained pliable, they ultimately became stiff and inflexible later on in the process after desiccation was complete. Similar findings were also reported by Panzer et al. (2013) in their experimental mummification study of human legs, wherein they suggested that the wrapping and positioning of the limbs likely occurred after an initial stage of desiccation in natron.

Interestingly, while some attention has been paid to the treatment of the upper body in ancient Egyptian mummification (cf. Gray 1966, 1972), the same cannot be said for the process of embalming the lower body. Consequently, it remains unknown whether the legs and feet were also deliberately posed or if they merely remained in whatever reposed position they happened to fall into on the embalming table.

1.4 Implications for mummy imaging studies

The studies discussed above demonstrate that although the limbs may appear to remain in approximately anatomical articulation, an appreciable degree of manipulation likely occurred during the embalming process. For this reason, the paleoradiological diagnosis of pathological conditions in the limbs, such as osteoarthritis, cannot be carried out directly as one might in a clinical setting. Instead, the mummified human body requires consideration as a unique subject of study, perpetually lingering between the ontological categories of "human" and "artifact," "subject" and "object," "patient" and "specimen."

The purpose of this study, then, is to shed light upon the degree to which Egyptian human mummies truly represent ancient anatomical specimens, as opposed to artifacts, with respect to the integrity of their limbs and particularly the legs. To what extent do mummies represent the state of the body in life, as opposed to an artificially imposed state curated during the embalming process? To what extent does the evidence of possible pathological processes found in mummies actually represent the health status of the living individual versus the physical intervention of the embalmers? And most importantly, how might we discern between paleopathological evidence and the effects of embalming, and how might both of these processes be distinguished from postmortem handling damage?

1.5 Research questions to be addressed

In order to increase the accuracy of our retrospective diagnoses in mummified human remains, particularly of joint pathologies such as OA, these questions must be explored in detail and the potential confounding factors resolved prior to undertaking paleoepidemiological studies on a large scale. This study examines evidence of limb manipulation and positioning in a sample of eighty one (n=81) Egyptian human mummies archived in the IMPACT radiological database, including forty-one (n=41) CT scans, thirty-eight (n=38) plain film x-ray images. The individuals in this sample span five major periods in Egypt's history and represent at least ten different sites. Additionally, the sample has a representative sex ratio composed of an approximately equal split of males and females, and also spans a relatively broad range of ages at time of death. For this reason, although the individuals recorded in this study derive from too disparate spatial and temporal contexts to

be considered as a 'population' as it might exist in reality, they may provide a rough representation of the Egyptian mummification tradition as a whole.

This project addresses two main areas of interest regarding the treatment of the limbs during mummification. First, how were the legs manipulated during embalming? Does leg positioning follow a similar pattern of variation over time as arm and hand positioning (see for example Gray, 1972)? Do particular positions of the legs correspond with arm and hand positioning in the same individual? Do particular arrangements of the hands and feet correspond with positioning of the arms and legs, respectively, or are they treated separately?

Second, are there any unusual variations in limb treatment and/or positioning present in this sample which fall well outside the expected mummification procedure based on the existing textual and bioarchaeological evidence? Do these variants occur only as isolated cases, or are there any overarching patterns?

Due to the exploratory nature of this project, the primary null hypothesis to be tested is that limb treatment occurs independently of any of the demographic variables recorded (i.e. age, sex, time period, and site), and that there are no significant relationships between lower limb treatment and other stylistic aspects of mummification such as arm and hand positioning. The alternative hypothesis to be offered is that lower body positioning is in fact related to these other factors, suggesting that the embalming of the legs was a deliberate, dynamic process much like that applied to other elements of the body (see Wade et al., 2011; Wade, 2012). The purpose of these tests will be to look for relationships between limb positioning and other variables which may represent either individual variation –or differences in embalming techniques – which may in turn shed light on changes in the embalming process both between individual cases and across time and space.

1.6 Exploring lower limb treatment

In order to address these questions, I analyze the presence/absence of each skeletal element and its orientation in the body, the articulation of the joints, and the overall positioning of the limbs. The integrity of the overlying soft tissue (muscle, tendons, skin, etc.) and wrappings is also evaluated wherever possible.

In order to address the research questions posed above, a general overview of limb positioning is included for the entire sample of eighty one (n=81) individuals and analyzed for patterning within and between demographic categories, as well as between stylistic elements such as hand and arm position. The results of this analysis are then interpreted based on the existing literature regarding the mummification tradition in Egypt, as well as the social and historical contexts from which the sample derives. The purpose of doing so is not only to shed light on the existing variation within the mummification tradition, but also to provide a discussion of some of the ways in which social inequalities may be reflected in the funerary treatment of individuals.

As a whole, this project discusses ancient Egyptian mummification as a variable and dynamic process that was often adapted to suit the particular situation in which it was employed. In doing so, I hope to shed light on a previously under-researched area within the existing literature regarding the treatment of the legs during embalming, as well as helping to clarify the potential affect of the embalming process itself on the accuracy of future paleopathological studies of the limbs of Egyptian mummies.

1.7 Chapter outline

The subsequent chapters in this study are as follows:

The first chapter (Chapter 1 –Introduction) provides an outline of the project, including information regarding the rationale behind the study of limb treatment and positioning in Egyptian mummies.

The second chapter (Chapter 2 –Background) provides the historical and social context for the remaining chapters, with particular focus on sex and age in Egyptian society.

The third chapter (Chapter 3 –Literature Review) compiles evidence from both contemporaneous and modern studies as to the treatment of the limbs in the Egyptian mummification tradition in order to demonstrate the gap in the existing scholarship to be addressed in this study.

The fourth chapter (Chapter 4 –Materials and Methods) outlines the procedures followed with regard to sample selection and data collection, including the standards used for age and

sex estimation. This chapter also details the statistical methods used to analyze the data for patterning of limb treatment and positioning within and between demographic groups, as well as between the upper and lower body in the same individuals.

The fifth chapter (Chapter 5 –Results) outlines the results of a series of qualitative statistical analyses of limb positioning among the entire sample (n=81) presented as a series of tests of hypotheses.

The sixth chapter (Chapter 6 –Discussion) synthesizes the results reported in the previous chapter and ties them in to the relevant textual, archaeological and osteological evidence discussed previously in the literature review (Chapter 2).

The final chapter (Chapter 7 –Conclusions) summarizes the outcomes of this study and situates it in the context of both past and future research on the treatment and positioning of the limbs in Egyptian mummies. It also provides suggestions for future avenues of research which may be of interest based on the results reported here.

Chapter 2

2. Background

This chapter provides information regarding the historical and social context for this research. The initial sections of this chapter briefly outline the relevant historical and political developments associated with each time period covered in this study, while the remaining sections discuss perceptions of age and sex in ancient Egyptian society as they relate to funerary treatment.

2.1 Historical Context

The sample included in this study spans the following five time periods: the New Kingdom (1550-1069 BCE), Third Intermediate (1069 –664 BCE), Late (664 –332 BCE), Ptolemaic (332 –30 BCE), and Roman (30 BCE –395 CE). For the purpose of this review, only a basic overview for each time period is provided, however, detailed reviews are available elsewhere (see Trigger et al., 1983; Starr, 1991; Shaw, 2000, etc.).

New Kingdom (1550 –1069 BCE)

The New Kingdom period in Egypt was characterized by military expansion, largely precipitated by the expulsion of the Hyksos from Egypt by the 18th Dynasty Pharaoh Ahmose (1575-50 BCE) (see Budge, 1925: pp.49-50; Starr, 1991: pp.88). As a result of Egypt's expanding borders, as well as the influx of foreigners from various neighbouring countries, foreign goods and materials became much more common than in previous periods (Starr, 1991: pp.91) including those used for embalming (see Ikram, 2003: pp.55).

The New Kingdom period also featured a number of important rulers, including the female pharaoh Hatshepsut who reigned from 1490-68 BCE and is most notable for being a full pharaoh in her own right as opposed to a queen or consort (see Starr, 1991: pp.90) and depicted using masculine pronouns and imagery (see Budge, 1925: pp.53). Also in the New Kingdom period was the rule of the 'heretic' king Amenhotep IV also known as Akhenaten (1367—1350 BCE) during the Amarna period, a brief period characterized by drastic

religious reform[1] as well as changes in the dominant art forms of the time (see O'Connor 1983; Starr, 1991). The latter changes were short-lived, however, and largely reversed during the brief reign of the succeeding pharaoh, Tutankhamun (1347—39 BCE) (Budge, 1925; Starr, 1991).

Third Intermediate (1069 –664 BCE)

Egypt's Third Intermediate Period was characterized by political fragmentation and the decentralization of pharaonic rule in favour of localized provincial rulers (O'Connor, 1983; Taylor, 2000). During this period, positions of authority became hereditary, often passing through several generations within a single family (Taylor, 2000).

The Third Intermediate Period also saw a turn toward 'archaism,' wherein Libyan and Kushite rulers attempted to legitimize their claim to authority by adopting older Egyptian religious beliefs and traditions (O'Connor, 1983: pp.189, 243; Taylor, 2000: pp.338). The latter also applied to burial practices as the focus shifted from the construction of elaborate tomb structures toward the preservation of the body itself; as a result of these efforts, the 21st Dynasty is commonly viewed as the 'height' of mummification in Egypt with respect to embalming technologies (see Taylor, 2000: pp.364).

Late (664 –332 BCE)

Following the decentralization of pharaonic authority during the Third Intermediate Period, the Late period saw the reunification of Egypt under a single centralized ruler, however, it was also under Persian domination for much of this period (see O'Connor, 1983; Lloyd, 2000a).

In contrast to the archaism of the previous period, Lloyd (2000a) suggested that Late period art and iconography combined continuity with older traditions alongside new innovation (pp.391). The latter has also been interpreted in a negative light as a 'Janusgesicht,' a

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1 The main religious reforms associated with the Amarna period in Egypt are (1) The introduction of worship of the Aten (the sun disk) in the place of Amun (Amen), the dominant god of the Egyptian pantheon prior to this period; and (2) Changes in the structure of religious worship. The latter meant that Aten, the dominant god, was to be worshiped directly by the pharaoh and his family, while the remainder of the population were to worship the pharaoh himself (Starr, 1991: pp.93).

“national schizophrenia characteristic of a culture in a state of advanced decay” (O'Connor, 1983: pp.195). Funerary practices again returned to the construction of elaborate monuments and tomb structures, although individuals were commonly buried with lesser quantities of grave goods than in previous periods (Lloyd, 2000a).

Ptolemaic (332 –30 BCE)

Beginning with the arrival of Alexander the Great in 332 BCE, the Ptolemaic period was characterized by a heavy Hellenistic influence as Egypt came under the rule of the Ptolemies (Lloyd, 2000b: pp.396). During this time, Egypt's capital was moved to Alexandria and the claim to rule became based first on military conquest, then on divine right following Ptolemy II (309 –246 BCE) (pp.408).

During the Ptolemaic period, the Egyptian population was “pushed beyond the limits of endurance by famine, rampant inflation, and an oppressive and vicious administrative system operated by officials who were all too often corrupt and beyond the effective control of central government” (Lloyd 2000b: pp.419-20). In an attempt to assert their right to power in Egypt, the ruling class also implemented the equation of various Greek gods and goddesses with counterparts from the traditional Egyptian pantheon (see O'Connor, 1983; Peacock, 2000). Perhaps as a result of changes in the dominant religious beliefs, the mummification tradition also began to decline during this period as methods of embalming became increasingly less thorough (see Ikram, 2003). The Ptolemaic period in Egypt finally ended when it fell to Rome in 30BCE (Lloyd, 2000b).

Roman (30 BCE –395 CE)

The Roman period began when Egypt fell to Rome and Augustus entered as ruler in 30 BCE (Peacock, 2000). During this period, Egypt was divided into locally-governed 'nomes' and Rome became increasingly reliant upon Egypt for its agricultural production, particularly grain (Peacock, 2000).

Although much of Egypt's rich artistic and literary tradition continued throughout the Roman period, the Romans remained suspicious of native Egyptians and prevented them from entering into administrative positions (Peacock, 2000). From the mid-first century onward, Christianity also became an increasingly prominent presence in Egypt, although traditional

Egyptian funerary practices continued into the 4th century CE (Peacock, 2000). The Roman period ended with the Arab conquest of 642 CE (Peacock, 2000).

2.2 Social context –age

In addition to the historical developments discussed above, a few aspects of social life in ancient Egypt should also be discussed in order to provide adequate context for the discussions to come later in the remainder of this volume.

Age in bioarchaeology

Sofaer (2006) described three ways of defining age: (1) Chronological, defined by the passage of time in years; (2) Biological, as defined through the physiological aging process; and (3) Social, the socio-culturally constructed definition of the appropriate attitudes and behaviours for a particular age group (pp.118). While the results of this study are largely based upon biological age –from which chronological age may then be inferred– the final category of social age is arguably the most important to our understanding of the life experiences of the ancient peoples we study. The present section is thus intended to provide social context for the biological and chronological discussions of age to follow below.

Children and 'childhood'

Like many aspects of social life in ancient Egypt, much of what we know about perceptions of age comes from funerary contexts and thus lends itself readily to the discussion of the Egyptian mummification tradition as a whole. One such example is the depiction of children[2] in art (e.g. tomb frescoes), wherein they typically appeared as miniature adults, smaller than their parents but lacking in the accurate anatomical proportions of a juvenile individual (Meskell, 2002). This portrayal was also reflected in the grave goods accompanying child burials, which generally consisted of miniature versions of adult-associated provisions, rather than objects specifically made for use by children (see Meskell, 1999; 2002).

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2 Note that the terms 'child' and 'childhood' are used here to refer to individuals not having reached maturity or adult status in society, the delineation of which are discussed below. However, it should also be noted that these terms are imperfect representations of the complexity of attitudes toward age both within and between particular social contexts; for this reason, 'child' is used here to refer to social age, whereas the term 'Juvenile' or 'Subadult' is used to refer to biological or chronological age.

Subsequently, Janssen & Janssen (2007) suggested that portrayals of 'childhood' in ancient Egyptian society were largely based upon an individual's status in their community, rather than their chronological age (pp.23). Body modification such as the full or partial shaving of the hair was related to the socialization of children and their respective social status (see Meskell, 1999), however, the particulars of the life stages represented by these changes in hairstyle over the life cycle are presently unknown. An individual's portrayal as a 'child' could also be indicated by their lack of clothing, however, there is sufficient archaeological evidence to suggest that the depiction of nakedness was not necessarily reflective of reality, as a number of items of children's clothing have been recovered from various sites (Meskell, 2002: pp.85; Janssen & Janssen, 2007: pp.29).

Transitioning to adulthood

Considerable debate exists as to how ancient Egyptians delineated 'child' status and what marked an individual's transition into adulthood. One possibility is the attainment of puberty, however, the role of sexual maturity in defining a person's social age seems to have been more complex than has been supposed in the past. Nudity as an indicator of child status did not necessarily relate to sexual maturity, as some representations have been identified in which a younger individual was shown nude yet was also clearly at least part way through puberty. One such example is an unprovenanced statue dating to the New Kingdom (reproduced in Janssen & Janssen, 2007: pp.24) in which a young girl stood between her parents holding a duck. The girl was naked while both of her parents were clothed, however, she also appeared to have the beginnings of breasts, suggesting that her status as a child was not directly reflective of her having entered puberty.

Janssen & Janssen (2007) also discussed a ritual known as “knotting the band” which appeared in a number of sources as part of the transition of a boy into adulthood and seemed to relate to clothing (pp.91), however, the specifics of the ritual, including the age at which it was performed, remain unknown.

Circumcision has also been proposed as a possible ritual divide between childhood and adulthood in ancient Egypt, however, considerable uncertainty exists as to the actual prevalence of this practice particularly among non-royal individuals. There is also debate as

to whether female genital mutilation (FGM) was practiced in ancient Egypt or whether circumcision was reserved solely for men (see Knight, 2001 for a review).

Janssen & Janssen (2007) suggested that circumcision likely took place for boys around the age of puberty, rather than in infancy, and was initially obligatory for all youth but eventually became required only of individuals entering into certain professions, such as the priesthood. However, this assertion is largely based upon the –relatively few – visual and textual representations of the procedure being performed and does not necessarily reflect the reality of the practice.

In his *Histories* (5th Century BCE), Greek historian Herodotus (discussed in further detail below) attributed the practice of circumcision to the Egyptians specifically, in contrast to other neighbouring groups, and suggested that the procedure was undergone for the purpose of cleanliness (see de Sélincourt, 1971: pp.116). However, the reliability of this account is uncertain. Additionally, while some Egyptian mummies have been identified as circumcised (see Knight, 2001: pp.332; Meskell, 2002: pp.88 for examples), the nature of the mummification procedure often precluded the possibility of discerning either way, making it somewhat problematic to rely upon circumcision as the marker of entry into adulthood when discussing age-related differences in funerary treatment.

Another possible marker for the entry of an individual into adulthood could have been marriage, however, there did not appear to have been any specific ritual carried out to mark this occasion (see Trigger, 1983; Meskell, 2002; Janssen & Janssen, 2007). Janssen & Janssen (2007) suggested that the entry into married life "implied the very end of one's youth" and may have signified an individual's final initiation into adulthood (pp.91). However, the lack of a formal ceremony (see Meskell, 1999: pp.157), as well as the apparent ease of divorce and the multiplicity of relationship arrangements (see Janssen & Janssen, 2007: pp.93-5 for review) seemed to suggest that 'marriage,' at least in the way in which we use the term, may not have played as important a role as it has in other societies and at different times. Furthermore, girls and boys appear to have reached 'marriageable' age at different times, suggesting that marriage as a marker of adulthood cannot be considered uniform between genders (Meskell, 2002).

Due to the ambiguity discussed above, Meskell (2002) suggested that the transition to adulthood may have been a gradual progression beginning earlier than puberty rather than representing a child/adult dichotomy. One way in which we can address this suggestion is by looking for differences in mummification between age groups, as well as between other social categories such as sex. While there is some evidence of differences in mummification styles among younger individuals dating to the Graeco-Roman period (see Davey et al., 2014), similar investigations remain to be done using samples from other time periods. The present study will contribute to this gap in the existing literature and shed light upon possible age differences in body positioning among mummies spanning a broader range of temporal contexts.

Personhood

A further subject of debate within Egyptology is on the 'personhood' of children and adolescents in ancient Egypt. For many scholars, high rates of child mortality indicated that very young children probably were not considered full 'people,' however, the combination of archaeological evidence of burials of children with the fact that names were assigned at birth, rather than later in life, seemed to imply otherwise (see Meskell, 1999; Wheeler, 2009 for reviews). Meskell (1999) described a variety of burial practices recorded from the Eastern Necropolis at Deir el-Medina which could be carried out following the death of a child (pp. 169-171), all of which seemed to imply at least some level of care for the deceased. Similarly, Wheeler (2009) found that individuals of all ages received similar mortuary treatment in the Roman period cemetery of Kellis 2 in the Dakleh Oasis.

Janssen & Janssen (2007) suggested that children –both male and female – were of considerable economic importance to their households, particularly those from lower class families who would have been expected to carry out various tasks for their parents from a relatively young age. This was reflected in the language used to refer to children as the “staff of old age” upon which their elderly parents could lean (pp. 131). Male children in particular were often introduced into the professions of their fathers at a young age and both formal education and vocational training such as apprenticeships began relatively early in life (Meskell, 2002; Janssen & Janssen, 2007). This is further supported by findings from the site

of Abydos where children's' footprints were found on known work sites alongside those of adults (Meskell, 2002: pp.83).

In addition to the ambiguity surrounding childhood, it remains unclear whether or not adolescents represented a distinct category in ancient Egyptian social life. Based on linguistic evidence as well as visual and textual representations, Janssen & Janssen (2007) suggested that adolescence was a viewed as a separate stage in the life cycle distinct from both childhood and adulthood (pp.144). However, the introduction of children directly into their adult roles discussed above seems to imply otherwise.

Old age

Although younger individuals make up a larger proportion of the sample used in the present study, a short discussion of the roles of older adults is also relevant to our understanding of perceptions of age in ancient Egypt. As is the case with defining 'childhood,' defining 'old age' also poses difficulty. Portrayals of older individuals in Egyptian art and storytelling typically focused upon the declining strength of the body. One such example is the *Story of Sinuhe*, a fictionalized account of a courtier during the reign of Amenemhat I and Sesostris I, in which Ptahhotep dreamed about his return home after a long journey:

> Would that my body was young again!
>
> For old age has come, feebleness has overtaken me.
>
> My eyes are heavy, my arms weak;
>
> My legs fail to follow.
>
> The heart is weary; death is near (Janssen & Janssen. 2007: pp. 143).

Visual depictions of older individuals typically indicated their age via grey hair and the presence of rolls of fat around their midsection, however, the latter signifiers of “success, wealth, and indolence” seem to have been reserved solely for middle-aged, upper class men (Meskell, 1999: pp.62).

Subsequently, the role of older women in ancient Egyptian society is also unclear, largely due to the emphasis on youth in conceptions of beauty. Janssen & Janssen (2007) described a few instances in which 'Wise Women' were consulted with respect to social disputes, however, the

specific nature of this role is unknown and depictions of elderly women in general remain scarce (see pp.147; 151). Much like the examination of younger individuals discussed above, this study will also address possible differences in body positioning between younger and older adults in order to examine the possibility that differences in social age may be reflected in their mortuary treatment.

2.3 Social context –sex

The use of the concepts of sex and gender in archaeology have been heavily discussed elsewhere (see Sofaer, 2006 for a detailed review) and will thus only briefly be covered here. However, in order to discuss possible differences in the treatment of male and female bodies during embalming, it is first necessary to define how these categories are delineated and what they may have meant for the lived experiences of the individuals under study.

Sofaer (2006) pointed out that the identification of gendered artifacts, while useful in some contexts, still relied upon osteologically-determined biological sex as a foundation for analysis. In order for objects to be assigned to a particular gender, they first had to be associated with a body, which was in turn assigned a biological sex based on skeletal characteristics. In this respect, while gender archaeology purports to focus on a socially constructed 'gender,' in actuality it is often predicated upon biological sex. Additionally, gendered activities can also have a differential effect on the skeleton through both proliferative and degenerative changes (see Sofaer, 2006), making it possible in some cases to discern socially-proscribed gender via biological means.

With respect to ancient Egypt specifically, Meskell (1999) argued that that sex/gender binary should not be applied to ancient Egyptian data and should instead be replaced by a more nuanced concept of 'sex' encompassing the complexities of experience, expression and performance of sexual differences (see pp.75). For this reason, the remainder of the present study will refer to 'sex' rather than 'gender,' however it should be noted that this is intended to incorporate these nuances and does not refer only to biological sex.

Women in ancient Egypt

Relatively little is known about the lives of women based upon textual and iconographic depictions, likely due to the importance of literacy to Egyptian society. While the ruling

class, including scribes, state officials and the clergy, were literate, most Egyptians likely had much lower levels of literacy (Janssen & Janssen, 2007). Additionally, while a few examples of writing attributed to women have been found such as the depiction of Qenamun's wife with a scribal palette beneath her chair (see Meskell, 2002: pp.85), girls in general were not formally educated and were thus also not literate (Meskell, 2002; Janssen & Janssen, 2007).

As a consequence, while the activities and experiences of upper class men in ancient Egypt are well documented, other groups (e.g. slaves, women, and children) did not receive the same coverage in either textual or iconographic sources. For this reason, it is difficult to discern precisely how –or whether – sex differences were expressed in Egyptian society.

Accordingly, considerable debate exists regarding the status of women in ancient Egypt. Some sources seemed to imply that women had a relatively high degree of social and economic mobility (see for example Trigger, 1983: pp.312), however, others pointed out that the status of women was heavily dependent upon their relationships to men, both by birth as well as through marriage. Janssen & Janssen (2007) described several different terms used to delineate the various categories of partnership which women occupied in relation to men: women were variously described as 'wives' and 'concubines,' as well as 'living with' or just 'with' their male companions (pp.94-5). As mentioned above, divorce seems to have been relatively common (see Janssen & Janssen, 2007: pp.93), whereupon women may have been entitled to only one third of the assets acquired during a marriage, while their husband received two-thirds (see Meskell, 2002: pp.101; Janssen & Janssen, 2007: pp.93).

In his *Histories*, Herodotus suggested that women attended market and were involved in trade, while men stayed home and did the weaving (see de Sélincourt, 1971: pp.115). In contrast, however, others portrayed women as having a much more precarious status, particularly in situations of divorce wherein the rupture of ties between women and their families left them in a life of financial insecurity (Meskell, 1999).

Based on documents from Deir el-Medina it appeared that women were able to own land in their own names, however, the practical implications of this remain somewhat uncertain. Janssen & Janssen (2007) suggested that women 'owning' land afforded them roughly the same rights as men over their property (pp.180). However, other scholars have offered alternative interpretations of the same evidence. Meskell (2002) proposed that women may

have been listed as 'owning' land as placeholders of a sort, 'owning' the land in a legal sense but not necessarily wielding any power over it as an asset (see pp.110).

The financial instability of women also seems to have carried over into their provision for the afterlife. Meskell (1999) described several cases in which women received a poorer quality embalming than did their husbands in spite of being interred in the same tomb (see pp.186-8), a disparity which became increasingly marked among higher status individuals:

> On a gross scale, the wealthier a man became in the 18th Dynasty at Deir el-Medina, the more likely he was to have greater relative wealth in comparison with his wife or offspring. Conversely, for individuals who were less wealthy and had somewhat lower status, differences on the basis of age, sex, ethnicity and even marital status were minor (Meskell, 1999: pp.203).

Subsequently, while textual and iconographic evidence seems to suggest that women were afforded a relatively high degree of social and economic mobility, further research on the relevant archaeological and bioarchaeological evidence is needed in order to paint a more complete picture of sex differences in ancient Egyptian society. As described above, the present study aims to address some of the ambiguity surrounding perceptions of age and sex in ancient Egypt by exploring differences in body treatment during mummification.

Chapter 3

3. Literature Review

In spite of the generous wealth of information concerning the process of artificial mummification undertaken by the Egyptians during and immediately following the Dynastic period, relatively little has been written about the treatment of the legs specifically. Most of our information regarding the specifics of the embalming process comes from one of three types of sources: (1) Contemporaneous accounts, including Egyptian documents; (2) Early mummy studies involving unwrapping and dissection; and (3) Mummy imaging studies. Interestingly, while the various types of sources offer differing perspectives on the mummification process, very little scholarship exists on the treatment of the limbs. Furthermore, virtually all of the existing studies focus upon the arms and hands when discussing the limbs, usually at the expense of the legs. For this reason, it is somewhat difficult to reconstruct the exact treatment of the legs based on the existing body of literature. However, this further emphasizes the relevance of examining the legs prior to undertaking any type of paleopathological study of the limbs, as this will allow us to better account for the effect of embalming and desiccation on the appearance of the tissues.

3.1 The Egyptian Book of the Dead (*The Papyrus of Ani*) –c. 1500-1400 BCE

One of the most complete Egyptian sources pertaining to embalming and mummification is the *Papyrus of Ani*, commonly known as the *Book of the Dead*, which has been dated to approximately the 18th Dynasty but likely incorporated material from much earlier sources, possibly dating as far back as the Predynastic period (See Budge, 1967[1895]: pp.ix-xlvii for detailed review). The text as it stands comprised a series of chapters to accompany the entirety of the funeral process –including the embalming itself – and included both ritual incantations and instructions to be followed by the priests[3] entrusted with preparing the dead for the afterlife.

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3 See Leca, 1980: pp.137; Ikram, 2003: pp.57 for details regarding the priesthood charged with preparing the dead.

While it should be noted that the funerary traditions of ancient Egypt, as those of any other society, cannot be treated as static but were rather changing entities in response to various other social and economic factors, the core values behind mummification seem to have remained relatively constant. Based on these texts, the embalming of the deceased appears to have fulfilled two main purposes: (1) to stave off the 'corrupting' effects of decomposition upon the body after death; and (2) to perfect the form of the physical, corruptible body (the *khat*) into a spiritual, incorruptible body (the *sahu*), the functionality of which could be restored such that it might "walk about as it pleaseth" (Budge, 1967[1895]: pp.4).

Preventing Corruption

One of the main reasons for embalming the body was to halt the destruction of the tissues by decomposition after death. Meskell (1999) described,

> Terror and disgust were evoked through confrontation with the dead body, and spells like those from the *Coffin Texts* or *Book of the Dead* could be invoked to maintain the transitional state of the corpse. There was an explicit concern over bodily fluids, such as sweat, and with the body's loss of integrity through the presence of maggots (pp.121).

Throughout the *Book of the Dead*, decomposition or decay (also termed 'corruption') of the body was consistently portrayed as the proverbial 'enemy' of those aligned with Osiris and Horus. Subsequently, triumph over the decay of the body represented the victory of good over evil. Chapter XLV "The Chapter of Not Corrupting in the Underworld" read:

> O thou whose limbs are without motion like unto [those of] Osiris! Let not thy limbs be without motion, let them not corrupt, let them not pass away, let them not decay; let it be done unto me even as if I were the god Osiris (Budge, 1967[1895]: pp. 316).

Similarly, in Chapter LXXXIX, the mummified Ani pleaded with the god Annitu to restore his soul to his body and to "make thou me to stand up like those beings who are like unto Osiris and who never lie down in death" (Budge, 1967[1895]: pp. 318).

Because decomposition was associated with evil, embalming the body was necessary in order that it become united with the soul in the underworld and 'come forth' as a singular being (i.e. an 'Osiris') into eternal life. For example, Chapter LXXXIX "The Chapter of Causing the

Soul to be United to its Body in the Underworld" entreated: "May he behold his body, may he rest in his glorified frame, may he never perish, and may his body never see corruption" (Budge, 1967[1895]: pp.318). Similarly, Chapter LXXXV, Line 2 read: "I have not entered the house of destruction; I have not been brought to naught, I have not known decay" (pp.338).

While the bulk of these texts focused on the ritual aspects of the Egyptian funerary tradition, a few references to the material procedures of embalming were also present. Several references were made to the purification of the body with natron, including the following incantation intended to be recited aloud by the *kher heb* priest during the presentation of offerings to the mummy of the deceased:

> Thou art stablished among the gods they brethren, thy head is purified for thee with natron, thy bones are washed clean with water, and thou thyself art made perfect with all that belongeth unto thee (Budge, 1967[1895]: pp.cxl).

Similarly, in Chapter LXXIX, Lines 7-8, the deceased proclaimed, "I am pure […] I have brought unto you perfume, and incense, and natron" (pp.336). Additionally, a further section also appeared to refer to the wrapping of the body. Chapter CXXV, Lines 13-16 described the deceased entering into the House of Osiris, becoming "swathed" in the apparel therein, and given an unguent (Budge, 1967[1895]: pp.345).

These references demonstrated that the application of embalming materials to the body served not only the practical purpose of virtually halting the natural processes of decomposition, but also to purify the individual symbolically in preparation for the afterlife.

Restoring functionality to the body

In addition to staving off decomposition, the mummification process was also intended to restore the body's functionality for use in the underworld, the "coming forth of the soul to walk about every place that it please" (Budge, 1967[1895]: pp.4).

The *Book of the Dead* mentioned numerous physical activities to be carried out by the deceased both during the journey to the *Tuat* as well as in their final resting place. Perhaps unsurprisingly, many of these required the use of the legs. The deceased was variously

described as “walking” (Chap. I [pp.267, 273]; Chap. LXXVIII [pp.333]; Chap. LXXXV [pp. 338]); “standing” (Chap. I [pp.273]; Chap. XXVI [pp.308]; Chap. LXXXIX [pp.318]); “kneeling” (pp.259; Chap. XVII [pp.277]); and “sitting” (Chap. CXLVI [pp.300]; Chap. XXVI [pp.308]), as well as climbing both stairs (Chapter I; Budge, 1967[1895]: pp.265) and ladders (Budge, 1967[1895]: pp.Lxxi). The specific naming of these tasks further emphasized the importance of restoring the functionality of the limbs through the embalming process.

Additionally, one vignette (reproduced in Budge, 1967[1895]) appears to show the mummy of Ani propped upright in his coffin in order to receive offerings from mourners at the doorway to his tomb (pp.265, Figs. 1 & 2). While the accuracy of this image in representing the actual happenings of the funeral process is somewhat uncertain, the portrayal of the mummy standing upright seems to imply that the lower body may have been positioned in such a way as to be able to bear weight, even after the rather lengthy funerary period had passed.

Legs as symbols of power

In addition, the legs also bore symbolic significance, as the restoration of the legs was used to signify the regaining of power –and, presumably, mobility – following confrontation with an adversary. Janssen & Janssen (2007) described a number of visual and textual representations emphasizing the Pharaoh's physical strength and athletic prowess, further supporting the concept of able-bodiedness as a source of ritual and social power in ancient Egyptian society (pp.111).

Egyptian texts typically depicted the body as a series of networked parts (i.e. the heart, eyes, etc.) which remained separate yet interconnected (see Meskell, 1999: pp.115-117 for discussion), thereby emphasizing the importance of each body part individually while still demonstrating the need for the reunion of the parts for use by the deceased in the afterlife. The *Book of the Dead* continually paralleled the embalming of the deceased with the reassembly and mummification of the god Osiris by his wife, Isis. In having his or her own body embalmed, the deceased was also symbolically re-enacting the embalming of Osiris by bringing together his limbs (See Ch. LXXXIV, Lines 10-11 [pp.340]; Ch. CXLVI, Lines 4-8 [pp.294]).

Following the completion of embalming, the various parts of the body became assigned to a particular god or goddess (see for example Budge, 1967[1895]:pp.356); additionally, the right side of the body became aligned with Horus (i.e. the triumph of good) while the left was aligned with his adversary, Set, the brother and killer of Osiris (see Budge, 1967[1895]: pp.lxxii). A similar perception of the right and left sides of the body was also described in the Ebers medical papyrus wherein the "breath of life was thought to enter through the right ear, whereas the breath of death enters through the left" (Meskell, 2002: pp.61).

The restoration of the legs and feet to the gods also symbolized the restoration of their powers and subsequent triumph over evil. In Chapter CXLVI, Lines 78-79, Ani proclaimed: "I have made Osiris, the overlord of the netherworld, to be victorious over his enemies [...] I have caused the god to have the power of his legs" (Budge, 1967[1895]: pp.299). Similarly, in Chapter XVIII, Lines 3-4, Osiris conquered his enemies on the night when his thigh, heel and leg are brought into his coffin (Budge, 1967[1895]: pp.304).

Accordingly, the restoration of control over the legs featured prominently in the chapters pertaining to the reanimation of the body after mummification in preparation for the afterlife. Two chapters were devoted specifically to the legs. The first, Chapter XCII entitled "The Chapter of Opening the Tomb to the Soul of the Shadow, Of Coming Forth by Day, and of Getting Power Over the Legs" read:

> Saith Osiris, the Scribe Ani, triumphant: 'The place of bondage is opened, that which was shut is opened, and[...]; the place of bondage is opened unto my soul [according to the bidding of] the eye of Horus/ I have bound and stablished glories upon the brow of Ra. **[My] steps are made long, [my] thighs are lifted up; I have passed along the great path, and my limbs are strong** (Budge, 1967[1895]: pp.319, emphasis added).

The importance of the reanimation of the legs in the creation of a perfected 'Osiris' was reiterated in a further chapter (Chapter LXXIV) called "The Chapter of Walking with the Two Legs, and of Coming Forth Upon Earth" (see Budge, 1967[1895]: pp.320).

Two additional chapters regarding the restoration of the heart to the body also emphasized the reanimation of the legs. Lines 1-9 of Chapter XXVI entitled the "Chapter of Giving a Heart Unto Osiris Ani in the Underworld" stated,

> May my mouth be given unto me that I may speak with it, and my two feet walk withal, and my two hands and arms to overthrow my foe. May the doors of heaven be opened unto me; may Seb, the Prince of the gods, open wide his two jaws unto me; may he open my two eyes which are blinded; **may he cause me to stretch out my feet which are bound together; and may Anubis make my legs firm that I may stand upon them.** […] I know my heart, I have gotten the mastery over my heart, I have gotten the mastery over my two hands and arms, I have gotten the mastery over my feet, and I have gained the power to do whatsoever my ka pleaseth (Budge 1967[1895]: pp.308, emphasis added).

Similarly, Chapter XXVII, Lines 1-5 described 'Osiris Ani' as having "gotten power over his own limbs" (see Budge, 1967[1895]: pp.312), thereby gaining bodily autonomy in the afterlife.

Taken together, the texts comprising the *Book of the Dead* clearly demonstrated the importance of the limbs to the Egyptian view of the afterlife and, consequently, their relevance to the mummification process.

3.2 *The Rites of Embalming* –c. First Century CE

In addition to the aforementioned funerary texts, a few other Egyptian sources also depict some elements of the mummification process. Leca (1980) discussed two Theban papyri known as the "Rites of Embalming" which described the steps undertaken during the embalming process. These sources, known as the Third Boulaq Papyrus and exhibit No. 5 158 at the Louvre, respectively, have been radiocarbon dated to the first century of the Common Era. However, the particular phrasing used suggested that both pieces are copies of much older documents dating to the New Kingdom (1580-1085 BCE) (Leca, 1980: pp.248). Interestingly, the wrapping of the lower body appeared at the end of these treatises, whereas other accounts described the wrapping process as proceeding from the feet upward (see for example Budge, 1925: pp.344).

While the latter two papyri did not provide any details regarding evisceration and/or excerebration methods, they did outline the ritual treatment of the limbs during the mummification procedure. Maspero's (1875) translation of "Le Ritual de L'Embaumement"

in his *Mémoire sur Quelques Papyrus du Louvre* described the embalming of the limbs in some detail:

> After these things perform the embalming operations on the right and left arms, and then the ... and the children of Horus, and the children of Chent-aat, shall carry out the embalming operations on the two legs of the deceased. Rub the feet, legs, and thighs of the deceased with black stone (?) oil, and then rub them a second time with the finest oil. Wrap the toes in a piece of cloth, draw two jackals upon two pieces of linen with colours mixed with water perfumed with anti, and each jackal shall have his face turned towards the other; the jackal on the one bandage is Anubis, lord of Hert; the jackal on the other is Horus, lord of Hebennu. Put Anubis on the right leg, and Horus on the left leg, and wrap them up in fine linen. To complete the embalming of the legs, take six measures of anchamu flowers, natron and resin, and mix with water of ebony gum, and put three measures on the right leg and three measures on the left. Then put some fresh (?) senb flowers made into twelve bundles (?) on the left leg, and twelve bands of linen, and anoint with the finest oil (Maspero, 1875, In Budge, 1925: pp.344).

3.3 Herodotus' *Histories* –c. Fifth Century BCE

The most commonly cited account of ancient Egyptian embalming practices comes from Book II of Herodotus' *Histories*, in which he detailed his own experiences in visiting Egypt in combination with secondhand accounts from various people he encountered on his travels. For the purpose of this chapter, only those aspects of embalming pertaining to the legs will be discussed, however, the full text of Herodotus' section on Egyptian embalming as translated by de Sélincourt (1971) is reproduced in Appendix A.

In the second book of his *Histories*, Herodotus described three different modes of embalming dictated by the income level of the decedent's family, each of which employed a slightly different method of preservation. The most expensive form involved the total evisceration and excerebration of the deceased by surgical means, followed by packing of the body cavity with various materials. The body was then packed in natron for a period of seventy days[4] after which it was wrapped in linen coated with a gum (resin) adhesive, which presumably

4 Some uncertainty exists as to whether this number pertains to the packing of the body in natron or the total time elapsed during the embalming from beginning to end. Other sources

acted both as an antibacterial and a physical barrier to protect the remains from decomposition (Aufderheide, 2003: pp.225; Ikram, 2003: pp.55). In contrast, removal of the viscera apparently took place via chemical dissolution, or not at all, in the middle and cheapest options, respectively (See de Sélincourt, 1971: pp.133-4).

The only description in which Herodotus explicitly mentioned the effect of the treatment on the limbs was that of the middle cost option, wherein evisceration took place via cedar oil injected into the body cavity through the anus prior to desiccation. Following the “pickling” of the body in natron for the requisite number of days, the body was drained of its remaining (liquefied) viscera and cedar oil, leaving it in a highly desiccated state. Herodotus described,

> The effect of it is so powerful that as it leaves the body it brings with it the stomach and intestines in a liquid state, and as the flesh, too, is dissolved by the natrum nothing of the body is left but the bones and skin (de Sélincourt, 1971: pp.134).

Although Herodotus claimed in his narrative that the portion of his account dealing with embalming came from his own “direct observation and research” (see de Sélincourt, 1971: pp.138), the reliability of this description is uncertain. However, it should be noted at this point that Herodotus' account seemed to imply that the soft tissues of the limbs, aside from the skin, were dissolved by the natron in which the body was packed.

The latter observation seemed also to precede the “mere skeletons wrapped in 'cerecloth'” described more than a millennium later by Granville (1825) and other writers of that era (pp.285). Granville (1825) described a mummy presented by the King of Denmark to the Museum of the Royal Society of Göttingen in which “not only had the viscera been removed, but that the muscles also, and every soft part, had been taken away by accurate dissection, made with some sharp instrument; for nothing was found to intervene between the dry substance of the bones and the bandages” (pp.286). Unfortunately, it is unclear from this description whether or not the other soft tissues of the limbs, such as the internal structures of the joints, were impacted similarly.

The final and least expensive method of embalming was described in the least detail of the three, and appeared to have involved only the dissolution of the intestines followed by the drying of the body in natron. Herodotus' description did not refer at all to wrapping in either

of the middle or lower cost forms of embalming, suggesting that the desiccating action of the natron may have been considered sufficient for preservation in these cases. However, based on the existing evidence it seems more likely that wrapping was in fact employed in these cases but was simply not mentioned in Herodotus' account, perhaps because it was considered ubiquitous across the embalming profession.

3.4 Other sources from the ancient world

In addition to Herodotus' account, a second text written by Diodorus Siculus in the first century of the Common Era also described the Egyptian mummification tradition in some detail. The full text of this passage as taken from Iskander (1980) is reproduced in Appendix B.

Like Herodotus, Diodorus did not address the treatment of the limbs directly; however, it can be inferred based on his descriptions of the body overall that the limbs were likely also treated accordingly. Of particular interest was his description of the final product of mummification, wherein the soft tissue was preserved to such a degree that the individual retained his or her features as they were in life. Having treated the the body with cedar oil and aromatics for “over thirty days,” Diodorus described:

> [T]hey restore it to the relatives with every member of the body preserved so perfectly that even the eyelashes and eyebrows remain, the whole appearance of the body being unchangeable, and the cast of the features recognisable. Therefore, many of the Egyptians keeping the bodies of their ancestors in fine chambers, can behold at a glance those who died before they themselves were born. Thus, while they contemplate the size and proportions of their bodies, and even the very lineaments of their faces, they present an example of a kind of inverted necromancy and seem to live in the same age with those upon whom they look (Iskander, 1980: pp.6).

Like Herodotus' description of the most expensive form of mummification available at the time of his writing, the procedure described by Diodorus also appeared to rely on the drying effect of natron in combination with the antimicrobial and water-repelling action of oil and/or resin as the main preservative agents. While this passage did not refer to the limbs directly, the assertion that the body maintained its proportions and size in life following

mummification suggests that the particular embalming procedure described in this excerpt must have involved relatively little distortion of the tissues. Alternately, it may also have involved some form of restorative molding or packing of the limbs, as has been described elsewhere and is discussed in further detail below, which was used to reproduce a more lifelike appearance in the body's form.

As outlined in the previous sections, the limbs played an important role in the ritual aspects of the mummification procedure, as they required restoration of functionality for use by the deceased in the afterlife. Subsequently, while the treatment of the limbs –particularly the legs – was largely excluded from depictions of the embalming procedure by both Greek and Egyptian sources, the ritual emphasis placed on the appendages seems to indicate a greater degree of attention than was previously thought. For this reason, it seems pertinent that a detailed study of limb treatment that includes the legs be performed to shed light on this heretofore neglected aspect of the mummification tradition in Egypt.

3.5 Timeline of mummification practices in Egypt

Although the sources discussed above have been invaluable in the past to our understanding of the mummification process, modern mummy studies have demonstrated that the specifics of the embalming process changed considerably both over time and between social classes (See for example Wade, 2012). When considered within their respective historical contexts, these sources may provide valuable insight into the "Classical" (18th Dynasty) Egyptian embalming procedure or, potentially, those of the period during which the accounts were written. However, they fail to capture the dynamic nature of the mummification tradition as a whole. For this reason, modern studies of mummified human remains are also necessary to our understanding of the specifics of artificial mummification in Egypt.

Meskell (1999) characterized the Egyptian funerary industry as an "industry in the modern sense of the word with specific groups, such as embalmers, mourners, or libation pourers, who made a living out of funerary services" (pp.110). The embalming trade in Egypt was a hereditary vocation carried out by a specific class of priests who were responsible for carrying out both the physical and ritual aspects of preparing the dead for the afterlife (Leca, 1980: pp.137; Ikram, 2003: pp.57). The latter could involve either communal ritual –mainly

for those of elite social status – or smaller individual rites for people of lower economic or social status, such as children (see Meskell, 1999: pp.110).

Changes in the specific methods of Egyptian embalming over time have been well-documented by a number of scholars (See Gray, 1967; Iskander, 1980; Peck, 1998; Aufderheide, 2003: pp.212-259; Ikram, 2003; Raven & Taconis, 2005; Wade, 2012 for detailed reviews) and will thus only be briefly outlined here. However, it should also be noted that while a particular style of embalming might have been more prominent in a particular period, multiple types of embalming technology were often employed at one time depending on the social status of the deceased (Iskander, 1980) and the preferences of a particular school of embalmers (Ikram, 2003).

Several authors have noted stylistic variations in mummification between time periods which have been used to indicate the particular period in which the mummification was performed (Smith, 1914; Gray, 1967, 1972; Leca, 1980; Russell et al., 1980). Overall body positioning changed over time, moving from a flexed 'contracted' position on the left side to an extended supine position by Dynasty 4, a transition which Dunand and Lichtenberg (2006) suggested may have occurred in order to facilitate the evisceration of the body via abdominal incision.

The positioning of the limbs also seems to have varied over time, however, the only major examination of limb positioning in Egyptian mummies to date was Gray's (1972) study of arm and hand positioning. Based on x-rays of one hundred and eleven (n=111) individuals, Gray (1972) established a seriation of arm and hand positioning in both royal and non-royal Egyptian mummies based on time period. His results suggested that arm positioning followed a close enough sequence to allow for its use as a diagnostic tool to establish the time period during which a particular individual was embalmed (see for example Gray, 1973). In contrast, the positioning of the lower body has yet to be studied, perhaps due to the relative exclusion of the legs and feet from the existing accounts of mummification described above.

In addition to stylistic changes across time, several authors have also pointed to regional differences in the particulars of the embalming process (e.g. route of excerebration) as evidence of the existence of different schools of embalming practitioners (See Morton, 1844; Lamb, 1901; Shafik et al, 2008; Wade, 2012). Initially, mummification was restricted to upper class individuals, such as kings and other royalty; however it eventually passed

gradually through the lower classes in what has been described as the 'democratisation of the afterlife' (See Gray, 1967; Callender, 2000; Wade, 2012). Accordingly, Meskell (1999) noted that elite status and its accompanying economic mobility inherently facilitates access to "transformative bodily treatments, in life and death, so that an enhanced bodily status is inextricably tied to privileged social status" (pp.111).

3.6 Limb flexibility during embalming

At present, some disagreement exists with respect to the degree of desiccation that took place prior to the posing and wrapping stages of the embalming process. Some researchers (e.g. Sandison, 1963) pointed to the remarkable preservation of the bandages overlying the skin as evidence that the mummies must have been virtually entirely desiccated prior to the application of wrappings. However, several features have been identified which point to a considerable amount of suppleness in the limbs following the initial drying period.

Although the particulars of the embalming process changed over time, the primary mode of preservation of Egyptian mummies was the removal of water from the body, resulting in almost total dehydration of the tissues and thereby staving off the destructive effects of decomposition. The main desiccating agent used in ancient Egyptian mummification was a naturally occurring salt known as natron or *netjry* a mixture of sodium bicarbonate, sodium carbonate, sodium sulphate and sodium chloride (Zimmerman et al, 1998; Ikram, 2003). The use of natron for the removal of water from the tissues operated according to roughly the same principles as those applying to naturally desiccated mummies, wherein a concentration gradient is created as water transfers out through the skin's surface (See Aufderheide, 2011). As described previously, natron was also ascribed ritual significance in the *Book of the Dead* and used to purify the body of the deceased during the funeral rites (See Budge, 1967[1895]: pp.cxl).

Plant resins and oils imported into Egypt from Lebanon and Syria (Ikram, 2003: pp.55) as well as beeswax (Buckley et al., 2001) were also used to fill the cavities of the body in place of the removed or dissolved organs. The addition of these materials further aided in the preservation of the remaining soft tissues by inhibiting bacterial growth through spontaneous polymerization, or the creation of a crosslinked aliphatic network within the body tissues and their accompanying wrappings (Buckley et al., 2001).

In addition to filling the body cavity, a number of sources, including the *Rites of Embalming* described the use of oils or other fats massaged into the skin to restore suppleness and facilitate posing of the limbs following desiccation in natron (e.g. Dawson, 1927; Leca, 1980; Ikram, 2003) as well as to help accelerate water loss by maintaining a high concentration gradient at the skin's surface (Aufderheide, 2011) and protect the tissues from microbial action (Buckley et al., 2001). The *Book of the Dead* also contained references to the anointing of the body with oil (See Budge, 1967[1895]: pp.cxli).

Based on their fatty-acid distribution, Buckley et al. (2001) found that plant oils –and occasionally animal fats- seemed to have comprised the primary components of the embalming agents used in mummification, likely acting as a less costly base into which more expensive, exotic ingredients could be mixed. Oils used for this purpose could have included imports such as juniper and cedar oils, respectively, as well as locally-produced goods such as lettuce and castor oils (Ikram, 2003). However, the specific composition of the embalming agents used varied across time, moving increasingly toward the use of 'drying oils' (e.g. coniferous resins) and beeswax in later periods (Buckley et al., 2001: pp.839).

Accordingly, Panzer et al. (2013) suggested that although little is known regarding what precisely was done to the body while it soaked in natron, a number of possibilities exist:

> Although it is often assumed that nothing was done to the body during this period, it may well have been that the ancient embalmer changed the natron periodically as it absorbed body fluids, washed exposed surfaces to minimize bacterial multiplication, or directly applied heat with sun exposure. **Also the position of the body may have been altered as the desiccation proceeded** (pp.1534, emphasis added).

Several cases, both of ancient and experimentally mummified human tissues, have shown evidence of having retained at least some moisture prior to the posing and wrapping stages of embalming. In their experimental replication of an 18th Dynasty Egyptian mummification, Brier and Wade (1997) found that the limbs initially remained supple enough to be flexed manually, but became rigid and inflexible later (Zimmerman et al., 1998). Likewise, in their experimental mummification study of human lower limbs, Panzer et al. (2013) found that desiccation continued to advance beyond the initial ~40 day drying period, suggesting that

absorption by the wrappings as well as natural evaporation may have also played key roles in the removal of water in the body after the initial drying in natron.

Similar effects have also been documented in ancient mummies. One such case is the mummy of Nefer-Mut, housed at the Royal Ontario Museum, whose abdomen and legs appeared to have shrunken away from their overlying wrappings, suggesting that the remains were not fully dried at the time of their application (Nelson, 2008).

Imprinting in the skin by overlying embalming materials or other objects applied during the mummification process has also been noted by a number of researchers, suggesting that the body likely retained at least some degree of suppleness during this part of the procedure. In an early study of the ancient Egyptian mummification tradition, Granville (1825) noted the presence of wrinkles in the skin of the fleshier parts of the body of a Theban female mummy, including the upper thighs, arms, abdomen, and breasts, which seemed to represent the imprints of the overlying bandages.

Similar impressions caused by jewelry were also found in the skin of the limbs of the 11th Dynasty pharaoh Mentuhotep II's six queens and princesses found accompanying his temple at Deir-el-Bahari (Aufderheide, 2003: pp.228; Ikram, 2003: pp.62). Leca (1976) attributed the apparent incomplete desiccation of two female individuals from the latter burial to a poor embalming job overall,[5] resulting in decomposition, mold growth, and, as a consequence, extreme fragility (pp.164).

The degree of flexibility remaining in the limbs following the completion of mummification seemed to have varied considerably between individuals, perhaps based on the type of embalming employed during the particular time period during which they were prepared. Many older accounts described human mummies as being extremely brittle upon examination, particularly those having been desiccated using natron. Budge (1925) described, “The arms, legs, hands, and feet of such mummies break with a sound like the cracking of chemical glass tubing; they burn very freely and give out great heat (pp.208). Similarly, Granville (1825) also described a mummy dissected by members of the Royal

5 The bodies of Mentuhotep II's queens and princesses are supposed to have been partially eviscerated via an injection of cedar oil introduced anally, then dried using externally applied natron (Leca, 1980; Ikram, 2003), apparently in accordance with the procedure outlined by Diodorus (See de Sélincourt, 1971: pp.133).

Society which disintegrated almost entirely during examination (pp.283). In a later study, Gray (1967) related these extreme levels of fragility to the imperfect desiccation of mummies dating prior to the 18th Dynasty, which "fall to dust when unwrapped, leaving little but bones" (pp.35).

In contrast, other mummies seem to have remained fairly flexible, even after thousands of years. Granville (1825) described individuals believed to be treated using hot liquid resin or bitumen as bearing soft, pliant capsular membranes in the joints and muscles that yielded slightly to pressure (pp.305). Similarly, Shafik et al (2008) described King Tutankhamun's arms as being "no longer crossed over the chest," implying that the arms had been repositioned in the interim since the mummy's initial examination (pp.1).

Given the evidence discussed above, it appears that –at least in some cases – the body was posed while the tissues retained enough moisture as to be easily manipulated without breaking, whilst simultaneously being dry enough to maintain the positioning. This implies that the body was likely being posed after an initial stage of drying in natron but before the body was fully desiccated.

3.7 Subcutaneous packing and the height of mummification

As discussed above, the mummification tradition in Egypt reached its height during the Third Intermediate Period, peaking in terms of both style and functionality during the 21st Dynasty (see Taylor, 2000: pp.364). During this time, the embalming process became increasingly elaborate and eventually evolved to include the introduction of packing materials under the skin –over the muscle – to simulate a lifelike appearance in the contours of the body.

Historically, the existing archaeological literature attributed subcutaneous packing solely to the Third Intermediate Period and, specifically, the 21st Dynasty; however, more recent CT studies have suggested that the procedure was introduced earlier than was previously assumed. In their study of thirteen royal Egyptian mummies dating from the 18th through 20th Dynasties, Saleem et al. (2015) found evidence of subcutaneous packing in 12 out of 13 individuals studied (92%), four (n=4) of which showed packing of the extremities. Of those four, three (n=3) individuals (Tutankhamun, Seti I, and Amenhotep III, respectively) had packing materials throughout the extremities, including the arms, forearms, hands, thighs,

legs, and feet, whereas the remaining individual (Ramesses III) only exhibited subcutaneous packing of the thighs (pp.3).

By introducing foreign materials into the body beneath the skin, embalmers sought not only to restore to the body those elements which were removed during the earlier stages of evisceration and excerebration, but also to restore the form of the body as it existed in life. Smith (1914) described,

> For this purpose artificial eyes were inserted, the form of the body molded into shape, for which a variety of foreign materials was used as stuffing, any defects in the skin were remedied by neat patching, and any shortcomings, such, for instance, as the deficiency of hair in women, was remedied by the help of a wig or other device (pp.193).

The stuffing materials used in this process included mud, butter, resin, linen, sand, or sawdust and were introduced into the body through several incisions in the skin (Iskander, 1980; Ikram, 2003: pp.68), the locations of which may have been based on the Rhind Magical Papyrus and were described in detail by Smith (1914).

The majority of the subcutaneous packing was introduced through the normal embalming incision in the left ventral flank; however, other incisions were sometimes employed to facilitate the distribution of the stuffing under the skin of the limbs. Leca (1980) described,

> This material was pushed up between the gums and cheek to the edge of the eye sockets until the cheeks regained their curves, and then down into the chin to recreate the oval shape of the face. Next they plunged a hand up through the incision in the side of the body, and with extraordinary dexterity managed to loosen the skin of the neck and insert mud into the space they made... They used the same method to loosen and fill up the skin of the thighs, but were not able to reach further than the knee by hand. So they had recourse to long rods which reached down into the leg and pushed in the stuffing (pp.161).

Additionally, Smith (1914) also noted the presence of incisions in the feet, as well as more rarely in the backs of the ankle and knee, respectively, for easier distribution of packing materials into the lower extremities. An additional incision may also be seen in the area of the right buttock, used when “special difficulty was encountered” in packing the body.

The process of packing under the skin would also have required a considerable level of skill in order to carefully separate the skin from the underlying muscle (See Smith, 1914 for description), as well as determine precisely the correct quantity and composition of the stuffing materials. Based on the smooth, homogenous appearance of the packing materials on CT scans, as well as the remarkable degree of intactness of the overlying skin, Saleem et al. (2015) concluded that subcutaneous packing was likely carried out prior to desiccation while the body remained moist and supple (pp.5).

In some cases, the packing process appears to have been carried out incorrectly, resulting in damage to the skin and the underlying soft tissues of the limbs. According to Ikram (2003), "Some embalmers were too enthusiastic, and some mummies, or parts thereof, split open owing to a combination of over-packing and the chemical reaction of the packing materials" (pp.68). Similarly, Leca (1980) described a botched embalming dating to the Twenty-First Dynasty:

> A new technique of mummification was tried on Henattaui, which should have made the body more lifelike but on this occasion led to disaster. Her mouth was stuffed with tampons of natron which swelled when they came into contact with fat, and too much mud was injected under her skin with the result that, instead of reproducing the natural contours of the body, it literally burst through the skin, splitting it at the corners of her lips and tearing it from the eyes down around the cheeks so that is came off in strips as if it were a cardboard mask (pp.71).

While the macabre appearance of the mummy is unfortunate, cases such as these may also help to shed light on the precision with which the process must have been carried out in other –more successful – embalmings, as well as the sequence in which the steps were applied. In this respect, although the legs were rarely discussed in the literature pertaining to the Egyptian mummification tradition, the existing evidence seems to suggest that the legs would have been given a fair amount of consideration during the height of the Egyptian embalming tradition.

3.8 Decomposition and the decline of the mummification tradition in Egypt

With the decline in the popularity of mummification toward the end of the Dynastic period, the overall quality of embalming decreased considerably. Some corpses were treated hastily, being dried in natron and covered in resin without evisceration or excerebration taking place (Ikram, 2003: pp.71). Unfortunately, leaving the organs *in situ* would have exposed these remains to the effects of decomposition to a much greater extent than was seen in previous periods, often resulting in dismemberment and/or the loss of body parts either due to scavengers or advancing putrefaction. To this end, Leca (1980) –somewhat facetiously- remarked, "A deceased person from this period presenting himself before the tribunal in the next world would have been lucky if he still had all his limbs and viscera with him, and certainly could not expect to have them in order" (pp.164).

In many cases, 'repairing the damage' done by decomposition involved the introduction of foreign materials into the body to reconstruct the approximate shape of the missing element. Ikram (2003) described,

> During the process of mummification it was not unknown for various body parts to go missing. They would fall off as a result of over-desiccation or might even fall prey to dogs or rodents. In these cases, the embalmer provided substitutes in the form of palm ribs, the bones of other animals and modeled mud" (pp.73).

In other cases, prosthetic limbs, hands, or feet could also be added after death to restore the appearance of the appendages (Ikram, 2003: pp.73). While some of these prosthetic appendages may have been used in life, many show no signs of use or are entirely non-functional based on their construction. Gray (1966) described one case of an adult male aged 50-60 dating to the Ptolemaic period whose left arm appeared to have been amputated in life and replaced with a an artificial forearm and hand fashioned entirely of cloth in a 'gauntlet-shaped' structure. Based on the construction of this 'hand,' it seems apparent that it would not have been a functional prosthesis, but rather represented an attempt by the embalmer to restore the appearance of the missing appendage after death.

In other, more unusual cases, elements from multiple individuals were also incorporated into a single mummy, forming what have been termed 'composite mummies.' Aufderheide et al. (1999) described a case from the Roman Period cemetery at Ismant El-Kharab in which what appeared to be a single adult mummy turned out to be a composite of body parts from at least four separate individuals:

> The 'body' was composed of a 50-55-year-old female pelvis and severely osteophytic spine, the head of a 30-35-year-old female with minimal dental attrition, the soft-tissue-covered left leg of a 7-year-old child including both feet, and the right leg of the splinted bones of a 3-year-old child. A long, wooden stick (palm-leaf rib) extended from the pelvis through the neck area on which the head was impaled. Simple anatomy establishes that this body clearly is a melange of parts from different bodies. All of these and other skeletal structures were lashed firmly by means of linen straps to a frame composed of palm-leaf ribs. Linen sheets and straps had been deployed to cover all structures in such a way as to present the contours of an adult human body (pp.204).

They also found two other possible composites, Body 12-5 from autopsy 7 and Body 8-5 from autopsy 11, respectively. While cases like this obviously do not represent the majority of mummified individuals, it is worth noting that this type of embalming did occur as the substitution of body parts could interfere with the interpretation of paleopathological evidence.

While these restorations are certainly of interest to understanding the intention behind the mummification process, they are also relevant to our ability to perform paleopathological analyses upon the limbs. In some cases, the limbs may be entirely missing, thereby negating our ability to examine them. One such example are the legs of Manchester Museum mummy No. 1770 which were replaced with wooden prostheses during the Ptolemaic period, potentially due to the unidentified body being found in an advanced state of decomposition (Ikram, 2003: pp.73). Similarly, Ciranni et al. (2005) also described a mummy whose feet had been replaced by wedges of wood fixed with metallic pivots, which they interpreted as an attempt to compensate for a failure of the normal embalming process (pp.7). It should be noted, however, that although the loss of these elements due to decomposition may be a valid explanation, we also do not have sufficient evidence to exclude the possibility of the limbs

having been diseased, or subjected to substantial trauma, which might have led embalmers to introduce these replacements at a later time.

3.9 Post- and perimortem trauma

In addition to restorations aimed at remedying the state of the body itself, several cases have been found in which bodies appear to have been altered in order to fit their intended casings. Gray (1966) described two cases in which the limbs were manipulated in order to conform the body to the dimensions of a particular coffin, both dating to later periods in Egypt's mummification tradition. One of these, a young male, appeared to have had both femora deliberately broken and their distal ends discarded in order to shorten the legs, while the other, a young female, had two tibiae added to extend the length of her legs (Gray, 1966, 1973).

Leca (1980) also stated that postmortem fractures aimed at making the body fit into a smaller coffin were common in mummies, particularly those dating to later periods when the mummification tradition was entering into decline (pp.44). Similarly, Raven & Taconis (2005) also reported findings of a 22nd Dynasty female mummy having been subjected to extensive postmortem trauma, including multiple fractures, prior to the application of the overlying bandages (pp.103).

As demonstrated above, considerable textual and bioarchaeological evidence suggests that the limbs were treated in a deliberate, thoughtful manner, during mummification, much like the rest of the body. A number of features of interest, including subcutaneous packing, have been identified in the limbs of individuals from various contexts; however, the exact procedures enacted on the limbs during embalming remain somewhat of a mystery. For this reason, a detailed, methodical survey of limb embalming in Egyptian mummies will shed light on the way in which the appearance of the limbs may have changed during the embalming process.

Chapter 4

4. Materials and Methods

This chapter outlines the materials and methods used to examine a sample of eighty one (n=81) individuals archived in the IMPACT radiological database for evidence of limb manipulation during embalming, with a primary focus on limb positioning.

As was discussed in the preceding chapters, this research builds upon existing trends in mummy studies wherein the focus has shifted from the presentation of individual case studies and use of small sample sizes toward larger comparative studies such as those of the Horus group of researchers (see Allam et al. 2009, 2011; Thompson et al. 2013, 2014) and the creation of large-scale archaeological databases such as the University of Manchester's Mummy Tissue Bank (Lambert-Zazulak, 2003).

The inclusion of larger sample sizes is mainly due to innovations in digital imaging technology and data sharing which allow for direct comparison between larger numbers of individuals which would previously have been virtually impossible due to the financial and spatial constraints inherent in studying ancient mummies. One result of this movement toward the use of digital technology to facilitate both biological and cultural comparative studies is the Internet-Based Mummy Picture Archiving and Communication Technology (IMPACT) radiological database housed at The University of Western Ontario (Nelson & Wade, 2015).

4.1 IMPACT radiological database

The IMPACT radiological database is a large-scale, multi-institutional collaborative project aimed at the creation of a 'digital museum' of mummies. Its main purpose is to allow researchers access to large numbers of primary datasets in order to facilitate large-scale anthropological and paleopathological investigations using non-destructive medical imaging technologies (Nelson & Wade, 2015). The project will ultimately comprise of two databases running concurrently, one a mini-PACS housing the radiographic images, and the other containing context information for the individuals archived in this project. The radiographic database is the source of the data used in this project.

The IMPACT radiological database currently houses radiographic images of over 100 Egyptian human and animal mummies and includes a combination of plain-film x-ray films and CT scans. The individuals archived in this database are housed at various institutions around the world and represent a broad range of time periods and sites in Egypt's history, making them an appropriate sample for use in studies aimed at addressing both cultural and biological research questions. As will be discussed in greater detail below, the software package used for viewing and manipulating the datasets allows for the examination of both cultural aspects (e.g. stylistic variations in wrappings, artifact inclusion, etc.) as well as biological features including both skeletal and soft tissue of mummies through their digital 'unwrapping' using non-destructive imaging technologies.

The main image format of the CT scans used in this project is Digital Imaging and Communications in Medicine (DICOM), a medical imaging industry standard aimed at the robusticity of the data in response to changes in the technological instruments used both for scanning and viewing or editing the resulting images. The images reside on a server ("Anubis") and are then viewed and processed using a dedicated software package without actual transfer of the data to the end user.

ORS Visual Web Pro

The software package used for viewing and manipulating the CT scans used for this project is ORS Visual Web Pro (see http://theobjects.com/en/), which includes a web-based mini-PACS for the archival of medical images. The program allows the user not only to view both CT scans and plain-film x-ray images using a regular web browser, but also to manipulate their appearance (e.g. adjusting windowing and leveling, isolating particular features of interest, etc.) without altering the primary datasets. It also produces 3D renderings which may then serve as digital osteological models following the virtual 'removal' of the soft tissue and isolation of the skeleton.

The plain-film radiographic images used in this project were generally saved in standard image file formats (.TIFF or .jpg) and were viewed and edited using Adobe Photoshop CS6 Version 13.0 Extended. In most cases, little to no editing was required, however, those instances in which the image quality was particularly poor or included a number of

overlapping structures sometimes required adjustment of the brightness and contrast of the images.

4.2 Sample Selection

The individuals included in this study were selected based on the completeness and availability of their radiographic images in the IMPACT database as of the time of recording (approximately September 2014-March 2015). For the purpose of this study, the 'upper body' was defined as the head and neck, trunk/axial skeleton, arms, and hands, although only the arms and hands are included in the limb positioning analysis. The 'lower body' was defined as the pelvis, legs, and feet, although the pelvis was excluded from the limb positioning analysis.

Because the aim of this research was to explore the role of the legs in the embalming process, those individuals currently archived in the IMPACT database for whom visualizations of the lower body were unavailable were excluded from the final sample used in this study. Some of the full body scans used in this study ended above the level of the feet, in which case the feet were excluded from the analysis but positioning was recorded for the remainder of the body. In some cases, certain individuals in the database were also excluded from the sample if their skeletons were excessively damaged and/or disarticulated, as this precluded the possibility of being able to discern the positioning of their limbs. Of the ninety nine human mummies from the IMPACT database assessed for inclusion in this study (n=99), a final sample of eighty one individuals was chosen based on the criteria listed above (n=81).

Due to the nature of the database in which these individuals are archived, the sample used in this study was not intended to be treated as representative of any particular 'real-life' population, and therefore did not require randomization. However, some effort was made to include individuals from as wide a range of age at death estimates, time periods and sites as possible based on the current population of the IMPACT database. Additionally, although it was not deliberately selected as such, the sample also included a roughly equal number of male and female individuals.

The sample composition used for this study is listed in Table 1 below.

Table 1: Summary of sample used in this study

IMPACT ID	Name	Designation	Age	Sex	Time Period	Site	Modality
IMP00001			Adult	M	3IP	Thebes	CT
IMP00002	Nefer-Mut ("Justine")	910.5.3	Adult	F	3IP	Thebes	CT
IMP00003		910.13	Infant	I	Roman	Unknown	CT
IMP00004		U.N	Juvenile	M	Unknown	Unknown	CT
IMP00005	Djedmaatesankh		Adult	F	3IP	Thebes	CT
IMP00007	Pa-Ib		Adult	F	Late	Unknown	CT
IMP00008	Cleo		Adult	F	Ptolemaic	Unknown	CT
IMP00009	Hetep-Bastet		Older Adult	F	Late	Unknown	CT
IMP00010	Theban Female	RM2717	Adult	F	Roman	Thebes	CT
IMP00011	Theban Male	RM2718	Adult	M	New Kingdom	Thebes	CT
IMP00012	Ptolemaic Female	RM2720	Adult	F	Ptolemaic	Unknown	CT
IMP00021		Fleming	Subadult	M	3IP	Unknown	CT
IMP00022	Girl from Thebes		Juvenile	F	Unknown	Thebes	CT
IMP00025	Sheryet Mehyet		Adult	F	3IP	Unknown	PF
IMP00027		Genova 469	Older Adult	M	Roman	Unknown	PF
IMP00028		Genova 470	Adult	F	Late	Unknown	PF
IMP00029	Pasherienaset		Adult	M	Late	Edfu	PF
IMP00030		Vienna	Subadult	F	Unknown	Unknown	PF
IMP00031	Nesmut		Juvenile	F	3IP	Gurneh	PF
IMP00032		Wayne County	Adult	M	3IP	Unknown	PF
IMP00033		E.0452	Juvenile	I	Late	Fayum	PF
IMP00035		E.1045	Adult	F	Roman	Antinopolis	PF
IMP00036		E.1184	Juvenile	I	Unknown	Unknown	PF
IMP00040		E.3974	Adult	M	Ptolemaic	Abydos	PF
IMP00041		E.3975	Adult	I	Ptolemaic	Hawara	PF
IMP00043		E.5889	Adult	F	Late	Thebes	PF
IMP00044		E.5890	Adult	I	Late	Thebes	PF
IMP00055		E.9015	Juvenile	I	Unknown	Unknown	PF
IMP00056		E.9016	Juvenile	I	Unknown	Unknown	PF
IMP00058		Liverpool 1	Adult	F	Roman	Unknown	PF
IMP00059		Liverpool 2	Subadult	F	Roman	Unknown	PF
IMP00060	Pedeamun	Liverpool 3	Subadult	M	Late	Thebes	PF
IMP00061		Liverpool 4	Adult	M	Late	Thebes	PF
IMP00062		Liverpool 5	Adult	M	Unknown	Unknown	PF
IMP00063		Liverpool 6	Adult	F	Unknown	Unknown	PF
IMP00064	"Child Mummy"	Liverpool 7	Juvenile	M	Roman	Hawara	PF
IMP00065		Liverpool 8	Adult	M	Ptolemaic	Unknown	PF
IMP00066		Liverpool 9	Adult	F	Late	Thebes	PF
IMP00067		Liverpool 10	Adult	M	Late	Unknown	PF
IMP00068		Liverpool 11	Adult	M	Late	Unknown	PF
IMP00069		Liverpool 12	Subadult	M	Ptolemaic	Hissayeh	PF
IMP00070		Liverpool 13	Adult	M	Ptolemaic	Unknown	PF
IMP00071	Nesmin	Liverpool 14	Adult	M	Ptolemaic	Akhmim	PF
IMP00072		Liverpool 15	Adult	M	Unknown	Unknown	PF
IMP00073		Liverpool 18	Adult	F	Late	Kostamneh, Nubia	PF
IMP00081	Nofret	C47710	Adult	F	Ptolemaic	Akhmim	PF
IMP00082	Bahka		Older Adult	F	Unknown	Thebes	CT
IMP00083	Braided Lady		Adult	F	New Kingdom	Thebes	CT
IMP00088	Nesmutaatneru	95.1407a	Older Adult	F	3IP	Thebes	PF
IMP00089		"Tasmania"	Juvenile	I	Unknown	Unknown	PF
IMP00090		"New Zealand"	Adult	Unknown	Unknown	Unknown	Other
IMP00093	Tash Pen Khonsu	EA1989.13	Adult	F	Ptolemaic	Unknown	PF
IMP00094	Leiden Cat. 1	H.III.P1.	Adult	M	3IP	Thebes	CT
IMP00095	Leiden Cat. 2	L.XXI.3.	Older Adult	F	3IP	Thebes	CT
IMP00096	Leiden Cat. 3 – Khonsuemma'a	L.XXI.1.	Adult	M	3IP	Thebes	CT
IMP00097	Leiden Cat. 4	AMM 17.	Older Adult	F	3IP	Thebes	CT
IMP00098	Leiden Cat. 5 – Ta(net)kharu/Tadis	AMM 21/22	Older Adult	F	3IP	Thebes	CT
IMP00099	Leiden Cat. 6 – Ta(net)kharu/Tadis	AMM 21/22	Older Adult	F	3IP	Thebes	CT
IMP00100	Leiden Cat. 7 – Petament	AMM 20	Older Adult	M	3IP	Thebes	CT
IMP00101	Leiden Cat. 8	EG-ZM115	Older Adult	M	3IP	Thebes	CT
IMP00102	Leiden Cat. 9 – Petisis	AMM 19	Older Adult	M	Late	Thebes	CT
IMP00103	Leiden Cat. 10 – Hor	AMM 3	Adult	M	Late	Thebes	CT
IMP00104	Leiden Cat. 11 – Harerem	AMM 23	Older Adult	M	Late	Thebes	CT
IMP00105	Leiden Cat. 12 – Pawiamen	AMM 6	Adult	M	Late	Thebes	CT
IMP00106	Leiden Cat. 13 – Ity?	H.III.VVV App.2	Unknown	F	Unknown	Thebes	CT
IMP00107	Leiden Cat. 14 – Kek	AMM 4	Adult	F	Late	Thebes	CT
IMP00108	Leiden Cat. 15 – Inamonefnebu	AMM 1	Adult	M	Late	Thebes	CT
IMP00109	Leiden Cat. 17 – Peftjauneith	AMM 5	Unknown	M	Late	Unknown	CT
IMP00110	Leiden Cat. 18 – Keref	AMM 12	Juvenile	M	Late	Mendes Djedet/Hermopolis Parva	CT
IMP00111	Leiden Cat. 19	AMM 2	Adult	M	3IP	Thebes	CT
IMP00112	Leiden Cat. 20 – Diptah	AES 14	Older Adult	F	Ptolemaic	Akhmim	CT
IMP00115	Leiden Cat. 23	AMM 14a	Juvenile	I	Ptolemaic	Unknown	CT
IMP00117	Leiden Cat. 26 - Tasherytdjedhor (Sensaos)	AMM 8	Subadult	F	Roman	Thebes	CT
IMP00122	Herakleides		Adult	M	Roman	Unknown	CT
IMP00123	Thesaberu	22114	Adult	F	Ptolemaic	Akhmim	PF
IMP00124		22116	Juvenile	F	Ptolemaic	Akhmim	Other
IMP00125	Lady Takhar	22118	Adult	F	Ptolemaic	Thebes	PF
	Leiden Cat. 28 (Gray 22)	AMM 9	Adult	M	Roman	Thebes	CT
	Leiden Cat. 29	AMM 10	Subadult	M	Roman	Thebes	CT
	Leiden Cat. 31	AMM 24	Older Adult	M	Roman	Thebes	CT
	Peta Mumija	AMZ 01	Unknown	Unknown	Unknown	Unknown	CT

4.3 Age Estimates

Demographic information for the individuals in this sample was obtained from the previous work of Dr. Andrew Wade (see Wade, 2012), with the exception of the mummies housed at the Museum of Antiquities, in Leiden, Netherlands, which was taken directly from the museum's catalogue (see Raven & Taconis, 2005). Age and sex estimates were confirmed wherever possible using the relevant osteological standards described below.

Based on the estimated age ranges, the individuals were initially designated according to one of the following categories: (1) Infant/neonate (<1 year); (2) Juvenile (1-10 years); (3) Subadult[6] (11-18 years); (4) Adult (19-39 years); and (5) Older adult (>40 years). These categories were based on those described in Buikstra & Ubelaker (1994) but were adapted for use on a population bearing a shorter life expectancy (hence designating 'older adults' as those over 40 years of age at death, rather than 50 years as is standard within osteology). In order to facilitate the analyses of limb positioning, the Subadult, Adult, and Older Adult age categories were then collapsed into two broader groups, roughly defined according to average age of puberty[7], in order to better reflect the social age (see Chapter 2 and Sofaer, 2006: pp.119) of the individuals studied: Juveniles (≤10 years at death) and Adults (>10 years at death).

Each individual was designated to a particular age category based on the lower end of the age estimates obtained (i.e. an individual believed to have fallen within the range of 35-50 years of age at death would be considered 'Adult,' even though the upper end of the range might put them into the 'Older Adult' category). This is primarily due to the broadness of the initial age estimates upon which these categorizations were based; additionally, designating younger individuals according to the lower end of their estimated range ensures that they are treated

6 It is worth noting here that the individuals categorized as Juveniles in this study are also technically 'subadult.' However, for simplicity's sake, the term 'Subadult' (capitalized) will be used to refer to older subadults in keeping with convention in human osteology.

7 Since determining age of puberty in an ancient population with any precision is generally not possible, 'puberty' is defined in this study according to the upper end of the Juvenile osteological category (age 1-10 years at death). While 10 years appears to be a young age at which to reach puberty, even in modern societies, the dividing line between Juveniles and Adults was set at a low age in order to increase the likelihood that all individuals falling above that age would have at least started puberty.

as being their youngest possible age. Designation of each individual according to a developmental category, rather than a specific age range, is sufficient for this type of study as the intent is not to chart changes specific to individuals, but rather to look for broader patterns of variation in mummification practices. However, it could prove useful in the future to obtain more specific estimates to examine potential variation within these categories.

The final sample used in this study includes individuals representing a relatively wide range of age categories, particularly given the limitations inherent in using data collected from a collaborative database. Age estimates were possible for all but three of the individuals in the sample (n=78). The majority of the sample (n=44; 56.4%) was classified as Adults ranging from 19-35 years at time of death, however, each of the age categories described below was represented by at least one individual (as in the case of the Infant/Neonate group). The final breakdown of the sample is as follows: one Infant/Neonate <1 year (n=1; 1.2%); twelve Juveniles 1-10 years (n=12; 14.8%); seven Subadults 11-18 years (n=7; 8.6%); forty four Adults 19-39 years (n=44; 56.4%); fourteen Older Adults >40 years (n=14; 17.3%); and three for whom age estimates could not be obtained because the images were inadequate (n=3; 3.7%).

4.4 Sex Estimates

The sample used in this study is roughly equally distributed between males and females, with thirty-five males (n=35; 43.2%), thirty-five females (n=35; 43.2%) , nine of indeterminate sex (n=9; 11.1%), and two for whom sex estimates could not be obtained (n=2; 2.5%).

Sex estimates for this sample were largely based on those in Wade (2012), but were confirmed using the osteological standards[8] described below and/or soft tissue features wherever possible. Where possible based on the available visualizations, sex estimations were confirmed using non-metric traits of the pelvis, including the overall shape of the pelvic inlet as well as the subpubic angle, greater sciatic notch (see Krogman & Iscan, 1986; Buikstra & Ubelaker, 1994: pp.16-21) as well as the ischiopubic ramus, subpubic concavity and the presence of a ventral arc (see Phenice, 1969). Wherever possible, skeletal sex

8 See Sofaer (2006) for a detailed review of critiques of osteological methods of sex estimation.

estimates were also confirmed on CT scans based on the visualization of soft tissue features of both primary and secondary sex characteristics.

Sex was only recorded in Juvenile and Subadult individuals if clear indication could be established, either in the preserved soft tissue or in the cultural materials accompanying the burial. Those cases in which sex could not be determined via either of these means were recorded as 'Indeterminate' due to the lack of an established osteological standard for sex estimation developed for use on juvenile and subadult remains (see Brickley & McKinley, 2004 for a review).

4.5 Time Period & Site

Estimated dates for this sample cover a roughly 2,000 year span and represent five different periods in Egypt's history (see Chapter 2). Time period estimates were available for sixty-seven (n=67; 82.7%) individuals out of the total sample (n=81). The breakdown of time period representation in this sample is as follows: New Kingdom (n=2; 2.5%); Third Intermediate Period (n=17; 21.0%); Late (n=21; 25.9%); Ptolemaic (n=15; 18.5%); Roman (n=12; 14.8%); plus fourteen individuals for whom time period estimates were not available (n=14; 17.3%).

As is often the case in mummy studies, contextual information was somewhat difficult to obtain for this sample. This is in part due to the effects of tomb robbing, as well as the poor recording practices used at the time when many of these mummies were collected (i.e. the late nineteenth and early twentieth century), in addition to the focus of antiquarianism upon the recovery of archaeological –as opposed to biological – finds. Also, the removal and relocation of royal mummies to protect them from tomb robbers (see Janssen & Janssen, 2007: pp.165) as well as the reuse of tombs (see Taylor, 2000: pp. 333; Meskell, 2002: pp.206) further complicates the issue of establishing provenance for many individuals.

For this reason, time period and site location were only recorded in those cases in which this information could be easily verified based on well-documented contextual information and/or previous examination of accompanying materials (e.g. external casings, grave goods, etc.). In

some cases, time period[9] had also been previously determined based on mummification style, as demonstrated through the chosen routes of excerebration and evisceration. Those individuals whose dates overlapped between two or more periods were assigned to the earlier period in order to simplify comparisons between groups, as well as to allow for consideration of the possible emergence of a particular variant according to the earliest possible date.

Site data were available for a total of fifty individuals from this sample (n=50 of 81; 61.7%) and may be broken down as follows: Abydos (n=1 of 50; 2.0 %); Akhmim (n=5 of 50; 10.0%); Antinopolis (n=1 of 50; 2.0 %); Edfu (n=1 of 50; 2.0%); Fayum (n=1 of 50; 2.0%); Gurneh (n=1 of 50; 2.0%); Hawara (n=2 of 50; 4.0%); Hissayeh (n=1 of 50; 2.0%); Kostamneh, Nubia (n=1 of 50; 2.0%); Mendes Djedet/Hermopolis Parva (n=1 of 50; 2%); Thebes (n=35 of 50; 70.0%).

Unfortunately, information regarding socioeconomic status was only available for very few individuals in this sample and is thus excluded from this investigation. However, this would be a very valuable subject of research and should be pursued in the future.

4.6 Limb Positioning Variables

The main body of research from which the organization of the limb positioning portion of this study derives from the work of P.H.K. Gray on stylistic variation in arm and hand positioning over time among ancient Egyptian mummies (cf. Gray, 1972, 1973). The arm and hand positions recorded in the present study were roughly based on those designated in Gray (1972) with additional input from a chart of general mummification features included in Aufderheide (2003), both of which were aimed at the seriation of mummies based on stylistic changes in mummification across time.[10] While Gray (1972) only included positioning of the arms and hands, the table presented in Aufderheide (2003) included the legs. However, the latter limited the description of the legs to either 'extended' or 'flexed' without consideration of their rotation, and also entirely excluded both the hands and feet.

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9 See Gray, 1967; Iskander, 1980; Peck, 1998; Aufderheide, 2003; Ikram, 2003; Raven & Taconis, 2005; Wade, 2012 for reviews of changes in mummification techniques across time.

10 Adapted from Bertoldi and Fornaciari (1997).

For this reason, these two previous sets of limb positioning variables needed to be adapted to meet the level of detail necessitated by the present investigation. Operational definitions of all of the limb positioning variables examined in this study are provided in Appendix C. The upper body variables examined in this study were as follows: (1) Arm extension/flexion (n=76); (2) Hand position (n=74); and (3) Hand flexion (n=63). Arm extension was recorded as a general category of arm positioning (cf. Gray, 1972), while hand position was intended as a more specific descriptor of the variants present within the extended arm category.

The lower body variables examined in this study were as follows: (4) Leg position (n=74); (5) Leg rotation (n=71); (6) Foot flexion (n=54); (7) Foot rotation (n=55); (8) Foot position (n=55); and (9) Toe position (n=43). A further variable, (10) Leg extension, was also recorded; however, it was excluded from the statistical analyses because all of the individuals studied (n=81 of 81; 100%) had extended legs. As shown in the table of operational definitions provided in Appendix C, the arms, hands, and feet were assessed with both left and right sides together while the rotation of the legs was recorded first for both together (i.e. having at least one leg rotated), then for each leg individually. The latter was added once the rotated variant of the legs and feet had been identified (see Chapters 5 and 6 below) in order to look for patterning in the side on which the rotation took place.

As with the upper body variables described above, the lower body variables recorded in this study were aimed at capturing both general and specific variants in limb treatment. Leg rotation and foot rotation were each intended to capture general patterns (i.e. the presence or absence of a particular variant, such as rotated legs), while additional variables (e.g. left and right leg rotation; foot position) were used to record specific details within the general categories. For example, an individual identified as having rotated feet (general) would then be further categorized based on the direction in which their feet were rotated (specific). Operational definitions of each variable are included in the tables provided in Appendix C.

4.7 Statistical Analysis of Limb Positioning

Because the subject matter of this study is necessarily qualitative in nature, the statistical tests which could be carried out on the data are limited to tests of independence based on proportions of counts. There were two main statistics used in this project to test for relationships between variables in this sample using crosstabulations: (1) Chi-Square, and (2)

Exact significance, calculated using an algorithm based on the Chi-square statistic (see below). However, additional tests (e.g. Odds Ratio, multilinear regression, etc.) could also be applied to some of these data in the future to further shed light on the patterns identified in this study (see Morgan et al., 2011: pp.116).

The chi-square statistic is used to compare proportions of counts of particular categories either within a group or between two or more groups, as in a stratified sample, and is represented by the value χ^2. Chi-square is based on an assessment of deviation from the expected values for a sample if the variation therein were a result of the vagaries of sampling (i.e. due to chance), rather than representing actual relationships between variables (see Drennan, 1996: pp.188). The expected values for each combination of categories, represented by a square or cell in the table, are calculated using the marginal totals for each row and column. To calculate the expected value for a particular cell, the marginal row and column totals are multiplied, then divided by the grand total count for the entire table to obtain an average for each cell (Drennan, 1996: pp.188).

The actual observed counts obtained from the sample are then compared to these expected values in terms of deviations from expected values using the chi-square statistic, calculated using the following expression:

$$\chi^2 = \Sigma(O_i - E_i)^2/E_i$$

Where O_i = the observed value for the *i*th cell of the table; and E_i = the expected value for the *i*th cell of the table. The resulting value for χ^2 is then looked up in a table (see Drennan,1996: pp.190) relative to the appropriate number of degrees of freedom[11] to determine the probability that the difference in the observed and expected proportions occurred randomly as a result of the sampling process, rather than representing actual differences within the sample. This probability is expressed as the significance value *p*.

Although the chi-square statistic may be used on a table of any number of dimensions, it is somewhat limited when applied to smaller samples as the accuracy of the significance (*p*) values produced is contingent upon the size of the expected counts for each cell in the table.

11 Degrees of freedom = (number of rows – 1)(number of columns – 1) (see Drennan, 1996: pp.189; Baxter, 2003: pp.129).

There is some debate as to how small is 'too small,' however, the general rule of thumb used in archaeology requires that no expected value in the table be less than 1 and that no more than 20% of the expected values be less than 5 (Drennan, 1996: pp.197; Baxter, 2003: pp.129).

In instances where the expected counts for each cell in the table are too low, exact significance values can be calculated to circumvent the impact of small sample size on the accuracy of the calculations. In the case of two-by-two tables, *p* values can be calculated using Fisher's Exact Test, expressed as follows:

p=(A+B)! (C+D)! (A+C)! (B+D)! / N ! A ! B ! C ! D !

(see Drennan, 1996: pp.198). For tables larger than two-by-two, exact significance values can also be calculated, however, the process requires the use of a computer statpack (see below).

Due to the relatively small sample size used in this study (n=81), the latter proved to be the most useful way of assessing the independence of the variables in this sample, as well as providing the most accurate *p* values. Subsequently, all of the *p* values obtained in this study represent the exact significance of the relationship and were calculated using the Exact Tests algorithms based on the Chi-square statistic included as part of the Crosstabs function of the IBM SPSS 20 statpack (see Mehta & Patel, 2011 for a detailed review on the use of exact tests).

For those cases in which the null hypothesis of independence could be rejected (i.e. a pair of variables was significantly related) it was also relevant to determine which particular pairs of categories, as represented by individual cells in the table, contributed most to the lack of independence of the variables. In order to do so, standardized residuals were used, wherein cells having higher residuals were treated as having the greatest contribution to the lack of independence of the variables (see Baxter, 2003: pp.129).

Significance for this sample was based on a 5% confidence interval (p=.05) and described using the conventions suggested in Drennan, 1996 wherein significance values are discussed in terms of “high” and “low” based on their proximity to 0 (i.e. *p*-values approaching 0 would be considered of “high” significance because they are very unlikely to occur due to chance) (pp.192). It should be noted here, however, that the use of these terms is not intended

to indicate the strength of the relationship between the variables, but rather to describe the degree of certainty with which we are able to conclude that the difference in the observed versus expected values did not occur due to chance. Thus, for example, the *difference* between the observed and expected values for a particular pairing of variables may be described as 'very significant' (i.e. having a *p*-value approaching 0) as it is unlikely to be a result of random variation due to sampling. However, this does not necessarily indicate that a condition of one variable may be used to accurately predict the condition of the other.

Because the purpose of this study was to examine the sample for broad patterns, rather than seeking to establish any hard rules or 'types,' establishing the probability of a statistically significant relationship between variables was deemed adequate for the present analysis. However, it could be useful in the future to build upon this research using other statistical techniques aimed at determining the effect size and strength of the association between variables (e.g. Phi or Cramer's V).

The statistical analysis presented in the following chapter (Chapter 5 – Results) follows roughly the order in which the relevant research questions were presented in Chapter 1. The upper and lower body (as described above in Section 4.6) were first assessed separately at each stage in the analysis, then grouped together and tested for relationships between variables within the body as a whole.

First, the sample was tested for relationships between upper and lower body positioning variables, respectively, and time period (cf. Smith, 1914; Gray, 1972; Leca, 1980; Russell et al., 1980, etc.). Next, the same procedure was carried out for limb positioning and site to address the possibility of site differences in embalming schools (cf. Morton, 1844; Lamb, 1901; Shafik et al., 2008; Wade, 2012, etc.).

After assessing relationships to time period and site, respectively, the limb positioning variables recorded in this study were tested relative to each other to look for relationships between particular variants. The upper and lower body, respectively, were each tested for the independence of variables within the whole sample, then further tested with the sample stratified first into age categories, then into sex categories. All variables within the upper and lower body were tested against each other since, as discussed previously, the analysis carried out in this study was intended to be exploratory in nature and had never been done before.

The final stage of this analysis involved testing for independence between upper and lower body variables in order to determine whether specific variants in a particular limb could be tied in to broader styles of mummification in the body overall. Again, all of the limb positioning variables recorded in this study were included in this analysis and were first tested in the entire sample, then further tested with the sample divided into age and sex categories, respectively.

Chapter 5

5. Results – Limb Positioning

This chapter details the results of the analysis of limb positioning and treatment in the sample selected for inclusion in this study.

The results of the statistical analyses are presented first with the upper and lower body variables discussed separately, then in combination to look for relationships between the two. Within each of these sections, the results are further subdivided according to the stratification of the sample: first, the results are laid out for the entire sample, then for the sample when stratified first by age, and then finally by sex.

As described in Chapter 4, the initial section of this chapter (Section 5.1) addresses the existing scholarship on mummification styles and time period (cf. Smith, 1914; Gray, 1967, 1972; Leca, 1980; Russell et al., 1980, etc.) as well as site (cf. Morton, 1844; Lamb, 1901; Shafik et al., 2008; Wade, 2012, etc.). The remaining sections then deal with the other research questions posed in Chapter 1 regarding other possible factors influencing limb treatment, including age and sex, which have not been studied before in the limbs.

In order to shed light on the treatment of the lower body during mummification, a number of tests of independence were also performed on variables pertaining to the legs and feet. The main purpose of doing so was to look for relationships between particular features of the positioning of the legs and feet in order to test the hypothesis that the legs were being deliberately manipulated in a similar manner as that applied to the upper body (cf. Gray, 1972). The results of Gray's (1972) study demonstrated temporal changes in upper body positioning across time, however, it did not address the positioning of the legs. Because the lower body has never been studied in this manner before and there were no particular patterns expected other than possible temporal variation as seen in the upper body, all lower body variables were treated equally when testing for independence.

As described in the previous chapter (see Chapter 4), the tests of independence carried out on these data are aimed at comparing observed versus expected proportions among pairs of variables. Due to the relatively small sample size (n=81), the *p*-values provided all represent

exact significance values calculated using the Exact Tests function of IBM SPSS 20 (see above, and Mehta & Patel, 2011). Wherever the expected cell counts were sufficiently large, the χ^2 value is provided. However, the majority of the tables used in this analysis produced expected cell counts which did not fit the acceptable guidelines of having all expected counts >1 and no more than 20% <5 (see Drennan, 1996: pp.197; Baxter, 2003: pp.129). Additionally, as discussed above, the particular cells (i.e. combinations of categories) that contributed the most to the lack of independence of the variables discussed were determined using standardized residuals (see Baxter, 2003: pp.130).

5.1 Body Positioning by Time Period and Site

Upper Body Variables by Time Period

The first null hypothesis of independence (H_0) tested here is that upper body position – expressed through arm flexion, hand position, and hand flexion – is consistent across time periods in ancient Egypt. The alternative hypothesis (H_a) is that upper body positioning covaries with time period, as proposed by Gray (1972). Time period data were available for sixty seven individuals out of the total sample (n=67 of 81; 82.7%). The results of the tests of independence for this section are listed in Table 2 below; the significance (*p*) values listed are exact (see above and Chapter 4). Significant values based on a 5% confidence interval ($p \leq .05$) are indicated by an asterisk (*).

Table 2: *P*-values for Upper Body variables by Time Period

VARIABLE	Time Period
Arm flexion	.000*
	n=64
Hand position	.000*
	n=62
Hand flexion	.006*
	n=5

Based on the tests of independence carried out in this study, there are significant relationships between time period and arm flexion (p=.000); hand position (p=.000); and hand flexion (p=.006). Accordingly, the null hypothesis of independence (H_0) should be rejected.

Among those individuals in this sample dating to the New Kingdom period (1550-1069 BCE) (n=2), there are no examples of either the crossed pectoral (n=0 of 2; 0%) or inner thigh (n=0 of 2; 0%) hand positions. The remaining two positions (outer thigh and pubis, respectively) occurred in equal proportions (n=1 of 2; 50%). Among individuals from the Third Intermediate period (1069-664 BCE), greater proportions than expected[12] have their hands positioned over either the inner thigh (n=6 of 14; 42.9%) or the pubis (n=7 of 14; 50%) compared to the remaining two positions. There are no individuals dating to the Third Intermediate period identified in this sample with their hands positioned at the outer thighs (n=0 of 14; 0%) and only one in the crossed pectoral position (n=1 of 14; 7.1%). Among those dating to the Late period (664-332 BCE), a greater proportion than expected (n=8 of 20; 40%) have their hands positioned over the inner thigh, while a smaller proportion than expected have their hands in the crossed pectoral position (n=1 of 20; 5%). During the Ptolemaic period (332-30 BCE), a much higher proportion than expected have their hands in the crossed pectoral position (n=11 of 15; 73.3%), while the proportions for the remaining three positions are smaller than expected: inner thigh (n=2 of 15; 13.3%); outer thigh (n=0 of 15; 0%); and pubis (n=2 of 15; 13.3%). A much greater proportion of Ptolemaic period individuals than expected also have their hands flexed (n=7 of 13; 53.6%) as opposed to relaxed (n=6 of 13; 46.2%). There are no (n=0 of 13; 0%) individuals with the hands positioned at the outer thigh dating to the Ptolemaic period in this sample. Finally, the individuals dating to the Roman period (30 BCE-641 CE) show a greater proportion than expected with the hands positioned at the outer thigh (n=9 of 11; 81.8%) and a smaller proportion than expected with the hands over the pubis (n=2 of 11; 18.2%). There are no examples of either the crossed pectoral[13] or inner thigh variants dating to the Roman period in this sample (n=0 of 11; 0%).

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12 Based on the statistical model described in Chapter 4.

13 But see Section 6.1 below for a discussion of the crossed pectoral hand position outside the Ptolemaic period.

Lower Body Variables by Time Period

The first null hypothesis (H_0) tested in this section is that lower body positioning[14] occurs independently of time period in this sample. The alternative hypothesis (H_a) is that lower body positioning covaries with time period. The results of the tests used to test this hypothesis (H_0) are listed below in Table 3.

Table 3: *P*-values for Lower Body variables by Time Period

VARIABLE	Time period
Leg position	.643
	n=62
Leg rotation	.511
	n=58
Foot rotation	.077
	n=44
Foot position	.166
	n=44
Foot flexion	.864
	n=45
Toe position	.004*
	n=36

*Indicates significance based on a 5% confidence interval ($p \leq .05$).

14 'Lower body positioning' is used here to describe the following variables: (1) Leg position; (2) Leg rotation; (3) Foot position; (4) Foot rotation; (5) Foot flexion; (6) Toe position.

Most of the lower body variables examined in this study occur independently of time period. There is some variation in foot rotation between time periods, however the relationship is not statistically significant (p=.077). A greater proportion of individuals dating to the Roman Period than expected have their feet rotated (n= 5 of 9; 55.6%) as opposed to non-rotated (n=4 of 9; 44.4%). There is at least one individual with rotated feet representing each time period except for the Third Intermediate Period, in which all (n=9 of 9; 100%) of the individuals studied have the feet in a non-rotated position.

The relationship between toe position and time period is significant for this sample (p=.004). A much greater proportion than expected of Late period individuals for whom toe data were available have curled toes (n=9 of 10; 90%) as opposed to straight (n=1 of 10; 10%), while a much greater proportion than expected of Ptolemaic period individuals have straight toes (n=6 of 7; 85.7%) rather than curled (n=1 of 7; 14.3%). Both of the individuals dating to the New Kingdom for whom toe data were available have straight toes (n=2 of 2; 100%), while seven of the Third Intermediate individuals also have straight toes (n=7 of 10; 70%). The Roman period individuals are fairly evenly split between straight (n=3 of 7; 42.9%) and curled (n=4 of 7; 57.1%) toes.

Based on these results, the null hypotheses of independence (H_0) cannot be rejected for any of the lower body variables described above, aside from toe position, for which the null hypothesis can be rejected.

Upper Body Variables by Site

The null hypothesis (H_0) tested in this section is that upper body positioning occurs independently of site in this sample. The alternative hypothesis (H_a) is that upper body positioning covaries with site, potentially representing regional differences in mummification styles. Site data were available for fifty individuals out of the total sample (n=50 of 81; 61.7%). The results of the tests of independence between the variables in this section are listed below in Table 4.

Table 4: *P*-values for Upper Body variables by Site

VARIABLE	Site
Arm flexion	.000*
	n=47
Hand position	.000*
	n=47
Hand flexion	.000*
	n=43

*Indicates significance based on a 5% confidence interval ($p \leq .05$).

Based on these results, there are very significant relationships between site and arm flexion (p=.000); hand positioning *(*p=.000); and hand flexion (p=.000) in this sample. However, the majority of sites recorded are represented by only a very small number of individuals. It is worth noting, though, that all of the individuals from Akhmim for whom upper body positioning data could be recorded have their hands in the crossed pectoral position (n=5 of 5; 100%), a significantly higher proportion than expected. Conversely, there are no individuals from Thebes in this sample with their hands in the crossed pectoral position (n= 0 of 33; 0%), a much smaller proportion than expected. A greater proportion than expected of the individuals from Thebes have their hands positioned over the inner thighs (n=14 of 33; 42.4%). A much greater proportion than expected of individuals from Akhmim for whom upper body data were available have flexed hands (n=4 of 5; 80%), while a greater proportion of individuals from Thebes have relaxed hands (n=28 of 30; 93.3%).

Based on these results, the null hypothesis of independence (H_0) should be –at least tentatively – rejected as there appears to be a statistically significant relationship between upper body positioning and site in this sample.

Lower Body Variables by Site

The null hypothesis (H_0) tested in this section is that lower body positioning occurs independently of site in this sample. The alternative hypothesis (H_a) is that lower body positioning covaries with site in this sample. The results of the tests of independence carried out for this section are listed below in Table 5.

Table 5: *P*-values for Lower Body variables by Site

VARIABLE	Site
Leg position	.520
	n=45
Leg rotation	.712
	n=42
Foot rotation	.027*
	n=38
Foot position	.133
	n=38
Foot flexion	.020*
	n=36
Toe position	.484
	n=31

*Indicates significance based on a 5% confidence interval ($p \leq .05$).

As shown above, there is a statistically significant relationship between foot flexion and site in this sample (p=.020). All of the individuals from Hawara for whom foot data could be obtained have their feet bent under at the midfoot (n=2 of 2; 100%), a much greater

proportion than expected. A much smaller proportion than expected of individuals from Thebes for whom foot data could be obtained have their feet bent under (n=3 of 26; 11.5%) while the remaining proportions are as follows: flexed (n=15 of 26; 57.7%) and relaxed (n=8 of 26; 30.8%).

As shown above, there is also a statistically significant relationship between foot rotation and site in this sample (p=.027). Individuals with rotated feet were identified at all sites apart from two at which all individuals have non-rotated feet: Abydos (n=1 of 1; 100%); and Akhmim (n=4 of 4; 100%).

Based on these results, the null hypothesis of independence (H_0) should be rejected for foot flexion and foot rotation as both of these variables have statistically significant relationships with site. The null hypothesis (H_0) cannot be rejected for leg position, leg rotation, foot position, or toe position, respectively.

5.2 Upper Body Variables

In addition to testing for temporal and spatial differences in limb positioning, this study also examines the relationships between body positioning variables, as well as age and sex, to look for possible patterning. The null hypothesis (H_0) to be addressed in this section is that the upper body variables examined in this study occur independently of each other in this sample. The alternative hypothesis (H_a) is that these variables are related in this sample. The results of the tests of independence carried out on the variables for this section are listed below in Table 6. Because arm flexion and hand position are essentially general and specific descriptors of the same mummification feature (see Chapter 4), they were not tested against each other in this section and are hence excluded from the table below.

Table 6: *P*-values for Upper Body variables (non-stratified)

VARIABLE	Hand flexion	Arm flexion	Hand position
Hand flexion			
Arm flexion	.000*		
	n=63		
Hand position	.000*		
	n=63		

*Indicates significance based on a 5% confidence interval ($p \leq .05$).

The most notable pattern uncovered regarding the upper body is the relationship between the positioning of the arms and the hands. The relationship between the flexion of the hands relative to arm flexion is very statistically significant (χ^2=19.934, p=.000). There is a positive relationship between flexed arms[15] and flexed hands, as well as between extended arms and relaxed hands, respectively. Conversely, there are negative relationships between extended arms and flexed hands, as well as flexed arms and relaxed hands, respectively. Of those with their hands in the crossed pectoral position, the majority have flexed hands (n=10 of 15; 66.7%). Conversely, the majority of those with the arms in any of the extended positions have relaxed hands (n=43 of 48; 89.6%).

The relationship between hand flexion relative to hand positioning is also very statistically significant (p=.000). A much greater proportion than expected of those with their hands crossed pectorally have flexed hands (see above). There are no individuals recorded in this sample with their hands positioned over the inner thigh and the hands flexed (n=0 of 17; 0%), a much smaller proportion than expected. A smaller proportion than expected of individuals with their hands positioned over the pubis also have flexed hands (n=2 of 18; 11.1%).

15 Note: All of the individuals identified in this study as having flexed arms had their hands in the crossed pectoral position (n=15 of 15; 100%).

Based on these results, the null hypotheses of independence (H_0) should be rejected as there are statistically significant relationships between hand and arm positioning in this sample.

Upper Body Variables by Age

In order to shed further light on the role of demographic and life history variables in determining the treatment of the upper body, the sample was stratified by age and sex, respectively. This section will outline the results of the tests of independence for each combination of variables when the sample is stratified by age for the purpose of exploring the ways in which social differences between age groups (see Chapter 2) are reflected in the treatment of the body after death.

The sample was first divided into Juveniles (≤10 years) and Adults (>10 years) to obtain a basic assessment of the relationships between upper body treatment and sexual maturity, whereupon more precise age categories (Juveniles 1-10 years, Subadults 11-18 years, Adults 19-39 years, and Older Adults >40 years, respectively) were further implemented in order to look for differences within the initial Adult (>10 years) grouping.

The first null hypothesis (H_0) tested in this section is that upper body positioning occurs independently of age and/or sexual maturity. The alternative hypothesis (H_a) is that upper body positioning is related to age and/or sexual maturity. The results of the tests of independence for this section are listed below in Tables 7 and 8, as well as Appendix F. Table 7 lists the results when age is treated as a variable against which the upper body variables are tested for independence, while Table 8 and Appendix F list the results of testing the upper body variables against each other with the sample stratified by age (pre- and post-puberty, and osteological age, respectively). Again, since arm flexion and hand position are two different descriptors of the same aspect of mummification style, they were not tested against each other in this section and are thus excluded from the table below.

Table 7: *P*-values for Upper Body variables by Age (non-stratified)

VARIABLE	Arm flexion	Hand position	Hand flexion
Age (Juveniles ≤10 years; Adults >10 years)	.131	.025*	.676
	n=74	n=72	n=61

*Indicates significance based on a 5% confidence interval ($p \leq .05$).

There is a statistically significant relationship between age (Juveniles ≤10 years; Adults >10 years) and hand position in this sample ($p=.025$). Among Juveniles (≤10 years), greater proportions than expected have their hands in the crossed pectoral position (n=5 of 10; 50%) or at the outer thigh (n=3 of 10; 30%), respectively, compared to the remaining two positions: inner thigh (n=0 of 10; 0%) and pubis (n=2 of 10; 20%).

There is also a statistically significant relationship between age (Juveniles 1-10 years; Subadults 11-18 years; Adults 19-39 years; and Older Adults >40 years) and hand position in this sample. A much greater proportion than expected of Subadults (11-18) for whom upper body positioning could be recorded have their hands positioned at the outer thigh (n=4 of 7; 57.1%). There are no Subadults recorded in this study with their hands positioned over the pubis (n=0 of 7; 0%). Among Adults (19-39), the four hand positions recorded occur in approximately the expected frequencies: crossed pectoral (n=10 of 41; 24.4%); inner thigh (n=10 of 41; 24.4%); outer thigh (n=7 of 41; 17.1%); and pubis (n=14 of 41; 34.1%). A much greater proportion than expected of Older Adults have their hands positioned over the inner thigh (n=7 of 13; 53.8%).

Based on these results, the null hypothesis of independence (H_0) cannot be rejected for age and either arm flexion or hand flexion; however, the null hypothesis (H_0) should be rejected for hand position and age as they are significantly related in this sample.

The second set of hypotheses addressed in this section pertain to the relationship between the respective upper body variables when the sample is stratified by age. The null hypothesis (H_0) tested here is that arm flexion, hand position and hand flexion occur independently of each other in this sample when stratified by age. The alternative hypothesis (H_a) is that the

latter upper body variables are significantly related when the sample is stratified by age. The results of the tests of independence carried out on the variables in this section are listed below in Table 8 and Appendix F.

Table 8: *P*-values for Upper Body variables (stratified by Age –pre/post puberty)

Juveniles (≤10 years) n=9			
VARIABLE	Hand flexion	Arm flexion	Hand position
Hand flexion			
Arm flexion	.464		
Hand position	.357		
Adults (>10 years) n=52			
VARIABLE	Hand flexion	Arm flexion	Hand position
Hand flexion			
Arm flexion	.000*		
Hand position	.000*		

*Indicates significance based on a 5% confidence interval ($p \leq .05$).

Based on the results listed above, the relationship between hand flexion and arm flexion is very significant in Adults (>10 years) (p=.000) and is not significant in Juveniles (≤10 years) (p=.464) in this sample. As shown in the table in Appendix F, within the Adults (>10 years) grouping, the relationship between hand flexion and arm flexion is very significant among Adults (19-39 years) (p= .009) and is not significant among Subadults (11-18 years) (p=.167) or Older Adults (>40 years) (p= .077). Among Adults (19-39), there is a positive relationship between flexed arms and flexed hands and there are negative relationships between flexed hands and extended arms, as well as between relaxed hands and flexed arms, respectively. Of the total of nine (n=9) Adults with flexed arms, the majority also have flexed

hands (n=6 of 9; 66.7%). Conversely, the majority of Adults with extended arms have relaxed hands (n=21 of 25; 84%).

Based on the results listed above, there is also a very significant relationship between hand flexion and hand position among Adults (>10 years) (p=.000) but not in Juveniles (≤10 years) (p=.357). Within the Adult (>10 years) grouping, however, the relationship is only very significant among Adults (19-39 years) (p= .009), and is not significant among either Subadults (11-18 years) (p= .333) or Older Adults (>40 years) (p=.154). Among Adults (19-39 years), there are positive relationships between the crossed pectoral hand position and flexed hands (n=6 of 9; 66.7%), and between the inner thigh hand position and relaxed hands (n=9 of 9; 100%), respectively. There are also negative relationships between the crossed pectoral position with relaxed hands (n=3 of 9; 33.3%), and the inner thigh position with flexed hands (n=0 of 9; 0%).

Based on these results, the null hypothesis of independence (H_0) should be rejected for Adults (19-39 years) as upper body positioning is related to age in the latter group, but cannot be rejected for either Juveniles (≤10 years), Subadults (11-18 years), or Older Adults (>40 years).

Upper Body Variables by Sex

In addition to age, the sample was also stratified by sex in order to look for potential differences in upper body treatment between males and females. This section outlines the results of the relevant tests of independence when the sample is stratified by sex.

The first null hypothesis (H_0) addressed here is that upper body positioning occurs independently of sex in this sample. The alternative hypothesis (H_a) is that upper body positioning is related to sex in this sample. The results of the tests of independence carried out for this section are listed below in Tables 9 and 10 below. Table 9 lists the results when sex is treated as a variable against which the upper body variables are tested for independence, while Table 10 lists the results of the upper body variables tested against each other with the sample stratified by sex.

Table 9: *P*-values for Upper Body variables by Sex (non-stratified)

VARIABLE	Sex
Arm flexion	.908
	n=66
Hand position	.667
	n=64
Hand flexion	.530
	n=57

There are no significant relationships between sex and hand position (χ^2=1.565, p=.667), sex and arm flexion (χ^2=.013, p=.908), or sex and hand flexion (χ^2=.516, p=.530) in this sample. Based on these results, the null hypothesis of independence (H_0) cannot be rejected for any of the upper body positioning variables.

The second null hypothesis (H_0) tested in this section is that the upper body variables occur independently when the sample is stratified by sex. The alternative hypothesis (H_a) is that the upper body variables are related within each sex group. The results of the tests of independence carried out for this section are listed in Table 10 below.

Table 10: *P*-values for Upper Body variables (stratified by Sex)

Males n=29			
VARIABLE	Hand flexion	Arm flexion	Hand position
Hand flexion			
Arm flexion	.001*		
Hand position	.001*		
Females n=28			
VARIABLE	Hand flexion	Arm flexion	Hand position
Hand flexion			
Arm flexion	.144		
Hand position	.145		

*Indicates significance based on a 5% confidence interval ($p \leq .05$).

The relationship between hand flexion and arm flexion is very significant in males (p=.001) and is not significant in females (p=.144). There are positive relationships in males between flexed arms and flexed hands (n=4 of 5; 80%) as well as between extended arms and relaxed hands (n=23 of 24; 95.8%). Among females, a greater proportion of those with extended arms also have relaxed hands (n=18 of 22; 81.8%), however the relationship is not statistically significant. Among females with flexed arms, equal proportions have flexed (n=3 of 6; 50%) and relaxed hands (n=3 of 6; 50%). Additionally, while only one male individual with extended arms had flexed hands (n=1 of 24; 4.2%), four females with extended arms had flexed hands (n=4 of 22; 18.2%).

Accordingly, the relationship between hand flexion and hand position is also very significant in males (p=.001) but is not significant in females (p=.145). As described above, there is a positive relationship between the crossed pectoral arm position and flexed hands in males

(n=4 of 5; 80%) but there are no significant relationships with hand flexion for any of the other hand positions.

Based on these results, the null hypothesis of independence (H_o) should be rejected for males but not for females, as there are only significant relationships between hand flexion, hand position, and arm flexion among the former group.

5.3 Lower Body Variables

The null hypothesis (H_0) addressed here is that the variables comprising lower body positioning occur independently of each other in this sample. The alternative hypothesis (H_a) is that there are relationships between lower body variables in this sample. The results of the tests of independence carried out in this section are listed in Table 11 below.

Table 11: *P*-values for Lower Body variables (non-stratified)

VARIABLE	Leg position	Leg rotation	Foot rotation	Foot position	Foot flexion
Leg position					
Leg rotation	.374				
	n=70				
Foot rotation	.719	.000*			
	n=54	n=55			
Foot position	.775	.000*			
	n=54	n=55			
Foot flexion	.256	.558	.004*	.005*	
	n=53	n=54	n=51	n=51	
Toe position	.711	.056	.175	.221	.016*
	n=43	n=43	n=42	n=42	n=43

*Indicates significance based on a 5% confidence interval ($p \leq .05$).

As shown in the table above, the relationship between toe position and leg rotation is approaching significance ($\chi^2=4.740$, $p=.056$). There is a positive relationship between non-rotated legs and straight toes (n=12 of 16; 75.0%) as well as between rotated legs and curled toes (n=16 of 27; 59.3%). There is also a negative relationship between non-rotated legs and curled toes (n=4 of 16; 25%).

There is a significant relationship between foot position and leg rotation in this sample ($\chi^2=14.824$, $p=.000$). There is a positive relationship between rotated legs and rotated feet (n=15 of 15; 100%), as well as between non-rotated legs and non-rotated feet (n=23 of 40; 57.5%). There is also a significant relationship between the rotation of the right leg and foot position is very significant ($p=.000$), as is the rotation of the left leg relative to foot position ($p=.006$) (see Section 4.7 for rotation scoring).

The majority of those for whom foot data were available with non-rotated feet also have non-rotated legs (n=23 of 40; 57.5%). Of those with rotated feet, all also have at least one leg rotated (n=15 of 15; 100%). The most common variant of leg rotation is the lateral rotation of the right leg at the knee, occurring in the majority of individuals with their feet in the rotated right position (n=10 of 14; 71.4%). Twelve individuals with non-rotated feet also had a laterally rotated right leg (n=12 of 40; 30.0%).

There were no individuals identified in this sample with rotated feet and non-rotated legs (n=0 of 15; 0%). However, seventeen individuals with non-rotated feet had at least one leg rotated (n=17 of 40; 42.5%). A table listing the demographic composition of the individuals identified in this sample with rotated legs and non-rotated feet is provided below in Appendix E and will be discussed later.

As shown above, there is a very significant relationship between foot flexion and foot position in this sample ($p=.005$). There is a positive relationship between the non-rotated foot position and flexed feet: of those with non-rotated feet, a greater proportion than expected have their feet flexed (n=20 of 37; 54.1%). There is also a positive relationship between the rotated right foot position and a 'bent under' flexion: a greater proportion than expected of those with their feet in the rotated right position have their feet bent under (n=6 of 13;

46.2%). There are also negative relationships between a non-rotated position and bent under flexion, and between a rotated right position and flexed feet. The proportions of relaxed feet among those with both rotated (n= 5 of 14; 35.7%) and non-rotated (n=13 of 37; 35.1%) feet are roughly those that were predicted.

There is also a significant relationship between toe position and foot flexion in this sample (p=.016). All of those with the feet bent under at the midfoot have curled toes (n=5 of 5; 100%), whereas the majority of those with flexed feet have straight toes (n=14 of 20; 70%). Individuals in this sample with relaxed feet had straight and curled toes in equal proportions (n=9 of 18; 50%).

Based on these results, the null hypothesis of independence (H_0) should be rejected for foot position and leg rotation; foot position and flexion; and foot flexion and toe position, respectively, as these pairs of variables are significantly statistically related in this sample. The null hypothesis (H_0) cannot be rejected for any of the other combinations of lower body variables based on the results of these tests.

Lower Body Variables by Age

In order to look for age differences in lower body treatment, the sample was first grouped according to Juveniles (≤10 years) and Adults (>10 years), then further stratified into detailed age categories as described above. This section outlines the results of the relevant tests of independence when the sample is stratified by age.

The first null hypothesis of independence (H_0) tested in this section is that lower body positioning occurs independently of age and/or sexual maturity in this sample. The alternative hypothesis (H_a) is that lower body positioning differs between age groups. The results of the tests of independence carried out for this section are listed below in Tables 12 and 13, as well as in Appendix G. The results shown in Table 12 are those when age is treated as a variable against which the lower body variables are tested for independence.

Table 12: *P*-values for Lower Body variables by Age (non-stratified)

VARIABLE	Age (Juveniles ≤10 years; Adults >10 years)
Leg position	1.000
	n=73
Leg rotation	.342
	n=69
Foot rotation	.003*
	n=53
Foot position	.002*
	n=53
Foot flexion	.087
	n=52
Toe position	.433
	n=42

*Indicates significance based on a 5% confidence interval ($p \leq .05$).

As shown above, the relationship between foot rotation and age is very significant when the sample is categorized according to attainment of puberty (Juveniles ≤10, Adults >10) (p= .003). The same is also true when the lower body is tested by osteological age grouping (Juveniles ≤10, Subadults 11-18, Adults 19-39, Older Adults >40) (p=.001). The majority of both Juveniles (n=6 of 9; 66.7%) and of Subadults (n=4 of 6; 66.7%) in this sample have rotated feet, while much smaller proportions than expected of Adults (n=4 of 26; 15.4%) and Older Adults (n=1 of 12; 8.3%) have rotated feet. The most common variant of foot rotation is the rotation of the feet to the right of the midline; this variant is present in five Juveniles (n=5 of 9; 55.6%) and seven Subadults (n=4 of 6; 66.7%) in this sample. Of those for whom

foot positioning could be recorded (n=38), only one (n=1 of 38; 0.03%) individual, classified as a Juvenile, has the feet rotated to the left.

Based on these results, the null hypothesis of independence (H_0) should be rejected for foot position and age (defined either by sexual maturity or skeletal development) as these variables are significantly related in this sample, but cannot be rejected for any of the other lower body variables and age.

The second null hypothesis (H_0) tested in this section is that the variables comprising lower body positioning occur independently when the sample is stratified by age. The alternative hypothesis (H_a) is that there are statistically significant relationships between lower body variables when the sample is stratified by age. The results of the tests of independence carried out in this section are listed below in Table 13 for pre- and post-puberty age categories and in Appendix G for osteological age categories.

Table 13: *P*-values for Lower Body variables (stratified by Age –pre/post puberty)

Juveniles (≤10 years)					
VARIABLE	Leg position	Leg rotation	Foot rotation	Foot position	Foot flexion
Leg position					
Leg rotation	1.000				
	n=12				
Foot rotation	1.000	.067			
	n=10	n=10			
Foot position	1.000	.133			
	n=10	n=10			
Foot flexion	.852	1.000	.556	.619	
	n=9	n=9	n=9	n=9	
Toe position	1.000	.171	.107	.107	.250
	n=8	n=8	n=8	n=8	n=8

Table 13: *P*-values for Lower Body variables (stratified by Age –pre/post puberty) Cont'd

Adults (>10 years)					
VARIABLE	Leg position	Leg rotation	Foot rotation	Foot position	Foot flexion
Leg position					
Leg rotation	.318				
	n=57				
Foot rotation	.332	.004*			
	n=43	n=43			
Foot position	.332	.004*			
	n=43	n=43			
Foot flexion	.190	1.000	.063	.063	
	n=43	n=43	n=40	n=40	
Toe position	.672	.375	1.000	1.000	.098
	n=34	n=34	n=33	n=33	n=34

*Indicates significance based on a 5% confidence interval ($p \leq .05$).

The relationship between foot rotation and leg rotation is very significant in Adults (>10 years) (p=.004) and is not significant in Juveniles **(**≤10 years) (p=.067). Among Adults, there is a positive relationship between rotated legs and rotated feet and a negative relationship between rotated feet and non-rotated legs. As described previously, there were no (n=0 of 55; 0%) individuals identified in this study with non-rotated legs and rotated feet from any of the age categories. However, as discussed above, of those for whom leg and foot data were available, seventeen have rotated legs and non-rotated feet (n=17 of 55; 30.9%). Of those with rotated legs and non-rotated feet, the majority are Adults >10 years (n=15 of 17; 88.2%),

while the remaining two are a single Juvenile ≤10 years (n=1 of 17; 5.9%), and one individual of unknown age (n=1 of 17; 5.9%).

As shown in Appendix G below, within the more precise osteological age groupings, the majority of both Adults (19-39 years) (n=8 of 12; 66.7%) and Older Adults (n=7 of 8; 87.5%) with rotated legs had non-rotated feet in this sample, although the relationship is not statistically significant in the latter group. In contrast, the majority of Juveniles (n=5 of 7; 71.4%) and Subadults (n=4 of 4; 100%) had both the legs and feet rotated.

The relationship between foot position and leg rotation is also very significant in Adults **(**>10 years) (p=.004) and is not significant in Juveniles (≤10 years) (p=.133). Within the Adult (>10 years) grouping, the relationship is significant in Adults (19-39 years) (p= .033) and is not significant in either Subadults (11-18 years) (p=.067) or Older Adults (p=.167). Among Adults (19-39 years), a greater proportion than expected of those with the rotated right foot position have rotated legs (n=4 of 12; 33.3%). Additionally, there is a positive relationship between the rotated right foot position and the lateral and medial rotations of the right and left legs, respectively.

Based on these results, the null hypothesis of independence (H_0) cannot be rejected among Juveniles (1-10 years), Subadults (11-18 years), or Older Adults (>40 years) for any of the variables examined. Among Adults (19-39 years), the null hypothesis of independence (H_0) cannot be rejected for any of the pairs of variables tested except for foot rotation and leg rotation, and foot position and leg rotation, respectively, as these variables are significantly related in this age group.

Lower Body Variables by Sex

In addition to age, the sample was again stratified by sex to test for independence between lower body variables.

The first null hypothesis (H_0) tested in this section is that lower body positioning occurs independently of sex in this sample. The alternative hypothesis (H_a) is that lower body positioning is related to sex in this sample. The results of the tests of independence carried out for this section are listed below in Tables 14 and 15 below. Table 14 lists the results when sex is treated as a variable against which the lower body variables are tested for

independence, while Table 15 lists the results of testing the lower body variables against each other with the sample stratified by sex.

Table 14: *P*-values for Lower Body variables by Sex (non-stratified)

VARIABLE	Sex
Leg position	.539
	n=64
Leg rotation	.622
	n=60
Foot rotation	.813
	n=47
Foot position	.740
	n=47
Foot flexion	.720
	n=47
Toe position	1.000
	n=39

In addition to the rotation of at least one leg (as shown in the table above), the legs were also considered individually according to the direction in which they were rotated (see Appendix C). The relationship between sex and the rotation of the right leg is not statistically significant in this sample (p=1.000). However, the relationship between sex and the rotation of the left leg is significant (p=.018). While the majority of females for whom lower body data were available have a non-rotated left leg (n=26 of 29; 89.7%), a considerable proportion of males have their left leg rotated laterally (n=9 of 31; 29%). In contrast, the rotation of the right leg occurs in roughly the same proportions between the sexes: in this

sample twelve females (n=12 of 29; 41.4%) and twelve males (n=12 of 29; 38.7%) had a laterally rotated right leg.

Based on these results, the null hypothesis of independence (H_0) cannot be rejected for any of the lower body positioning variables, except for the rotation of the left leg as the latter is significantly related to sex in this sample.

The second null hypothesis (H_0) addressed in this section is that the lower body positioning variables occur independently when the sample is stratified by sex. The alternative hypothesis (H_a) is that the latter variables are related when the sample is stratified by sex. The results of the tests of independence carried out for this section are listed below in Table 15.

Table 15: *P*-values for Lower Body variables (stratified by Sex)

Males					
VARIABLE	Leg position	Leg rotation	Foot rotation	Foot position	Foot flexion
Leg position					
Leg rotation	.412				
	n=31				
Foot rotation	1.000	.058			
	n=23	n=23			
Foot position	.694	.122			
	n=23	n=23			
Foot flexion	.119	.859	.524	.325	
	n=24	n=24	n=22	n=22	
Toe position	.628	1.000	.628	.777	.095
	n=19	n=19	n=19	n=19	n=19

*Indicates significance based on a 5% confidence interval ($p \leq .05$).

Table 15: *P*-values for Lower Body variables (stratified by Sex) Cont'd

Females					
VARIABLE	Leg position	Leg rotation	Foot rotation	Foot position	Foot flexion
Leg position					
Leg rotation	1.000				
	n=29				
Foot rotation	.608	.019*			
	n=24	n=24			
Foot position	.608	.019*			
	n=24	n=24			
Foot flexion	1.000	.741	.008*	.005*	
	n=23	n=23	n=22	n=22	
Toe position	1.000	.057	.628	.628	.255
	n=20	n=20	n=19	n=19	n=20

*Indicates significance based on a 5% confidence interval ($p \leq .05$).

As shown above, the relationship between leg rotation and foot rotation is statistically significant in females (p=.019) and is approaching significance in males (p=.058). There are positive relationships among both sexes between rotated legs and rotated feet and between non-rotated legs and non-rotated feet, respectively. There are negative relationships among both sexes between rotated legs and non-rotated feet, and between non-rotated legs and rotated feet. The seventeen (n=17) individuals with rotated legs and non-rotated feet described above comprise the following: seven females (n=7; 41.2%); six males (n=6; 35.3%), and two of indeterminate sex (n=2; 11.8%). The relationship between the rotation of the right leg and foot rotation is significant in males (p=.019) and is not very significant in

females (p=.069), while the relationship between the rotation of the left leg and foot rotation is not significant in males (p=.118) and is not very significant in females (p=.076).

Accordingly, there is a statistically significant relationship between leg rotation and foot position among females (p=.019) but not in males (p=.122). However, the relationship between the rotation of the right leg and foot position is significant in males (p=.013) and is not very significant in females (p=.069), while the relationship between the rotation of the left leg and foot position is not significant in males (p=.132) and is not very significant in females (p=.076). Of those females with their feet in the rotated right position, the majority have a laterally rotated right leg (n=6 of 7; 85.7%), while the remainder have a non-rotated right leg (n=1 of 7; 14.3%). Similarly, the majority of males with the feet rotated to the right also have a laterally rotated right leg (n=3 of 5; 60%), however, one male individual has his feet positioned to the right with his left leg rotated medially (n=1 of 5; 20%).

Greater proportions than expected of both males and females with their feet rotated right also show a medial rotation of the left leg (males n=1 of 5; 20%; females n=2 of 7; 28.6%), however, the relationship is not statistically significant (males p=.132; females p=.076). Overall, the rotation of the left leg occurs more often in males in this sample regardless of foot positioning. Of the twenty-three (n=23) males for whom leg and foot rotation data could be recorded, nine (n=9 of 23; 39.2%) have their left leg rotated in either a lateral (n=8 of 23; 34.8%) or medial (n=1 of 23; 4.3%) direction. Among females (n=24), only three (n=3 of 24; 12.5%) have a rotated left leg: one (n=1 of 24; 4.2%) in a lateral direction and two (n=2 of 24; 8.3%) in a medial direction.

Among females with their feet in a non-rotated position, ten (n=10 of 17; 58.8%) have non-rotated legs and seven (n=7 of 17; 41.2%) have rotated legs. Similarly, among males with rotated feet, eight (n=8 of 17; 47.1%) have non-rotated legs and nine (n=9 of 17; 52.9%) have rotated legs. As mentioned previously, all of the individuals in this study with their feet in the rotated right position (n=14) also have rotated legs, regardless of sex.

Among those individuals with rotated legs and non-rotated feet discussed above (see table in Appendix E), the sex distribution is as follows: seven females (n=7 of 17; 41.2%); six males (n=6 of 17; 35.3%); and two of indeterminate sex (n=2 of 17; 11.8%).

The relationship between foot flexion and left leg rotation is not significant in males (p=.281), however, there is a significant positive relationship between the medial rotation of the left leg and the bent under foot flexion in females (p=.040). Of the two females identified as having a medially rotated left leg, both have their feet bent under at the midfoot (n=2 of 2; 100%).

The relationship between foot flexion and foot rotation is very significant in females (p=.008) and is not significant in males (p=.524). Similarly, the relationship between foot flexion and foot position is very significant in females (p=.005) and is not significant in males (p=.325). Among females with their feet rotated to the right, the majority have their feet bent under at the midfoot (n=4 of 7; 57.1%), while the majority of females with non-rotated feet have their feet flexed (n=9 of 15; 60%). In contrast, the relationship between foot flexion and positioning seems to be slightly less straightforward among males and is not statistically significant (see above). Of the four (n=4) males with their feet rotated to the right, one has his feet bent under (n=1 of 4; 25%), two have their feet flexed (n=2 of 4; 50%), and one has relaxed feet (n=1 of 4; 25%).

The relationship between toe position and leg rotation is approaching significance in females (p=.057) and is not significant in males (p=1.000). The majority of females with a laterally rotated right leg have curled toes (n=8 of 11; 72.7%), while a similar proportion of females with a non-rotated right leg have straight toes (n=7 of 9; 77.8%). In contrast, curled and straight toes occur in roughly equal proportions among males with their right leg rotated either laterally (curled toes n=4 of 7; 57.1%; straight toes n=3 of 7; 42.9%) or medially (curled toes n=1 of 2; 50.0%; straight toes n=1 of 2; 50.0%). There are no significant relationships between toe positioning and the rotation of the left leg among either sex (males p=.228; females p=.217).

The null hypothesis of independence (H_0) should be rejected in females for the following combinations of variables: leg rotation and foot rotation; leg rotation and foot position; foot flexion and left leg rotation; foot flexion and foot rotation; and foot flexion and foot position, respectively, as these pairs of variables are significantly related among females in this sample. The null hypothesis (H_0) cannot be rejected for any of the other combinations of lower body variables in females.

The null hypothesis of independence (H_0) should be rejected in males for the following combinations of lower body variables: right leg rotation and foot rotation; and right leg rotation and foot position, respectively, as these pairs of variables are significantly related among males in this sample. The null hypothesis (H_0) cannot be rejected for any of the other combinations of lower body variables in males.

5.4 Upper & Lower Body Variables

In addition to testing for independence within the upper and lower body separately, the body was also considered as a whole in order to look for relationships between arm and leg positioning variants. This section outlines the results of the tests of independence between upper and lower body variables.

The null hypothesis (H_0) tested here is that the variables that comprise upper and lower body positioning occur independently in this sample. The alternative hypothesis (H_a) is that upper and lower body positioning are related in this sample. The results of the tests of independence carried out for this section are listed below in Table 16.

Table 16: *P*-values for Upper and Lower Body variables (non-stratified)

VARIABLE	Arm flexion	Hand position	Hand flexion
Leg position	1.000	.020*	.712
	n=71	n=69	n=59
Leg rotation	.088	.217	1.000
	n=68	n=66	n=59
Foot rotation	.305	.009*	.703
	n=53	n=52	n=48
Foot position	.305	.005*	.576
	n=53	n=52	n=48
Foot flexion	.118	.335	.349
	n=52	n=50	n=47
Toe position	.011*	.049*	.139
	n=41	n=41	n=39

*Indicates significance based on a 5% confidence interval ($p \leq .05$).

There are no significant relationships between foot position and arm flexion (p=.305) or between leg rotation and arm flexion (χ^2=3.425, p= .088). A greater proportion than expected of those individuals with flexed arms have non-rotated legs (n=11 of 16; 68.8%), however, the relationship is not statistically significant.

As shown above, there is a significant relationship between leg position and hand position in this sample (p=.020). A much greater proportion of individuals with their hands positioned over the inner thigh have their legs positioned apart than expected (n=8 of 18; 44.4%). A

smaller proportion than expected of those with their hands positioned over the pubis have their legs positioned apart (n=2 of 20; 10%).

The relationship between foot position and hand position is also very significant (p=.005). Examples of the rotated right foot position are present for each of the hand position variants, although most of the individuals for whom lower body data were available have their legs in a non-rotated position (n=37 of 52; 71.2%) regardless of hand position. However, of those with the hands positioned at the outer thigh, the majority have their feet rotated to the right (n=8 of 12; 66.7%).

There are also significant relationships between toe position and both arm flexion (p=.011) and hand position (p=.049), respectively. Of those individuals with flexed arms, a greater proportion than expected have straight toes (n=9 of 10; 90%), while those with extended arms are fairly evenly split between straight (n=13 of 31; 41.9%) and curled (n=18 of 31; 58.1%) toes. The one exception among the latter grouping is those with their hands positioned over the pubis, of which the majority have curled toes (n=8 of 12; 66.7%).

Based on these results, the null hypothesis of independence (H_0) should be rejected for the following combinations of upper and lower body variables: leg position and hand position; foot position and hand position; toe position and arm flexion; toe position and hand position, respectively, as these pairs of variables are significantly related in this sample. The null hypothesis (H_0) cannot be rejected for any of the other combinations of upper and lower body variables tested.

Upper & Lower Body Variables by Age

This section outlines the results of the tests of independence carried out on the upper and lower body variables when the sample is stratified by age at death. Age groups were defined as described above in the previous sections on the upper and lower body, respectively.

The null hypothesis (H_0) tested in this section is that upper and lower body positioning occur independently when the sample is stratified by age. The alternative hypothesis (H_a) is that upper and lower body positioning are significantly related when the sample is stratified by age. The results of the tests of independence carried out for this section are listed below in Table 17 as well as in Appendix H. The results shown in Table 17 are those when the upper

and lower body variables are tested against each other for independence with the sample stratified into pre- and post-puberty age categories. The results in Appendix H are for the same pairings of variables but with the sample stratified into osteological age categories.

Table 17: *P*-values for Upper and Lower Body variables (stratified by Age –pre/post-puberty)

Juveniles (≤10 years)			
VARIABLE	Arm flexion	Hand position	Hand flexion
Leg position	1.000	.455	1.000
	n=11	n=11	n=8
Leg rotation	.491	.515	.375
	n=11	n=11	n=8
Foot rotation	.033*	.107	.107
	n=10	n=10	n=8
Foot position	.033*	.019*	.107
	n=10	n=10	n=8
Foot flexion	.095	.105	.646
	n=9	n=9	n=7
Toe position	.464	1.000	1.000
	n=8	n=8	n=6

*Indicates significance based on a 5% confidence interval ($p \leq .05$).

Table 17: *P*-values for Upper and Lower Body variables (stratified by Age –pre/post-puberty) Cont'd

Adults (>10 years)			
VARIABLE	Arm flexion	Hand position	Hand flexion
Leg position	1.000	.007*	1.000
	n=59	n=57	n=50
Leg rotation	.185	.531	1.000
	n=55	n=53	n=49
Foot rotation	1.000	.131	.131
	n=41	n=40	n=38
Foot position	.675	.130	.131
	n=41	n=40	n=38
Foot flexion	.889	.406	.381
	n=41	n=39	n=38
Toe position	.025*	.195	.195
	n=32	n=32	n=32

*Indicates significance based on a 5% confidence interval ($p \leq .05$).

As shown in the table above, there is a statistically significant relationship between leg position and hand position among Adults (>10 years) (p=.007) but not among Juveniles (≤10 years) (p=.455). As seen in the table in Appendix H below, within the Adults >10 years grouping, the relationship is very significant among the Adults (19-39 years) group (p= .001); and is not significant among either Subadults (11-18 years) (p=.269) or Older Adults (p=.634). Among Adults (19-39), a greater proportion than expected have their hands

positioned at the inner thigh and the legs positioned apart (n=6 of 10; 60%). Among Older Adults, both of the individuals identified with their legs apart have their hands positioned over the inner thigh (n=2 of 2; 100%), however, the relationship is not statistically significant.

Conversely, the relationship between foot position and hand position is statistically significant among Juveniles (≤10 years) (p=.019) and is not significant among Adults (>10 years) (p=.130). Among Juveniles, the majority of those with their hands in the crossed pectoral position have non-rotated feet (n=3 of 4; 75%). Similarly, all of the Adults (n=6 of 6; 100%) and Older Adults (n=1 of 1; 100%) with their hands in the crossed pectoral position have non-rotated feet, although the relationships are not statistically significant. There is only one Subadult identified in this study with their hands in the crossed pectoral position (n=1 of 6; 16.7%); this individual is one of only two in the entire sample for whom upper and lower body data were available who have crossed pectoral hands and rotated feet. All of the Juveniles in this sample with their hands positioned at the outer thigh have rotated feet (n=3 of 3; 100%), while the majority of Subadults with the outer thigh hand position also have rotated feet (n=3 of 4; 75%).

As shown above, there is also a statistically significant relationship between foot rotation and arm flexion in Juveniles (p= .033) but not in Adults (p= 1.000). The relationship between foot positioning and arm flexion is also significant in Juveniles (p= .033) but not in Adults (p= .675). Among Juveniles, there is a positive relationship between flexed arms and non-rotated feet (see above).

There is a statistically significant relationship between toe position and arm flexion among Adults (>10 years) (p=.025) but not among Juveniles (≤10 years) (p=.464). As shown below in Appendix G, there are no significant differences in toe positioning relative to arm flexion between the three Adult subgroups (Subadults 11-18 years, Adults 19-39 years, and Older Adults >40 years). Within the latter subgroups, a greater proportion than expected of Adults (19-39) with extended arms have straight toes (n=7 of 12; 58.3%), however, the reverse is true of Juveniles (n=0 of 4; 0%) and Older Adults (n=4 of 10; 40%). Subadults with extended arms are evenly split between straight (n=2 of 4; 50%) and curled (n=2 of 4; 50%) toes.

Based on these results, the null hypothesis of independence (H_0) should be rejected for all subgroups within Adults (>10 years) for toe position and arm flexion; and toe position and arm position, respectively, as these pairs of variables are significantly related within this age group. The null hypothesis of independence (H_0) should also be rejected for arm position and leg position in Adults (19-39 years) only. The null hypothesis of independence (H_0) cannot be rejected for any of the other combinations of upper and lower body variables in Adults (>10 years).

The null hypothesis of independence (H_0) should also be rejected in Juveniles (≤10 years) for the following combinations of variables: foot position and arm position; foot rotation and arm flexion; and foot position and arm flexion, respectively, as the relationships between these pairs of variables are statistically significant within the latter age group.

Upper & Lower Body Variables by Sex

This section outlines the results of the relevant tests used to examine the sample for relationships between upper and lower body variables with the sample stratified by sex.

The null hypothesis (H_0) tested in this section is that upper and lower body positioning occur independently in this sample when it is stratified by sex. The alternative hypothesis (H_a) is that upper and lower body positioning are significantly related when the sample is stratified by sex. The results of the tests of independence carried out for this section of the study are listed below in Table 18. The results shown in Table 18 are those when the upper and lower body variables are tested against each other with the sample stratified by sex.

Table 18: *P*-values for Upper and Lower Body variables (stratified by Sex)

Males			
Variable	Hand Position	Arm Flexion	Hand Position
Leg Position	.119	1.000	1.000
	n=30	n=32	n=28
Leg Rotation	.496	.138	.648
	n=28	n=30	n=27
Foot Rotation	.207	1.000	1.000
	n=21	n=22	n=20
Foot Position	.225	1.000	1.000
	n=21	n=22	n=20
Foot Flexion	.572	.772	.353
	n=21	n=23	n=21
Toe Position	.237	.471	.471
	n=18	n=18	n=18

Table 18: *P*-values for Upper and Lower Body variables (stratified by Sex) Cont'd

Females			
Variable	Hand Position	Arm Flexion	Hand Position
Leg Position	.192	1.000	1.000
	n=30	n=30	n=26
Leg Rotation	.552	.639	.652
	n=28	n=28	n=26
Foot Rotation	.130	.273	.283
	n=23	n=23	n=22
Foot Position	.273	.273	.283
	n=23	n=23	n=22
Foot Flexion	.176	.482	.314
	n=22	n=22	n=21
Toe Position	.166	.087	.471
	n=19	n=19	n=19

As shown above, none of the upper and lower body variant combinations are significantly related when the sample is stratified by sex. Based on these results, the null hypothesis of independence (H_0) cannot be rejected for any of the combinations of upper and lower body variables when the sample is stratified by sex.

Summary of results

The results of this study demonstrate that upper and lower body positioning did not occur randomly in this sample, but instead show relatively clear patterning. As shown above, some aspects of limb positioning are related to time period (cf. Gray, 1972) or site (e.g. hand and

arm position, foot position), while others relate to social factors such as age (e.g. foot rotation; hand and foot positions) and sex (e.g. left leg rotation) which are specific to the individual. As a whole, these results support the idea that lower body positioning and treatment was being carried out deliberately in conjunction with other stylistic aspects of mummification such as the positioning of the arms and hands.

Chapter 6

6. Discussion

This chapter provides an interpretation of the results outlined in Chapter 5 with respect to the research questions posed in Chapter 1, as well as previous research. As stated in Chapter 5, the statistical analysis carried out in this study first addresses the relationship between body positioning and time period (cf. Smith, 1914; Gray, 1967, 1972; Leca, 1980; Russell et al., 1980, etc.) and site (cf. Morton, 1844; Lamb, 1901; Shafik et al., 2008; Wade, 2012, etc.) in order to contribute to the existing research on this subject outlined in Chapter 3. Following those initial sections, this analysis also examines the relationship between limb positioning and age and sex, respectively, to shed light on the possible roles of social variables in determining body treatment and positioning during mummification. There is some precedent for age-specific mummification treatment (see Davey et al., 2014), however, this has yet to be examined in the limbs. The present chapter discusses the results in Chapter 5 in the same order as they were presented above.

As described in the final section of Chapter 5, the results of this study show that some aspects of limb positioning do relate to time period and site, as expected based on previous research. However, other aspects seem to relate to age and sex, suggesting that limb positioning in mummies may have been more complex a process than was previously assumed.

Rotated Feet & Legs

The most remarkable body positioning variant uncovered during the course of this investigation is the rotation of the feet to the right of the midline, designated here as the 'rotated right' foot position. It is remarkable because it has apparently escaped mention in the extensive literature on mummies. This variant is present in fourteen (n=14) individuals representing 25.5% of all of the mummies in this sample for whom foot position data could be obtained. Of these fourteen individuals, seven are female (n=7 of 14; 50%), five male (n=5 of 14; 35.7%), and two of indeterminate sex (n=2 of 14; 14.3%). The age composition of this group is as follows: five Juveniles 1-10 years (n=5 of 14; 35.7%), four Subadults 11-18 (n=4 of 14; 28.6%), four Adults 19-39 (n=4 of 14; 28.6%), and one Older Adult >40 (n=1 of 14; 7.1%). As was discussed in a previous section, there is at least one example of this

positioning from each of the time periods represented in this sample, with the exception of the Third Intermediate Period.

The rotation of the legs and feet is of particular interest because not only is it present in a relatively sizable proportion of the sample examined in this study, but it has also not been documented previously in the existing literature on limb treatment and positioning during mummification (see Chapter 3 for review). This is particularly interesting given the degree of manipulation that likely would have taken place in order to form the body into this configuration. As is discussed in greater detail below, some of the individuals examined in this study have both the feet and lower legs rotated to the right, while others have only the lower leg (i.e. the tibia) rotated with the feet facing forward. Based on their presentation on the radiographic images used in this study, both of these variants would have involved a torsion of the lower leg at the knee, resulting in a rotation of the tibia on its long axis. The latter seems to represent a deliberate action by the embalmer, although it remains unclear how or why it was performed.

While the extent of rotation of the legs and/or feet varies considerably among those individuals presenting with this foot position, the basic features are consistent across this group: (1) The soft tissue appears to be relatively intact over the legs and feet; and (2) The knee and ankle joints remain roughly articulated with little/no evidence of postmortem trauma. Taken together, both of these features suggest that the body was likely being positioned in these individuals when it was not fully desiccated, further supporting the findings of both the modern experimental mummification studies outlined in Chapter 3 above (see Brier & Wade, 1997; Zimmerman et al., 1998; Panzer et al., 2013) as well as the bioarchaeological evidence of incomplete desiccation at the time of wrapping (see Granville, 1825; Leca, 1976; Aufderheide, 2003; Ikram, 2003; Nelson, 2008, etc.).

Due to the prevalence of rotated legs and feet in this sample, the following sections focus largely on the relationship between lower body variables as they relate to this variant.

6.1 Body Positioning by Time Period and Site

Upper Body Variables by Time Period

The results of the statistical tests described in the previous chapter demonstrate a relatively straightforward sequence of changes in upper body positioning across the time periods represented in this sample, suggesting that the existing variation in arm and hand position is not a random occurrence. These results further support the previous seriation proposed by Gray (1972).

In his pioneering radiological study of 111 ancient Egyptian mummies, Gray (1972) noted shifts in the dominant[16] positioning of the arms and hands between time periods, suggesting that the positioning of the upper body might prove useful in dating a particular mummy. Among his sample, individuals ranging from Dynasty 21 through to the start of the Ptolemaic period all had their arms in an extended position, with some variation in the positioning of the hands; the outer thigh hand position, however, was only found in a single individual. Gray (1972) also noted a change in the favoured positioning of the arms and hands during the Ptolemaic period toward a crossed pectoral position with the right arm crossed over the left. Finally, during the Roman period the arms reverted back to an extended position, but this time with the hands positioned at the outer thigh. Gray's (1972) basic seriation of arm and hand positioning is laid out below in Table 20.

Table 19: Summary of Gray's (1972) seriation of arm & hand positioning

Time Period	Arm & Hand Position
Roman	Extended; hand position still varies but Outer Thigh position is favoured.
Ptolemaic	Flexed; Crossed pectoral
Dynastic (Dynasty 21-start of Ptolemaic)	Extended; hand position varies but Outer Thigh position is rare

16 It is important to note here that while Gray's (1972) seriation was based upon the dominant positioning in each period, other variants of upper body positioning continued to be employed throughout the periods studied as was discussed above in Chapter 3.

The IMPACT sample used in this study follows a similar sequence of upper body positioning, although –as reported by Gray (1972) – various positions of the hands and arms are present in all periods. The individuals dating to the New Kingdom (1550-1069 BCE), Third Intermediate (1069-664 BCE), and Late periods (664-332 BCE), respectively, for whom upper body was available show a clear preference for an extended arm position with various positions of the hands. The outer thigh hand position is less frequent during these three periods compared to either the inner thigh or pubis positions, however, it is found in a few individuals. There are no individuals in this sample dating to the Third Intermediate Period with the hands positioned at the outer thighs (n=0 of 14; 0%).

As was the case among Gray's (1972) sample, the Ptolemaic period in this study is characterized by a shift in prevalence toward the crossed pectoral hand position (n=11 of 15; 73.3%), with the right arm crossed over the left, and away from the other three positions. Although not noted in Gray's (1972) study, the hands are also flexed much more frequently during this period (n=7 of 13; 53.8%) compared to the other time periods either before or after the Ptolemaic. In most of these cases, the left hand is flexed while the right is relaxed over the left portion of the chest, however, a few instances were also recorded in which both hands were relaxed in the crossed pectoral position. As discussed above, there are no (n=0 of 13; 0%) individuals with the arms positioned at the outer thigh dating to the Ptolemaic period in this sample.

It should also be noted that although the crossed pectoral position became most prevalent during the Ptolemaic period, examples of this position have been found in earlier periods, mainly among royal mummies (see for example Gray, 1972; Harris & Wente, 1980). Within this sample, there were two individuals with their hands in the crossed pectoral position dating to earlier periods: (1) IMP00025 “Sheryet Mehret” dating to the Third Intermediate period; and (2) IMP00029 “Pasherienaset” dating to the Late period.

Finally, as described by Gray (1972), the Roman period individuals in this sample seem to represent a shift back toward extended arms, this time with a preference for the outer thigh hand position (n=9 of 11; 81.8%). Again, it should be noted here that the crossed pectoral position was still in use after the Ptolemaic period. Although there were no individuals in the sample used for this study with the latter hand positioning variant dating to later periods, an

additional individual archived in the IMPACT radiological database and designated as IMP00006 (“Lady Hudson”) dates to the Roman period and has her hands in the crossed pectoral position. Her remains are too fragmentary to meet the criteria for inclusion in this study, however, it seems relevant to include her here as an example of older mummification styles carrying on into later time periods.

Lower Body Variables by Time Period

As discussed previously in Chapter 5, most of the lower body variables examined in this study are not significantly related to any particular time period, quite unlike the upper body.

There is some variation in foot rotation between time periods, however, as discussed above, the difference is not statistically significant (p=.077). Rotated feet are relatively rare compared to non-rotated feet in all periods up until the Roman period (30 BCE– 641 CE), in which five of a total of nine individuals have rotated feet (n=5 of 9; 55.6%). As described previously, at least one individual with rotated feet has been identified for each time period except for the Third Intermediate Period, in which all of the individuals studied have the feet in a non-rotated position (n=9 of 9; 100%).

While the meaning of the rotation of the feet in the manner noted in this study remains somewhat of a mystery, it seems relevant to note that the only period in which this variant does not occur in this sample happens to be the one described as the 'height' of the mummification tradition in Egypt (see for example Gray, 1967: pp.35; Taylor, 2000: pp.364). During this period, the embalming process was at its most complex and, as a result, was often more successful in terms of the preservation of the body. It is also the period during which subcutaneous packing of the limbs came into practice (see Saleem et al., 2015), suggesting that the limbs were likely being treated differently during this time. If we are to assume that the Third Intermediate Period does in fact represent the 'crème de la crème' of Egyptian embalming technologies, the results of this study seem to imply that the rotation of the legs represents a less-than-ideal –or at the very least, less standardized – variant of lower body treatment. However, at the present time, no concrete conclusions can be drawn.

The second lower body positioning variant discussed here is the positioning of the toes. Somewhat surprisingly, toe position appears to follow a particular sequence across time in

this sample: the two earliest periods, the New Kingdom and Third Intermediate, respectively, are mainly characterized by straight toes. Both (n=2; 100%) of the individuals dating to the New Kingdom have straight toes, while seven (n=7; 70%) of the Third Intermediate individuals also have straight toes. However, it should be noted that the sample size is very small for these sites.

The Late period individuals in this sample suddenly show a much higher proportion (n=9 of 10; 90%) of individuals with curled toes than straight. However, the shift seems to reverse in the Ptolemaic period wherein the majority (n=6 of 7; 85.7%) again have straight toes, then pick back up in the Roman period with a fairly even split between straight (n=3 of 7; 42.9%) and curled (n=4 of 7; 57.1%) toes.

Based on the fact that the less common variant of curled toes dominates only in the Late period, this seems to imply that the state of the toes may be affected by the style of embalming employed at a particular time. This could be an interesting avenue for future study, however, the logistics of doing so might prove difficult as it would likely require comparing the toes of mummified versus non-mummified individuals from the same period to determine whether the curling of the toes was present regardless of the embalming process used. The obvious limitation here is that the articulation and preservation of the toes is largely dependent upon the embalming process; however, it is not inconceivable that some individuals who were not fully mummified might still have intact toes.

Upper Body Variables by Site

As with time period, upper body positioning varies significantly between sites in this sample. However, the relative lack of contextual information available for so many mummies (see Chapter 4) makes the generalizability of these data somewhat limited.

As discussed previously, most of the sites are represented by only a very small number of individuals –in some cases, only a single mummy – making it difficult to discern any particular patterns. Two sites do seem to show some form of trend, however: (1) All of the individuals from Akhmim have their hands in the crossed pectoral position and the majority of these have flexed hands, and (2) Greater proportions of individuals from Thebes have the hands positioned over the inner thighs or the pubis relative to the other positions, and nearly

all have relaxed hands. Additionally, there were no individuals found from Thebes with the hands in the crossed pectoral position.

These results appear to support the idea of regional variations in specific embalming practices (see Morton, 1844; Lamb, 1901; Shafik et al, 2008; Wade, 2012). However, there may be an alternative explanation based on an added temporal dimension. Unfortunately, the relatively small sample size used in this study –as well as the paucity of contextual information – makes it difficult to make broad comparisons between time periods within sites. However, it seems likely that the apparent patterning between the two sites noted above is more readily explained by variation between periods, rather than actual differences in mummification practices between sites.

In both of these cases, the key here seems to be the relationship between the Ptolemaic period and the crossed pectoral hand position, as was discussed previously. First, all of the aforementioned individuals from Akhmim date to the Ptolemaic period (n=5 of 5; 100%), potentially explaining why the crossed pectoral position seems to be ubiquitous at this site.

Second, the total sample from Thebes (n=32) can be broken down into time periods as follows: New Kingdom (n=2 of 32; 6.3%); Third Intermediate (n=13 of 32; 40.6%); Late (n=11 of 32; 34.4%); Ptolemaic (n=1 of 32; 31.3%); and Roman (n=5 of 32; 15.6%). Again, what appears to be inter-site variation may be more easily explained by time period. The Ptolemaic is underrepresented at this site compared to the earlier Dynastic periods (New Kingdom, Third Intermediate, and Late, respectively), perhaps explaining why there are fewer individuals with crossed pectoral hand positioning than would be expected were hand positioning due to chance.

Because of the small sample size used in this study, temporal explanations of differences in upper body positioning seem more justified with respect to the rest of the data. However, this does not preclude the possibility of regional differences in embalming, it merely emphasizes the limitations placed upon studies of this nature with respect to contextual information.

Lower Body Variables by Site

As described above, there were no significant relationships found in this study between site and any of the lower body positioning variables other than foot flexion and foot positioning,

respectively. Unfortunately, site comparisons for both of these variables are subject to the same limitations as those discussed above, as most of the sites are represented by only a very small number of individuals in this sample.

As mentioned previously, the greatest proportion of individuals from Thebes have their feet flexed while a much smaller proportion than expected have their feet bent under at the midfoot. This variation could potentially represent a site difference in the positioning of the feet, however, it may also be explained by time period, much like upper body positioning. Although there is no statistically significant relationship between foot flexion and time period in this sample, the greatest proportions of individuals for whom foot data were available from both the Third Intermediate and Late periods, respectively, do have flexed feet (see above). The latter two periods also make up the greatest proportions of the sample from Thebes, suggesting that this variation may again be better explained by temporal –rather than spatial – differences.

As was discussed in Chapter 5, there is a statistically significant relationship between site and foot rotation in this sample. Individuals with rotated feet were identified at all sites apart from two (Abydos and Akhmim) at which all individuals have non-rotated feet. However, as with arm positioning, both of these instances are probably better explained by temporal variation, as all of the individuals from each of these sites date to the Ptolemaic period (Abydos n=1; Akhmim n=4).

6.2 Upper Body Variables

In addition to looking for patterning in limb positioning between time periods and sites, this study also examines body positioning variables in relation to each other, as well as to age and sex.

The results of this study show a significant difference in hand flexion relative to arm flexion and hand position. As discussed previously, there is a significant positive relationship between flexed arms and flexed hands, as well as between extended arms and relaxed hands, respectively.

These results build upon the original study of arm and hand positioning by Gray (1972) (see above) by providing further insight into the role of the hands in upper body positioning.

Based on the findings of the present study, it seems clear that the hands were not merely passively involved in the positioning of the arms; instead, they appear to have been deliberately molded into a particular configuration, at least among those with flexed arms.

As was mentioned above, most of the individuals identified in this study as having flexed arms and hands had one hand –usually the left – flexed, while the other remained relaxed on the chest. This could potentially tie in to the practice of burying the deceased with the crook and/or flail clasped in the hands in imitation of depictions of Osiris (see Nunn & Andrews, 1977: pp.342 for example). Most of the mummies in this sample were not holding anything in their hands, however, it does not seem unreasonable to suggest that such objects might either have been removed sometime after burial (see Chapter 4). Alternately, flexing the hand(s) could represent a symbolic clasping, rather than an actual grasp around an object.

Upper Body Variables by Age

As described in Chapter 5, there is a statistically significant relationship between age category and hand position in this sample. However, as with the apparent site differences in upper body positioning, the differences seen in these age groups may also be a function of time period, rather than representing age-related differences in mummification practices.

Of the five (n=5) Juveniles identified above with the hands in the crossed pectoral position, two date to the Ptolemaic period (n=2 of 5; 40%), while the remaining three date to unknown periods (n=3 of 5; 60%). This does not entirely preclude the possibility that the increased prevalence of the crossed pectoral hand position in Juveniles is due to age. However, it also does not eliminate time period as a potential factor, as the three undated individuals could also be from the Ptolemaic period. Unfortunately this relationship may not be easily explored at the present time given the paucity of contextual data for these –and many other – mummies, as discussed in Chapter 4.

The relationship between the Older Adults with the hands positioned at the inner thigh and time period is slightly less conspicuous than the Juveniles discussed above, however, the same explanation may still apply. Of the seven (n=7) Older Adults with the hands positioned over the inner thigh, four individuals date to the Third Intermediate Period (n=4 of 7; 57.1%), two date to the Late period (n=2 of 7; 28.6%), and one dates to an unknown period (n=1of 7;

0.14%). Although these individuals do not derive from a single period unlike the Juveniles discussed above, these results still fall within the seriation of arm and hand positioning proposed by Gray (1972) in which the arms were usually in an extended position prior to the Ptolemaic period. Furthermore, the only Older Adult dating to the Ptolemaic period has her hands in the crossed pectoral position, further supporting the time period hypothesis.

As discussed previously, there is a also very significant relationship between hand flexion and arm flexion and positioning among Adults (19-39 years), but not among the other age groups. Among Adults (19-39 years), there is a positive relationship between flexed arms and flexed hands; there are negative relationships between flexed hands and extended arms, as well as between relaxed hands and flexed arms, respectively. The remaining age groups seem to show a similar pattern although the relationships are not statistically significant.

Based on these results, it appears that variation in upper body positioning is still best explained by differences in time period, as discussed in the previous section, rather than by differences in the age at death of the deceased.

Upper Body Variables by Sex

As discussed above, there are no significant relationships between sex and any of the upper body positioning variables examined in this study. However, there do appear to be sex differences in the relationship between hand flexion, hand position, and arm flexion. In particular, the relationship between flexed hands and the crossed pectoral hand position discussed above seems to apply mainly to males, and is less straightforward in females. A majority of males with extended arms have relaxed hands, while the majority of those with their arms flexed also have flexed hands (see Section 5.2).

By comparison, the relationship between hand flexion and hand positioning seems to be less rigid in females. Like their male counterparts, the majority of females with extended arms have relaxed hands. However, among the total of six (n=6) females with their hands in a crossed pectoral position equal proportions have flexed (n=3 of 6; 50%) and relaxed hands (n=3 of 6; 50%). Furthermore, while only one male individual with extended arms had flexed hands (n=1 of 24; 4%), four of those females with extended arms had flexed hands (n=4 of 22; 18.2%).

Based on these results, the relationship between hand flexion, hand position, and arm flexion described in the previous sections appears to be more relevant to males than females, as the latter seem to show more variability in terms of the positioning of the hands relative to the arms. This does not, of course, mean that the hands were not being deliberately positioned in female individuals, or that the hands of women were less important in the embalming process. On the contrary, these findings emphasizes the degree of variability of hand positioning in this sample, as well as highlighting the inadequacy of normative descriptions of the mummification process (see Chapter 3) to represent the treatment of individuals from different social and demographic categories.

6.3 Lower Body Variables

As described in Chapter 5 as well as in the sections above, there is a positive relationship between the rotation of the legs and feet in this sample. All of the individuals identified in this study with rotated feet also have at least one leg rotated, while the majority of those with non-rotated feet also have non-rotated legs (see Section 5.3). The most common variant of leg rotation is the lateral rotation of the right leg at the knee, as discussed above. Interestingly, however, rotation of the lower legs does not only occur in those cases with rotated feet, as might be expected given the anatomical relationship between the two: in this sample, seventeen individuals were identified with at least one rotated leg but non-rotated feet (see Appendix E).

These results suggest that the lower legs were being rotated in conjunction with the feet, but that the feet were not necessarily rotated with the legs in a number of cases. Alternately, the feet and legs could have initially been rotated together, then the feet returned to a non-rotated position. The latter seems like a valid possibility, given that the rotation of the lower legs is clearly visible on radiographic images but would not necessarily be evident to the naked eye; in this respect, the embalmer may have thought they were returning the legs to a neutral, non-rotated position along with the the feet but were in fact leaving the tibiae rotated within the leg(s).

The highly varied demographic profiles of the seventeen individuals with rotated legs and non-rotated feet (see table in Appendix E) seem to further support the idea that the rotation of the legs and feet may not represent a deliberate body position, but rather be a result of the

embalming process. Furthermore, nearly all of those individuals with rotated legs and non-rotated feet for whom provenance information was available came from Thebes, aside from the individual designated IMP00112 (“Diptah”) from Akhmim. While it is difficult to say for certain whether this is meaningful or not, it could be suggested that the rotation of the legs could be a result of the particular embalming procedure used by the school at Thebes (See Morton, 1844; Lamb, 1901; Shafik et al, 2008;Wade, 2012), perhaps due to differences in the state of either decomposition and/or desiccation of the body at the point of posing and wrapping in the mummification process.

Additionally, although it is difficult to confirm at what point in the embalming process the rotation of the legs and feet would have taken place, one possibility could be during the evisceration and packing of the body in natron. Dunand and Lichtenberg (2006) suggested that the extended supine position of the body may have been introduced to facilitate the evisceration of the body via an abdominal incision in the left side (see Chapter 3). Based on the directionality of the rotated legs and feet identified in this study, a similar explanation could apply here as well as the lower body would have been rotated away from the side through which the organs were removed.

Potentially, the embalmer would have rotated the lower legs and feet to the right of the midline, away from the side through which evisceration was to take place, in order to stretch out the flank in preparation for the abdominal incision. Subsequently, the embalmer could have attempted to straighten the feet during or after the desiccation phase had taken place but was either unable to do so or, for some reason, chose not to. The latter concept will be revisited below when discussing the relationship between the rotation of the legs and feet among different age groups in this sample.

In addition to leg and foot rotation discussed above, there is also a significant relationship between foot position and flexion. For the purpose of this analysis, it is assumed that the 'relaxed' flexion represents the natural posture of the feet rather than a deliberate position; in contrast, both the 'flexed' and 'bent under' flexions would have required some form of manipulation, and are thus of greater interest to this study. As stated in Chapter 5, there is a positive relationship between the non-rotated foot position and flexed feet, as well as between rotated feet and a 'bent under' (plantar) flexion.

There are also significant relationships between toe position and foot flexion in this sample. Of those for whom foot data were available, all individuals with the feet bent under at the midfoot have curled toes whereas the majority of those with flexed feet have straight toes (see Section 5.3). Individuals in this sample with relaxed feet had straight and curled toes in equal proportions (n=9 of 18; 50%), further supporting the idea that the relaxed position is probably not a deliberate variant.

As was discussed in a previous section, there seems to have been a notable increase in the proportion of individuals with curled toes dating to the Late period, suggesting that curled toes may be a result of changes in embalming styles or could relate to differences in lifestyle, clothing, etc. which might restrict the feet. Two of the five individuals with the feet bent under at the midfoot and curled toes date to the Late period (n=2 of 5; 40%), however, one of these individuals dates to the Roman period (n=1 of 5; 20%), while the remaining two are from unknown time periods (n=2 of 5; 20%). This seems to support the idea that the curling of the toes may not simply be a function of time period, but may also relate to the manipulation of the feet during embalming. However, further study is required to draw any definite conclusions.

Lower Body Variables by Age

As stated in Chapter 5, there is a significant relationship between foot positioning and age in this sample. The majority of both Juveniles and Subadults in this sample have rotated feet, while much smaller proportions of Adults and Older Adults have rotated feet (see Section 5.3). As discussed previously, the most common variant is the rotation of the feet to the right of the midline; among those for whom foot data could be obtained, this variant is present in five Juveniles (n=5 of 9; 55.6%) and four Subadults (n=4 of 6; 66.7%) in this sample. Of those for whom foot positioning could be recorded (n=38), only one (n=1 of 38; 0.03%) individual, classified as a Juvenile, has the feet rotated to the left.

There are also differences in the significance of the relationship between leg rotation and foot position between age categories in this sample. As described previously, there were no individuals identified in this study with non-rotated legs and rotated feet from any of the age categories (n=0 of 55; 0%). Interestingly, however, the majority of both Adults (n=8 of 12; 66.7%) and Older Adults (n=7 of 8; 87.5%) with rotated legs had non-rotated feet in this

sample, although the relationship is not statistically significant in the latter group. In contrast, the majority of Juveniles (n=6 of 7; 85.7%) and Subadults (n=4 of 4; 100%) with rotated legs also had rotated feet. Of those with rotated legs and non-rotated feet (see above), the majority are Adults (n=15 of 17; 88.2%), while the remaining two are a single Juvenile (n=1 of 17; 5.9%) and one (n=1 of 17; 5.9%) individual of unknown age.

These results seem to have two implications: (1) That there may be a different relationship between the treatment of the legs and feet in Adults and Older adults versus the two younger age groupings; and (2) That Subadults were being treated more similarly to Juveniles –at least with respect to leg and foot rotation – than to their older counterparts, Adults and Older Adults, respectively.

The latter is particularly relevant as there is some debate as to whether individuals classified as Subadults based on biological age (see Sofaer, 2006: pp.119) would have been considered 'children' or 'adults' based on social age. The results of this study seem to suggest that puberty likely was not the defining factor between 'children' and 'adults'; this accords with Janssen & Janssen's (2007) suggestion that 'childhood' was defined by social status rather than biological age (see pp.23). Additionally, these results suggest that although adolescence may have been seen as distinct from adulthood, individuals in this age group may not have been considered distinct from younger (prepubescent) subadults as had been previously proposed (see Janssen & Janssen, 2007: pp.144).

Finally, it seems necessary here to tie in this discussion of age differences in foot and leg rotation to the previous sections in which explanations for this variant were offered (see above). If the lower legs and feet were being twisted to the right during embalming then rotated back to centre after the evisceration was complete, as proposed above, then individuals with both the feet and legs rotated would seem to represent an incomplete version of this procedure. In this respect, it is particularly interesting that the latter variant (rotated legs and feet) appeared more frequently among Juveniles and Subadults in this sample compared to the two older age groups as it seems to imply that younger people were receiving a less thorough embalming treatment.

The possibility of younger individuals receiving a less complete mummification procedure accords with previous assertions that ancient Egyptian society considered children as

'incomplete adults,' rather than complete beings in their own right (see for example Janssen & Janssen, 2007: pp.127), at least during the Dynastic periods. Additionally, these results also accord with Meskell's (1999) research on the necropoleis at Deir el-Medina in which she found that the funerary treatment of children showed clear evidence of concern for their attainment of the afterlife yet was less costly than that of older individuals (see pp.131).

Lower Body Variables by Sex

As described in Chapter 5, the only significant sex difference in lower body positioning is in the rotation of the left leg. While the majority of females have a non-rotated left leg, a considerable proportion of males have their left leg rotated laterally (see Section 5.3). In contrast, the rotation of the right leg occurs in roughly the same proportions between the sexes. Additionally, when the sample is stratified by sex, there remains a statistically significant relationship between leg and foot rotation among both males and females. As mentioned previously, all of the individuals in this study with their feet in the rotated right position also have rotated legs, regardless of sex (see above).

These results seem to imply that the legs were usually being rotated with the feet, as discussed previously, regardless of sex. This is further supported by those seventeen individuals described above (see Appendix E) as having rotated legs and non-rotated feet: among those individuals, the sex distribution is as follows: seven females (n=7 of 17; 41.2%); six males (n=6 of 17; 35.3%); and two of indeterminate sex (n=2 of 17; 11.8%).

As outlined in Chapter 5, both males and females also show a similar pattern in the rotation of the right leg relative to foot position, although the relationship is only statistically significant in males and only in the right leg. In contrast, the rotation of the left leg seems to occur more often in males regardless of foot position, suggesting that some aspect of the embalming process involving the rotation of the legs and feet (see above) may have differed based on sex.

As described previously, the medial rotation of the left leg is significantly related to the 'bent under' foot flexion in females, however, the relationship between foot flexion and positioning seems to be slightly less straightforward among males and is not statistically significant. As

discussed in Chapter 5, there is also a significant relationship between toe position and the rotation of the right leg in females.

Taken together, these results seem to imply the existence of two main variants of lower body positioning, both of which are more precisely carried out in females than in males: (1) Both legs in a non-rotated position with non-rotated, flexed feet, and straight toes; and (2) At least one leg rotated –usually the right in a lateral direction – with the feet rotated to the right and bent under, with curled toes.

The females in this sample with their feet rotated to the right do not seem to have any particular commonalities in terms of age, time period, or site (see table in Appendix D), suggesting that the results discussed in this section probably cannot be explained by temporal or spatial differences (unlike the apparent age differences in upper body positioning discussed in the previous sections).

The significance of the relationship between toe position and the rotation of the right leg in females is also not easily explained, as the eleven (n=11) individuals with a laterally rotated right leg derive from a variety of time periods. Of these, one (n=1 of 11; 0.09%) New Kingdom; three (n=3 of 11; 27.3%) Third Intermediate; one (n=1 of 11; 0.09&) Late; one (n=1 of 11; 0.09%) to the Ptolemaic; and three (n=3 of 11; 27.3%) to the Roman period. The remaining two (n=2 of 11; 18.2%) derive from unknown periods.

However, the majority of females with a rotated right leg (n=9 of 11; 81.2%) are from Thebes, while only one (n=1 of 11; 0.09%) is from Akhmim, and one (n=1 of 11; 0.09%) is from an unknown location.

It should also be taken into account, however, that Thebes is overrepresented in this sample, as was discussed in the initial sections of this chapter which dealt with body positioning and site. Thus the fact that the aforementioned groups of individuals with rotated legs mainly derive from Thebes may be a result of sample composition. However, the possibility of localized embalming practices should not be ruled out either and is worth exploring in the future.

6.4 Upper & Lower Body Variables

As was described in the previous chapter, there appears to be a significant relationship between hand and leg position in this sample. Most of the individuals studied have their legs positioned together, regardless of the position of their hands. However, among individuals with their hands positioned at the inner thigh, a fairly large proportion have their legs positioned apart (see Section 5.4). The most likely reason for this seems to be the placement of visceral packages between the legs, a practice which became common in the 26th Dynasty (664-525 BCE) (see Gray, 1967: pp.36) and continued through the Late period, although the identification of these materials was beyond the scope of this study (see Chapter 7 for a discussion). As described in Chapter 5, a greater proportion than expected of Late period individuals in this sample had their hands positioned at the inner thigh. Accordingly, a sizable minority of Late period individuals also have their legs positioned apart; this is a greater proportion than is seen in any of the other time periods, although the relationship between time period and leg position is not statistically significant.

In addition to hand and leg position, there is also a significant relationship between hand and foot position. Examples of the rotated right foot position are present for each of the hand position variants, although most of the individuals examined in this study have their legs in a non-rotated position regardless of hand position. However, of those with the hands positioned at the outer thigh, the majority have their feet rotated to the right (see Chapter 5). This again appears to tie in to time period, as the popularity of the outer thigh hand position increased considerably during the Roman period (see Gray, 1972). As was discussed in the initial sections of this chapter, there is also an increased prevalence of rotated feet among Roman period individuals in this sample. Taken together, this suggests that the combination of the outer thigh hands position with rotated feet may represent a particular variant of embalming that was carried out during the Roman period.

There are also significant relationships between toe positioning and arm flexion and hand position in this sample (see Section 5.4). Again, these results are best explained by their relation to temporal variation in the mummification process. As described in the earlier sections of this chapter, both hand and toe position are significantly related to time period, although the reasoning behind the latter is less clear (see above).

Upper & Lower Body Variables by Age

The relationship between hand and leg position above only seems to apply to adults in this sample. Among Adults (19-39 years), the majority of those with the arm hands positioned over the inner thigh have their legs positioned apart (n=6 of 10; 60%), while only one individual was identified with parted legs and any of the other hand positions within this age grouping. Among Older Adults, both of the individuals identified with their legs apart have their hands positioned over the inner thigh, however, the relationship is not statistically significant.

This seems to confirm the age-related difference in the positioning of the body proposed above, at least among the individuals in this sample, and suggests that the body positioning variants described in the previous section may only apply to adults.

As described in the previous chapter, the relationship between hand and foot position is only statistically significant in Juveniles (1-10 years) (p=.019), although patterns are found among both Adults and Older Adults.

The relationship between the outer thigh hand position and the rotated right foot position described in the previous sections seems only to apply in Juveniles and Subadults in this sample and not to either of the two older age groups. All of the Juveniles in this sample with their hands positioned at the outer thigh have rotated feet (n=3 of 3; 100%), while the majority of Subadults with the outer thigh hand position also have rotated feet (n=3 of 4; 75%). This pattern does not appear to be present in either Adults or Older adults, although there are relatively few individuals with the outer thigh hand position from either of these groups from which to draw inferences.

Of these two combinations of hand and foot positioning, only the latter seems to represent an actual age difference in body positioning, as the former shows similar patterning across age groups despite the lack of statistical significance in Adults and Older Adults. The second pairing of arm and foot positions discussed here may be related to age, as the outer thigh hand position and the rotated right foot position seem to appear together more often than not in Juveniles and Subadults but not in their older counterparts. However, as was discussed previously, both of these variants are related to a particular time period: Gray (1972) reported

that the outer thigh hand position gained popularity during the Roman period, while the results of this study show an increased prevalence of the rotated right foot position among Roman period individuals in this sample.

The relationship between toe position and arm flexion and hand position described in the previous section appears to show similar patterns across all age groupings, although the relationships are not statistically significant in Juveniles. Among all age groups, the majority of those with flexed arms have straight toes. Despite what the statistical analyses appear to suggest, the only recognizable pattern in toe position relative to arm flexion in this sample (straight toes and the crossed pectoral hand position) seems to be present across age groupings, and thus is probably not a function of age. Instead, the more likely deciding factor appears to be time period. As was discussed previously, the crossed pectoral hand position is related to the Ptolemaic period (see also Gray, 1972), while toe position also shows significant temporal change.

Upper & Lower Body Variables by Sex

As was discussed previously in Chapter 4, there were no statistically significant relationships between any of the combinations of upper and lower body positioning variables when the sample is stratified by sex. Although this seems like a somewhat anticlimactic end to the present chapter, the lack of significant results for this section is relevant to our understanding of the interaction between sex and other variables (age, time period) in determining the positioning of the body during embalming.

These results suggest that although there are some sex differences in certain aspects of upper and lower body positioning (e.g. the rotation of the left leg in males), the overall configuration of the body as a whole does not seem to be influenced by sex. As we have seen above, the greatest influencing factor –at least of those covered in this study – seems to be time period, with males and females receiving similar treatment throughout with some minor variations. This is particularly interesting given that sex differences in social and economic status are relatively well documented (see Chapter 2).

Summary

The results discussed here demonstrate a number of patterns within and between the upper and lower body positioning variables assessed in this study, suggesting that the limbs were being deliberately manipulated during the embalming process. Most of the variation in limb positioning identified in this study seems to relate to changes in the embalming tradition between time periods, as proposed previously by Gray (1972), although different styles of embalming remain present throughout (see Chapter 3). However, some aspects also vary based on the age and sex of the decedent, supporting the idea that funerary treatment may have related to social status in this sample.

Chapter 7

7. Conclusion

As was discussed in Chapter 1 of this volume, the overarching purpose of this study is to shed light on the treatment and positioning of the lower body in Egyptian mummies, a previously neglected area of research in mummy studies, in preparation for a future large-scale paleoradiological study of osteoarthritis (OA) (see Chapter 1). The results of this research demonstrate that the limbs were of both symbolic and pragmatic significance to the mummification process and were certainly subject to manipulation during embalming, although to varying degrees. For this reason, future studies of OA need to account for these changes in order to accurately perform retrospective diagnoses on mummies as they clearly impact not only the radiographic appearance of the limb as a whole, but also the articulation of the joints.

In Chapter 3, a review of the relevant literature showed that although the limbs –particularly the legs – are rarely discussed with respect to the mummification process, their importance to the success of the deceased in the afterlife is supported by both Egyptian and other ancient texts. As was shown in Section 3.1, the *Papyrus of Ani* also known as the *Egyptian Book of the Dead* contained numerous references to the limbs of the deceased, particularly the legs which symbolized the mobility and capacity for action of the soul within the body (see for example Budge, 1967[1895]: pp. 299). As such, the ritual restoration of the functionality of the limbs during embalming was instrumental to the ability of the deceased to carry out his or her requisite activities in the world to come (see pp.267, 273, 259, 300, etc. for examples).

Despite their ritual significance, other contemporaneous sources regarding the Egyptian mummification tradition contained relatively little information about the treatment of the limbs. The two Theban papyri known as the “Rites of Embalming” discussed in Section 3.2 did describe in some detail the ritual treatment of the limbs by the priest, however, they bore little reference to the accompanying material processes of embalming. In contrast, the most commonly cited account from Herodotus' *Histories* (see Section 3.3) focused almost entirely upon the material aspects of mummification with little consideration of its ritual significance. Subsequently, Herodotus' account focuses largely upon the mechanisms of preservation (i.e.

the removal of the organs and wrapping of the body) at the expense of the finer details of the procedure, such as the positioning of the limbs.

As a result of this limited coverage in the relevant contemporaneous accounts, the limbs have largely been neglected in more recent mummy studies and are often assumed to have remained roughly as they appeared in life.

One particular area of interest is the flexibility of the limbs during embalming and, in particular, the point in the mummification process at which they were positioned. Some disagreement exists as to whether the body would have been fully desiccated prior to the posing of the limbs, however, the existing body of evidence seems to suggest that the latter procedure was likely carried out midway through the embalming process when the limbs remained supple enough to bend (see Zimmerman et al., 1998; Panzer et al., 2013) yet dry enough to retain their positioning.

As described above in Section 3.6, several sources mention the use of oils or other fats massaged into the skin to restore suppleness and facilitate posing of the limbs following desiccation in natron (e.g. Dawson, 1927; Leca, 1980; Ikram, 2003).This is further supported by mummies such as those of the 11th Dynasty pharaoh Mentuhotep II's six queens and princesses found accompanying his temple at Deir-el-Bahari (see Leca,1976; Aufderheide, 2003: pp.228; Ikram, 2003: pp.62) as well as Nefer-Mut (see Nelson, 2008), whose remains show evidence of further desiccation after their initial wrapping.

The issue of sequencing of the mummification process seems to be further complicated by the introduction of subcutaneous packing in and around the Third Intermediate Period (see Smith, 1914; Taylor, 2000; Saleem, 2015). Section 3.7 above outlines the practice of inserting various materials (see Iskander, 1980; Ikram, 2003: pp.68) under the skin through strategically-placed incisions (see Smith, 1914) in order to restore the contours of the body to a lifelike state. Based upon the results of their study of thirteen royal Egyptian mummies dating from the 18th through 20th Dynasties, Saleem et al. (2015) concluded that the insertion of these materials likely occurred while the body remained moist, prior to its desiccation in natron (pp.5).

As discussed above in Chapter 6, the results of this study seem to support the idea that the limbs were being manipulated and posed while the body was dry enough to retain its positioning but prior to the completion of desiccation. The rotation of the legs and feet described earlier in this study also seems to have been carried out while the limbs were still supple, although the latter variants may represent an artifact of the embalming process rather than a deliberate positioning (see Chapter 6).

Additionally, Section 3.8 describes several examples of poorly executed embalmings carried out mainly following the end of the Dynastic period in Egypt (~332 BCE) when the mummification tradition was on the decline which seem to indicate unprecedented levels of decomposition compared to those of earlier periods (see for example Ikram, 2003: pp.71). In several cases this appears to have required the introduction of foreign materials (see Ikram, 2003: pp.73) and/or prostheses (see Gray, 1966) or even elements from other individuals (see Aufderheide, et al., 1999) to restore the parts of the body lost to decay or the activity of hungry scavengers. This appears to imply that the procedure was often being carried out differently – and arguably less effectively – during later periods, further emphasizing the variability of the mummification tradition as a whole. These differences likely tie in to the historical and political changes occurring in Egypt during the latter periods, wherein external rulers turned to 'archaism' in an attempt to assert the legitimacy of their power (see Chapter 2); this in turn may have led to an increased emphasis on maintaining the appearance of continuity with the original Egyptian mummification tradition without the continuation of the ideological basis behind it (i.e. changing from an emphasis on the body itself toward focusing on the external stylistic aspects of the mummy in later periods).

Taken together, these various lines of evidence described above paint a rich, highly-variable picture of the mummification tradition in Egypt and, particularly, the role of the limbs in the embalming process. However, as these sources demonstrate, the limbs –and especially the legs – have been grossly under-studied in the existing scholarship on Egyptian mummification. It is precisely this gap in the literature which this study attempts to address by shedding light not only on changes in the positioning of the limbs over time and between social and demographic categories, but also by providing individual case studies illustrating some of the interesting variants of limb treatment that have been found to date.

This final section revisits the research questions posed at the beginning of this volume and attempts to answer them based upon the results reported in this study.

7.1 Sequencing Across Time

In order to build upon the existing scholarship on limb positioning in ancient Egyptian mummies, the first order of business in this study was to determine whether or not lower body positioning follows a similar sequence to that of the upper body described by Gray (1972).

As described in Chapters 5 and 6 above, the relationships among the upper body variables in this study support Gray's (1972) seriation of arm and hand positioning and appear to follow a relatively straightforward sequence over time, although different variants continued to be employed throughout. However, only some of the lower body variables examined here show evidence of temporal change, suggesting that time period was not the only factor in determining the treatment of the legs and feet.

As discussed in Chapter 6, the apparent differences in limb positioning between sites in this sample is also likely better explained by temporal changes, however, the relative lack of contextual information for these individuals –and often mummies in general – makes this assertion somewhat difficult to test at the present time.

7.2 Upper & Lower Body Positioning

In addition to the temporal patterning discussed above, the second major research question explored in this study was whether there were relationships between the variables describing upper and lower body positioning. The main purpose of doing so was to build upon the aforementioned seriation of arm positioning (see Gray, 1972) and shed light on the relationships among positioning variables both within and between the upper and lower body, respectively. Additionally, this part of the study was also intended to help clarify whether the positioning of the legs and feet were dictated solely by changes in the mummification tradition over time, or whether they varied based on upper body position in this sample.

Upper Body

As described in Chapters 4 and 5, the results of this study show relatively clear patterning between the hands and arms, as well as between the legs and feet in this sample, suggesting that these elements of the body were being positioned in conjunction. Specifically, it seems that the positioning of the upper body among this sample can be divided into two general variants: (1) The arms flexed and crossed across the chest with at least one hand –usually the left – flexed; and (2) The arms in any of the three extended positions (hands over the pubis, or at the inner or outer thighs, respectively) with the hands relaxed.

Lower Body

Similarly, although the model is followed somewhat less rigidly, lower body positioning in this sample can also be divided into two basic variants: (1) Both legs in a non-rotated position with non-rotated, flexed feet, and straight toes; and (2) At least one leg rotated with the feet rotated to the right and bent under, with curled toes.

Arguably the most interesting finding of this study is the rotation of the legs and feet, usually to the right of the midline of the body, as this had apparently escaped mention in the existing body of literature on mummies. As described above in Chapter 5, this variant appears in fourteen mummies in this sample (n=14), representing 25.5% of all individuals in this study for whom lower body positioning could be assessed. Although it is more prevalent among Juveniles and Subadults in this sample, this variant is present in individuals from all age categories and is roughly evenly split between sexes (females n=7; males n=6; indeterminate n=2).

The results of this study suggest that the lower legs were being rotated to accompany the feet, but that the feet were not necessarily always rotated along with the legs (see Section 5.3). As proposed in Chapter 6, an alternate explanation for this variant is that the legs and feet were initially rotated together but that the feet were then returned to a non-rotated position following that stage in the embalming.

These results imply not only that the hands and feet were being manipulated into particular configurations along with the arms and legs, respectively, but also imply a level of attention to detail in the embalming of the limbs which has not been previously addressed. Rather than

simply allowing the hands and feet to fall into a natural posture, both of these elements were clearly being molded into the correct form to suit the overall positioning of the body and were thus modified from their state in life. As a result, paleopathological studies of the limbs cannot rely upon the previous assumption that the appearance of the lower body in a mummy is representative of their state in life, but rather require additional consideration to account for the changes resulting from embalming.

Furthermore, the rotation of the legs and/or feet brings the joints out of their proper alignment, although the articular surfaces often remain touching. This could have direct implications for future paleopathological studies of joint disease (see Chapter 1) which often rely upon the assumption that mummified limbs are preserved in their state in life, as the lower body in this sample bears considerable evidence of deliberate manipulation.

Upper & Lower Body

As described above, several statistically significant relationships were found between upper and lower body variables in this sample, however, many of them again appear to be best explained by temporal changes in the mummification tradition. As discussed in Section 5.4, there is a significant relationship in this sample between the inner thigh hand position and the positioning of the legs apart, the latter of which may tie in to the practice of placing visceral packages between the legs which came into practice during the Late period (see section 5.4).

The two other main relationships found among upper and lower body variables in this sample also seem to relate to temporal changes in the overall embalming procedure. The relationships described above between the outer thigh hand position and rotated right foot position seem to tie in to the Roman period (see Section 5.4). Similarly, the relationship found between flexed (crossed pectoral) arms and straight toes also seems to relate to time period, as the former is known to have had a considerable increase in prevalence during the Ptolemaic period (see Gray, 1972) while the latter also show fairly consistent change across time (see above).

The results of this study support the alternative hypothesis stated above that the positioning of the upper and lower body is related and, subsequently, is likely to have occurred in conjunction during the posing and/or wrapping stage of embalming. However, most of the

relationships between upper and lower body positioning in this study seem to further relate to time period, suggesting that these relationships my have also been subject to temporal change.

7.3 Body Positioning and Age

The third alternative hypothesis put forth to explain the variation in limb positioning observed in this sample was that body positioning was related to the age at time of death of the individual. According to this hypothesis, the positioning of the upper and lower body was dictated not only by the time period during which the embalming took place, but also according to the categorization of the individual based upon their age and/or attainment of sexual maturity.

As discussed in Chapter 5, the results of this study seem to show age differences in body positioning within this sample, however, like upper and lower body positioning, some of these variations may be more accurately explained based on time period. For example, although the Juveniles (1-10 years) in this sample showed a higher prevalence of the crossed pectoral hand position, the majority of this group were also from the Ptolemaic period in which the latter position was the most common variant (see Gray, 1972). Similarly, the Older Adults (>40 years) group had a higher prevalence of the inner thigh hand position but were also related to time periods in which the arms were usually extended, suggesting that there may be a temporal dimension to this relationship.

One variant of body positioning that does seem to relate to age in this sample, however, is the rotation of the feet. The rotated right foot position described above is more prevalent among Juveniles and Subadults in this sample and in fact appears in the majority of individuals from both of these groups. Additionally, the majority of both Adults and Older Adults in this sample with rotated legs had non-rotated feet, further supporting the hypothesis of an age component to lower body positioning in this sample. If the proposed explanation for the rotation of the legs and feet stated above is correct, these results seem to suggest that younger individuals were receiving an incomplete –less thorough – version of this part of the embalming procedure. However, these results do seem to support the idea that younger individuals were considered 'people' in their own right, worthy of the investment of time and resources to prepare them for the afterlife (see Chapter 2 for discussion), given that they were

still receiving a relatively elaborate mummification treatment much like their older counterparts.

As discussed in Chapter 5, the relationships between the upper and lower body positioning also seem to differ between age categories in this sample. For example, the pairing of the inner thigh hand position with parted legs discussed in the previous section seems only to apply to Adults (19-39 years) and Older Adults (>40 years), but not in either of the younger age groups. In contrast, the pairing of the outer thigh hand position with rotated feet seems to be specific to Juveniles (1-10 years) and Subadults (11-18 years) in this sample, although both of these variants are also tied to the Roman period (see above, and Gray, 1972).

Taken together, these results suggest that the positioning of the lower body was being carried out differently in younger individuals (Juveniles and Subadults) versus their older counterparts (Adults and Older Adults). This is particularly interesting as it seems to have two main implications for our understandings of the social construction of age in ancient Egyptian mummies: (1) That individuals classified into either the Juvenile or Subadult groups in this sample were somehow differentiated from older individuals by the persons carrying out their embalming; and subsequently, (2) That Subadults were being treated more similarly to Juveniles than to either Adults or Older Adults, at least with respect to the lower body.

7.4 Body Positioning and Sex

The final alternative hypothesis offered in this study was that upper and lower body positioning differed between males and females among the individuals in this sample.

The results of this study show no significant relationships between sex and any of the upper body variables recorded, however, there do appear to be sex differences in the relationships between variables within the upper body. As discussed in Section 5.2, the relationships between hand and arm positioning described above are mainly seen in males while females seem to have a greater degree of variation in their hand positioning relative to their arms.

Conversely, the opposite seems to be true of the lower body. As described in Section 5.3, the only lower body variable that is significantly related to sex in this sample is the rotation of the left leg, which is more prevalent among males. However, the relationships between lower

body positioning variables seem to show more consistent patterning among females than males (see Section 5.3).

As discussed in Chapters 4 and 5, there were no significant sex differences in the relationships between upper and lower body variables, respectively, suggesting that the overall position of the body was likely dictated by factors other than sex.

7.5 Summary and Final Conclusions

Despite the relative lack of information in the existing literature regarding the treatment of the legs and feet during mummification, the results of this study demonstrate that the positioning of the lower body was not merely a result of passive neglect, but rather a deliberate process similar to that enacted upon the upper body. Subsequently, these results provide fairly unequivocal support for the hypothesis that the positioning of the lower body was a dynamic, purposefully varied process that was deliberately enacted upon the deceased in order to afford them an appropriately reconstructed body suitable for use in the afterlife.

Additionally, while most of the existing accounts describing the Egyptian mummification process were necessarily written by –and often about – upper class males (see Chapter 2), studies such as the one presented here allow us to formulate a more comprehensive picture of the variation within this tradition. Although mummification was initially reserved for the upper classes, modern mummy studies have revealed a shift over time toward what has been called the 'democratisation' of mummification, as the practice slowly trickled down through the lower levels of Egyptian society (see Callender, 2000; Wade, 2012). In this respect, while the very poorest members of Egyptian society –as well as royal mummies – may still be underrepresented in this type of study, the physical evidence of the mummification process provides at least some insight into those cases which might have been excluded from formal documentation (e.g. women, children, and the elderly).

This research sets a precedent for future studies of limb treatment and positioning which could include individuals from an even broader range of time periods and sites than those currently represented in the IMPACT radiological database, as well as individuals from different socioeconomic strata (e.g. royals, or the very poor) who were not included in the present study. Based upon the results of this study as well as those reported in Davey et al.

(2014), it could be interesting to explore age differences in body positioning using a larger sample of Juvenile and/or Subadult mummies from different time periods. Additionally, more complex statistical methods (e.g. multivariate regression) could also be employed.

Furthermore, focusing on those cases which present unusual variations (e.g. having rotated legs and/or feet) also provides insight into the thought process behind the Egyptian embalming procedure. From one angle, the lack of intactness of the body –and thus coherence with the Egyptian concept of the proper preparation for the afterlife – could be reflective of the status of the deceased individual, indicating that they were deemed unsuitable for a proper embalming, for whatever reasons. In this respect, future studies aimed at exploring the rotation of the legs and feet in greater detail could shed light on the nature of this positioning, particularly with respect to its role in the embalming process itself and the possibility that these cases may represent an incomplete –or at least less thorough – mummification than those individuals whose feet are in a neutral, forward-facing position.

Alternately, we can turn the focus on the embalmer and his choice to defy the conventions dictated by the normative worldview of the time and, potentially, the accompanying standards of the embalming profession. In this respect, these unusual cases could represent a number of different scenarios ranging from the purely pragmatic (e.g. the need to stretch out the flank to perform the abdominal incision for evisceration) to the ideological (e.g. changing the final configuration of the body to fit the particular embalmer's view of the 'proper' mummy). Alternately, and perhaps more likely, these cases could be the result of experimentation on the part of the embalming practitioner, either as a form of education or as an effort toward innovation later in an established career.

One avenue for future research is upon the evidence of peri- and postmortem trauma in mummies (see Chapter 3) as possible artifacts of the mummification process, which could in turn highlight some of the nuances of the embalming techniques employed at a particular time. Additionally, a further area of interest for the future is the inclusion of visceral packages between the legs during the Late period (see Chapter 6 above) which may in turn relate to the positioning of the legs apart; while the identification of the viscera within the wrappings was beyond the scope of the present study, a more detailed examination of the relationship

between the placement of the viscera with body positioning could help to shed further light on changes in mummification technologies across time.

Regardless of how we choose to interpret these differences, however, the question still remains why these particular individuals were deemed suitable subjects for any of these treatments, whether experimental, ideological, or simply practical in nature. Were these individuals considered to be exempt from the normative emphasis on intactness in the treatment of the dead, or less vulnerable to the effects of an improper burial? Or were they somehow perceived as less deserving of the full status of 'Osiris' in the afterlife? While the answers to these questions will likely never be definitively found, they are worth considering as they may greatly enhance our understanding not only of the Egyptian embalming tradition and its impact on our ability to perform paleopathological investigations using mummies, but also of ancient the Egyptian worldview as a whole.

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Appendices

Appendix A: Excerpt from Herodotus' *Histories*, Book II (Translated by de Sélincourt, 1971) –On Embalming (pp. 133-4)

"Embalming is a distinct profession. The embalmers, when a body is brought to them, produce specimen models in wood, painted to resemble nature, and graded in quality; the best and most expensive kind is said to represent a being whose name I shrink from mentioning in this connexion; the next best is somewhat inferior and cheaper, while the third sort is cheapest of all. After pointing out these differences in quality, they ask which of the three is required, and the kinsmen of the dead man, having agreed upon a price, go away and leave the embalmers to their work. The most perfect process is as follows: as much as possible of the brain is extracted through the nostrils with an iron hook, and what the hook cannot reach is rinsed out with drugs; next the flank is laid open with a flint knife and the whole contents of the abdomen removed; the cavity is then thoroughly cleansed and washed out, first with palm wine and again with an infusion of pounded spices. After that it is filled with pure bruised myrrh, cassia, and every other aromatic substance with the exception of frankincense, and sewn up again, after which the body is placed in natrum, covered entirely over, for seventy days –never longer. When this period, which must not be exceeded, is over, the body is washed and then wrapped from head to foot in linen cut into strips and smeared on the underside with gum, which is commonly used by Egyptians instead of glue. In this condition the body is given back to the family, who have a wooden case made, shaped like the human figure, into which it is put. The case is then sealed up and stored in a sepulchral chamber, upright against the wall. When, for reasons of expense, the second quality is called for, the treatment is different: no incision is made and the intestines are not removed, but oil of cedar is injected with a syringe into the body through the anus which is afterwards stopped up to prevent the liquid from escaping. The body is then pickled in natrum for the prescribed number of days, on the last of which the oil is drained off. The effect of it is so powerful that as it leaves the body it brings with it the stomach and intestines in a liquid state, and as the flesh, too, is dissolved by the natrum nothing of the body is left but the bones and skin. After this treatment it is returned to the family without further fuss.

The third method, used for embalming the bodies of the poor, is simply to clear out the intestines with a purge and keep the body seventy days in natrum. It is then given back to the family to be taken away.

When the wife of a distinguished man dies, or any woman who happens to be beautiful or well known, her body is not given to the embalmers immediately, but only after the lapse of three or four days. This is a precautionary measure to prevent the embalmers from violating the corpse, a thing which is said actually to have happened in the case of a woman who had just died. The culprit was given away by one of his fellow workmen. If anyone, either an Egyptian or a foreigner, is found drowned in the river or killed by a crocodile, there is the strongest obligation upon the people of the nearest town to have the body embalmed in the most elaborate manner and buried in a consecrated burial-place; no one is allowed to touch it except the priests of the Nile –not even relatives or friends; the priests alone prepare it for burial with their own hands and place it in the tomb, as if it were something more sacred than the body of a man."

Appendix B: Excerpt from Diodorus Siculus' (1st Century BCE) Account of Egyptian Mummification (Iskander, 1980, In Harris & Wente, 1980: pp. 4)

"When a person amongst them dies, all his relatives and friends, putting mud upon their heads, go about the town lamenting, until the time of burying the body. In the meantime they abstain from bathing and from wine and all kinds of delicacies, neither do they wear fine apparel. They have three manners of burial: one very costly, one medium and one modest. Upon the first a talent of silver is spent, upon the second twenty minae, but in the third there is very little cost. Those who attend to the bodies have learned their art from their forefathers. These, carrying to the household of the deceased illustrations of the cost of burial of each kind ask them in which manner they desire the body to be treated. When all is agreed upon, and the corpse is handed over they (*sc.* the relatives) deliver the body to those who are appointed to deal with it in the accustomed manner.

First, he who is called the scribe, laying the body down, marks on the left flank, where it is to be cut. Then he who is called the cutter takes an Ethiopian stone, and cuts the flesh as the law prescribes, and forthwith escapes running those who are present pursuing and throwing stones and cursing, as though turning the defilement [of this act] on to *his* head. For whosoever inflicts violence upon, or wounds, or in any way injures a body of his own kind, they hold worthy of hatred. The embalmers, on the other hand, they esteem worthy of every honour and respect, associating them with priests and being admitted to the temples without hindrance as Holy men. When they have assembled for the treatment of the body which has been cut, one of them inserts his hand through the wound in the corpse into the breast and takes out everything *excepting the kidneys and the heart.* Another man cleanses each of the entrails, sweetening them with palm-wine and with incense. Finally, having washed the whole body, they first diligently treat it with cedar oil and other things or over thirty days, and then with myrrh and cinnamon and [spices], which not only have the power to preserve it for a long time, but also impart a fragrant smell. Having treated it, they restore it to the relatives with every member of the body preserved so perfectly that even the eyelashes and eyebrows remain, the whole appearance of the body being unchangeable, and the cast of the features recognisable. Therefore, many of the Egyptians keeping the bodies of their ancestors in fine chambers, can behold at a glance those who died before they themselves were born.

Thus, while they contemplate the size and proportions of their bodies, and even the very lineaments of their faces, they present an example of a kind of inverted necromancy and seem to live in the same age with those upon whom they look."

Appendix C: Operational Definitions of Limb Positioning Terms Used in this Study (Based on Gray, 1972)

Upper Body Positioning	
Arm Flexion	
E (Extended)	Arms are extended downward at the elbow and may be either straight or relaxed/slightly bent.
F (Flexed)	Arms are bent at the elbow.
X (Absent)	Elements are either absent from images or too poorly visualized to be recorded.
Hand Position	
CP (crossed pectoral)	Arms are crossed with the hands lain over the chest toward opposing shoulders.
P (pubis)	Arms are extended downward with the hands placed on the mid-line anterior to, or slightly inferior to, to the pubic symphysis. Hands should be touching or near touching and may be crossed or folded, although this is not necessary.
IT (inner thigh)	Arms are extended downward with the forearms lain over the pelvis and the hands placed toward the medial half of the thigh (not on the midline). Hand are not touching or near touching and palms may be placed either in an anterior-posterior or medio-lateral orientation.
OT (outer thigh)	Arms are extended downward with arms running parallel to the midline of the body and the hands placed at the lateral half of the thigh. Palms may be oriented either in an anterior-posterior or medial-lateral direction.
X (absent)	Elements are either absent from images or too poorly visualized to be recorded.

Hand Flexion	
F (flexed)	Fingers are bent or curled in toward palm to a greater extent than in a relaxed posture.
R (relaxed)	Fingers are straight or slightly curved but not bent in toward palm.
X (absent)	Elements are either absent from images or too poorly visualized to be recorded.
Lower Body Positioning	
Leg Flexion	
E (extended)	Legs are straight at the knee.
F (flexed)	Legs are bent at the knee.
X (absent)	Elements are either absent from images or too poorly visualized to be recorded.
Leg Position	
T (together)	Legs are pressed together and are touching or near touching at the knee.
A (apart)	Legs are separated and are not touching or near touching at the knee.
X (absent)	Elements are either absent from images or too poorly visualized to be recorded.
Leg Rotation	
R (rotated)	At least one of either the left or right legs is rotated on the long axis of the bone (see below)
N (non-rotated)	Legs are in normal rotation (roughly parallel to the midline).
X (absent)	Elements are either absent from images or too poorly visualized to be recorded.

Leg Rotation (for left and right legs separately)	
L (lateral)	Leg is rotated laterally on the long axis away from the midline of the body.
M (medial)	Leg is rotated medially on the long axis toward the midline of the body.
N (non-rotated)	Legs are in normal rotation (roughly parallel to the midline).
X (absent)	Elements are either absent from images or too poorly visualized to be recorded.
Foot Flexion	
F (flexed)	Dorsiflexion; plantar planes of feet are at or near perpendicular to the long axis of the body.
R (relaxed)	Plantar surfaces of feet are at an obtuse angle relative to the long axis of the body. Feet fall naturally away from the leg but not bent at the midfoot.
B (bent)	Plantarflexion; feet are bent inferiorly at the midfoot beyond the normal range of motion expected in a relaxed foot.
X (absent)	Elements are either absent from images or too poorly visualized to be recorded.
Foot Rotation	
R (rotated)	Feet are rotated either to the right or left of the midline (see below).
N (non-rotated)	Feet are in normal rotation approximately aligned with the midline of the body.
X (absent)	Elements are either absent from images or too poorly visualized to be recorded.

Foot Position	
RR (rotated right)	Feet are rotated to the right of the midline (oriented toward the individual's right, oriented left in an anterior-posterior view).
RL (rotated left)	Feet are rotated to the left of the midline (oriented toward the individual's left, oriented right in an anterior-posterior view).
N (non-rotated)	Feet are in normal rotation approximately aligned with the midline of the body.
X (absent)	Elements are either absent from images or too poorly visualized to be recorded.
Toes	
S (straight)	Toes are straight or slightly curved as would be expected in populations that did not wear restrictive footwear, but are not bent or curled under toward the plantar surface.
U (curled)	Toes are curled under toward the plantar surface of the foot, must be to a greater extent than a natural curve.
X (absent)	Elements are either absent from images or too poorly visualized to be recorded.

Appendix D: Table of Individuals with Rotated Right Foot Position

IMPACT ID	Name	Age	Sex	Time Period	Site
IMP00004	Unknown	Juvenile	Male	Unknown	Unknown
IMP00010	Leiden Cat. 18	Juvenile	Male	Late	Mendes Djedet/ Hermopolis Parva
IMP00022	Girl from Thebes	Juvenile	Female	Unknown	Thebes
IMP00033	E.0452	Juvenile	Indeterminate	Late	Fayum
IMP00059	Liverpool 2	Subadult	Female	Roman	Unknown
IMP00063	Liverpool 6	Adult	Female	Unknown	Unknown
IMP00069	Liverpool 12	Subadult	Male	Ptolemaic	Hissayeh
IMP00073	Liverpool 18	Adult	Female	Late	Kostamneh, Nubia
IMP00082	Bahka	Older Adult	Female	Unknown	Thebes
IMP00083	Braided Lady	Adult	Female	New Kingdom	Thebes
IMP00115	Leiden Cat. 23	Juvenile	Indeterminate	Ptolemaic	Unknown
IMP00117	Leiden Cat. 26	Subadult	Female	Roman	Thebes
Unassigned	Leiden Cat. 28	Adult	Male	Roman	Thebes
Unassigned	Leiden Cat. 29	Subadult	Male	Roman	Thebes

Appendix E: Table of Individuals with Rotated Leg(s) and Non-rotated Feet

IMPACT ID	Name	Age	Sex	Time Period	Site
IMP00001	Unknown	Adult	Male	3IP	Thebes
IMP00010	Theban Female	Adult	Female	Roman	Thebes
IMP00012	Ptolemaic Female	Adult	Female	Ptolemaic	Unknown
IMP00027	Genova 469	Older Adult	Male	Roman	Unknown
IMP00056	E.9016	Juvenile	Indeterminate	Unknown	Unknown
IMP00094	Leiden Cat. 1	Adult	Male	3IP	Thebes
IMP00095	Leiden Cat. 2	Older Adult	Female	3IP	Thebes
IMP00097	Leiden Cat. 4	Older Adult	Female	3IP	Thebes
IMP00098	Leiden Cat. 5	Older Adult	Female	3IP	Thebes
IMP00100	Leiden Cat. 7	Older Adult	Male	3IP	Thebes
IMP00102	Leiden Cat. 9	Older Adult	Male	Late	Thebes
IMP00103	Leiden Cat. 10	Adult	Male	Late	Thebes
IMP00105	Leiden Cat. 12	Adult	Male	Late	Thebes
IMP00107	Leiden Cat. 14	Adult	Female	Late	Thebes
IMP00108	Leiden Cat. 15	Adult	Male	Late	Thebes
IMP00109	Leiden Cat. 17	Unknown	Male	Late	Unknown
IMP00112	Leiden Cat. 20	Older Adult	Female	Ptolemaic	Akhmim

Appendix F: Table – *P*-values for Upper Body variables (stratified by age –osteological)

Subadults (11-18 years)			
VARIABLE	Hand flexion	Arm flexion	Hand position
Hand flexion			
Arm flexion	.167		
Hand position	.333		
Adults (19-39 years)			
VARIABLE	Hand flexion	Arm flexion	Hand position
Hand flexion			
Arm flexion	.009*		
Hand position	.009*		
Older Adults (>40 years)			
VARIABLE	Hand flexion	Arm flexion	Hand position
Hand flexion			
Arm flexion	.077		
Hand position	.154		

Appendix G: Table – *P*-values for Lower Body variables (stratified by age –osteological)

Subadults (11-18 years)					
VARIABLE	Leg position	Leg rotation	Foot rotation	Foot position	Foot flexion
Leg position					
Leg rotation	.467				
Foot rotation	.467	.067			
Foot position	.467	.067			
Foot flexion	1.000	1.000	1.000	1.000	
Toe position	1.000	.400	.400	.400	1.000
Adults (19-39 years)					
VARIABLE	Leg position	Leg rotation	Foot rotation	Foot position	Foot flexion
Leg position					
Leg rotation	.415				
Foot rotation	1.000	.033*			
Foot position	1.000	.033*			
Foot flexion	.314	.884	.072	.072	
Toe position	1.000	.350	1.000	1.000	.406

*Indicates significance based on a 5% confidence interval ($p \leq .05$).

***P*-values for Lower Body variables (stratified by age –osteological) Continued**

Older Adults					
VARIABLE	Leg position	Leg rotation	Foot rotation	Foot position	Foot flexion
Leg position					
Leg rotation	1.000				
Foot rotation	1.000	1.000			
Foot position	1.000	1.000			
Foot flexion	.682	.745	.167	.167	
Toe position	1.000	.242	1.000	1.000	.106

Appendix H: Table – Upper and Lower Body variables (stratified by Age – osteological)

Subadults (11-18 years)			
VARIABLE	Arm flexion	Hand position	Hand flexion
Leg position	.333	.269	.333
Leg rotation	1.000	.600	1.000
Foot rotation	1.000	.600	1.000
Foot position	1.000	.600	1.000
Foot flexion	1.000	1.000	1.000
Toe position	1.000	1.000	1.000
Adults (19-39 years)			
VARIABLE	Arm flexion	Hand position	Hand flexion
Leg position	.660	.001*	.655
Leg rotation	.056	.248	1.000
Foot rotation	.539	.269	.091
Foot position	.539	.269	.091
Foot flexion	.601	.516	.147
Toe position	.245	.223	1.000

*Indicates significance based on a 5% confidence interval ($p \leq .05$).

Upper and Lower Body variables (stratified by Age – osteological) Continued

Older Adults (>40 years)			
VARIABLE	Arm flexion	Hand position	Hand flexion
Leg position	1.000	.634	1.000
Leg rotation	1.000	1.000	1.000
Foot rotation	1.000	1.000	1.000
Foot position	1.000	1.000	1.000
Foot flexion	1.000	.864	1.000
Toe position	.455	.221	.455

Curriculum Vitae

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