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Social Stratification & Mummification in Ancient Egypt: The Inevitability of Variability in the Post-New Kingdom Mummification Program

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Abstract

This study examined the connection between social status and mummification in post-New Kingdom Egypt using a sample of sixty-one (n=61) adult non-royal Egyptian human mummies archived in the IMPACT radiological database. The purpose of this research was two-fold. First, as they have been uncritically accepted by both the academic community and popular literature, the validity of Classical mummification accounts offered by Herodotus and Diodorus Siculus was assessed. Second, four features of mummification with status connotations (arm position, amulets, cranial resin, estimated stature) were tested using exploratory data analysis in search of any potential connections with each other or specific time periods. The results of this study not only challenge the accuracy of Classical accounts discussing ancient Egyptian mummification but demonstrate that arm positioning and cranial resin have potential associations with specific time periods, geographic regions, and each other. Ultimately, following the democratization of mummification in the New Kingdom, this research highlights the inevitable variability of the mummification program in post-New Kingdom Egypt.

Keywords:

Mummies, mummification, ancient Egypt, social stratification, paleoradiology, paleoimaging, IMPACT radiological database, variability

Lay Person Summary

This study examines the connection between social status and mummification from the New Kingdom until the end of what is considered "ancient Egypt", during the Roman Period. The sample used in this study consists of 61 (n=61) adult non-royal Egyptian human mummies which are currently archived in the IMPACT (Internet Mummy Picture Archiving and Communication Technology) radiological and context database. The purpose of this research was two-fold. First, the validity of Classical accounts contemporary with ancient Egypt, written by the ancient historians Herodotus and Diodorus Siculus, was assessed, as they have been uncritically accepted by both the academic community and popular literature. Second, four features of mummification related to social status (arm position, the presence of amulets, the treatment of cranial resin after the brain was removed, and estimated stature) were tested using exploratory data analysis in search of any potential connections with each other or specific time periods. The results of this study were able to challenge the accuracy of the Classical mummification accounts, as those studies did not demonstrate the true variability of the mummification program. This means that academic and popular accounts of Egyptian mummification need to recognize this variability, rather than uncritically accepting the Classical accounts. This study was also able to highlight potential associations for arm positioning and the treatment of cranial resin, likely based on geographic region and/or specific time periods. Ultimately, this research highlights the inevitable variability of the mummification program in post-New Kingdom Egypt as mummification became available to individuals of lower social status during the New Kingdom.

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Chapter 1:

Introduction

Given its status as one of the first great civilisations, ancient Egypt (lower-case "a" utilised per Shaw, 2000) has long been a focus of scholarly inquiry, yet the expanse of time between that period and the present ensures that, paradoxically, ancient Egypt is both well-documented and poorly understood. Ancient Egyptian social stratification and mummification, in addition to having a complex relationship with one another, are perfect examples of this paradox, as they are both well-documented yet relatively unexplained. Most conventional knowledge on ancient Egyptian mummification comes from the Greek historian Herodotus, whose accounts, must no longer be uncritically accepted (Buckley & Evershed, 2001; Abdel-Maksoud & El-Amin, 2011; Gessler-Löhr, 2012; Jones et al., 2014). This thesis seeks to elucidate the relationship between ancient Egyptian social structure, class, and mortuary practices by focusing on the variability that can be seen when comparing different features of mummification across different time periods. Specifically, this research will focus on the mummification processes utilized on non-royal individuals. It should be noted that most ancient Egyptian individuals were not mummified, therefore, being mummified did imply that an individual had some sort of accumulated wealth or differential status, especially prior to the New Kingdom. Although mummification would eventually become more widespread, it remained a luxury. The 'non-elite' individuals studied here are outside of what would be considered royalty or nobility but were still able to afford to be embalmed. Whether lower class (e.g. labourers, craftsmen, etc.) or upper class (scribes, priests, etc.), these non-royals make up the overwhelming majority of those who were mummified. This non-elite focus is significant because the study of burial practices in ancient Egypt has not only lacked examinations utilizing large-scale comprehensive synthetic studies (Cox, 2015), but has traditionally been fixated on royals and elites, which has greatly, and inaccurately, impacted the way ancient Egypt is understood (Richards, 2005).

This thesis will answer two questions:

Should we continue to rely on the ancient Egyptian mummification accounts of Herodotus?

&

By looking at non-royal mummification, which features indicate differential status, and in which ways, if any, are they correlated?

Period	Dynasty	Dates
Roman Period	Roman Rule (Emperors)	30 BCE- 395 CE
Ptolemaic Period	Ptolemaic Dynasty	332- 30 BCE
Late Period	26-30	664-332 BCE
Third Intermediate Period	21-25	1069- 664 BCE
New Kingdom	18-20	1550-1069 BCE
Second Intermediate Period	15-17	1650-1550 BCE
Middle Kingdom	11-14	2055-1650 BCE
First Intermediate Period	9-11	2160-2055 BCE
Old Kingdom	3-8	2686-2160 BCE
Early Dynastic Period	1-2	3000-2686 BCE
Naqada (I-III)	Pre-Dynastic	4000-3000 BCE
Badarian Period	Pre-Dynastic	4400-4000 BCE

Table 1.1 **Chronology of Ancient Egypt (Shaw, 2000)**

This thesis will examine the connection, and influence, of social stratification on mummification in ancient Egypt. The timeline of ancient Egypt in this thesis will follow Ian Shaw (2000) and *The Oxford History of Ancient Egypt* (Table 1.1). In order to provide the appropriate context, I will present information regarding the specifics of royal mummification as well as the origins of mummification in ancient Egypt; including both natural and anthropogenic forms. This is important for two reasons. First, the practice of anthropogenic mummification began as an exclusively royal mortuary ritual and elements of this practice can be traced back to the Old Kingdom and perhaps even the Early Dynastic Period. The association of mummification with royalty occurred concurrently with the emergence of the Egyptian state and the despotic leadership of pharaohs (Bard, 2000).

Secondly, due to these royal origins of anthropogenic mummification in Egypt, it is assumed that many, and perhaps most, features of mummifications were first, and exclusively, practiced by royals before being adopted by lower socioeconomic classes. By the Middle Kingdom, there is evidence for a burgeoning middle class (which was still relatively elite) that now had the option to become mummified (Malek, 2000; Richards, 2005), and by the New Kingdom, it is believed that the practice of mummification had become widely democratized (Shaw, 2000; Aufderheide, 2003). Although many features utilized in royal Old Kingdom mummification were used in all subsequent ancient Egyptian periods, demonstrating a basic structure to the practice, certain aspects of mummification became highly variable through time. This is especially true as of the New Kingdom once mummification became available to the majority of the population (Aufderheide, 2003). This variability was a direct product of one's socioeconomic status and/or their (or their family's) access to resources (Taylor, 2000; Ikram, 2003). This opened the door for a variety of mummification options that may be associated with the agency and identity of the individual to be mummified and their family. What was once an exclusive practice with a seemingly specific outline, became something utilized by a significant portion of the population, most of whom were not of royal or elite status. It is reasonable to assume then, that most of the variability seen in mummification stems from non-elite individuals, and to truly explore this variability, a proper sample, as well as a comprehensive literature review, is necessary.

This work aims to address issues that have hindered mummy studies in the past. Shifting from presenting individual case studies to comparative studies with larger samples, has been deemed vital for the field (Cox, 2015). This has proven to be difficult as few meaningful synthetic comparative studies of Egyptian mummies, across all social strata, exist (Cox, 2015). Comprehensive compilations of x-rays and CT scans of ancient Egyptian royals (Elliot-Smith, 1912; Harris & Wente, 1981; Taylor & Antoine, 2014; Hawass & Saleem, 2016) have been very popular, dominating this area of research, while little synthetic work, let alone those using CT scans, have been published on non-elite mummies (but see Gray, 1973; Raven & Taconis, 2005; Loynes, 2015).

Since the 1970s and the introduction of New Archaeology, bioarchaeology has been trending towards a more population-focused approach. Mummy studies, however, have taken a little more time to adapt as individual case-studies have often been the standard because of the nature of the distribution of mummies. One of the biggest reasons for this has been the practical difficulties involved in collecting large groups of mummies to examine in a comparative manner. Recent technological advancements and ideological shifts have helped push the field towards comparative studies. The greatest example of this has been the Horus Group. Beginning with a team of five cardiologists searching for atherosclerosis in twenty-two ancient Egyptian mummies (Allam et al., 2009), the team would eventually integrate experts from many different fields and increase their sample size considerably, incorporating mummies from different time periods all over the world (Allam et al., 2009; Allam et al.,2011; Abdelfattah et al., 2013; Thomas et al., 2013; Thompson et al., 2014; Thompson et al., 2014; Zink et al., 2014). The creation of large-scale databases in both archaeology and biology have also helped facilitate this ideological shift in bioarchaeology. Prime examples of these include the University of Manchester's Mummy Tissue Bank (Lambert-Zazulak, 2003), Duke University's *Morphosource* (Boyer, Gunnell, Kaufman, & McGeary, 2016) and the IMPACT radiological mummy database (Nelson & Wade, 2015). This research will be done using the IMPACT (Internet Mummy Picture Archiving and Communication Technology) radiological mummy database.

The Internet-Based Mummy Picture Archiving and Communication Technology (IMPACT) radiological and context database is a large-scale, multi-institutional, collaborative research project focused on the digital preservation of mummified remains that provides qualified scholars with access to primary datasets from around the world (Nelson & Wade, 2015). IMPACT was created to enable and facilitate large-scale anthropological and paleopathological analyses of mummified remains while promoting (and encouraging) the use of non-destructive digital imaging.

There are many issues that have impacted meaningful analyses in bioarchaeology, and this is especially true of mummy studies. These include the inability to gain access to primary datasets, reliance on long-standing stereotypes regarding burial practices, and costly constraints (in terms of both time and money). By using IMPACT, I have negated most of these hardships' researchers endure when trying to engage in large-scale comparative mummy studies. Additionally, by using the post-processing software applications *Dragonfly* 4.1 and ORS Visual^{SI}, I have been able to digitally unwrap these mummies in a non-destructive and non-invasive manner.

Much of the conventional wisdom involving ancient Egyptian mummification rests upon accounts that were written over 2000 years ago when the Greek historian Herodotus described three forms of mummification that differed in cost and method employed (Herodotus, 440 BCE [1971]). However, Herodotus' account does not discuss how variable the practice was, and is, in my opinion, an over-simplification (cf. Wade & Nelson, 2013). Furthermore, the proliferation of these generalisations and over-simplifications has been aided by the focus on royals and elites. By utilising the IMPACT database, and focusing on non-elite mummification, my master's research allows me to address this shortcoming.

The IMPACT database has over 100 ancient Egyptian individuals, however, not all of them were eligible for this study. Although children have become an important area of research in archaeology since being marginalized in past archaeological works (cf. Baxter, 2008), they will not be used in this research as age represents a potentially confounding variable that could affect mortuary treatment. As a result, subadult individuals (M3 not yet in occlusion, long bone epiphyses not yet fused) in IMPACT have been removed from my sample. Additionally, technical issues involving some of the scans have required the removal of a few other individuals from my sample for fear that using these data would result in faulty examinations and results (details presented in Chapter 3). For these reasons, this study will include sixty-one individuals (N=61) who are confirmed adults (minimum age of~18 years) (Appendix A). With this sample of sixty-one individuals, combined with existing published datasets, I will be able to properly investigate variability in ancient Egyptian mummification.

The following chapters of this thesis will elaborate and expand upon this introduction. Chapter 2 is composed of information from my literature review and will provide proper context for understanding social structure, stratification and mummification in ancient Egypt; both individually and in relation to one another. Due to the comprehensive nature of Chapter 2, it has been split into five different sections. Chapter 2.1 details which primary sources exist from ancient Egypt about mummification, giving special attention to the accounts of Herodotus. Chapter 2.2 focuses on the social stratification of ancient Egypt, while Chapter 2.3 discusses the origins and evolution of mummification, from its inception to its banning in the Christian Roman era. This section on mummification also serves as a checklist of sorts as Chapters 2.2 and 2.3 are both organized in chronological order by period, and when necessary, by Dynasty. Chapter 2.4

will provide a brief review of non-destructive methods in mummy studies, particularly those involving radiology; and how the discipline has evolved. Here, there is a focus on computed tomography, as this is the primary method utilized in this research. Although brief, Chapter 2.5 is crucial, as it deals with ethical considerations and interdisciplinarity within the disciplines of Bioarchaeology and mummy studies. In Chapter 3, I will present the materials and methods while Chapters 4, 5, and 6 will present the results, discussion, and conclusion, respectively.

Overall, this work provides a more accurate understanding of ancient Egypt, from the pre-Dynastic Badarian culture, until the end of what is considered ‘ancient Egypt’ during the Roman occupation; a period of over 6000 years. The relationship between social stratification and the ancient Egyptian mummification program has also allowed us to better understand aspects of agency and identity amongst these non-elites. Although "we are separated from the ancient Egyptians by time and by culture" (Ikram, 2003, X), we must do our best to accurately represent the complexities of this ancient civilisation, rather than continue to make generalisations. I believe this thesis to be a necessary step in the right direction.

Chapter 2:

Literature Review:

2.1. The Importance & Inadequacy of Herodotus

Most of our practical knowledge concerning ancient Egyptian mummification rests upon the account of Herodotus (Herodotus, 440 BCE [1972]), whose account is contemporary with the Persian occupation of Egypt during the Late Period (664-332 BCE) (Shaw, 2000). This account, (which will be described in greater detail below) written more than 2000 years ago, describes three separate tiers of mummification. It is clear these tiers differed in both cost and method employed. However, when examined closely, the description is very brief and quite vague. It should be noted that the terms ‘excerebration’ and ‘evisceration’, which are not used by Herotodus, are used heavily throughout this thesis, and should be understood as the removal of the brain, and the removal of internal organs, respectively.

I want to make it abundantly clear, however, that this work is not meant to discredit Herodotus, who, as a historian, was interested in far more than the specificities of this mortuary ritual in Egypt. My critiques are better directed at modern academia and popular literature for uncritically accepting these accounts and ultimately using them to generalise over 4500 years of ancient Egyptian mortuary rituals (Buckley & Evershed, 2001; Abdel-Maksoud & El-Amin, 2011; Gessler-Löhr, 2012; Jones et al., 2014).

Ancient Egyptian mortuary rituals and burial practices differed according to one's economic and social status (Ikram, 2003), and the accounts of Herodotus lend credence to this fact. Outside of this, these accounts should be understood for what they are; an oversimplification of mummification practices during the Late Period. Herodotus fails to discuss the history of the practice, the extreme variability of the mummification program, and how mummification evolved over the thousands of years leading up to this particular period and occupation of ancient Egypt. Additionally, his accounts were released prior to the Ptolemaic and Roman occupations of Egypt, which both brought further innovations and variability to the mummification program.

The main reason these Herodotean descriptions are held in such high regard is that not much else exists in the way of primary sources detailing mummification in ancient Egypt. There is, however, an ancient Egyptian papyrus scroll, known as the Apis Embalming Ritual: P. Vindob. 3873 (Vos, 1993), from sometime during the late Ptolemaic/early Roman period, that explains in both Hieratic and Demotic scripts, how to wrap a mummy (Vos, 1993). Unfortunately, it mostly includes directions on how to wrap the mummy's "horns, tail, and all four of its legs-because the procedure described is to be performed not on a human, but on a bull" (Riggs, 2014, 77). This papyrus is particularly important because the cult of the Apis bull originates from the ancient capital of Memphis, near the Serapeum in Saqqara, where many mummified bulls were placed, demonstrating the significance and longevity of this ritual (Riggs, 2014). What remains of this text emphasizes, in great detail, the intricate wrapping process involved, however, there is unfortunately no mention of evisceration, desiccation via natron salt, or any inner or outer treatment of oils and/or resins.

Although a few other surviving (but fragmentary) papyrus scrolls detailing human mummification from the early first century CE exist, they contain significantly less detail than the Apis Embalming Ritual. These papyri focus primarily on the wrapping of specific organs before their placement in canopic jars (Riggs, 2014). As canopic jars were no longer being used during the Roman period, these papyri written in Hieratic with some Demotic notations, must have been recreations of older texts (Riggs, 2014). Unfortunately, the original context has been lost and the origins of these brief, but important texts, remains unknown. Two other human mummification documents from the second century CE also exist, however, they both discuss the final stages of the procedure after all the treatments and subsequent wrapping of the body had been achieved, revealing no new insights (Andrews, 2004). By default, Herodotus' accounts are technically the most complete.

Accounts from the first century BCE Greek historian Diodorus Siculus on Egyptian mummification are sometimes referred to in addition to Herodotus. However, they mostly reiterate what Herodotus had said hundreds of years earlier and are less detailed in general (Diodorus, 50 BCE [1933]). This account does, however, mention something Herodotus did not, as Diodorus briefly mentions that both the heart and kidneys remained inside the body cavity of the deceased during and after the evisceration portion of the mummification ritual, however, if the heart was removed, it was said to have been replaced by a metallic or stone scarab (Diodorus, 50BCE [1933]).

The accounts of both Herodotus and Diodorus briefly discuss the resin that was applied to the body during mummification to prevent growth of bacteria and rehydration. However, many still debate the ingredients or organic materials making up the substance, as well as its specific purpose. Researchers seem to agree that it was most likely used for preservation (preventing bacteria growth and/or rehydration) or as some sort of bonding agent (Buckley & Evershed, 2001; Buckley, Clark, & Evershed, 2004; Jones et al., 2014). As for the actual organic makeup of the resin, Herodotus' accounts are the most detailed, mentioning the use of myrrh, cassia, palm wine, cedar oil (still widely disputed) and 'gum' (or gum Arabic) (Herodotus, 440 BCE [1972]; Buckley & Evershed, 2001), while Diodorus, who also mentions myrrh, adds the use of cinnamon (Diodorus, 50 BCE [1933]. The descriptions provided by Diodorus are undoubtedly insightful, however they do not add much to the earlier accounts of Herodotus.

Overall, Herodotus' accounts are actually quite short and have been translated into about two paragraphs. Additionally, one of these 'paragraphs' amounts to only two sentences. In these two paragraphs, Herodotus describes three different tiers of mummification, based on one's socioeconomic status. According to Herodotus, the most expensive way to be mummified involved excerebration before completely eviscerating the abdomen, followed by a treatment of a variety of spices before being sewn back up. The body was then placed in natron for seventy days, before finally being washed and wrapped from head to foot in linen strips and smeared on the under side with gum, instead of glue (Herodotus, 440 BCE [1972]).

If "for reasons of expense" (Herodotus, 440 BCE [1972], 161), the second quality is called for, no incisions are made as the intestines remain in the body, however, oil of cedar is injected into the body with a syringe per āno, which is subsequently plugged to halt any liquid from escaping. Next, the body is placed in natron, after which, the oil inside is drained, bringing with it the individual's now dissolved stomach contents, including the intestines (Herodotus, 440 BCE [1972]).

The third, and shortest description, is said to have been specifically for "embalming the bodies of the poor" (Herodotus, 440 BCE [1972], 161). Here, the body was simply purged of all its intestines and placed in natron for 70 days, before being given back to the family of the deceased (Herodotus, 440 BCE [1972]).

One of the various issues with Herodotus' accounts is that the brain is only mentioned as part of the most elite mummification process and ignored for the lower two options. This is problematic because there is proof that, as of the New Kingdom (1550-1069 BCE) (Shaw, 2000), a period that began over a thousand years before the accounts of Herodotus, embalmers were excerebrating individuals across all social strata (Wade, Nelson, & Garvin, 2011; Wade & Nelson, 2013). This is but one example and Chapter 3.7 will provide a more elaborate breakdown of common mummification features unmentioned by Herodotus, further proving that these classical accounts must not be uncritically accepted.

Recently, these accounts have been challenged by researchers using radiology to explore evisceration (Wade & Nelson, 2013) and excerebration (Wade, Nelson, & Garvin, 2011; Wade & Nelson, 2013). These studies (Wade, Nelson, & Garvin, 2011; Wade & Nelson, 2013) empirically tested the assertions made by Herodotus and Diodorus Siculus, ultimately challenging the statements they made about evisceration and excerebration. Furthermore, other researchers have reported on chemical analyses which suggest that the seventy days discussed by Herodotus was either false, as ideal desiccation could be achieved after about forty days in natron, or included the entirety of the mummification procedure (including the wrapping, the prayers, the anointing, the procession, etc.) rather than the specific time the body spent laying in natron (Brier, 1994; Andrews, 2004). What these critiques suggest then is that these classical accounts of ancient Egyptian mummification are far more valuable as stepping-stones, used to further elucidate the relationship between social stratification and various mummification processes; rather than their current use as a means to generalize more than 4500 years of Egyptian mortuary treatments. Consequently, I will be using statistical testing to further evaluate whether these mummification accounts are accurately indicative of what was happening before, and during, the life of Herodotus.

2.2: Literature Review: Social Stratification in Ancient Egypt

2.2.1 Early Egyptian Social Structure

Ancient Egypt is often described as "a civilisation obsessed with status" (Redford, 2001c, 301) and social stratification in ancient Egypt is quite complex. For the purposes of this thesis, social stratification will be described simply as members of different levels within the social hierarchy having the ability to mobilize different resources based on their power, wealth, education, and/or occupation, with some of these resources and positions carrying more prestige than others (Redford, 2001c). The ultimate example of this was the Great Pyramid at Giza. The complex hierarchical social structure is often depicted, quite fittingly, as a pyramid (Figure 2.1). Although this is a basic and rudimentary breakdown of ancient Egyptian social structure, this visual aid demonstrates the multiple layers and complexity that this ancient culture developed early on. It should be noted that these levels were in no way static as the later periods of ancient Egypt, where control of the empire was held under foreign rule, further complicated this system. For example, during the Ptolemaic period, scribes experienced upward social mobility and gained prestige due to their ability to act as intermediaries between Egyptians and the Greco-Macedonians, while Egyptian soldiers, who were still seen as extremely important, were no longer considered of high social or economic status as their Greek counterparts were favoured (Lloyd, 2000). In this scenario, these two levels of individuals would have switched positions in Figure 2.1.

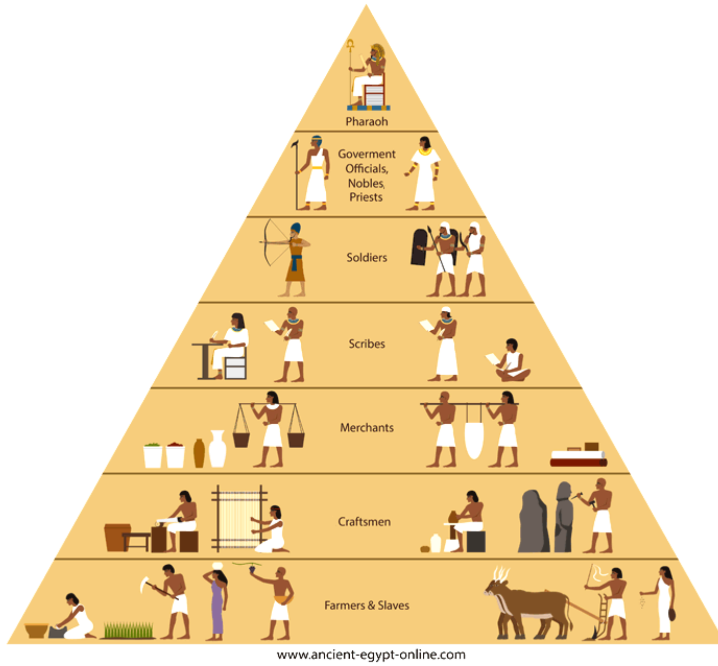


***Figure 2.1.* Idealized Breakdown of Egyptian Social Structure.**
Source: https://www.ancient-egypt-online.com/ancient-egypt-social-structure.html

Unsurprisingly, there has been a profusion of literature on ancient Egypt which can make it difficult to produce a focused review on any topic. I am most concerned with the social organization of ancient Egypt, the emergence of the Egyptian state and the social differentiation that ensued, as well as the history and evolution of mummification, rather than a complete and comprehensive look at the general history of ancient Egypt. However, it is important to contextualize how Egypt became the complex and stratified society it was throughout the Dynastic periods and the periods that followed. By the beginning of the very first Dynasty, ancient Egyptian civilisation as we have generally come to understand it began, but "this was preceded by a very long sequence of prehistoric cultural development" (Bard, 2005, 2).

The most crucial and major geographic feature of Egypt, the Nile river, as well as its extremely fertile floodplains, have been identified by many authors and researchers as the most significant attraction for habitation and settlement (Wenke, 1991; Shaw, 2000; Ikram, 2003; Nicoll, 2004; Richards, 2005; Bard, 2005; Zakrzewski, 2003; Bard, 2015). Major confirmation of widespread settlement (as evidenced by numerous archaeological sites) can be seen by the Late Paleolithic/Early Neolithic (around the early Holocene) eras (Shaw, 2000; Nicoll, 2004; Bard, 2015). From this point on, population and social structure seem to both be on the rise and the Nile should be acknowledged as one of the most significant factors.

Although the Dynastic Period, the Late Period, and the Greco-Roman periods are of the greatest interest and significance to my research for their synonymy with the practice of mummification, some of the earlier periods, or 'cultures', do show evidence of larger-scale settlement and stratification. Some researchers have even posited that proper mummification was practiced during these pre-Dynastic periods, pushing its origins back 1500 years (Jones et al., 2014). Personally, I am not wholly convinced of this assertion as it is predicated on resin-use, and to me, this is more indicative of some sort of body treatment, not necessarily evidence of purposeful mummification.

Nevertheless, the importance of the pre-Dynastic Badarian culture (4400-4000 BCE) (Shaw, 2000) is often discussed due to the nature of their burials which reveal the earliest evidence of social stratification in ancient Egypt (Shaw, 2000; Ikram, 2003; Zakrzewski, 2003; Bard, 2005; Jones et al., 2014). Stratification is demonstrated by the assessment of Badarian grave goods which show unequal wealth distribution with the majority of these wealthier graves being separated into one specific area of the burials at the small sites of Qau el-Kebir, Hammamiya, Mostagedda, and Matmar (Hendrickx & Vermeersch, 2000). This culture, which displays the earliest evidence of agriculture in Upper Egypt, also had burial goods demonstrating clear evidence of trade with other settlements (Hendrickx & Vermeersch, 2000; Bard, 2005). Additionally, Badarian funerary goods that indicate that they had a very early belief system of life after death have also been discovered (Ikram, 2003). These burials also contain the earliest recognizable amulets in ancient Egypt (Andrews, 1994). Even though these were all recovered from funerary contexts, it is believed that “their magical properties were primarily intended to provide aid in life; it was only subsequently that they were taken to the grave” (Andrews, 1994, 8). The use of amulets will remain integral to Egyptian burials (from simple interment to the most lavish mummification procedures) for more than four thousand years. In these earliest examples, we can actually see the first appearance of popular forms like the jackal (who is associated with the God Anubis) and the archaic form of the crouched falcon (associated with the God Horus) (Andrews, 1994; Andrews, 2004). All these aspects solidify the Badarian culture as a pivotal and foundational period in ancient Egypt.

Following the Badarian culture, was the Naqada culture, which is traditionally split into three successive periods from 4000-3200 BCE (Shaw, 2000). Naqada I and Naqada II show significant variability in burial practices, for example, a few individuals from Naqada II were buried in "larger, more elaborate tombs containing richer and more abundant offerings" (Midant-Reynes, 2000, 53). For this reason, many researchers believe that social stratification was present in this culture, or at the very least, more expressed than it was in Naqada I or for the Badarians (Midant-Reynes, 2000; Bard, 2005). Some have also proposed the potential existence of a "managerial elite" (Bard, 1989, 241; Richards, 2005, 70) during this particular period which would have stretched the social hierarchy even further. It should also be noted that some researchers have discussed the possibility of mummification originating during Naqada II as some of the examined bodies seem to be wrapped purposefully with linen (Midant-Reynes, 2000; Ikram, 2003).

While there is evidence of burials for kings at some Naqada III cemeteries, showing clear signs of social stratification in both socioeconomic status and burial practice, other cemeteries are considered "impoverished compared to the earlier Naqada II burials" (Bard, 2000, 63) in terms of artifacts. By the end of Naqada III, which led into Dynasties 0 and 1 (~3150 BCE) (Shaw, 2000), Upper Egypt and Lower Egypt became politically unified, signifying the true beginnings of the Egyptian state and its complex social hierarchies (Bard, 2000; Bard, 2005; Bard, 2015; Ikram, 2003; Richards, 2005; Shaw, 2000).

2.2.2 The Early Dynastic Period & Old Kingdom Egypt

Zakrzewski (2003, 219) has stated, "in less than 2,000 years, the Egyptian population changed from being an egalitarian hunter-gatherer/pastoral population to a highly ranked agricultural hierarchy with the pharaoh as the divine ruler." Starting around 3100-3000 B.C.E., all of Egypt was unified from Aswan to the Nile Delta. The first and second Dynasties are usually considered a "formative period of Egyptian history, when the basics of Egyptian bureaucratic state, art, architecture, and religion were established" (Ikram, 2003, 4). During this time, royal cemeteries were established at Abydos (where the earliest kings of Egypt were buried), as well as Saqqara, while nonroyal cemeteries appeared around the Abydos area, as well as the Memphis necropolis (Podzorski, 1993; Bard, 2000; Bard, 2015). The appearance of differential burial practices by the first Dynasty is not only evidence of social stratification, but an indication of how important mortuary rituals were becoming (Bard, 2005). A literate and functioning bureaucracy, as well as tremendous organization, is required to "build and maintain the elaborate royal funerary places, and social differences are clearly illustrated by different non-royal burials" (Ikram, 2003, 4). At this point in time, there is clear evidence for a complex and stratified social structure in Egypt. The political system (which was adhered to throughout most of the Dynastic Period), is known as ‘Oriental Despotism’, which is, according to David O’Connor (1974), who borrowed the concept from Wittfogel (1952), a system where followers of a single leader are subservient by their own volition, following by consent, rather than by fear or through force.

The division between the rulers (and their kin) and the rest of society grew much larger during the Old Kingdom (2686-2181 BCE) (Shaw, 2000); the age of the pyramid (Wenke, 2009). The Old Kingdom has been the primary focus of many researchers for its significance in terms of social organization and its early examples of mummification (O'Connor, 1974; Shaw, 2000; Ikram, 2003; Zakrzewski, 2003; Bard, 2005; Zaki, Hussein, & Abd El-Shafy El Banna 2009; Jones et al., 2014; Bard, 2015). The earliest evidence of its strong centralized control came with a massive change in funerary architecture, as the third Dynasty pharaoh Djoser built his monumental step-pyramid in Saqqara (O'Connor, 1974; Shaw, 2000; Bard, 2005; Bard, 2015). This construction was pivotal, not only because it inspired the construction of the other pyramids, but "in the sense that it conveys a modified picture of the relation between the state and its subjects"(Bard, 2005, 39). A not-so-fine line had been drawn between royals and everyone else.

Zaki, Hussein, and Abd El-Shafy El Banna (2009) address this particular divide in their study and evaluation of osteoporosis in the remains of seventy-four Old Kingdom individuals unearthed in the Giza necropolis from two different social classes (high officials and workers). This Old Kingdom sample is useful here because it allows for a clear comparison of two very different social classes. Using dual energy x-ray absorptiometry to measure bone density and scanning electron microscopy to look at bone structure, the researchers found osteoporosis was far more prevalent in male workers than male high officials. The researchers suggest that the poorer nutritional status of these workers combined with the physicality of pyramid-building, is to blame (Zaki, Hussein, & Abd El-Shafy Banna, 2009). The results for females, however, is inverted, as high officials were more likely to experience osteoporosis. As osteoporosis is generally more prevalent in females, the researchers attribute this inversion to the sedentary lifestyle of high-status women, while poorer women engaged in some physical activity (Zaki, Hussein, & Abd El-Shafy Banna, 2009). Using bioarchaeological methods on the deceased, researchers were able to show how different lifestyles, which were directly dependent on one's social class, affected the body in significantly different ways.

Another way in which social stratification affects ancient human remains can be seen in Zakrzewski (2003). Here, stature and the pattern of body proportions were investigated in a series of six time-successive Egyptian populations (from the Badarian period until the Middle Kingdom) in the Abydos region. This was done in order to investigate how the development and eventual intensification of agriculture affected human growth, while also relating the findings to the emergence of the stratified Egyptian state. The human body experiences varying sensitive periods of growth for different body segments. When an individual experiences food shortages or extreme malnutrition during sensitive growth periods, the body is affected in a multitude of ways, including the presence of Harris lines on the long bones and growth stunting to differing degrees. Stunting occurs when malnourished during childhood (Zakrzewski, 2003).

Zakrzewski (2003, 202) believes that "in most past societies, elites were taller, healthier, or better fed than the poorer members." While some bioarchaeological studies show little to no differences between commoners and elites in terms of stature and health (White et al., 1993), there are many examples, in a variety of global studies, that smaller statured individuals are, more often than not, of comparatively lower status (Haviland, 1967; Schoeninger, 1979; Allison, 1984; Angel, 1984; Cohen, 1989; Cook, 1984; Steegman & Haseley, 1988). In her own Egyptian sample, Zakrzewski (2003) found that overall stature increased in Egyptians from the Predynastic period until the start of the Dynastic period, which was then followed by an overall decline in height. This initial increase in stature alongside the development of agriculture is seen as a result of greater reliability of food production and the initial formation of social rankings. Around the time of the Old Kingdom, however, a decline in height became apparent. Zakrzewski attributes this decline to the further intensification of agriculture and the greater social complexity of this period, resulting in a stratified social hierarchy. In this period, individuals of lower status would have received fewer resources than those of high status as differential access to nutrition and healthcare was present. This decline in stature continued into the Middle Kingdom, potentially indicating an even greater divide being created by this social hierarchy.

Overall, Old Kingdom Egypt can be defined as a lengthy period of economic prosperity, particularly for those of higher status, and political stability that allowed for a centrally organized state ruled by a divine king. The Egyptian state was further administered by a literate elite selected at least partly on merit (Malek, 2000). Although a separation existed between royals and the public, some non-royal positions had higher status than others (Figure 2.1) and were seen as prestigious within society. For example, the pharaoh Djoser mentioned his architect and high-priest Imhotep (the supposed inventor of building in stone) on his statue base, demonstrating his importance within society (Malek, 2000). Unfortunately, the tomb of Imhotep, believed to be located near those of royals in Saqqara, has yet to be found (Malek, 2000). What has been discovered, however, is the massive mastaba-tomb of Pharaoh Khufu's vizier, Hemiunu to the West of the Great Pyramid, which he helped create for his king (Malek, 2000). The size and location of this burial displays this individual's important and prestigious role within the Old Kingdom.

Demonstrating even further the significance of this period, the Old Kingdom is traditionally considered the period in which true artificial mummification began (Bard, 2005; Bard, 2015), even by those who are suggesting that mummification may have began 1500 years earlier (Jones et al., 2014). It is widely believed that the way bodies desiccated naturally in the Egyptian climate, as seen in earlier periods, influenced the implementation of this mortuary ritual (Bard, 2005). The specific details of mummification, and how it varied by period, will be discussed in greater detail in a later section of this thesis, however, it should still be noted that the emergence of mummification correlated with the burgeoning social stratification of this period.

2.2.3 The First Intermediate Period & The Middle Kingdom

Although the Old Kingdom was prosperous for a long time, feuds between different dynasties, issues with foreign empires through both trade and colonialism (O'Connor, 1974), and even various climatic factors (Malek, 2000; Ikram, 2003) led to the demise of the centralized government for a period of over 100 years (2181–2055 BC) (Shaw, 2000). This era is referred to as the First Intermediate Period and is often considered a period of “political fragmentation” (Bard, 2005, 45). "Characterized by the rivalries of local rulers in their claims for power" (Seidlmayer, 2000, 118), another reason for the fall of the Old Kingdom is attributed to the growing power of different priesthoods and nobles (Ikram, 2003). This loss of centralized political control, shaped by a significant decrease in wealth and access to resources by the ruling class (Bard, 2015), was further complicated by these different priesthoods and nobles all vying for control of Egypt. While these troubles were experienced by the upper echelon of society, it should be noted that archaeological discoveries suggest a potential "thriving culture among the poorer levels of society" (Seidlmayer, 2000, 120). Therefore, rather than just being a period characterized by political turmoil and chaos, it was instead also a period of important shifts in centres of activity and dynamism (Seidlmayer, 2000). This dynamism may have even influenced the social structure of the following period; the Middle Kingdom.

Signified by the re-unification of Upper and Lower Egypt by the pharaoh Mentuhotep II, the Middle Kingdom (2055-1650 BCE) (Shaw, 2000) was a renewed period of prosperity where the borders of Egypt expanded into Nubia and the complexity of social organization increased (Bard, 2015; Richards, 2005). It was also the period in which the emergence of a middle-class first appeared (Callender, 2000; Zakrzewski, 2003; Richards, 2015). A large grouping of Middle Kingdom funerary stele discovered near Abydos demonstrate the wide ranges of potential socioeconomic status and presents the best archaeological evidence for this significant social shift (Richards, 2005). As the wealth of Middle Kingdom rulers continued to grow (particularly their mineral wealth) and the borders of Egypt expanded, a variety of new bureaucratic positions were created while new officials were named, which in turn, produced even more high-level positions across the empire, increasing “the size of the middle-class bureaucracy” (Callender, 2000, 176).

A study conducted by Al-Khafif and El-Banna (2015) demonstrates how reconstructing the diets of ancient cultures can help us understand social, economic and religious systems. This study tries to reconstruct the paleodiet of Elephantine nobles (or as the authors argue, those that would become the middle-class during this Middle Kingdom) buried at Qubbet el Hawa cemetery during the First Intermediate Period, the Middle Kingdom, and the Second Intermediate Period. Results seem to show that Elephantine nobles experienced some dietary hardships in the First Intermediate Period, which stabilized in the Middle Kingdom and remained quite similar during the Second Intermediate Period. The researchers interpreted this as evidence for the evolution of stability amongst the middle-class. This grouping of individuals, who experienced dietary hardships during the First Intermediate Period, acquired a much greater degree of social and nutritional stability during the Middle Kingdom, solidifying their power and access to resources as their diet remained similar and consistent once the Second Intermediate Period began.

2.2.4 The Second Intermediate Period & The New Kingdom

The fall of the Middle Kingdom into the Second Intermediate Period was characterized by another political fragmentation as different rulers each tried to conquer and gain control over the entirety of Egypt (Shaw, 2000; Bard, 2005; Bard, 2015). Portions of Egypt were also briefly governed by foreigners as the Hyksos people from Western Asia took control of certain areas (Bourriau, 2000). Although a unified Egypt was briefly lost, researchers (as previously discussed) have demonstrated the stability of certain social strata during this period (Al-Khafif & Banna, 2015). The eventual re-unification of Egypt by pharaoh Ahmose signified the beginning of "a period of renewal and consolidation" (Bard, 2005,60); the New Kingdom.

The re-unification of Egypt during the New Kingdom (1550-1069 BCE) (Shaw, 2000) ushered in a period of aggressive expansion as the borders of the Egyptian empire grew (Bard, 2005; Shaw, 2000). New colonial settlements brought forth the 'Egyptianization' of foreign individuals, such as the Nubians (Buzon, 2006; Buzon, 2008), who would be incorporated into the empire. Drastic changes to the empire prompted significant adjustments to the mortuary landscape during the New Kingdom, especially during the short-lived Amarna Period (Van Dijk, 2000; Kemp et al., 2013; Rose, Kemp, & Zabecki, 2015), as well as the creation and use of the Valley of the Kings (and Queens) for the sheltered burials of royals and their kin. During this time, the practice of mummification grew significantly (Van Dijk, 2000). The New Kingdom saw the "complete democratization" (Aufderheide, 2003, 228) of mummification as individuals across different social strata were now being mummified. For that reason, it is an extremely significant period within the scope of my research.

A case study of this period’s expansion and its effect on individuals of differing social status and ethnicity can be seen at the colonial Nubian New Kingdom site of Tombos. Here, studies were conducted in the hopes of understanding the effects of cultural contact and colonization on this site's Nubian non-elite individuals (Buzon, 2006; Buzon, 2008). After assessing biological relationships through patterns in burials and cranial dimensions, the data collected from 100 Tombos burials indicated that most individuals buried here could be considered middle-class (Buzon, 2006; Buzon, 2008). Based on the assessment of the remains from Tombos and comparisons with 1287 contemporary individuals from different Egyptian and Nubian burial sites, Buzon (2006; 2008) strongly believes Tombos had an ethnically and biologically mixed population where both immigrant Egyptians and native Nubians held administrative positions. At Tombos, cultural identity seems to have been fluid and one’s social status was not necessarily affected by one’s ethnicity. Health, however, was impacted in a different way during this transitional period, as the evidence seems to suggest that many individuals who experienced social mobility and gained prestige by becoming 'Egyptianized' were not protected from the physiological stressors and poor health conditions present during this time.

Recent research focusing on a unique example of a brief shift in social structure during the New Kingdom comes from the short lived, yet remarkably well-known, Amarna period (Kemp et al., 2013; Rose, Kemp & Zabecki, 2015). It is widely believed that Egypt was at its wealthiest, strongest and most serene when Amenhotep IV came to power, as the New Kingdom exuded political stability and peaceful relations with outsiders (Shaw, 2000; Bard, 2015). Five years into his reign, Amenhotep IV changed his name and become Akhenaten, forcibly prompting a "revolution in religion and the arts by espousing the sun disk as sole god and declaring all other gods to have ceased" (Bard, 2005, 60). Furthermore, Akhenaten rejected Memphis and Thebes as royal centres of administration and built his new city, Akhetaten, in modern day Tell el-Amarna, making it easier for the entire economy of Egypt to focus on the cult of his sole god (Shaw, 2000; Bard, 2005; Bard, 2015). This monotheistic revolutionary was considered a heretic by some, and as such, the Amarna period did not last long (Van Dijk, 2000). All the temples that were hastily built during his reign were later toppled and the old cults of the Egyptians were completely reinstated within fifteen years of Akhenaten's death (Shaw, 2000; Bard, 2005).

A study from 2013 summarizes the results of six seasons of excavation at the South Tombs Cemetery at Amarna consisting of skeletal remains belonging to 159 individuals, which contrasts the lives of elites and the lower-class workforce of this New Kingdom city (Kemp et al., 2013). By studying the stature of these individuals, the researchers found strong evidence of nutritional stress. They determined that most individuals belonging to the lower-class workforce, lived a life of "hardship with severe nutritional stress and extreme workloads" (Kemp et al., 2013, 75). Stress may have also stemmed from resistance to the new way of life implemented by Akhenaten. Another key point of this study demonstrated how complex the study of social status can be, as this cemetery displayed surprisingly very similar burial styles for all, while living spaces provided the clearest examples of social stratification. Perhaps during this unique period in ancient Egypt, less of an emphasis was placed on burial practices and the afterlife, therefore, displaying one's superior social positioning came in the form of their living space; not their dying space. It is also possible, however, that evidence of social stratification lies at another, unearthed, burial site.

Furthermore, another study (Rose, Kemp, & Zabecki, 2015) addressed the issues surrounding the supposed opulence of Tell el-Amarna. Both studies use the South Tombs Cemetery, containing individuals from multiple strata, where researchers found high levels of infant and adolescent deaths, iron deficiency, disease, and parasites (seemingly across social classes), disproving the period's supposed opulence and documenting the persistent stress these individuals must have felt, regardless of social status. It is also entirely possible, however, that this instance, like others, is more indicative of the interpretive issues surrounding paleopathology, such as the osteological paradox (Wood et al., 1992). To know for certain whether the osteological paradox applies in this particular case would require a full understanding of the archaeological and cultural contexts using contemporary comparisons. However, this is beyond the scope of this thesis.

Later on during the New Kingdom, after the fall of Akhenaten and the re-instatement of the 'old' ways, the Valley of the Kings and the Valley of the Queens were built in modern day Luxor as a means to protect pharaohs and their kin from the grave plundering and defilement that affected many of the rulers that had come before (Shaw, 2000; Bard, 2005). In Deir el-Medina, a worker's village has been unearthed that housed the individuals involved in the creation of these secluded burials for the ruling class of Egypt and luckily, it has given us a further glimpse into ancient Egypt's social stratification during the New Kingdom. Some bioarchaeologists have assessed the identity, as well as the social and financial situations of this village's population (Lesko, 1994; Meskell, 1998). Lesko (1994) demonstrates which societal roles were regarded as most important beneath the pharaoh (with a focus on viziers and governmental scribes) showing the complex division of social classes as there have been rigorous debates over wage earnings for different jobs. Lesko (1994) proposes that one's financial situation was not as indicative of one's social class as other factors, such as family reputation, connections, education, and skill, which seemed to have played significant roles. Meskell (1998) has discussed how age, sex, status, and life experience all contributed to degrees of social inequality. Meskell (1998) promotes the idea that the social identities of these individuals must be considered multifaceted and fluid, and assessed accordingly.

2.2.5 Post-New Kingdom Egypt

With the New Kingdom ending, and the Third Intermediate Period (1069-664 BCE) (Shaw, 2000) commencing, the Egyptian empire would change forever. Again, political fragmentation was a major element, however, this period was relatively stable in comparison to the other two intermediate periods. Its defining characteristic was the presence of multiple foreign powers, leading to a "substantial influx of non-Egyptians (Libyans and Nubians) permanently [modifying] the profile of the population" (Taylor, 2000, 330). This is a quality shared by every period following this Third Intermediate Period as well. For example, The Late Period's (664-332 BCE) (Shaw, 2000) population consisted of Nubians, Persians, Libyans, Assyrians, Greeks, Carians, and others from the Near East (Ikram, 2003). The Greek Occupation of Egypt began after Alexander the Great ended the Persian control of Egypt in 332 B.C.E., thus commencing the Ptolemaic era. Years of royal power struggles continued, (which can be said for most of Post-New Kingdom Egypt) and in 30 B.C.E. the Roman occupation of Egypt began under the emperor Octavian (Shaw, 2000).

These three periods share this quality of foreign rule and all come after the New Kingdom, a period widely considered the twilight of ancient Egypt (Ikram, 2003). Post-New Kingdom Egypt as a whole can be characterized by periods of high political tension where ruling was extremely unstable as many different people were vying for the title of pharaoh and ultimately, control of Egypt. Even during the Ptolemaic rule, a period considered one of the more stable successions of rulers, political instability was an issue. There were fifteen different rulers with the name Ptolemy, with many of their wives taking over their rule after death. The murder of many of these individuals, combined with political uprising from leaders in the South of Egypt, meant that any single ruler was constantly under threat (Lloyd, 2000).

A significant aspect of ancient Egyptian culture that was especially apparent as of the Third Intermediate Period, and that will be emphasized further in later chapters, was the employment of archaism in a variety of cultural and social aspects. Archaism is the conscious imitation or use of features or styles stemming from an earlier period (Kahl, 2010). In ancient Egypt, these features include art and sculpture, architecture, the names and titles of individuals, literature, and writing in general (Taylor, 2000; Redford, 2001a; Kahl, 2010). What must be remembered about archaism as a phenomenon in ancient Egypt is that it was a continuum and "an inherent feature of the culture" (Kahl, 2010, 5), and not just indicative of a particular period. Examples of archaism can be found as early as the Old Kingdom (Kahl, 2010), and by the Middle Kingdom, rulers were trying to revive aspects of Old Kingdom tradition and architecture, such as pyramid-building (Redford, 2001a). Dynastic Egypt has many examples of archaism engrained within the societal fabric and culture. The Third Intermediate Period, however, saw archaism being utilised by foreign rulers, as Libyan and Kushite leaders adopted older Egyptian beliefs and traditions in an attempt to legitimize their claim to pharaonic power (Trigger et al., 1983; Taylor, 2000; Redford, 2001a; Kahl, 2010). This use of archaism also resulted in the new foreign elite adopting Egyptian burial practices, such as mummification, as the Third Intermediate Period saw a shift from elaborate tomb construction to a focus on the body (Trigger et al., 1983; Taylor, 2000). The Third Intermediate Period is actually considered the apex of ancient Egyptian mummification in terms of embalming technologies (Taylor, 2000). After the Third Intermediate Period, archaism would proliferate across ancient Egyptian culture, eventually peaking during the Late Period (Kahl, 2010). Archaism was instrumental for many aspects of ancient Egyptian culture, and as will be seen in later chapters, it may have even stronger ties to embalming and certain mummification features.

On a final note concerning my discussion of Post-New Kingdom Egypt, I want to borrow an idea from a 2015 chapter written by Sonia R. Zakrzewski entitled "Behind Every Mask There is a Face, and Behind that a Story". Here, she explores how bioarchaeological studies help uncover the multiple identities of ancient peoples. In her assessment of burials at the Ptolemaic-Roman cemetery of Quesna, North of Cairo, she demonstrates that most burials were modest and consisted of individuals who were interred in simple pit graves, directly in the sand. The variability and complexity of Egyptian burial practices and mortuary rituals are clear from this example as it would be inaccurate to believe every ancient Egyptian was mummified. In fact, most burials were probably simple inhumations. The point of my research has been to elucidate mummification for non-elites, because they have been largely ignored (Richards, 2005), and I would be remiss if I did not make it clear that mummification was not the only way to deal with the body after death. Being reflexive and understanding these complexities is important because "whether skeletonised or mummified, each body or burial has many stories" (Zakrzewski, 2015, 157) waiting to be told.

The social structure, or at the very least, the rudimentary pyramidic example given in *Figure 2.1*, was generally adhered to throughout time in ancient Egypt, save for minor or brief changes. This includes the Greek example, where Egyptian soldiers and scribes switched positions within the social hierarchy as scribes became essential for translation and handling administrative duties for foreign rulers unfamiliar with the native tongue (Lloyd, 2000). Due to this relative stability (a word I use very loosely and cautiously) in social stratification, my dissection of these periods, from a political and social standpoint, will suffice as is as I believe anything further will begin treading on superfluous details, outside the scope of this research.

2.3: Literature Review: The Evolution of Mummification in Ancient Egypt

In this section of the chapter, I will provide a comprehensive account, or checklist of sorts, about what is presently known about mummification through each period in ancient Egypt. This assessment draws on the physical autopsies done on mummies (including the earlier version of these, known as mummy unwrappings), in addition to studies utilizing both x-rays and computed tomography. Although I have consulted a wide variety of sources, much of the information in this section comes from Arthur C. Aufderheide and his 2003 book “The Scientific Study of Mummies”. This book offers the most complete and detailed account of the specifics of mummification and how it varied period by period. When examined closely, many of these features and variations can, and should be, directly associated with one’s social status.

2.3.1 The Old Kingdom

Old Kingdom mummification established the blueprint for embalmers that was mostly adhered to until the end of ancient Egypt. The fundamentals of the process, which involved evisceration, desiccation with natron, and the use of hot liquid resin to prevent the growth of bacteria and rehydration, were so effective that they remained in use for thousands of years (Aufderheide, 2003).

One of the earliest examples of anthropogenic mummification comes from an Early Dynastic burial at the royal cemetery at Abydos. This is also at this site where we have, perhaps, the oldest association of funerary amulets with mummification. As previously discussed, the use of amulets in the burial practices of Egyptians is perhaps one of the oldest features associated with both the life and death of ancient Egyptians. Their use began even before mummification was practiced, during the Badarian culture, and went until the end of the mummification program over four thousand years later. Inside the tomb of pharaoh Djer, who was perhaps the second ever pharaoh in the newly unified Egypt, a wrapped arm was found with four bracelets, one of which was composed of “twenty-seven alternating gold and turquoise amuletic beads, each in the form of a *serekh,* a rectangular plaque decorated with characteristic palace façade panelling and surmounted by a falcon” (Andrews, 1994, 9). This falcon is believed to be the early and archaic form of the Elder Horus and not only put Djer in association with this God, but under the God’s protection.

Even in its earliest forms, with its exclusivity to royals, variation and experimentation did exist within the practice of mummification (Aufderheide, 2003). Some of the earliest experimentations can be found in the way individuals were treated with linen after the procedures mentioned above. The supposed remains of third Dynasty pharaoh Djoser show that his linen wrapped foot was covering a resin-soaked linen cast, on which artists had sculpted realistic anatomical features of the foot (Aufderheide, 2003). Another example comes from a late third/early fourth Dynasty tomb showing a mummy with individually linen-wrapped arms, while other contemporary and later Old Kingdom individuals have had their entire bodies enclosed in resin-soaked linen, with some of these even showing signs of sculpting over the face, genitalia and breasts (Aufderheide, 2003). In some instances, facial features were even painted in different colours (Aufderheide, 2003). One Old Kingdom mummification feature that was relatively consistent was the arms of mummified individuals, which were notably mostly positioned along the sides of the body (Aufderheide, 2003).

The Giza burial of Queen Hetepheres (the mother of Pharaoh Khufu who famously had the first of the three Great Pyramids built), contained canopic jars containing visceral packages in her sealed alabaster canopic chest (Andrews, 2004), demonstrating the earliest known uses of both natron and resin for purposeful artificial mummification (Bard, 2005). According to some, Queen Hetepheres also displays the clearest example of early resin used specifically as a preservative agent (Jones et al., 2014). It should be noted, however, that some researchers believe Old Kingdom mummification was less about preservation, and more about making the body look as alive as possible instead (Brier, 1994).

Evisceration was attained through a vertical transabdominal incision in the left flank with a stone knife (probably some sort of obsidian), followed by the embalmer reaching in and removing the viscera with a different knife (Aufderheide, 2003). The heart and proximal aorta were often left in place (Aufderheide, 2003) because the Egyptians believed it was the seat of intellect and emotions (Bard, 2005). According to Aufderheide (2003), the bladder, the prostate, and both kidneys were to be left in the body. Incisions made for evisceration were not usually closed, but sometimes resin-soaked linens were stuffed between the edges of the wound (Aufderheide, 2003). Additionally, excerebration, or the removal of the brain, an aspect that is often considered a later innovation from the Middle Kingdom (at the earliest), has recently been suggested to have occurred first in this period via transnasal craniotomies (Wade, Nelson, & Garvin, 2011).

2.3.2 The First Intermediate Period

Unfortunately, very little is known about mummification from this period because, in addition to being a relatively short period of about 105 years, not many examples exist. A well-preserved mummy from the ninth Dynasty was found to have been eviscerated and desiccated. However, it was lacking the molded surface features present on many Old Kingdom mummies, which in the few examples that exist, seems to be a consistent feature of the First Intermediate Period (Aufderheide, 2003). Therefore, the only practice unique to this period is the potential end of molded anatomical features.

2.3.3 The Middle Kingdom

There are conflicting ideas regarding Middle Kingdom mummification. For some, mummification during this period is considered widespread, yet ineffective overall (Callender, 2000). It was during this period that evisceration became more common while bodies were wrapped in lavish linen wrappings, however, residual flesh "seldom survived" (Callender, 2000, 182), making mummification harder to assess as many were skeletonised. Others have posited that Middle Kingdom mummification did exist, but the lack of examples means it was quite rare (Richards, 2005). Richards (2005) believes that "it was not at all common and was probably restricted to the wealthiest members of the elite" (Richards, 2005, 86). Perhaps the reason for this assessment is the lack of preserved soft tissue on what we would probably now consider skeletons, rather than the mummies they once were.

Recently, researchers have shown how the use of resin as a preservative agent in the mummification process was becoming far more prevalent during this period (Jones et al., 2014). This conflicts with earlier accounts that explain how "the body of the elite was occasionally wrapped in linen with none of the other processes of mummification" (Richards, 2005, 86) present. This is an example of how quickly information regarding ancient Egypt can change, as these contradictory statements are less than a decade apart. It is also a testament to the variability present in mummification during the Middle Kingdom. Once relegated to the pharaohs and their kin, mummification had now been extended to many members of the burgeoning middle-class of this period (Aufderheide, 2003), which inevitably led to more variability in the practice of mummification.

While most mummified individuals discovered from this period were eviscerated, the viscera did remain in the body of some, even though desiccation and soft-tissue preservation had been achieved (Aufderheide, 2003). This could even be found at the royal level, as the queens and princesses of pharaoh Mentuhotep were all un-eviscerated, even though their bodies went through desiccation, successfully preserving their soft tissue. This proves that variation in evisceration was present and perhaps even indicative of it being a cost-dependant attribute. Some mummies from this era have been discovered with a visceral prolapse (of the rectum or vagina), however, this is likely post-mortem in nature (Derry, 1942; Aufderheide, 2003). The use of natron and abdominal incisions on the left when evisceration was carried out continued from the Old Kingdom traditions, as well as the Old Kingdom arm positioning (along the sides), however, minor exceptions showing some crossed over the chest have been discovered (Aufderheide, 2003). Regarding excerebration, transnasal craniotomies were somewhat common in this period (Wade, Nelson, & Garvin, 2011).

2.3.4 The Second Intermediate Period

Similar to the First Intermediate Period, very few examples of mummification exist from this period as it was even shorter than the first. The best-known examples from this period do show that elements from the Old and Middle Kingdom persisted, however, embalming was done quite hastily, often with no excerebration administered (Aufderheide, 2003). Transnasal craniotomies, which were rising in previous periods, became less common during this time (Aufderheide, 2003). Evisceration with the subsequent use of canopic jars was also practiced by royals in this period as demonstrated by the thirteenth Dynasty King Hor's remains (Aufderheide, 2003). This discovery helps show that this tradition, that would be become very popular later on, was practiced on royals before anyone else. Other brief notes on new aspects of mummification from this period come from the evisceration of a seventeenth Dynasty mummy who was described as having a large amount of linen stuffed in the body cavity (Aufderheide, 2003). Another feature that would become more common in later periods, being first practiced by the royals, were burials where grave goods or items where directly attached to the body or linen-wrappings. This can be seen by the Second Intermediate Period King and last of the seventeenth Dynasty, Kamose, who had a dagger strapped to his arm (Aufderheide, 2003).

2.3.5 The New Kingdom

The New Kingdom is by far the best documented period in terms of social stratification and mummification as individuals across all social strata were being mummified. Mummification during this period is well-documented as many mummies have been discovered. Non-elite and low status mummification could be seen in ancient Egypt in growing numbers from this period onwards (Wade, Nelson & Garvin, 2011; Wade & Nelson, 2013). Excerebration became quite popular during this period and transnasal craniotomies seemed to be the primary method for this procedure as roughly 66% of Wade, Nelson, and Garvin's study (2011) of 130 New Kingdom mummies displayed convincing evidence. Cranial resin appears first in this period, but only in elites, suggesting that this feature was an “elaboration of the excerebration ritual, specific to the elite and aimed at distinguishing them from commoners" (Wade & Nelson, 2013, 4203). Others who were excerebrated had their heads either stuffed with resin-soaked linens or were simply left empty (Aufderheide, 2003). Here we have levels of the important excerebration process, and it seems likely that socioeconomic status heavily influenced the procedure.

Social stratification expressed in mummification can be seen in most other New Kingdom innovations as well. Evisceration of most organs was carried out and they were subsequently placed in canopic jars. However, it is believed that most elites would leave the heart intact (Hawass & Saleem, 2016). Further elaborations for royals or high-status individuals could also be seen occasionally as a scarab inscribed with prayers were sometimes inserted adjacent to the heart (Aufderheide, 2003). Although a feature associated with the New Kingdom, one of the earliest examples of this comes from the seventeenth Dynasty during the Second Intermediate Period, as King Sobkemsaf II was discovered with an inscribed scarab (Andrews, 2004).

Following these various procedures, body openings in all mummies were often closed with resin-soaked tampons (Aufderheide, 2003). Some tombs have been discovered with empty canopic jars belonging to non-eviscerated individuals as well as some individuals wrapped in linen without any of the embalming techniques (Aufderheide, 2003). It is likely then, that many of the steps involved in mummification were still important symbolically to lower status individuals, even if they could not afford every feature or detail.

Another aspect specific to royal mummification in the New Kingdom is the presence of subcutaneous packs (often treated with resin) (Loynes, 2015; Hawass & Saleem, 2016) placed throughout the body, often to give a more lifelike appearance, or to accentuate certain anatomical features. A common occurrence within Egyptian mummification, as has been shown, is the appearance of a feature that is first, and likely exclusively, utilized by royals, and eventually, over time, adopted ubiquitously by the lower classes in society. This trickle-down, or domino effect, can be seen in a variety of mummification features, however, one of the greatest and clearest examples of this is in fact subcutaneous packs. This will become clearer in the coming paragraphs that explore mummification in post-New Kingdom Egypt.

The presence of amulets lodged within the wrappings became far more prevalent during this period (Hawass & Saleem, 2016), however, both royals and those considered elites were also known to have jewellery, votives (*ushabti*), or scarabs placed in their wrappings as well (Aufderheide, 2003). Amulets had been used in Egyptian burials since before the Dynastic periods, and even, anthropogenic mummification, and similar to subcutaneous packing, can be considered an aspect first utilized exclusively by royals. Some researchers believe that until the Ptolemaic Period the positioning of amulets followed a certain pattern, after which, their positioning became random (Andrews, 1994). Although exact associations are still debated, x-ray technology has allowed researchers to document the location of these amulets and compare with others who have done the same showing many similarities in placement. Unfortunately, when most of the older physical autopsies were administered, the position of most amulets was not documented or left *in situ* before they were removed or unwrapped making it even harder to study their uses and associations (Andrews, 1994).

Royals and nobles were also sometimes given desired hair coiffures, while lower status (and royals who wanted it) would have their hair completely removed (Aufderheide, 2003) during the mummification process. Another indication of stratification can be seen occasionally when assessing fingernails and toenails, which were often tied to their corresponding digits to prevent falling off (Aufderheide, 2003; Andrews, 2004). In some examples from the British Museum, we can see that royals would sometimes use gold thimbles to keep the nails on instead of simply just tying them (Taylor & Antoine, 2014).

Perhaps one of the most variable aspects of mummification from this period onwards was arm positioning and could be used to reflect time periods, gender, and of course, socioeconomic status. In the eighteenth Dynasty, arms were laid along the sides with hands placed on the front thighs for women and over the genitals for men, however, women adopted the male positioning as the period progressed (Hawass & Saleem, 2016). In one example of an unknown woman dating to the eighteenth Dynasty, described by Gray (1972), her right arm was extended while her left was flexed with clenched fingers over the sternum. In the nineteenth and twentieth Dynasties, a 'royal' position was adopted as a crossed-arm position over the chest was consistent amongst rulers (Hawass & Saleem, 2016). Apart from royalty, however, very few New Kingdom mummies have crossed arms and after the twentieth Dynasty, it seems most New Kingdom mummies had extended arm postures (Elias, Lupton, & Klales, 2014). It should be noted that exceptions to the rules do exist, but for the most part, these dynasty-specific positions were adhered to during the New Kingdom (Hawass & Saleem, 2016).

Robert Loynes (2015) recently released a book detailing the CT scans of sixty human ancient Egyptian mummies and he found, potentially the earliest examples of a mummy with false eyes, a feature that became much more prominent in later periods. This twentieth Dynasty mummy with false eyes, or what Loynes calls 'eye-plates', was both eviscerated and excerebrated with only the heart remaining (Loynes, 2015).

2.3.6 The Third Intermediate Period

The Third Intermediate Period can be characterized as a time of experimentation within the practice of mummification. The twenty-first Dynasty saw the commencement of a brief, but distinct change within the embalming program as embalmers were trying to make the body look more realistic by using subcutaneous packing (Aufderheide, 2003). Perhaps this was to deter grave robbing by having the pharaoh appear more alive, or maybe, this was a stylistic choice, selected by the soon to be deceased individual. It should be noted, however, that some individuals from this period were discovered with no evidence of subcutaneous packing, no evidence of linen use and no appearance of resin (Loynes, 2015). Perhaps these examples all come from the end of the period. It would seem these individuals may have been on the lower end of the social status spectrum. On the other end of the spectrum, some royals and elites have been described as having mollusk shells implanted into the orbits to simulate realistic eyes, sometimes with pieces of stone, like obsidian, acting as the pupil (Gray, 1971; Aufderheide, 2003).

Andrews (2004) has also reported on a few aspects of Third Intermediate Period mummification worth noting here. According to Andrews (2004), mummies during the twenty-first and twenty-second dynasties often wore red leather straps over their shoulder which crossed at the front. These were either on top of the wrappings or just below the surface, and although they resemble a practical brace of sorts, they support nothing. Furthermore, Andrews (2004) reports that where these intersected, there was often strips of leather in the shape of a tassel on one end, while a counterpoise of a collar bearing the name of the king or high priest of Amun, was on the other. This aspect seems to be directly associated with individuals of royal and/or religious status. Andrews (2004) ends her discussion on this topic by discussing that many mummies, beginning in the twenty-fifth Dynasty, and lasting until the Roman Period, had an "outer covering of a network of blue glazed composition beads or even a complete multi-coloured beadwork shroud which almost looks knitted. Poorer clients had an imitation net painted on the outermost layer of their bandages [while] some mummies wore an actual net of knotted string" (Andrews, 2004, 33). These outer coverings will be referred to as bead nets going forward as this is how they are commonly described. It should be noted that many nets may be missing as well, as they could be easily removed or lost. Regardless, once again we can see levels to these aspects based on social status.

A twenty-first Dynasty feature seemingly shared by all social classes was arm positioning. The "royal" arm position from the New Kingdom had stopped being used, as the arms of both royal and non-royal mummies were now returned to side of the body while the hands were resting or covering the pubic area (Gray, 1972; Loynes, 2015; Hawass & Saleem, 2016). These twenty-first Dynasty innovations, however, did not usher in a new era of innovation within the technique of mummification. By the twenty-second Dynasty, it was clear that the overall quality of mummification, across all social classes, had significantly regressed (Aufderheide, 2003).

The Loynes (2015) study mentioned above involves quite a few mummies from this period and for this reason, I believe his greatest contribution has been in identifying aspects of Third Intermediate Period mummification. His detailed accounts have shed light on the twenty-second, as well as the twenty-fifth Dynasties because he had six mummies to assess from each period, for a total of twelve individuals (Loynes, 2015). All six of these twenty-second Dynasty mummies were excerebrated transnasally, with evidence of sphenoid perforation (Loynes, 2015). Subcutaneous packing was placed in the necks and cranium in five of these six individuals but different materials were used. In addition to linen, Loynes details a rather granular sort of material that was used, likely mud, dirt, and sawdust (Loynes, 2015). Furthermore, only one of these individuals shows retention of the eyes, while the other five have their sockets packed with linen; three of the six, however do have false eyes (Loynes, 2015). In terms of evisceration, two of the six individuals had incomplete versions of the procedure as their thorax was not done (Loynes, 2015).

The twenty-fifth Dynasty mummies seem to have a little more variation. In this sample, Loynes (2015) reports four of the six individuals were excerebrated via the foramen magnum. Five of these individuals have cranial packing, likely in the form of linen, while the one missing it seems to have had cheek and mouth packing done to restore their facial contours (Loynes, 2015). The eyes were only removed in one of these individuals, while the eyes of two were left completely untouched and *in situ* (Loynes, 2015). In three of these cases, linen packing was used to restore the shape of the eye and in two cases, eye plates (or false eyes) were inserted inside the globes (Loynes, 2015). Two of these six mummies have subcutaneous packing in their neck and chest, while one of these individuals seems to have had a rod inserted into the neck (Loynes, 2015), likely for stability or to make it appear lifelike. In all these cases, linen was used far less than the granular packing option (Loynes, 2015). Perhaps cost or access was a factor here.

What Loynes' (2015) work has demonstrated is that many options were available for these individuals in terms of how they wanted their body treated after death. What can also be said is that there is now less standardization in this practice, which is perhaps the result of more individuals being mummified. What did seem standard, or consistent within most of these mummies, was the fact that appearing lifelike, for whatever reason, was valued. This was also achieved in a variety of ways, again, acting as a testament to the growing variability and practice of mummification. It is also entirely possible, however, that this simply reflects the increased number of mummies now available to be found and studied.

2.3.7 The Late Period

Unfortunately, very few Late Period mummies have been discovered (Aufderheide, 2003; Wade, Nelson, & Garvin, 2011), especially ones that demonstrate significant changes from previous periods. Some examples from Nubia, however, do show that body wrappings in this geographical area differed from those in found in the Nile Valley, which had more complex geometric patterns, however, heavy use of resin is found in both areas (Aufderheide, 2003). Additionally, in some early instances, red linen shrouds were used for higher class individuals (Raven & Taconis, 2005). From this period, we also know that the bodies of children were almost always un-eviscerated while this was rarely the case for adults (Aufderheide, 2003). Subcutaneous packs were sometimes utilized, but they are dissimilar from those used in the preceding period as they do not seem to be mimicking a living individual (Elias, Lupton, & Klales, 2014; Loynes, 2015). They are, however, considered larger and much more distinct than they were in the preceding period (Elias, Lupton, & Klales, 2014).

In their own sample, Elias, Lupton, and Klales (2014) found that most Late Period arm positionings show crossed arms over the chest with bimodal hand positioning, however, the exact frequency of this remains unknown (Elias, Lupton, & Klales, 2014). Also, as is often the case for arm positioning, variability was present (Aufderheide, 2003). Some other suggestions for specific features of 'Late Period' mummification have been speculated upon, but the examples used are not confidently dated to this period (Aufderheide, 2003), therefore they have been omitted from this discussion.

Fortunately, Loynes (2015) also had eight Late Period mummies in his sample. All of these mummies come from the twenty-sixth Dynasty, which is significant, because this marks the beginning of the Late Period, but also, the last Dynasty of Egyptian-born individuals to rule Egypt before the Persian conquest and twenty-seventh Dynasty (Dodson & Hilton, 2004). In this group of eight, five individuals were excerebrated transnasally, one via the trans-orbital route, one of them was not excerebrated at all, while the other cannot provide a definitive answer (Loynes, 2015). Of these eight individuals, six were deemed suitable enough for analysis of the eyes. Five of these had packing in the eye-globe, while eye plates were used in the sixth individual (Loynes, 2015). Contents of the mouth were only able to be assessed in five of these individuals and in four cases granular material (in addition to or instead of linen) was utilized;

the fifth was left empty (Loynes, 2015). Unfortunately, only five trunks could be assessed and of these, all five were eviscerated via the left flank (showing a continuation of Old Kingdom traditions) with heart retention (Loynes, 2015). It should be noted that there is evidence for use of the perineal route, in conjunction with the abdominal flank incision for evisceration (Loynes, 2015), demonstrating variability once again, or that the left-flank incision could sometimes be used symbolically.

2.3.8 The Greco-Macedonian (Ptolemaic) Period

Under Greek rule, the Egyptian empire changed tremendously. Changes in the social organization, which have already been discussed, disrupted certain tiers in the social hierarchy (Brier, 1994; Bard, 2015). Mummification would not only continue, which was astounding considering Classical Greeks practiced cremation and mostly forbade cutting of the body (Brier, 1994), but would also experience a change. The emphasis on body preservation diminished, while a new focus on the exterior appearance, dissimilar to Third Intermediate Period and Late Period mummification, occurred. This focus was a little more polished as it seems the embalmers wanted to be artistic. For royals and elites, linens were used in great quantity, and not just haphazardly ripped apart, but rather, made to be uniform width with finished edges, enabling wrappers to make elaborate geometric patterns of squares, creating the illusion of depth (Brier, 1994). The arm positioning during this period was mostly flexed (Gray, 1972; Aufderheide, 2003; Elias, Lupton, & Klales, 2014; Loynes, 2015), and this probably aided embalmers with the weaving and creation of their embalming patterns.

The most common form of excerebration during this time was by far the transnasal craniotomy as it was practiced by individuals across all social levels, not just among the elites (Wade, Nelson, & Garvin, 2011). Other comprehensive studies have confirmed the widespread nature of excerebration during this time as the only exception Loynes (2015) had in his study was that of a child mummy. Furthermore, the use of resin, believed to have peaked in this era, continued to be associated with high status (Wade, Nelson, & Garvin, 2011; Wade & Nelson, 2013).

Packing of the eye globe could still be seen but according to Loynes (2015), was far less common than in previous periods. All evisceration in his Greco-Egyptian sample was done abdominally or perineally, while the heart remained *in situ* for three of the four mummies that were able to be assessed (Loynes, 2015). Additionally, filling the mouth with linen or resin-soaked linen was less popular during this period as, of the nine mummies assessed, four had zero filling while five had very little linen (Loynes, 2015).

2.3.9 The Roman Period

The Romans, before banning mummification in 392 CE (Brier, 1994), continued to emphasise the external appearance and arguably, took it even further than the Greeks did. Although the arm positions changed from flexed to being primarily extended in this period (Aufderheide, 2003), wrappings continued to be intricate. Sometimes they were thirteen layers deep, with diamond patterns emerging, and for those of higher status, a flat gold leaf could be visible within each diamond shaped enclosure (Aufderheide, 2003; Brier, 1994). It seems the elite were trying to find new ways to distinguish themselves from the lower classes of society by engaging in these lavish practices. Linens were now also being produced specifically for mummification and would commonly have prayers or distinct patterns inscribed on them (Aufderheide, 2003). Roman mummies were also filled generously with resin, with the surplus being poured over the bandages and over the body (Aufderheide, 2003). Skin gilding with gold, the use of mummy decorations, such as shrouds or masks, and the presence of individually wrapped limbs, are also indicators of high status during this time (Gessler-Löhr, 2012).

The largest group of mummies from the Loynes study (2015) is the seventeen individuals dated to the Roman Period. In this final period of ancient Egypt, a variety of excerebration techniques were utilized. The three individuals in this sample from Thebes were excerebrated transnasally while resin, as well as the linen packing for the mouth and eyes, varied in appearance (Loynes, 2015). Of the ten mummies found in Fayum, three are not excerebrated, five had definite transnasal craniotomies, while one had evidence for both a trans-orbital and trans-foramen brain extraction (Loynes, 2015). The other individual was not suitable for study. The three mummies of unknown provenience all had transnasal craniotomies, however no further treatment of the head was given (Loynes, 2015). Perhaps these geographical locations have their own preferred methods or specialities, making location an important factor for this practice. Moreover, eyes, in almost every instance, were left in place and desiccated without any further treatment (Loynes, 2015). This is a potential indicator that making the deceased appear lifelike was a dying tradition.

Eight of the sixteen assessable mummies were not eviscerated (Loynes, 2015). This rate of 50% seems extremely low, even during this Roman occupation of Egypt. To me, this is potential evidence of the shift in ideology that had the Romans placing a higher emphasis on the outside appearance of the mummified individual, rather than ensuring they were adhering to earlier elements of mummification. Evisceration remained fairly consistent across every previous period, therefore, this number is perhaps most telling of a paradigm shift within the mummification program.

Perhaps the most unique and recognizable addition to the mummification program by the Romans was the realistic mummy portraits created for the deceased between 50-350 CE (Aufderheide, 2003). These portraits, usually done on cedar or cypress wood over a layer of white gesso, were intended to be bound over the head of deceased individual after they were wrapped (Brier, 1994). These were commissioned during the individual's lifetime, to ensure that it was as realistic, or idealized, as possible (Brier, 1994); relative to cost of course. Just to have a mummy portrait done demonstrated an individual's wealth, however, recent studies have shown that there were levels to this funerary procedure (Gotthardt, 2019). Some substances, such as gold leaf or encaustic would have been far more expensive and required artisans of higher skill, while some portraits were painted on local or recycled wood, reducing cost (Gotthardt, 2019). As can be seen, even amongst the wealthy, levels of variation existed.

2.4: Literature Review: The Non-Destructive Study of Mummies

Much of the information in chapters 2.2 and 2.3 comes from Aufderheide (2003) and his detailed accounts of mummy autopsies. The objective of this study is to build on these descriptions using non-destructive and non-invasive methods, specifically, CT scans. The application of radiological methods in mummy studies has a long history. The use of CT scans in mummy studies, however, is fairly recent, and it has quickly become the gold standard in methodology for its promotion of conservation and preservation, while at the same time giving respect for the deceased individual being examined. Although computed tomography was developed for use in a clinical setting by medical professionals, it has been used for the scanning of Egyptian mummies for over forty years (Harwood-Nash, 1979). In that time, it has continued to prove its worth by helping uncover previously unknown information about ancient Egypt.

2.4.1 Early Radiology & Mummies

When contemporary researchers look back at the origins of mummy studies, it is immediately evident that early reports of mummy autopsies were "at best, detailed descriptions of destructive unwrappings" (Nelson & Wade, 2015, 942). X-ray technology, however, has been used within archaeological settings for some time. Radiography has proven to be extremely valuable to biological anthropologists and archaeologists and its applications are now widespread. When modern imaging methods are used in the study of bioarchaeological materials, like mummies, it is often given the names paleoradiology (Chhem & Brothwell, 2008) or paleoimaging (Beckett & Conlogue, 2016; Beckett & Conlogue, 2021). The invention of x-ray imaging, and its subsequent use in paleoradiological contexts, forever changed the way ancient materials, especially human remains, were studied. Before, and after the introduction of radiography, studies conducted on mummies involved destructive and irreparable measures in the form of unwrapping, dissections, and autopsies. Not only were these methods damaging, but their invasiveness disrupted the intrinsic nature of the mummification process, as it disrespected "the Egyptians' wish for eternal preservation" (Hoffman, Torres, & Ernst, 2002, 378).

X-rays were discovered in 1895 by Wilhelm Roentgen, and it did not take long for its application on ancient Egyptian mummies. Within the first year after Roentgen's discovery, physicist Walter Koenig used the technology to x-ray a mummified child and a cat, while medical practitioner Thurstan Holland x-rayed a mummified bird (Hughes, 2011). People were undoubtedly captivated by this new technology as scientists were using it on a variety of subjects. Three years later, in 1898, x-rays were used by the archaeological pioneer, Sir William Flinders Petrie, to look inside an adult mummy from Deshasheh dating to the fifth dynasty (Petrie, 1898). The quality of these radiographs is astounding, especially considering the year it took place, as the images revealed the presence of Harris lines in the bones, which remained unnoticed for decades (Chhem & Brothwell, 2008). The first x-rays of a royal Egyptian mummy took place five years later by Egyptian radiologist Dr. Khayat, who conducted his study on the New Kingdom pharaoh Thoutmosis (or Thutmose) IV (Chhem & Brothwell, 2008).

The use of radiology in mummy studies has evolved since its inception. In the earliest years, radiological studies were performed for a variety of reasons including distinguishing authentic mummies from fakes, to evaluate the bone age, to detect skeletal diseases, and to search for grave goods (Chhem & Brothwell, 2008). Although these particular research inquiries, and others, benefitted from the implementation of radiology, many limitations still existed. Early radiological studies focused primarily on the mummy wrappings and artifacts instead of the actual body itself, while "remarks were often confined to the grossest and most basic of observations" (Nelson & Wade, 2015, 942). There is no doubt that radiography altered and ultimately enhanced the way researchers dealt with ancient organic materials, but progress was necessary. One of the biggest limitations of plain film radiography is that "all the structures of the object are superimposed onto a single image plane" (Chhem & Brothwell, 2008, 26), which may obscure significant detail. CT scans eliminate this restriction. The invention of CT scanning, and its eventual use on mummies, signified the first time that a "noninvasive study could be performed to obtain information about the soft tissue and internal body cavities" (Hoffman, Torres, & Ernst, 2002, 378) of ancient Egyptian individuals.

2.4.2 Computed Tomography & Mummification

The CT scanner was invented in 1967 by Sir Godfrey Hounsfield, who was awarded the 1979 Nobel Prize in both Physiology and Medicine for its development (Chhem & Brothwell, 2008, 26). The first clinical CT scanner began operating in the early 1970s and represented a "quantum leap in diagnostic imaging" (Hughes, 2011, 58). Original CT scanners from the early 1970s were limited to scanning the head and brain as the opening was small. In 1976, the use of whole-body scanners began, and by 1980, CTs became widely available for medical applications (Chhem & Brothwell, 2008, 26). It was not long before CT scanning was used to “bring wonderful imaging potential to the arenas of anthropological and archaeological research” (Beckett & Conlogue, 2016, 22). Although CT scanning is not the only non-invasive method of inquiry that can be used on mummified human remains, it does represent the safest, clearest, and most efficient. When compared to conventional radiography, "CT intrinsically offers better contrast and spatial resolution" (Hoffman, Torres, & Ernst, 2002, 384).

CT images are produced by the processing of a large number of x-rays acquired through the object from many different angles (Chhem & Brothwell, 2008). This x-ray beam will then shine "through the patient or archaeological artefact and is absorbed differently depending on the material…the greater the density of material the greater the attenuation of the x-ray beam" (Hughes, 2011, 58). Computed tomography is a radiological procedure that creates cross-sectional images (or cuts/slices) by computer processing. Rather than sending x-rays in only one direction, CT scanning produces its more detailed images by using a mechanical x-ray source rotating around the patient to get a variety of scans at a multitude of angles. Detectors are situated opposite the x-ray source and as these x-rays pass through a patient, or in this case, a mummified corpse, they are detected and then transmitted to a computer. The images produced already have the capability to reveal many details, but with technological advancements, postprocessing software packages are often used to acquire even more information.

Since mummies do not move, the images produced by CT scans on the dead can often turn out clearer than those of living patients, as movements such as breathing can blur the image (Hughes, 2011). Additionally, the bioarchaeological applications of CT scans are not a health risk when used on mummies because "the total x-ray dose is less of a concern than it would be with a living subject" (Chhem & Brothwell, 2008, 15). It is no surprise that computed tomography has "emerged as the imaging modality of choice for the examination of Egyptian mummies due to its non-invasive cross-sectional nature and inherently superior contrast and spatial resolution" (Hoffman, Torres, & Ernst, 2002, 377).

In their 2002 study of nine Egyptian mummies, Hoffman et al. (2002) demonstrated some major differences between using regular radiography and CT scans. CT scans helped the researchers differentiate between organs and embalming/packing materials inside the bodies as the density, location, and simply the appearance of these materials became apparent after being obscured by conventional radiography. CT scans overcome the primary limitation of radiography as perceiving the depth at which any internal structures lay is extremely difficult with conventional x-rays.

On September 27th, 1976, Nakht, a fourteen year old boy who died around 3200 years ago in Egypt, became the first mummy to be CT scanned when his brain was examined at the Hospital of Sick Children in Toronto by researcher Derek Harwood-Nash and his team

(Harwood-Nash, 1979). These image slices (12mm thick) of the brain were informative, however, "no gross pathology was identified" (Harwood-Nash, 1979, 770). In November 1977, Harwood-Nash, with the help of pediatrician and paleopathologist Dr. Peter Lewin, as well as the curator of the Egyptian department at the Royal Ontario Museum, Dr. Nicholas Millet, performed the first whole-body CT scan of a mummy (Harwood-Nash, 1979). This examination was done on the body of a young Theban female from the twenty-second Dynasty named Djemaatesankh, as the CT scanner created images from her head to her hips (Chhem & Brothwell, 2008). Among other findings, these early scans helped the researchers recognize the presence of many packing materials (for example wax, mud and linen) deliberately placed inside the body as well as the clear presence of amulets (Harwood-Nash, 1979). In the time since these examinations were done, many researchers have recognized the value of CT scans in their anthropological and archaeological research. These pioneers are responsible for proving the value and efficacy of CT scanning in an archaeological setting and of course, the study of ancient Egyptian mummies.

2.5: Literature Review: Reflexivity in Bioarchaeology & Mummy Studies

2.5.1 Theoretical Framework & Interdisciplinarity

The theoretical framework I employ is the biocultural approach (Martin, Harrod & Pérez, 2013). This can be characterized by the "linking of demographic, biological, and cultural processes within an ecological framework" (Martin, Harrod & Pérez, 2013, 10). This approach has been instrumental in exploring the effects of social stratification and differential access to resources at both the population and the individual level (Martin, Harrod & Pérez, 2013, 10). This framework encourages "a multidimensional approach" (Martin, Harrod & Pérez, 2013, 10) that promotes collaboration across disciplines in an effort to link both biological and sociocultural philosophies.

A focus on population-level studies has traditionally been associated with processual archaeology, while a focus on the individual and an understanding of their identity has been associated with the research interests of post-processual archaeologists and forensic anthropologists (albeit for quite different reason). Martin, Harrod and Pérez (2013) have used the biocultural approach in their examination of stress and show how this framework factors in both individual physiological stressors as well as their impact on the population. Both affect one another and should be given similar attention. The biocultural approach then, is an amalgamation of these archaeological paradigms as the individual, as well as the entire population, are both considered in this reflexive integration of processual and postprocessual archaeology. To be reflexive, in my opinion, is to understand and then approach a situation holistically, recognizing the value different parts have in creating the whole. Reflexivity then, goes hand-in-hand with interdisciplinarity, and the biocultural framework.

In addition to my biocultural framework, I am also an avid proponent of interdisciplinarity. Although often considered a "terminological quagmire" (Choi & Pak, 2006, 352), the definition that resonates most with me is "the ability to analyze, synthesize and harmonize links between disciplines into a coordinated and coherent whole (Choi & Pak, 2006, 354). For a holistic and accurate analysis of CT scans, "close collaboration between clinical radiologists, medical imaging scientists, anatomists, pathologists, and bioanthropologists... [forming] a very strong interdisciplinary approach" (Chhem & Brothwell, 2008, 2), makes for best practice.

2.5.2 Ethical Considerations & Modern Bioarchaeology

Bioarchaeology is a discipline well-situated to address the many complexities involved in assessing ancient Egyptian social stratification as observed through ancient human remains as it serves to bridge the gap between the biological and social sciences (Larsen, 2006; Knudson & Stajanowski, 2008). Ethical considerations should be at the forefront of any bioarchaeological research. In addition to promoting interdisciplinarity, the use of CT scans within my research also reflects the ethical framework I work with, as it encourages the preservation and proper care of ancient individuals.

Many technological developments have afforded bioarchaeologists with "increasingly sophisticated tools with which to address questions about past populations" (Knudson & Stajonowski, 2008, 415). In the last 20 years, Bioarchaeology has placed a greater emphasis on being a more ethical and reflexive discipline (Kaufmann & Rühli, 2010; DeWitte, 2015). In the past, researchers rarely took a moment to reflect on how individuals wanted to be remembered and whether or not our modern assessments are accurately indicative of their life history (Meskell, 2003; Meskell, 2008). As a researcher utilizing the biocultural approach as a theoretical framework, these are all considerations that are vital to my research, and ultimately, my ethical framework.

While there is still no single official code of ethics to which one must adhere, many researchers and professional societies have tried to propose organized standards (Lonfat, Kaufmann & Rühli, 2015). Additionally, these same researchers have posited that the concept of "do no harm" (both physical and towards personal identity) should be extended to the deceased (Lonfat, Kaufmann & Rühli, 2015), a concept with which I agree. Furthermore, I have accepted the code of ethics proposed by the World Archaeological Congress in 1989, "The Vermillion Accords" (World Archaeological Congress, 1989). These proposed standards emphasise respect for the dead, and for descendant communities as well as the scientific community. This well-rounded and reflexive ethical ideology is one I have, and will continue, to abide by.

Chapter 3:

Methods & Materials

This chapter outlines the materials and methods utilized in the following examination of sixty-one ancient Egyptian mummified individuals. Variability in non-royal mummification within this sample was assessed through direct observation of CT scans and x-rays, in conjunction with the information collected on mummification from pre-existing datasets (see Chapter 2.3). The datasets for these individuals have been digitally archived in the IMPACT radiological mummy database housed at the University of Western Ontario (Nelson & Wade, 2015). This examination focuses on the varying features of Egyptian mummification across different time periods, emphasizing those features with clear ties to social stratification. Following the mummification feature "checklist" presented in Chapter 2.3, the mummified remains were evaluated for arm positioning, the appearance of foreign objects within the wrappings and/or body (i.e. precious amulets, votives, *ushabtis*…), excerebration and treatment with cranial resin, and estimated stature.

3.1 The IMPACT Radiological Mummy Database

The IMPACT radiological and context database has been my primary resource in terms of materials as it has granted me access to a large sample of non-royal ancient Egyptian mummies. This research will utilize both the radiological database, which contains the radiographic data for these individuals, as well as the contextual database, which contains all available pertinent information on each individual.

The IMPACT radiological database contains datasets for ~one-hundred and fifty mummified humans and animals, most of which are Egyptian in origin. As these scanned individuals were primarily non-royal adults, many were eligible for this sample. This particular thesis sample is predominantly composed of individuals who lived in post-New Kingdom Egypt, with only two mummies dating to the New Kingdom. This creates a range of around two-thousand years. With the democratization of mummification occurring during the New Kingdom (Aufderheide, 2003), having a sample with most individuals coming from after this shift, is beneficial for the examination of variability amongst non-royals.

The radiographic data found within IMPACT includes both x-rays and CT scans, however, the latter make up the majority. The standard image format in the medical imagining industry is DICOM-Digital Imagining and Communication in Medicine (Beckett & Conlogue, 2021). These DICOM images are stored within a master database (PACS), on a server entitled "*Anubis*". The primary method for accessing these has been by using a powerful computer, known as "*The Tomb",* located in the Bioarchaeology Imagining Lab at the University of Western Ontario. The strong processor with 32GB of RAM and the NVIDIA GTX Titan-X graphics card with 12GB of RAM are necessary to process IMPACT's many files and to run the software packages needed to view and process these DICOM images.

3.2 ORS & Dragonfly 4.1

The software packages utilized in this research for both viewing and manipulating the datasets of DICOM images were *Dragonfly 4.1 and* ORS Visual^{SI}, both created by Object Research Systems Inc. (https://www.theobjects.com/dragonfly/). These programs let users examine the biological and natural aspects of mummification, as well as the cultural and anthropogenic aspects, all in a non-destructive and non-invasive manner. With *Dragonfly 4.1* and ORS Visual^{SI}, mummies can be "unwrapped" digitally in a virtual space, allowing for the final wish of these once living individuals, the wish for eternal preservation, to be respected.

These applications produce accurate 3D reconstructions of these individuals from the CT scans that can be viewed in different layers based on density. This allows users to go from the outside of a mummy's wrappings (and even their coffin if that was also scanned) to even the smallest of bones in their examinations. Direct observations done while using these applications have made it possible to analyse mummified individuals remotely and non-destructively.

3.3 Sample Selection

As of April 2020, IMPACT contains the digital remains of one-hundred and twenty-eight human ancient Egyptians. In addition to being considered non-royal, there were three remaining criteria for inclusion within this study. The first of these was age as focusing the study on adult individuals eliminated potentially confounding effects of differential mortuary treatment. For example, during the Late Period, children were not eviscerated in almost every instance (for unknown reasons) while most adults were eviscerated (Aufderheide, 2003). After removing infants and subadults from the sample, we are left with eighty-two adult individuals.

The second criterion for the sample is more practical than demographic in nature and is based on the completeness and accessibility of the x-rays and CT scans. As IMPACT is dependant on the voluntary submission of radiographic data from researchers and institutions around the world, varying quality in the data submitted is an inherent limitation. Even though CT scans were preferred, plain x-ray images were also utilized to maximize the sample. Unfortunately, there were a handful of datasets that had mostly incomplete scans, corrupted files, or some other technical issue preventing them from being included in the sample.

In this sample, there are thirty individuals whose CT scans were assessed, with an additional twenty-six datasets of plain x-rays. Five datasets are represented by the modalities of both CT scans and plain x-rays. To properly assess all features, looking for commonalities, contradictions, and any sort of correlation with status, having a full body to assess is ideal. For this reason, mostly incomplete scans were removed from the sample. These include scans missing significant portions of the body, the entirety of the head, or scans that were solely of the head. Scans missing minor portions of the overall body, such as a hand, or feet, were kept in the sample and the issue was noted. In some cases, however, datasets remained in the sample because although their CT scan information was incomplete, enough x-rays remained to accurately assess most of the body. Additionally, in some instances, enough credible contextual information was available to assess certain areas of the body that were not available via x-ray or CT scan.

This sample is not meant to be representative of any specific 'living' population as there is a wide geographic and temporal range of ancient Egyptians included. Additionally, as there are not many examples of gender-specific features, besides arm positioning in the New Kingdom (Hawass & Saleem, 2016), it was not deemed necessary to test specifically for the association between biological sex and gendered practices. However, to be thorough, biological sex was evaluated and used while testing for association with status.

With these conditions, this thesis sample becomes sixty-one (N=61) and is summarised in Table 3.1 below:

Table 3.1: Sample Used in this Study

IMP Number	Name & Sex	Age	Institution	Period	Site/ Findspot	Modality
IMP00001	Pisa 1 (M)	25-35	Pisa University	Unknown	Unknown	CT Scan
IMP00002	Nefer Mut (F)	25-29	Royal Ontario Museum	Third Intermediate Period	Deir el-Bahari	CT Scan
IMP00005	Djedmaatesankh (F)	30-35	Royal Ontario Museum	Third Intermediate Period	Thebes	CT Scan
IMP00006	Lady Hudson (F)	34-50	Western University	Roman Period	Unknown	CT Scan
IMP00007	Pa-Ib (F)	30-34	Barnum Museum (Connecticut)	Late Period	Unknown	CT Scan
IMP00008	Sulman Mummy (F)	30	Chatham-Kent Museum	Ptolemaic Period	Unknown	CT Scan
IMP00009	Hetep-Bastet (F)	40+	UQUAM (Montreal)	Late Period	Unknown	CT Scan
IMP00010	RM2717 (F)	30-50	Redpath Museum (Montreal)	Roman Period	Thebes	CT Scan
IMP00011	RM2718 (M)	20-25	Redpath Museum (Montreal)	Ptolemaic Period	Thebes	CT Scan
IMP00012	RM2720 (F)	18-24	Redpath Museum (Montreal)	Roman Period	Hawara el-Maktaa	CT Scan
IMP00027	Genova 1 Female (F)	40-50	Civic Museum of Ligurian Archaeology (Genoa)	Unknown	Unknown	X-Ray
IMP00028	Genova 2 Male (M)	40-59	Civic Museum of Ligurian Archaeology (Genoa)	Unknown	Unknown	X-Ray
IMP00029	Pasherienaset (M)	25-30	Civic Museum of Ligurian Archaeology (Genoa)	Late Period	Nag el-Hassaia	X-Ray
IMP00035	Euphemia (F)	40+	Brussels Royal Museum	Roman Period	Antinoe	X-Ray
IMP00040	Toutou (M)	35-40	Brussels Royal Museum	Ptolemaic Period	Abydos	X-Ray
IMP00043	Female Mummy (F)	Adult	Brussels Royal Museum	Third Intermediate Period	Thebes	X-Ray

IMP00044	Female Mummy (F)	30-40	Brussels Royal Museum	Third Intermediate Period	Unknown	X-Ray
IMP00057	Padua Mummy (M)	30-35	University Museums of Padua	Ptolemaic Period	Unknown	CT Scan/X-Ray
IMP00058	Liverpool 1 (F)	Adult	World Museum Liverpool	Roman Period	Unknown	X-Ray
IMP00059	Liverpool 2 (F)	19	World Museum Liverpool	Roman Period	Unknown	X-Ray
IMP00060	Pedeamun (M)	Adult	World Museum Liverpool	Late Period	Thebes	X-Ray
IMP00061	Liverpool 4 (M)	Over 50	World Museum Liverpool	Late Period	Unknown	X-Ray
IMP00062	Liverpool 5 (F)	Over 50	World Museum Liverpool	Late Period	Unknown	X-Ray
IMP00063	Liverpool 6 (F)	Over 50	World Museum Liverpool	Late Period	Unknown	X-Ray
IMP00065	Harwennefer (M)	Adult	World Museum Liverpool	Ptolemaic Period	Abydos	X-Ray
IMP00066	Tetkhonsefankh (F)	Adult	World Museum Liverpool	Third Intermediate Period	Unknown	X-Ray
IMP00067	Liverpool 10 (M)	Adult	World Museum Liverpool	Late Period	Unknown	X-Ray
IMP00068	Liverpool 11 (M)	Over 50	World Museum Liverpool	Unknown	Unknown	X-Ray
IMP00070	Liverpool 13 (M)	Adult	World Museum Liverpool	Ptolemaic Period	Unknown	X-Ray
IMP00071	Mummy of Nesmin (M)	Adult	World Museum Liverpool	Ptolemaic Period	Akhmim	X-Ray
IMP00072	Liverpool 15 (M)	Adult	World Museum Liverpool	Late Period	Unknown	X-Ray
IMP00073	Ta-Enty (F)	Adult	World Museum Liverpool	Late Period	Kostamneh	X-Ray
IMP00078	Renpit-Nefert (F)	35-40	South Australia Museum	Late Period	Thebes	CT Scan/X-Ray
IMP00079	George (M)	25-30	South Australia Museum	Ptolemaic Period	Awarm	CT Scan/X-Ray
IMP00081	Nofret (F)	40-50	Kulturhistorisk Museum Oslo	Ptolemaic Period	Akhmim	CT Scan/X-Ray
IMP00082	Bahka (F)	20	Museum of World Treasures (Kansas)	New Kingdom	Thebes	CT Scan
IMP00083	Braided Lady (F)	25-29	Museum of World Treasures (Kansas)	New Kingdom	Unknown	CT Scan
IMP00088	Nesmutaatneru (F)	Over 50	Boston Museum of Fine Arts	Late Period	Thebes	X-Ray
IMP00092	Nesi-Hensu (F)	30-40	Archaeological Museum Zagreb (Croatia)	Late Period	Unknown	CT Scan

IMP00093	Tash Pen Khonsu (F)	Around 25	Canterbury Museum (New Zealand)	Ptolemaic Period	Akhmim	X-Ray
IMP00094	Mummy of a Man (M)	30-44	Leiden University (Netherlands)	Third Intermediate Period	Thebes	CT Scan
IMP00095	Mummy of a Woman (F)	52-60	Leiden University (Netherlands)	Third Intermediate Period	Thebes	CT Scan
IMP00096	Khonsuemma'a (Kherut) (M)	30-44	Leiden University (Netherlands)	Third Intermediate Period	Thebes	CT Scan
IMP00097	Mummy of a Woman (F)	40-52	Leiden University (Netherlands)	Third Intermediate Period	Thebes	CT Scan
IMP00098	Tadis or Ta(net)kharu (F)	52-60	Leiden University (Netherlands)	Third Intermediate Period	Thebes	CT Scan
IMP00099	Tadis or Ta(net)kharu (F)	40-52	Leiden University (Netherlands)	Third Intermediate Period	Thebes	CT Scan/X-Ray
IMP00101	Mummy of a Man (M)	44-55	Leiden University (Netherlands)	Third Intermediate Period	Thebes	CT Scan
IMP00103	Hor (M)	22-44	Leiden University (Netherlands)	Late Period	Thebes	CT Scan
IMP00104	Harerem (M)	45-55	Leiden University (Netherlands)	Late Period	Thebes	CT Scan
IMP00107	Kek (F)	21-24	Leiden University (Netherlands)	Late Period	Thebes	CT Scan
IMP00108	Inamonnefnebu (M)	22-44	Leiden University (Netherlands)	Late Period	Thebes	CT Scan
IMP00109	Peftjauneith (M)	22-44	Leiden University (Netherlands)	Late Period	Unknown	CT Scan
IMP00111	Mummy of a Man (M)	22-40	Leiden University (Netherlands)	Third Intermediate Period	Thebes	CT Scan
IMP00112	Diptah (F)	52-70	Leiden University (Netherlands)	Ptolemaic Period	Akhmim	CT Scan
IMP00113	Hor (M)	21-22	Leiden University (Netherlands)	Ptolemaic Period	Akhmim	CT Scan
IMP00122	Herakleides (M)	20-25	JP Getty Museum (California)	Roman Period	Unknown	CT Scan
IMP00123	Thesaberu (F)	24-30	Marischal Museum (Scotland)	Ptolemaic Period	Akhmim	X-Ray

IMP00125	Lady Ta Khar (F)	Adult	Marischal Museum (Scotland)	Ptolemaic Period	Thebes	X-Ray
IMP00126	Ti-Ameny Net (F)	30	University of Richmond	Late Period	Thebes	X-Ray
IMP00127	Nesiur (F)	18-22	Boonshoft Museum of Discovery (Dayton, OH)	Third Intermediate Period	Thebes	CT Scan
IMP00128	Ta-Kush (F)	Around 25	Maidstone Museum (England)	Late Period	Unknown	CT Scan

3.4 Sample Categorization

Traditionally, sample populations in bioarchaeological investigations are organized by gender and age. Additionally, the geographical provenience of these mummies, probably one of the hardest aspects to determine if it was not recorded while the body was *in situ*, will also be considered. However, although these factors will be given attention, the primary categorization for this sample will be time period. This factor will be the most telling in assessing and determining the extent of variability after the democratization of mummification because we can temporally assess the evolution and appearance of features. As mentioned above, this sample is composed of mummified individuals whose datasets have been shared by professionals from different institutions, scanned at different points in time, with different scanning protocols followed. As a result, scan quality and consistency, as well as the information they provide, cannot be controlled. The names of these mummies were provided by the institutions and professionals who shared their scans. In most cases, demographic information was provided by the institution of origin or the work of previous graduate students working with the IMPACT database (cf. Wade, 2012; Tennant, 2015). Age and sex estimates were confirmed or adjusted wherever necessary using the osteological standards set by Buikstra and Ubelaker (1994).

Age should not play a significant factor in this research as subadults were removed from my sample as to only examine adult individuals. The ages in this sample range considerably, but for the purpose of this chapter, I will use the estimated minimum age for each individual. There are twenty individuals with a minimum age of around 18-30 (N=20; 32.8%), there are twelve individuals aged 30-40 (N=12; 19.7%), ten who are around 40-50 (N=10; 16.4%), and seven individuals aged 50 and over (N=7; 11.4%). Additionally, twelve individuals (N=12; 19.7%), ten of which are x-ray datasets coming from the Liverpool World Museum collection, are confirmed adults but have no confirmed or confident age-range.

Biological sex was also recorded for this sample and the distribution of males to females is twenty-four (N=24, 39.3%) to thirty-seven (N=37; 60.7%). It should be noted, however, that this study recognizes recent trends in bioarchaeological studies which highlight the potential for obscuring data when solely using the discrete sex categories of male and female in understanding past social identities (Agarwal, 2012). Trends involving biological sex and mummification traits will be evaluated, but will not be the sole, or primary, category of focus.

The geographic location where these individuals were found, or the findspot, is perhaps one of the hardest aspects to uncover if it was not recorded after the body's initial discovery. Contextual information on Egyptian mummies is seldom complete, and unfortunately, tomb-robbing, poor data collection standards, the re-use of tombs, and the commercialisation and sales of mummified individuals during the nineteenth and twentieth centuries, has complicated this process (Shaw, 2000; Bard, 2005). Twenty-four individuals in this sample have no known provenience (N=24; 39.3%), twenty-three were found at Thebes (N=23; 37.7%), six mummies are from the site of Akhmim (N=6; 9.8%), two from Abydos (N=2; 3.3%), one from Antinoe (N=1; 1.65%), one from Awarm, Nubia (N=1; 1.65%), one from Deir el Bahari (N=1; 1.65%), one from Hawara el-Maktaa (N=1; 1.65%), one from Kostamneh, Nubia (N=1; 1.65%), and finally, one from Nag el-Hassaia (N=1; 1.65%). Burials from Thebes make up the majority of those with known provenience (N=23; 62.1%).

Dates for the individuals in this sample cover a range of around two thousand years and include five different cultural periods. Beginning with the New Kingdom, the period where the democratization of mummification occurred (Aufderheide, 2003), until the Roman occupation of Egypt, which eventually signified the end of 'ancient Egypt' and the practice of mummification (Shaw, 2000; Bard, 2005; Bard, 2015), this sample covers a vital point in Egyptian history in terms of mummification variability. Fortunately, fifty-seven individuals in this sample had an available time period estimate (N=57; 93.4 %). In order from earliest to most recent, this sample has two mummies from the New Kingdom (N=2; 3.3%), thirteen mummies from the Third Intermediate Period (N=13; 21.3%), twenty-one from the Late Period (N=21; 34.4%), fourteen individuals from the Ptolemaic Period (N= 14; 23%), and seven from the Roman Period (N=7; 11.5%). Only four individuals lack information regarding their time period (N=4; 6.5%).

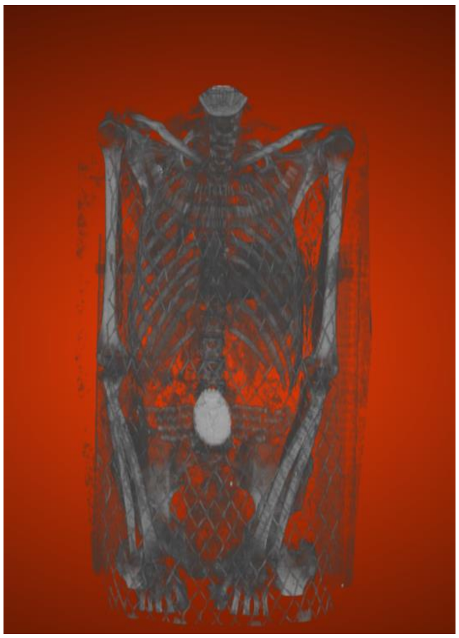
3.5 Mummy Assessments: Using ORS & Dragonfly

By utilising the ORS Visual[si] and *Dragonfly* 4.1 software packages, these mummies were analyzed and assessed in a non-destructive manner while focusing on the following four mummification features: arm position, amulets, cranial resin and estimated stature. These four features are by no means the only ones that can be linked to status, but they are the most predominant in the literature (see literature review section 2.3)

3.5.1 Arm Positioning

Arm positioning is a feature that changed many times throughout ancient Egypt and although there was often a standard associated with specific time periods, variability was always present. Even some of the earliest Old Kingdom mummies show variation in arm position as there are examples of individuals who did not adhere to the period's standard of having the arms placed alongside the body (Aufderheide, 2003). To aid in the assessments, the works of Gray (1972), Aufderheide (2003), Elias, Lupton, & Klales, 2014; Loynes (2015) and Hawass & Saleem (2016) have been helpful (and have proven that variability in arm positioning persisted in all cultural periods). These newer publications also re-iterate, and confirm, early assertions made by Grafton Elliot Smith (1912) regarding the royal arm position that existed prior to the 21st Dynasty, as the "posture of crossed arms had early associations with kingship" (Elias, Lupton, & Klales, 2014, 55).

Fortunately, these software packages make assessing arm position simple with the 'window and levelling' function, a "method to vary the contrast and density of the image displayed" (Beckett & Conlogue, 2021, 132). 'Window and levelling' allows the researcher to manipulate the object or specimen in question on the basis of the Hounsfield Units (HU), the quantitative scale used to represent the radiodensity, with the window representing the HU range of everything in the scan, while the level represents the mid-point of that range (Beckett & Conlogue, 2021; Beckett, Conlogue, & Nelson, 2021). Using this tool, the wrappings and soft tissue were removed, revealing the position in which the bones of their arms and hands were placed. For example, Figure 3.1 shows Hor (IMP00103), a male from the Late Period, whose arms are slightly flexed inwards to have the hands resting on the pelvis, while Figure 3.2 shows Bahka (IMP00082), a New Kingdom female, whose arms have been positioned straight down. For the purpose of classification and organization, the same coding system used by Robert Loynes (2015) was employed where F = Flexed Across Chest, EL = Extended Lateral, and EA = Extended Anterior.



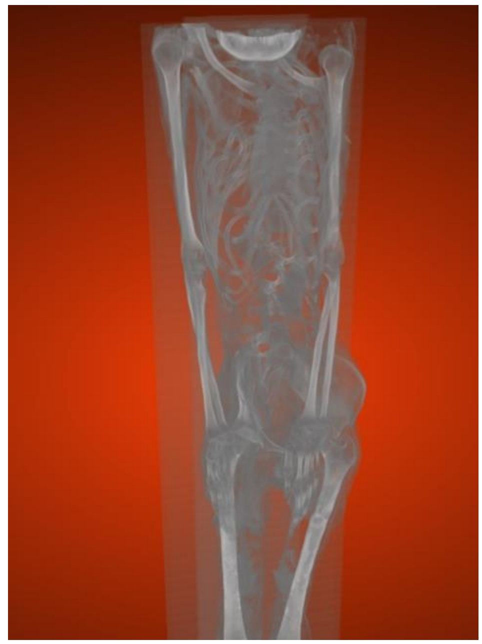


Figure 3.1 **(Left) 'Hor' (IMP00103) Extended Anterior Arm Position**
Figure 3.2 **'Bahka' (IMP00082) (Right) Extended Lateral Arm Position**

3.5.2 Amulets

Similar to arm positioning, the appearance of amulets or foreign objects, especially larger and more lavish pieces, can be found with some simple 'window and levelling' and digital unwrapping. One can be seen in Figure 3.1, as Hor has one of the more popular and common amuletic adornments across any time period in ancient Egypt on the outside of his burial shroud; a scarab with outstretched wings symbolizing renewal and rebirth. Amulets are one of the oldest features associated with mummification (Andrews, 2004) and by the New Kingdom, royal mummies demonstrate a large increase in quantity and types (Hawass & Saleem, 2016). For example, King Tutankhamun, had 143 objects scattered throughout his wrappings (Hawass &

Saleem, 2016). As could be expected after the democratization of mummification, the Third Intermediate Period saw a proliferation of amulets (Hawass & Saleem, 2016). However, due to the long connection between royals and amulets, as well as the inherent lavishness of having items made of metal or stone placed within the wrappings and body by embalmers, the appearance of amulets and other foreign objects in the body has been given special attention.

Figure 3.3 **Djedmaatesankh's (IMP00005) Chest Amulet**

The first amulet found in this sample was in Djedmaatesankh (IMP00005), a Third Intermediate Period female (Figure 3.3), who has what appears to be a bird, probably a vulture, with outstretched wings, on her midsection, while the oval-shaped bottom portion is a scarab (Jack, 1995). By using a 'look up table'(LUT) in *Dragonfly,* the amulet was not only visualized, but also confirmed to be of high attenuation, or, density (Figure 3.4). Essentially, LUT's are predefined colour maps used to make subtle changes (in this case, in attenuation) more visible (Russ & Neal, 2016). Arrows have also been added to Figure 3.4 for those not viewing this document in full colour. Furthermore, by using the 'probe' function, I was able to see that this amulet had a peak HU of 3071, which is the maximum possible value on the HU scale, confirming that the material was likely metallic (Gostner et al., 2012). This process is how all amulets in the sample were assessed.

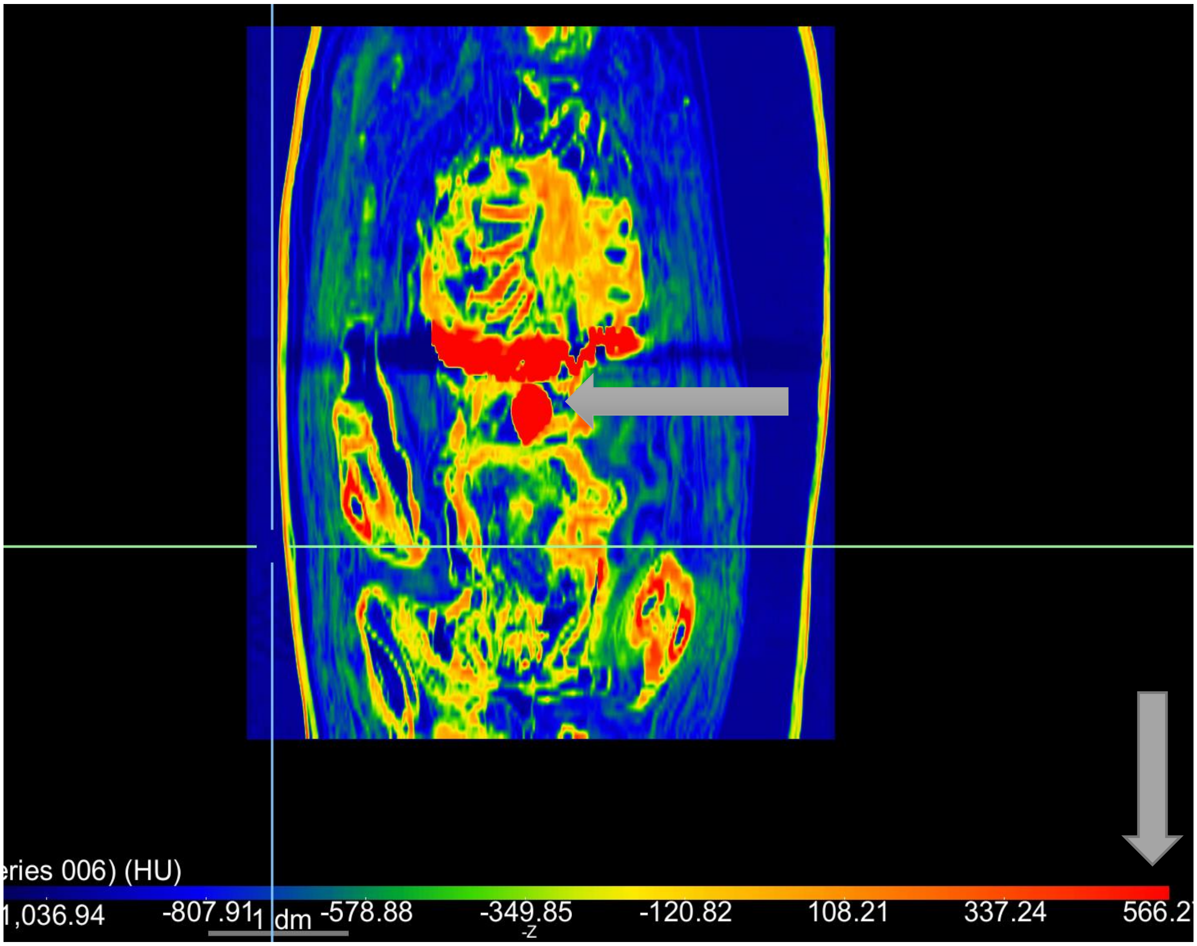


Figure 3.4 **Density of Djedmaatesankh's (IMP00005) Amulet**

Classifying and coding amulets can be difficult as many aspects can and should be considered, such as size, placement, material used, the iconography, and even the number of amulets found. For the purpose of this thesis a scale of 0-3 was established to code the levels of amulets and their apparent lavishness, according to ethnohistoric context, was used. On this scale, a 0 indicates no amulets or foreign objects of note within the body or wrappings, while 1-3 on the scale denotes the size, type and/or amount found with a "3" being the most lavish in the sample. More specifically, a "1" is used for mummies who have very clear evidence of amulets that are no longer apparent (either from being removed and/or stolen, as can be seem through interruptions in the wrappings or traces of missing gilded items (Gray & Slow, 1968; Lawson, 2016)). It should be noted that missing amulets are quite common in Egyptian mummies, so those labelled "1" have clear and irrefutable evidence of amulets once being included in their body/wrappings. No assumptions have been made regarding those missing amulets without clear evidence for their removal. A “2” on the scale represents individuals containing less than five amulets (e.g. Djedmaatesankh), and a “3” for five or more amulets inside the wrappings and body.

3.5.3 Excerebration and Cranial Resin

ORS and *Dragonfly* also allow the scans to be manipulated in a variety of ways to determine whether an individual was excerebrated, and if so, if they were subsequently treated with cranial resin. Having a lateral or sagittal view of the skull is one of the best ways to answer this question because not only is hardened resin easily visible, moving through the different slices will show whether or not there are perforations in the cribriform plate or damage to the ethmoid bone, both clear indicators of a transnasal craniotomy, which was the most prevalent excerebration method.

Lady Hudson (IMP00006), the resident mummy at the University of Western Ontario (Nelson & Kogon, 2021), provides a great example of cranial resin in an Egyptian mummy. In Figure 3.5, the arrow on the right points to a uniform density at the back of the skull; the hardened resin. This density is similar to where the other two arrows are pointing in Figure 3.5, however, that is because the nasal tampon (top left) and linen packing (bottom left) were also both treated with resin. This figure also shows that there is a clear passage to the cranial vault from the nose, indicative of a transnasal craniotomy.

Determining whether a substance in the skull is resin, residual brain matter, or something else, is of great importance. Generally, a uniform layer like the one in Lady Hudson is indicative of hardened resin, however, to ensure that was the case, its attenuation was also tested. In radiographic images, bone is dense, so appears bright, while air, which is not dense, appears black. In terms of Hounsfield Units (HU), resin is often measured around 71 HU (Gostner et al., 2012). Using the “probe” function in *Dragonfly,* Lady Hudson’s cranial resin ranged from 53-78 HU.

Unfortunately, lateral images or slices were not available for some of the mummies making it harder to assess excerebration and cranial resin. In these instances, antero-posterior x-rays of the skull were examined carefully for evidence of damage to the cribriform plate.

Additionally, in some of these images, the sutures of the back of the skull were visible from the front (Figure 3.6). Having an unimpeded view of these sutures allowed for the determination that there were no objects, resin or brain, obstructing this view.

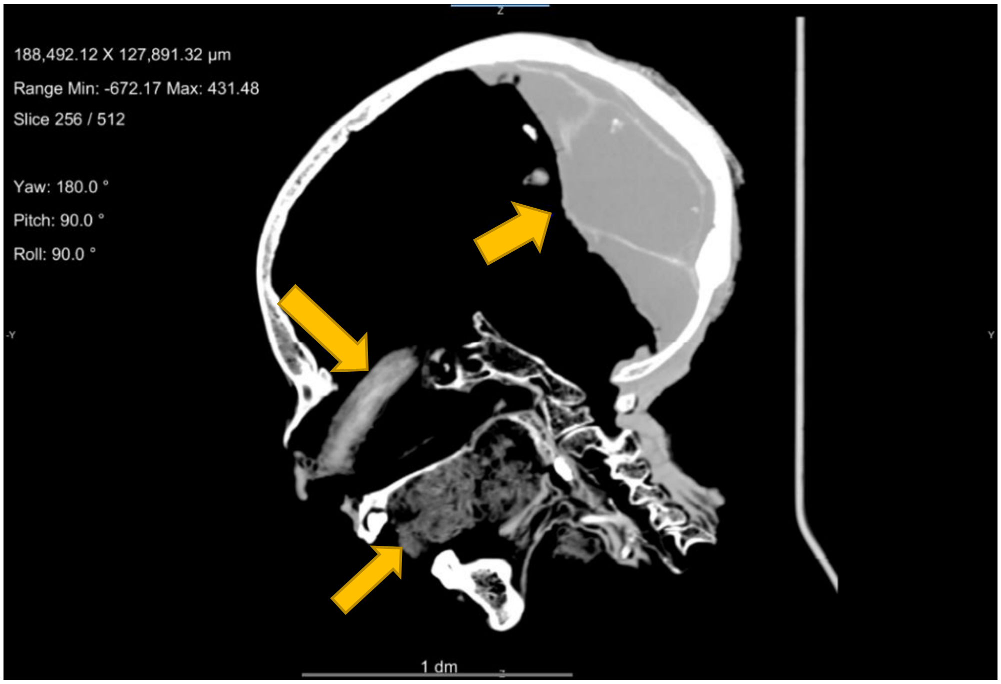


Figure 3.5 **View of Lady Hudson's Cranial Resin (IMP00006)**

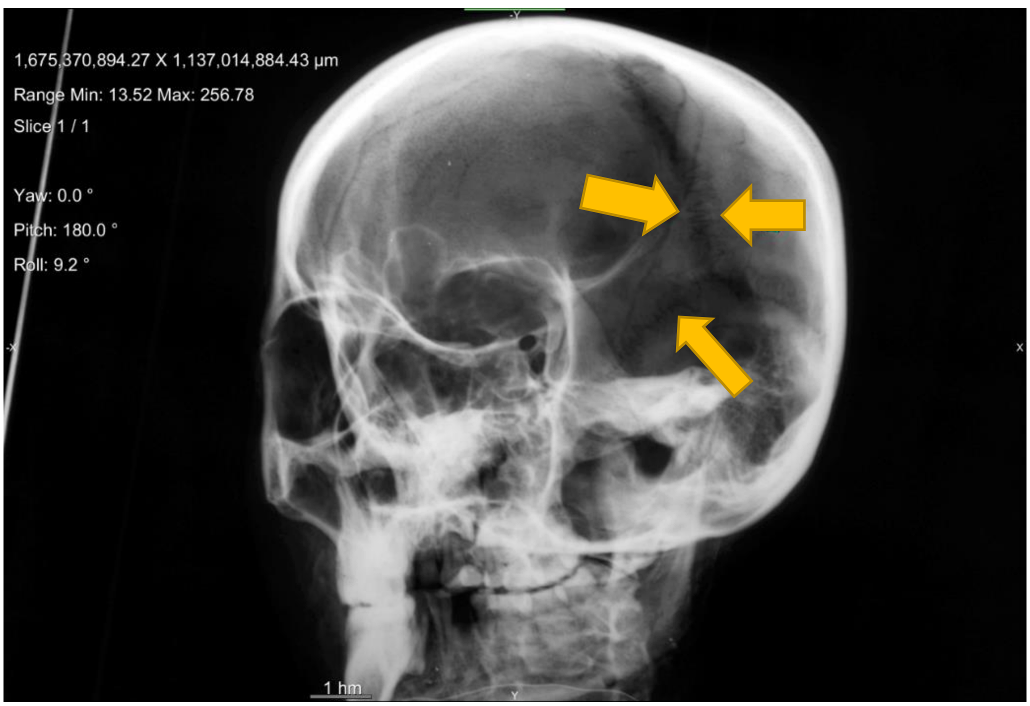


Figure 3.6 **Visible Sutures and Lack of Observed Resin Mass in the X-Ray of the Skull of "Liverpool 1" (IMP00058)**

In terms of scoring excerebration and cranial resin, a scale of 0-2 was utilised. A score of "N/A" was given to individuals whose cranial treatment could not be confidently assessed and scored. A "0" on the scale represents individuals who were not excerebrated, a "1" was given to individuals who had their brain removed with no subsequent treatment, and finally, a "2" was used to signify those who were excerebrated and then treated with cranial resin.

3.5.4 Estimated Stature

The final mummification feature given special attention for its link to social status, estimated stature (see literature review, section 2.3), was also assessed by working with and manipulating the scans, in addition to using the ruler function in Dragonfly and ORS (Figure 3.7). By manipulating the slices and adjusting the angles orthogonally, I was able to get clear images of the necessary long bones and acquired both the maximum and when required, the bicondylar lengths. The primary goal here was to digitally recreate how these measurements would be obtained using an actual osteometric board. Additionally, by using the "slab view" function (viewing a series of contiguous slices (the slab) through an average intensity projection) (following Spake et al., 2020), I was able to obtain, in most instances, clear images of the long bones. Long bone lengths were measured as first described by Martin (1928) and will be indicated by their "M" number. These lengths include both the maximum (M1) (Figure 3.8) and bicondylar lengths of the femur M2 (Figure 3.9), the true maximum length of the tibia (M1a) (Figure 3.10), the tibial length to the lateral condyle (M1b) (Figure 3.10), the maximum length of the humerus (M1) (Figure 3.11), and the maximum length of the radius (M1) (Figure 3.12). Having all six measurements was ideal, although stature could still be estimated as long as one of the six measurements was obtainable. It should be noted that Zakrzewski (2003) also obtained a measurement for the ulna, however, Raxter et al. (2008) did not, and because I am using their revised method for estimating stature, I used the same six measurements they did.

This thesis utilised the regression formula for estimating stature presented by Raxter et al. (2006; 2008). These researchers, who first offered a revision of the 'Fully Technique' (Raxter et al., 2006), an anatomical method for estimating stature, used this new revised method on a sample of 100 ancient Egyptian individuals to acquire stature, creating a new regression formula (Raxter et al., 2008).

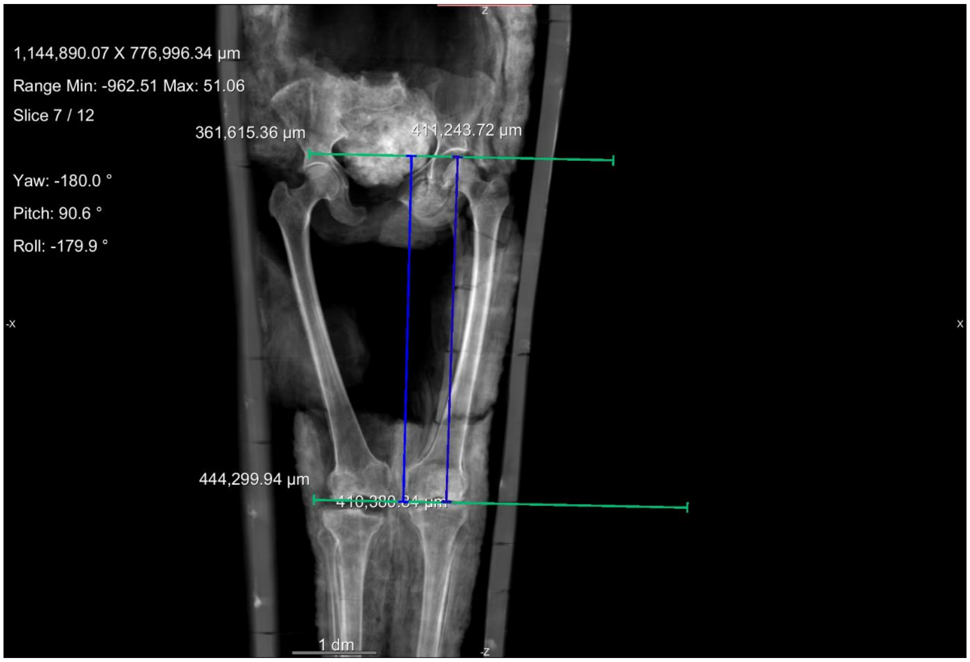
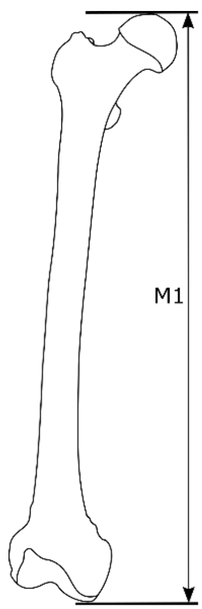


***Figure 3.7*. Using digital ruler to measure Lady Hudson's Femur (M1 & M2)**



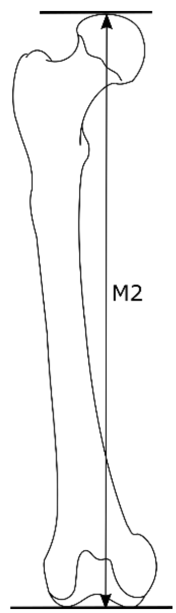
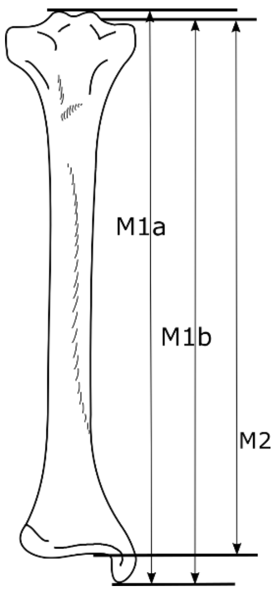
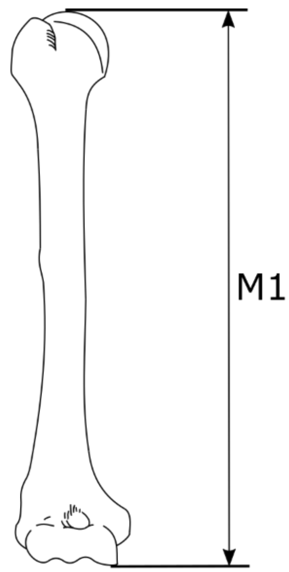


***Figure 3.8* Femur Maximum Length M1** ***Figure 3.9.* Femur Bicondylar Length M2**





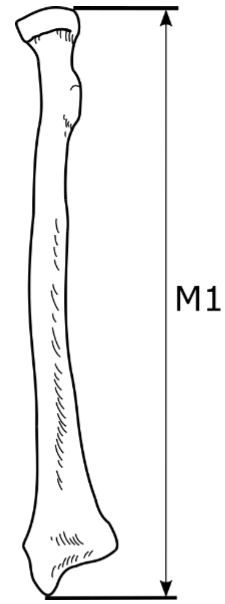


Figure 3.10 **(Left) Tibial Lengths (M1a Maximum Tibia Length + M1b Tibial Length to Lateral Condyle)**

Figure 3.11 **(Center) Humerus Maximum Length**

Figure 3.12 **(Right) Radius Maximum Length**

Credit for Figures 3.8-3.12: Joanna Motley

Raxter et al. (2008) include an extra step in their stature estimation formula to adjust for the age of individuals. I have chosen not to follow this extra step because even though my sample consists solely of adults, the age estimations within my sample are very broad for some and quite narrow for others. To avoid any potential issues with this particular aspect of my research, the entire sample will be treated as simply "adults", removing the extra step for age.

Estimated statures acquired in this sample will be compared to a royal ancient Egyptian sample (Hawass & Saleem, 2016). The Mann-Whitney test will be used to test whether the samples differ significantly from one another using a .05 p-value (Shennan, 1988). As these data are likely not normally distributed, the non-parametric Mann-Whitney U test is preferable to a regular t-test. Estimated statures will be entered into a Mann-Whitney U test calculator (https://www.socscistatistics.com/tests/mannwhitney/default2.aspx) to acquire critical values, which will be used to determine whether the differences in statures are significant. Additionally, *Z*-scores (or standard scores), will be used to assess how much the tallest male and female individuals deviate from the sex specific means of the royal and non royal samples. *Z*-scores are calculated by reconfiguring the data such that the mean is zero and data points are converted to the standard deviation units from 0 (Shennan, 1988; Drennan, 1996). Data points that lie more than 2 *Z*-scores from the mean are considered to be unusual and will therefore require some discussion.

The estimated stature of individuals in this sample will also be compared with the sample used by Zakrzewski (2003). It should be noted, however, that Zakrzewski (2003) used a different stature estimation formula (Robins & Shute, 1986). Stature estimates for five males and five females, chosen for the completeness and availability of their bone lengths, will be calculated using both formulas to see whether they were significantly different. The results of this comparison will also be tested using the Mann-Whitney U test. If proven to be similar they will be treated as equivalent. In her study of stature, Zakrzewski (2003) found that there was an overall increase in stature from the early-Dynastic until the Dynastic period, however, the propagation of social rankings would lead to an overall decline in stature as society became more stratified. As this sample begins temporally where that of Zakrzewski (2003) ends, overall stature from each period for both sexes will evaluated to verify whether average height continued to decline in the succeeding periods.

To ensure that my measurements were accurate, I engaged in both intra-observer testing and inter-observer testing with my Masters supervisor, Dr. Andrew J. Nelson. I began with the inter-observer testing as I wanted to make sure I was properly utilizing the ‘ruler’ function within the software packages, as well as guaranteeing I was accurately rotating the planes and keeping the measurements orthogonal. I began taking note of my own measurements on separate occasions to ensure consistency with results. To further test the accuracy of my measurements, and validate the results, the Technical Error of Measurement (TEM) was calculated, which is the standard deviation between repeated measurements (Perini et al. 2005). The equation to calculate TEM is as follows:

$$Absolute\ TEM = \sqrt{\frac{\sum d^2}{2n}}$$

Where: $\sum d2$ = summation of deviations raised to the second power &

n = total number of measurements taken

Even though I am using a sample of sixty-one individuals, I was unfortunately only able to estimate stature for thirty individuals. This was because some CT scan datasets did not allow me to obtain accurate dimensions for any of the six required measurements and all of the datasets that are purely x-rays could not be used because the magnification of the bone on the x-ray image is not known. I did, however, calculate the TEM for all thirty CT scanned individuals, for a total of 131 separate measurements, and obtained a range of 0.035-0.177 cm, or 0.35-1.77mm, with an average TEM of 0.1099 (cm).

In their own study, Colman et al. (2019) tested the accuracy of CT scans for obtaining osteometric measurements in forensic anthropology and determined that anything under 2mm should be considered as an "acceptable error". A 2018 study of using CT scans to obtain femoral measurements in modern Japanese populations left researchers with a TEM range of .499 to 1.078 (Chiba et al., 2018) while Toneva et al. (2016) had a range of .26-.59 in their study using CT scans. Furthermore, Spake et al. (2020), who also used the slab view of long bones to take their measurements, calculated their TEM values for intra-observer testing, and found a range of 0.25-0.66. Spake et al. (2020) also agree that in anthropology, anything below 2mm, is an "acceptable error". With my TEM of 0.35-1.77mm, this study falls well within this range.

3.6 Statistical Analyses

In addition to exploring the validity of classical mummification accounts, I have been concerned with which features of non-royal mummification are related to status and whether there is an association between certain features and time periods. As a result, the data are mostly qualitative in nature or are not normally distributed, calling for non-parametric testing. This limits the type of statistical testing to tests of association and exploratory data mining. Three main statistics were utilized in this project to test for relationships, connections, and contradictions; the chi-square test, the Fisher Exact test and cluster analysis.

3.7 Chi-Square Test & The Fisher Exact Test

The chi-square test is quite common in archaeology for its usefulness and ultimately, it works to bridge "concepts of statistical significance to concepts of the strength of the relationship between variables" (Shennan, 1988, 71). The chi-square statistic evaluates variability by comparing one's observed data versus the expected data given a specific claim. This can either be done within a group, or between two or more groups. The value of this statistic is represented by χ^2. One can find the expected values for specific cells when using a table by multiplying the marginal row and column totals then dividing that by the entire table's total count, obtaining an average, the expected value, for each cell (Drennan, 1996). This data is then compared to the actual observed data to test the goodness of fit.

The formula for the chi-square statistic is represented by the equation below:

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

In this equation, O_i represents the observed value for the *i*th cell of the table, while E_i represents the expected value for the *i*th cell of the table. This newly obtained value for χ^2 is compared to the values in the 'degrees of freedom' table (see Drennan, 1996, p.190) to determine the probability that the deviation (or lack of deviation) present is completely random. This probability becomes the significance (p) value.

The accounts of Herodotus, and to a lesser degree, Diodorus Siculus, are at the root of this project to explore variability in mummification. With both the academic literature and popular culture uncritically adopting their accounts (Buckley & Evershed, 2001; Abdel-Maksoud & El-Amin, 2011; Gessler-Löhr, 2012; Jones et al., 2014), this thesis tests the null hypothesis that the distribution of observed mummification features in this sample follows the Classical accounts of Herodotus and Diodorus. To do this fairly, as Herodotus and Diodorus wrote in the Late Period and Ptolemaic Period respectively, the seven Roman Period mummies in this sample have been removed for this test. It would be unreasonable to expect Herodotus and Diodorus to have been aware of how mummification would evolve in the proceeding periods, therefore, I was left with a sample of fifty-four mummies (N=54). Additionally, for a more precise analysis, I will also be testing the twenty-one Late Period mummies in my sample in a separate examination as they are relatively contemporaneous with Herodotus' accounts.

The lack of synthetic and comparative studies using large samples in mummy studies has been a growing issue in the field (Cox, 2015; Nelson & Wade, 2015), and comparatively, my test sample of fifty-four (N=54) addresses this shortcoming. In terms of statistical analysis however, a sample of fifty-four is small and could challenge the accuracy of the (p) values produced. To combat this, the general rule in statistical archaeology has been to require that no expected value in the chi-sqaure table be less than one and that no more than 20% be less than five (unless there is only one degree of freedom, in which case no category can be less than five) (Shennan, 1988; Drennan, 1996; Drennan, 2009). For that reason, a variant of the chi-square test, the Fisher Exact test, will be used as it tolerates having “0” as an expected value (Drennan, 1996; Drennan, 2009). Rather than a simple chi-square test, which gives an approximation, this test is a direct calculation of the significance probability and favors smaller sample sizes (Drennan, 1996; Drennan, 2009). With my null hypothesis being that the distribution of observed mummification features follows the Classical accounts of Herodotus and Diodorus, it is expected that zero individuals will demonstrate features outside ancient descriptions, meaning a value of “0” is expected for those designated “NO”, while the rest should be designated as “YES”.

The formula for the Fisher Exact test using a 2x2 table is as follows (Drennan, 1996; Drennan, 2009):

$$p = \frac{(A+B)!(C+D)!(A+C)!(B+D)!}{N!A!B!C!D!}$$

Where:

A = the observed frequency in the upper left cell of the two-by-two table;

B = the observed frequency in the upper right cell of the two-by-two table;

C = the observed frequency in the lower left cell of the two-by-two table;

D = the observed frequency in the lower right cell of the two-by-two table.

N = the sum of A + B + C + D

! = X! is read as “X Factorial”. Multiply X sequentially by each positive integer that is less than X.

Table 3.2. represents the type of table utilised in this thesis for the Fisher Exact test. In this example, the primary question, using ‘YES’ or ‘NO’ as answers, is whether mummified individuals in this sample confidently demonstrate that their embalmers practiced one of the three tiers of mummification laid out by Herodotus and Diodorus. If they do not, demonstrating at least one significant feature that lay outside Classical accounts, they are designated as “NO”.

	Expected	Observed
YES	**A**	**B**
NO	**C**	**D**

Table 3.2: **Fisher Exact Test Example**

As was laid out in Chapter 2.1, Herodotus only mentions excerebration as the top tier of mummification and because my entire sample consists of non-royal mummies, presumably being outside the "top-tier" of mummification reserved for the most elite, it would not be unreasonable to assume that the thirty-two excerebrated individuals (of the fifty-four) fall outside this description. To be fair and to give Herodotus the benefit of the doubt, however, I will assume that any individual in this sample who was excerebrated had access to this "top-tier" of mummification and were thus not removed from the "YES" mummies on this basis. Ten of these thirty-two individuals were designated "NO", however, because of their cranial resin treatment after excerebration, as that was not mentioned by either Classical historian. Of the remaining forty-four mummies, another four were designated as "NO" for having amulets inside them, a feature not discussed by Herodotus or Diodorus.

Although I have focused on the treatment of the body itself for this particular test, I do believe one period-specific outward aspect should be considered; the lavish bead-nets covering the burial shroud. This feature began during the 25th Dynasty, was popularized during the Late Period, and lasted until the Roman Period (Aufderheide, 2003; Andrews, 2004). Herodotus, who wrote during the Late Period, should have mentioned this popular, and seemingly common feature. Even within my own sample, this feature is extremely common. Of my twenty-one Late Period mummies, seventeen were assessable in terms of whether they had a bead net, and just under half of them (eight individuals, 47%) had one. There are also a handful of mummies from the preceding Third Intermediate Period and succeeding Ptolemaic Period who also have a bead net. Clearly, this is a feature Herodotus and Diodorus should have been aware of. After assessing the forty remaining mummies, another eight were designated "NO" for having this popular feature.

The thirty-two remaining mummies were examined more closely, and it was found that seventeen individuals had body treatment that fell outside the descriptions of both Herodotus and

Diodorus. Individuals who were uneviscerated were designated ‘NO’. Individuals treated with coarse or granular materials throughout the body, as well as those with large wads of linen or packing placed strategically within the chest, abdomen, or pelvis were also designated ‘NO’. Other prominent features designating an individual as “NO” include those with rolls of linen packed inside the globes and artificial eyes, as well as the inclusion of mummiform objects inside the abdomen (for example, two mummies, IMP00099 & IMP00101, have this unique feature). It should be noted that many of these mummies have more than one feature qualifying them as a “NO” in this test, for example, Peftjauneith (IMP00109), a Late Period male, had cranial resin, amulets within the body/wrappings and a bead net. Of the fifty-four mummies, thirty-nine were designated “NO”, with fifteen individuals being designated as “YES”. Calculations were first done manually, then tabulated and tabled electronically using the GraphPad Software statistical analysis tool (https://www.graphpad.com/) and Microsoft Excel.

3.8 Exploratory Data Analysis: Cluster Analysis

The general aim of classification studies is to discover the pattern of groupings in a dataset with few to no assumptions about the nature of that grouping. This process is often labelled as ‘cluster analysis’ (Shennan, 1988). Cluster analysis is considered one of the primary tools in most exploratory data techniques and is popular across many different scientific disciplines for its easy replicability and objectivity (Aldenderfer & Blashfield, 1984). Exploratory data analysis looks at data from a variety of positions and displays which individuals cluster together and further analysis explores the meaning of the cluster. Exploratory data analysis looks at data with both an “open mind and a healthy skepticism of traditional statistical summaries” (Clark, 1982, 58), as you are not searching for something specific but rather looking for links. It is a multivariate statistical procedure that, in this study, will show graphically which mummification traits, if any, are associated with one another in relation to socioeconomic status or time period. Specifically, this thesis utilized different hierarchical agglomerative methods which are the most dominant of the seven major families of clustering in terms of the frequency of its applied use (Aldenderfer & Blashfield, 1984). Additionally, as these mummification traits originated with royals, the work of Hawass and Saleem (2016), which provides the detailed analysis of seventeen CT-scanned adult New Kingdom Royals, was examined and used for comparison with this exploratory data analysis.

Clustering involves dividing your dataset into different groups, or clusters, in a way that is most meaningful to your dataset and research question. This technique, however, recognizes "objects can be similar to one another at different levels" (Shennan, 1988, 212). Therefore, clustering must be done in a meaningful way that captures the natural structure of the data (Shennan, 1988). For this research, clusters were created based on the chosen status-related features noted above; arm positioning, amulet presence, cranial resin, and estimated stature. Additionally, I have also used the categories of 'sex', 'age', and 'time period', in testing for association. To ensure all these features and demographic data could be tested together, I had to use numerical coding on a Microsoft Excel spreadsheet. Although numerical values were already created to scale the presence of amulets and cranial treatment of the mummies, I had to do the same for the other factors. Arm positioning was fairly simple as there were only three options. Extended arms with hands placed on hip/pubic area (EA) were scored as a "1", arms that were fully extended laterally (EL) were scored as "2", and arms that were flexed across the chest were scored with a "3". Stature was a little more complicated and involved using the "PERCENTILE" function in Microsoft Excel. By creating sex-specific and IMPACT sample-specific percentiles, I deemed individuals below the 25th percentile as 'short', scored with a "1", individuals between the 25th and 75th percentiles as medium, scored with a "2", and those above the 75th percentile as tall, scored with a "3" (following Mackey & Nelson, 2020).

To code the demographic information, numerical values were also used. Sex was scored as a "1" for males, and "2" for females. Age was coded using the minimum estimated age for each individual. Those who were aged 18-29 were given a "1", 30-39 year-olds were given a "2", those 40-49 were given a "3", while those 50 and over were given a "4". Individuals lacking clear information on their age estimate were given an "N/A". Time period was codified in chronological order using a scale of 1-5 in this order: New Kingdom, Third Intermediate Period, Late Period, Ptolemaic Period, and the Roman Period. Individuals lacking this information were given "N/A".

All of these numerically coded features tested using cluster analysis can be found on the spreadsheet in *Appendix B* along with the legend for their values in *Appendix C*. The information from this spreadsheet was then entered into the software package IBM SPSS v27 and tested using multiple cluster algorithms chosen following Aldenderfer and Blashfield (1984). These include group or average linkage, single linkage, complete linkage, and Ward's method (Ward, 1963). These algorithms create different clusters based on how the algorithm works. For example, single linkage only requires a single link between two cases for them to merge and ultimately links the two most similar entities in the matrix, while complete linkage is far more rigorous, as clusters are made on similarities shared by all members of that particular cluster (Aldenderfer & Blashfield, 1984). Average linkage is often seen as the antidote to the two extremes imposed by single and complete linkage, as it computes the average of the similarity of a case under consideration with all cases in the cluster (Aldenderfer & Blashfield, 1984). The final method I used, Ward's Method, is designed to minimize variance within clusters and usually tries to create roughly equal clusters if possible (Aldenderfer & Blashfield, 1984). Multiple methods and algorithms were used to assess whether clusters were real, or natural, and not just imposed on the data by the method (Aldenderfer & Blashfield, 1984). If groups remained clustered through multiple algorithms, it indicates replicability, which is one of the best validation procedures (Aldenderfer & Blashfield, 1984).

The process for analysing the different variables was carefully done, because depending on the variables used, some data could be obscured. This is because cluster analysis algorithms cannot use entries with missing values for any of the variables. For example, any time "estimated stature" was used as a variable, thirty-one of the sixty-one mummies in the sample were excluded, because I could only estimate the stature for thirty individuals, while the rest were left blank in the spreadsheet. To ensure I did not miss any potential connections, cross-referencing was utilized between different test-results with different variables, as well as associations and trends made in conjunction with the simple observations of the dataset.

I was hoping to use these statistical tests to accomplish two things. First, I was anticipating having a clear statistical test of whether the accounts of Herodotus and Diodorus are better treated as a stepping-stone for understanding mummification, rather than absolute fact, or conversely, whether these Classical accounts were indeed accurate. Second, and most importantly, I was trying to uncover whether the potential status indicators I chose to highlight (arm position, amulets, cranial resin, and stature) had any links with one another as well as any correlations with age, sex, and/or time period. Ultimately, these tests were being conducted to elucidate the relationship between non-royal mummification features and social differentiation.

Chapter 4:

Results

This chapter details the results from both the simple observations as well as the statistical testing of the sixty-one mummified individuals chosen for inclusion in this study. Simple observations were informed by the results of the mummy assessments seen in Appendix D. Following these results are those from both the observations used in the Fisher Exact test and the exploratory data analysis done via cluster analysis. Both the simple observations and statistical analyses of this non-royal sample will be evaluated alongside the work of Hawass and Saleem (2016), which includes the CT scans and analysis of seventeen adult ancient Egyptian individuals of confirmed royal status.

4.1 Results: Arm Position

I was able to acquire the arm positioning of all sixty-one mummies in the IMPACT sample (Table 4.1). Of the sixty-one individuals, thirty-seven (N=37; 60.7%) had their arms extended with the hands placed on the anterior of the body (EA). Ten individuals (N=10; 16.3%) also had their arms extended, although their arms and hands were placed alongside the thighs (EL), while the remaining fourteen (N=14; 23%) had flexed arms (F), crossed over their chests. Observations of arm positioning and specific time periods will be presented later in the chapter.

4.2 Results: Amulets

Of the sixty-one mummies in my sample, only eight mummies (N=8; 13.1%) had amulets placed inside the wrappings and/or body (see Table 4.2). Two of the eight mummies (Liverpool 2 and 13) do not currently contain amulets, but their published descriptions suggest that they once did (Gray & Slow, 1968; Lawson, 2016. Of the six individuals where amulets could be directly observed (N=6; 9.8%), four (N=4; 6.6%) had five or more amulets while the other two (N=2; 3.3%) had 1-3 amulets.

IMPACT ID	SEX	Time Period	ARM POSITION
IMP00001 Pisa 1	Male	Unknown	EL
IMP00002 Nefer Mut	Female	Third Intermediate Period	EA
IMP00005 Djedmaatesankh	Female	Third Intermediate Period	EA
IMP00006 Lady Hudson	Female	Roman Period	F
IMP00007 Pa-Ib	Female	Late Period	F
IMP00008 Sulman Mummy	Female	Ptolemaic Period	EA
IMP00009 Hetep-Bastet	Female	Late Period	EA
IMP00010 RM2717 "Theban Female"	Female	Roman Period	EL
IMP00011 RM2718 "Theban Male"	Male	Ptolemaic Period	EL
IMP00012 RM2720 "Ptolemaic Female"	Female	Roman Period	F
IMP00027 Genova 1 Female	Female	Unknown	EA
IMP00028 Genova 2 Male	Male	Unknown	EA
IMP00029 Pasherienaset	Male	Late Period	F
IMP00035 Euphemia	Female	Roman Period	EL
IMP00040 Toutou	Male	Ptolemaic Period	F
IMP00043 Female Mummy	Female	Third Intermediate Period	EA
IMP00044 Female Mummy	Female	Third Intermediate Period	EA
IMP00057 Padua Mummy	Male	Ptolemaic Period	F
IMP00058 Liverpool 1	Female	Roman Period	EL
IMP00059 Liverpool 2	Female	Roman Period	EL
IMP00060 Pedeamun	Male	Late Period	EA
IMP00061 Liverpool 4	Male	Late Period	EA
IMP00062 Liverpool 5	Female	Late Period	EA
IMP00063 Liverpool 6	Female	Late Period	EA
IMP00065 Harwennefer	Male	Ptolemaic Period	F
IMP00066 Tetkhonsefankh	Female	Third Intermediate Period	EA
IMP00067 Liverpool 10	Male	Late Period	EA
IMP00068 Liverpool 11	Male	Unknown	EA
IMP00070 Liverpool 13	Male	Ptolemaic Period	F
IMP00071 Mummy of Nesmin	Male	Ptolemaic Period	F
IMP00072 Liverpool 15	Male	Late Period	EA
IMP00073 Ta-Enty	Female	Late Period	EL
IMP00078 Renpit-Nefert	Female	Late Period	EA
IMP00079 George ("Nubian")	Male	Ptolemaic Period	EL
IMP00081 Nofret	Female	Ptolemaic Period	F
IMP00082 Bahka	Female	New Kingdom	EA
IMP00083 Braided Lady	Female	New Kingdom	EA
IMP00088 Nesmutaatneru	Female	Late Period	EA
IMP00092 Nesi-Hensu	Female	Late Period	F
IMP00093 Tash Pen Khonsu	Female	Ptolemaic Period	EA
IMP00094 Mummy of a Man	Male	Third Intermediate Period	EA
IMP00095 Mummy of a Woman	Female	Third Intermediate Period	EA
IMP00096 Khonsuemma'a (Kherut)	Male	Third Intermediate Period	EA
IMP00097 Mummy of a Woman	Female	Third Intermediate Period	EA
IMP00098 Tadis or Ta(net) Kharu	Female	Third Intermediate Period	EA
IMP00099 Tadis or Ta(net)Kharu	Female	Third Intermediate Period	EA
IMP00101 Mummy of a Man	Male	Third Intermediate Period	EA
IMP00103 Hor	Male	Late Period	EA
IMP00104 Harerem	Male	Late Period	EA
IMP00107 Kek	Female	Late Period	EA
IMP00108 Inamonnefnebu	Male	Late Period	EA
IMP00109 Peftjauneith	Male	Late Period	EA
IMP00111 Mummy of a Man	Male	Late Period	EA
IMP00112 Diptah	Female	Ptolemaic Period	F
IMP00113 Hor	Male	Ptolemaic Period	F
IMP00122 Herakleides	Male	Roman Period	EA
IMP00123 Thesaberu	Female	Ptolemaic Period	F
IMP00125 Lady Ta Khar	Female	Ptolemaic Period	EA
IMP00126 Ti-Ameny Net	Female	Late Period	EL
IMP00127 Nesiur	Female	Third Intermediate Period	EA
IMP00128 Ta Kush	Female	Late Period	EL

***Table 4.1* IMPACT Sample: Sex, Time Period, & Arm Position (EA= Extended Anterior; EL=Extended Lateral; F=Flexed)**

IMPACT ID	SEX	TIME PERIOD	AMULETS
IMP00012 RM2720 "Ptolemaic Female"	Female	Roman Period	1
IMP00059 Liverpool 2	Female	Roman Period	1
IMP00005 Djedmaatesankh	Female	Third Intermediate Period	2
IMP00029 Pasherienaset	Male	Late Period	2
IMP00070 Liverpool 13	Male	Ptolemaic Period	3
IMP00096 Khonsuemma'a (Kherut)	Male	Third Intermediate Period	3
IMP00097 Mummy of a Woman	Female	Third Intermediate Period	3
IMP00109 Peftjauneith	Male	Late Period	3

***Table 4.2* IMPACT Sample Mummies with Amulets (1=Individuals who have very clear evidence of amulets that are no longer apparent; 2= individuals containing less than five amulets; 3= Individuals containing five or more amulets)**

4.3 Results: Cranial Resin

Table 4.3 shows fifty-six of the sixty-one individuals in this sample (N=56; 91.8%) were assessable for potential excerebration and subsequent cranial resin treatment, while five individuals (8.2%) lacked plain x-ray images or CT scans clear enough to make a confident evaluation. It should also be noted that for one of the mummies (IMP00057-Padua Mummy), scans of the head were not available in IMPACT. However, a recent publication by researchers working with this mummy (Carrara & Scaggion, 2016) confirmed that the mummy had been excerebrated and treated with cranial resin. Of these fifty-six assessable mummies, twenty (N=20; 35.7%) of these individuals were not excerebrated. The remaining thirty-six mummies were all excerebrated. However, only thirteen (N=13; 23.2%) were treated with resin, with the other twenty-three (N=23; 41.1%) only having their brain removed with no further treatment.

Of the thirteen individuals who were treated with cranial resin after being excerebrated, eight were female (N=8; 61.5%), while five were male (N=5; 38.5%). In terms of time period, neither of the two mummies from the New Kingdom were excerebrated, let alone treated with resin. Only one of thirteen individuals (N=1; 7.7%) was dated to the Third Intermediate Period, while three (N=3; 23.1%) were dated to the Late Period and Roman Period. The remaining six (N=6; 46.1%) individuals, as well as the majority of these individuals treated with cranial resin, were dated to the Ptolemaic Period.

Although many individuals lack contextual information on their findspot, making it difficult to test variables for association with specific geographic regions, cranial resin treatment was still evaluated for potential correlations with specific regions. Of the thirteen resin-treated individuals, six (N=6; 46.1%) had unknown provenience with one individual (N=1; 7.7%) coming from Hawara el-Makta and another from Abydos. Two individuals (N=2; 15.4%) were found at Thebes, while the remaining three (N=3; 23.1%) individuals all came from Akhmim. This means that 50% of all individuals discovered at Akhmim in this sample were excerebrated and treated with cranial resin

IMPACT ID	SEX	Time Period	CRANIAL RESIN (0-2)
IMP00001 Pisa 1	Male	Unknown	1
IMP00002 Nefer Mut	Female	Third Intermediate Period	0
IMP00005 Djedmaatesankh	Female	Third Intermediate Period	0
IMP00006 Lady Hudson	Female	Roman Period	2
IMP00007 Pa-Ib	Female	Late Period	2
IMP00008 Sulman Mummy	Female	Ptolemaic Period	0
IMP00009 Hetep-Bastet	Female	Late Period	1
IMP00010 RM2717 "Theban Female"	Female	Roman Period	0
IMP00011 RM2718 "Theban Male"	Male	Ptolemaic Period	1
IMP00012 RM2720 "Ptolemaic Female"	Female	Roman Period	2
IMP00027 Genova 1 Female	Female	Unknown	1
IMP00028 Genova 2 Male	Male	Unknown	1
IMP00029 Pasherienaset	Male	Late Period	N/A
IMP00035 Euphemia	Female	Roman Period	0
IMP00040 Toutou	Male	Ptolemaic Period	0
IMP00043 Female Mummy	Female	Third Intermediate Period	1
IMP00044 Female Mummy	Female	Third Intermediate Period	0
IMP00057 Padua Mummy	Male	Ptolemaic Period	2
IMP00058 Liverpool 1	Female	Roman Period	1
IMP00059 Liverpool 2	Female	Roman Period	2
IMP00060 Pedeamun	Male	Late Period	1
IMP00061 Liverpool 4	Male	Late Period	1
IMP00062 Liverpool 5	Female	Late Period	1
IMP00063 Liverpool 6	Female	Late Period	0
IMP00065 Harwennefer	Male	Ptolemaic Period	2
IMP00066 Tetkhonsefankh	Female	Third Intermediate Period	1
IMP00067 Liverpool 10	Male	Late Period	0
IMP00068 Liverpool 11	Male	Unknown	0
IMP00070 Liverpool 13	Male	Ptolemaic Period	2
IMP00071 Mummy of Nesmin	Male	Ptolemaic Period	0
IMP00072 Liverpool 15	Male	Late Period	N/A
IMP00073 Ta-Enty	Female	Late Period	N/A
IMP00078 Renpit-Nefert	Female	Late Period	2
IMP00079 George ("Nubian")	Male	Ptolemaic Period	1
IMP00081 Nofret	Female	Ptolemaic Period	2
IMP00082 Bahka	Female	New Kingdom	0
IMP00083 Braided Lady	Female	New Kingdom	0
IMP00088 Nesmutaatneru	Female	Late Period	0
IMP00092 Nesi-Hensu	Female	Late Period	1
IMP00093 Tash Pen Khonsu	Female	Ptolemaic Period	0
IMP00094 Mummy of a Man	Male	Third Intermediate Period	1
IMP00095 Mummy of a Woman	Female	Third Intermediate Period	0
IMP00096 Khonsuemma’a (Kherut)	Male	Third Intermediate Period	1
IMP00097 Mummy of a Woman	Female	Third Intermediate Period	1
IMP00098 Tadis or Ta(net) Kharu	Female	Third Intermediate Period	1
IMP00099 Tadis or Ta(net)Kharu	Female	Third Intermediate Period	1
IMP00101 Mummy of a Man	Male	Third Intermediate Period	1
IMP00103 Hor	Male	Late Period	1
IMP00104 Harerem	Male	Late Period	1
IMP00107 Kek	Female	Late Period	0
IMP00108 Inamonnefnebu	Male	Late Period	0
IMP00109 Peftjauneith	Male	Late Period	2
IMP00111 Mummy of a Man	Male	Late Period	1
IMP00112 Diptah	Female	Ptolemaic Period	2
IMP00113 Hor	Male	Ptolemaic Period	2
IMP00122 Herakleides	Male	Roman Period	0
IMP00123 Thesaberu	Female	Ptolemaic Period	N/A
IMP00125 Lady Ta Khar	Female	Ptolemaic Period	N/A
IMP00126 Ti-Ameny Net	Female	Late Period	1
IMP00127 Nesiur	Female	Third Intermediate Period	2
IMP00128 Ta Kush	Female	Late Period	0

Table 4.3 **IMPACT Sample Individuals with Cranial Resin (N/A= Un-assessable; 0 = Brain intact; 1 = Excerebrated without Cranial Resin; 2= Excerebrated with Cranial Resin)**

4.4 Results: Estimated Stature

Unfortunately, stature was one of the hardest variables to assess as plain x-ray images did not allow long bone measurement to be estimated because of magnification issues. Additionally, some CT scans lacked clear images of the long bones that were necessary in order to estimate stature. Stature was estimated for thirty individuals (N=30; 49.2%), just under half of the sample. Of these thirty individuals, twenty (N=20; 66.7%) were female and ten (N=10; 33.3%) were male. Two were dated to the New Kingdom (N=2; 6.7%), eight to the Third Intermediate Period (N=8; 26.6%), eleven to the Late Period (N=11; 36.7%), five to the Ptolemaic Period (N=5; 16.7%), three to the Roman occupation (N=3; 10%), and one individual whose time period remains unknown (N=1; 3.3%). The technical error of measurement range obtained throughout the various long bone measurements of these thirty individuals was 0.35-1.77mm; which is an acceptable margin of error for anthropological and bioarchaeological research (cf. Colman et al., 2019; Spake et al., 2020) (See Chapter 3.5).

After running the "PERCENTILE" function in excel, separately for both biological sexes, the 25th percentile (used to define "short" individuals) for males in this sample was calculated to be 161.7cm, and 151.4cm for females. The 75th percentile (used to define "tall" individuals) for males was calculated to be 165.5cm and 155.5cm for females. Of the twenty females, five (N=5; 25%) were "short" individuals and five were "tall" individuals, with ten (N=10; 50%) falling into the "medium", or average, category. For males, of which there were ten, three (N=3; 30%) were "short", four (N=4; 40%) were "medium" height, with the other three (N=3; 30%) were "tall". The estimated stature of all thirty individuals, can be seen in Table 4.4. It should be noted that these percentiles were created using every available sex specific stature estimate in the sample and are therefore not time specific.

To further test the estimated stature statistics within the sample, the New Kingdom royal sample from Hawass and Saleem (2016), which also used Raxter et al. (2008) to estimate stature, was used for comparative analysis (Table 4.5). Ten (N=10; 58.8%) of these seventeen individuals held the prestigious title of pharaoh. Using the percentiles found in my own sample, I compared the estimated statures of the royal sample to see if the majority would be considered "tall". If the abundance of archeological work on this subject (Haviland, 1967; Schoeninger, 1979; Allison, 1984; Angel, 1984; Cohen, 1989; Cook, 1984; Steegman & Haseley, 1988;

Zakrzewski, 2003) is correct, and my sample truly is comprised of all non-royal individuals, it was assumed that this would be the case.

IMPACT ID	Sex	Period	Height (cm)	Percentile Designation
IMP00002 Nefret-Mut	Female	Third Intermediate Period	146.7	1
IMP00082 Bahka	Female	New Kingdom	147.7	1
IMP00098 Tadis or Ta(net) Kharu	Female	Third Intermediate Period	149	1
IMP00012 RM2720	Female	Ptolemaic Period	150.2	1
IMP00083 Braided Lady	Female	New Kingdom	150.3	1
IMP00126 Ti-Ameny Net	Female	Late Period	151.7	2
IMP00107 Kek	Female	Late Period	151.9	2
IMP00010 RM2717	Female	Roman Period	152.1	2
IMP00112 Diptah	Female	Ptolemaic Period	152.1	2
IMP00006 Lady Hudson	Female	Roman Period	152.5	2
IMP00099 Tadis or Ta(net)Kharu	Female	Third Intermediate Period	153	2
IMP00128 Ta Kush	Female	Late Period	153.7	2
IMP00092 Nesi-Hensu	Female	Late Period	154.1	2
IMP00005 Djedmaatesankh	Female	Third Intermediate Period	154.9	2
IMP00007 Pa-Ib	Female	Late Period	154.9	2
IMP00127 Nesiur	Female	Third Intermediate Period	157.4	3
IMP00078 Renpit-Nefert	Female	Late Period	158.6	3
IMP00008 Sulman Mummy	Female	Ptolemaic Period	160.2	3
IMP00009 Hetep-Bastet	Female	Late Period	161	3
IMP00097 Mummy of a Woman	Female	Third Intermediate Period	164.3	3
IMP00094 Mummy of a Man	Male	Third Intermediate Period	154.3	1
IMP00011 RM2718	Male	Ptolemaic Period	156.2	1
IMP00057 Padua Mummy	Male	Ptolemaic Period	161.6	1
IMP00111 Mummy of a Man	Male	Third Intermediate Period	161.9	2
IMP00103 Hor	Male	Late Period	162.8	2
IMP00001 Pisa 1	Male	Unknown	164.7	2
IMP00104 Harerem	Male	Late Period	165.2	2
IMP00108 Inamonnefnebu	Male	Late Period	165.6	3
IMP00122 Herakleides	Male	Roman Period	167.5	3
IMP00109 Peftjauneith	Male	Late Period	179.2	3

Table 4.4 **Height and Stature Percentiles in this Sample (Percentile Designation: 1 = Short; 2 = Medium; 3 = Tall)**

New Kingdom Royal Sample (Hawass & Saleem, 2016)			
Mummy Name (Dynasty)	**Sex**	**Age**	**Height (Percentile Designation)**
"So-Called" Thutmose I (18)	M	~20	157cm (1)
Thutmose II (18)	M	~30	173cm (3)
Thutmose III (18)	M	~40+	167cm (3)
Hatshepsut (KV60A) (18)	F	50-60	159cm (3)
Yuya (Father of Tiye) (18)	M	50-60	166cm (3)
Thuya (Mother of Tiye) (18)	F	50-60	145cm (1)
Amenhotep III (18)	M	50	154± 4 cm (1)
Queen Tiye (Elder KV65) (18)	F	40-50	145cm (1)
Younger Lady KV65 (Tut's Mother) (18)	F	25-35	158cm (3)
KV55 Skeleton ("Akhenaten") (18)	M	35-45	160cm (1)
Tutankhamun (18)	M	~19	167cm (3)
KV21A (18)	F	>21	148± 2.517cm (1)
KV21B (18)	F	~45	151± 2.517cm (2)
Seti I (19)	M	40-50	167cm (3)
Ramses II (19)	M	>70	170cm (3)
Merenptah (19)	M	50-60	171cm (3)
Ramses III (20)	M	~60	163cm (2)

Table 4.5 **Hawass and Saleem (2016) Royal Sample Stature & Percentile Designation Based on IMPACT Sample (1= Short; 2= Medium; 3=Tall)**

Of the seventeen adult mummies (Table 4.5) in Hawass and Saleem's sample (2016), the majority would indeed be considered tall when compared with my sample. Nine (N=9; 52.9%) of the seventeen would be "tall", two (N=2; 11.8%) would be "medium", and six (N=6; 35.3%) would be "short". Of those who would be considered "tall", seven were males (77.8%) while two were female (22.2%). This means that 63.6% of the men, and 33.3% of the women in the royal sample would be considered "tall" when compared with my non-royal sample. It is worth noting that eight of the ten pharaohs in this royal sample (80%) are individuals who would be considered tall in the non-royal sample. The average height of the royal sample was 165cm for males (N=11, SD=6.22) and 149.5cm for females (N=6, SD=6.23). The tallest male in the royal sample is Thutmose II at 173cm and the tallest female is KV60A, who is said to be the female ruler Hatshepsut, at 159cm (Hawass & Saleem, 2016). The non-royal average for men in this sample was 163.9cm (N=10, SD=6.78) and 153.8cm for women (N=20, SD= 4.55) with the tallest male being Peftjauneith (IMP00109) at 179.2cm and the tallest female being Mummy of a Woman (IMP00097) at an estimated 164.3cm. *Z*-scores were acquired for the tallest individuals in both samples. For the royals, Thutmose II had a *Z*-score of *1*.29, while Hatshepsut had a *Z*-score of 1.53. For the non-royals, Peftjauneith had *Z*-score of 2.26, while Mummy of a Woman had a *Z*-score of 2.31. These non-royal *Z*-scores are positive and above 2, meaning, they are above average, and unusual, in the sense that they are somewhat significantly taller than is expected of non-royal individuals (based on this IMPACT sample) (Drennan, 1996).

The royal and non-royal samples were compared using a Mann-Whitney U test to see if sex-specific sample average statures were statistically significantly different from each other. The value of *U* for females was 40, which was greater than the calculated critical value of 27, and 42 for males, which was greater than the calculated critical value of 26. The calculated *p*-value for females was .23 and .38 for males. Using a significance level of .05, the Mann-Whitney U test demonstrated that neither of these differences were significant.

The data from this non-royal sample were also evaluated alongside the work of Zakrzewski. (2003). For estimating stature, Zakrzewski (2003) used Robins and Shute (1986), while I used Raxter et al. (2008), therefore, I needed to ensure both sets of regression formulas would produce comparable results. Mean estimated statures were acquired for five males (IMP00011, IMP00103, IMP00104, IMP00109, IMP00122) and five females (IMP00002, IMP00006, IMP00007, IMP00009, IMP00082) using formulas from both Robins and Shute (1986) and Raxter et al. (2008) and the differences were calculated. Raxter et al.’s (2008) stature estimates differed on average -0.88cm for males and + 0.76cm for females from the estimates derived from Robins and Shute (1986). These differences were also compared using a Mann-Whitney U test with a significance level of .05. The differences were not significant, as the value of *U* for both males and females was 10, with a calculated critical value of 2. As differences for both sexes produced a *U* value of 10, in addition to being within 1cm of each other overall, estimates derived using both formulas will be treated as equivalent.

As the raw data was not made available in the article itself, Figure 4.1 is the figure Zakrzewski (2003) published as I could not recreate it myself. It demonstrated the ranges of estimated stature (cm) for men and women from the pre-Dynastic Badarian culture, to the Middle Kingdom. Figure 4.2 shows the results from my sample, using a figure similar to Zakrzewski (2003). Twenty-nine of the thirty individuals with estimated statures were used, as one individual (The male IMP00001 Pisa 1) was removed for having an unknown time period affiliation. Zakrzewski (2003) had 150 individuals, much more than the twenty-nine I had, however, I believe the comparison was still warranted for their temporal continuity. It should be noted that my sample did not have any New Kingdom males, and only one example for Roman males. Additionally, only two individuals were available for the categories of "New Kingdom Females", "Third Intermediate Period Males", "Ptolemaic Period Males", and "Roman Period Females", leaving only four categories ("Third Intermediate Females", "Late Period Males", "Late Period Females", and "Ptolemaic Females") with three or more entries for the boxplot. Consequently, the results should be interpreted cautiously.

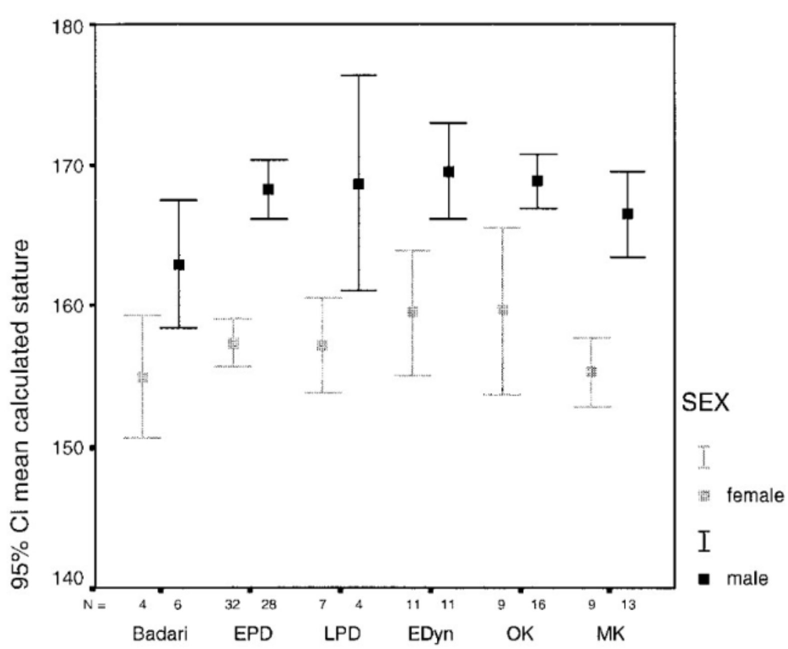


Figure 4.1 **Estimated Stature Ranges from Zakrzewski (2003): Figure 3**

Taking into account the large discrepancy in sample sizes between the two studies, a few things can be said regarding temporal changes in overall stature. Although overall stature for females stayed relatively similar across these periods, while males experienced more significant changes in stature from the Third Intermediate period to the Ptolemaic Period, both sexes experienced an increase in overall height that peaks during the Late Period. However, the decrease experienced by both sexes during the Ptolemaic Period seems to closely resemble Third Intermediate Period averages. While fairly similar for males, average stature for females in both periods was actually the same (Table 4.7).

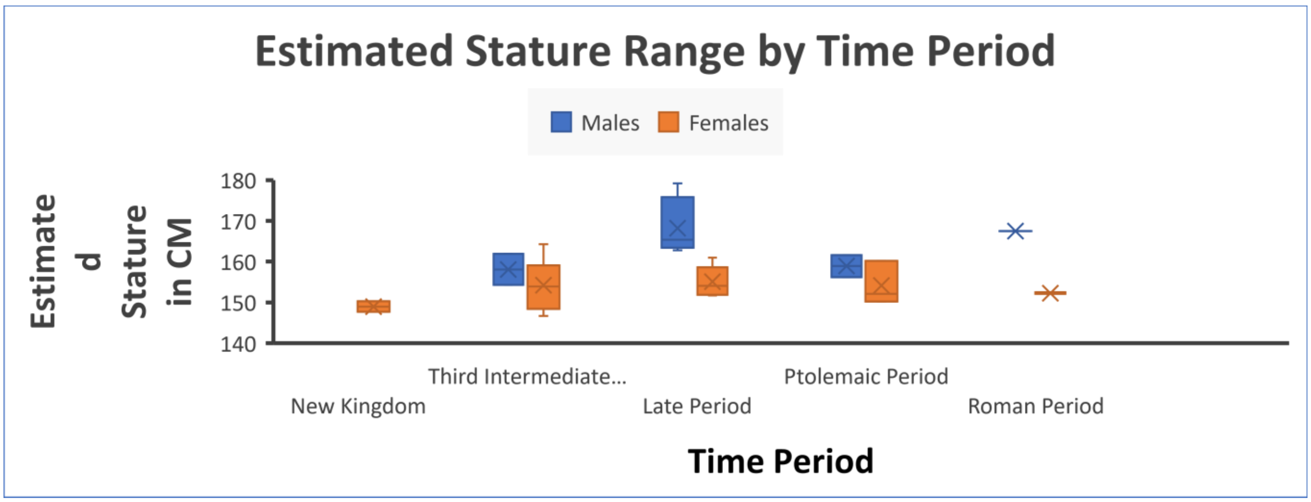


Figure 4.2 **Estimated Stature Range by Time Period**

Zakrzewski (2003) provides the mean estimated statures for both males and females for six successive time periods from the pre-dynastic Badarian culture until the Middle Kingdom (Table 4.6). To try and better evaluate the results of her analysis alongside my own, I tabled the mean stature for males and females by time period from the New Kingdom to the Roman Period (Table 4.7). Both tables have height listed in centimetres and include the number of individuals measured for each cell in parentheses. Additionally, the standard deviation for each cell is included as well for Table 4.7. The results of both datasets are plotted temporally in Figure 4.3, demonstrating a drop in stature from the Middle Kingdom to the New Kingdom for females, where a slight increase begins again until the Late Period; after which another decrease occurs. For males, there is a large drop from the Middle Kingdom to the Third Intermediate Period (as there is no data for New Kingdom males in this sample), before experiencing a notable increase in stature during the Late Period before abating again afterwards. Although stature seems to rise from the Ptolemaic Period to the Roman Period for males, I hesitate to take this as strong evidence as I only had one Roman Period male. Additionally, when plotted this way (Figure 4.3), the differences from period to period discussed by Zakrzewski (2003) seem far less significant. However, as there is a minor rise from the pre-Dynastic Badarian culture into the Old Kingdom (+5.9cm for males, +4.7cm for females), before dropping in the Middle Kingdom (-2.4cm for males, -4.4cm for females), her conclusions (section 2.2.2), while not as strong, are still feasible.

Time Period	**Males**	**Females**
Badarian Culture	162.9 (N=6)	154.9 (N=4)
Early Pre-Dynastic	168.3 (N=28)	157.3 (N=32)
Late Pre-Dynastic	168.6 (N=4)	157.2 (N=7)
Early Dynastic	169.6 (N=11)	159.5 (N=11)
Old Kingdom	168.8 (N=16)	159.6 (N=9)
Middle Kingdom	166.4 (N=13)	155.2 (N=9)
TOTAL (cm)	**167.9 (N=78)**	**157.5 (N=72)**

Table 4.6 **Zakrzewski (2003) Average Stature in CM by Sex & Time Period**

Time Period	**Males**	**Females**
New Kingdom	N/A	149 (N=2) *SD: 1.84*
Third Intermediate Period	158.1 (N=2) *SD: 5.37*	154.2 (N=6) *SD: 6.28*
Late Period	168.2 (N=4) *SD: 7.44*	155.1 (N=7) *SD: 3.46*
Ptolemaic Period	158.9 (N=2) *SD: 3.82*	154.2 (N=3) *SD: 5.31*
Roman Period	167.5 (N=1)	152.3 (N=2) *SD: 0.28*
TOTAL (cm)	**163.2 (N=9)** ***SD: 7.19***	**153 (N=19)** ***SD: 4.55***

Table 4.7 **Average Stature in CM by Sex & Time Period in This Sample**

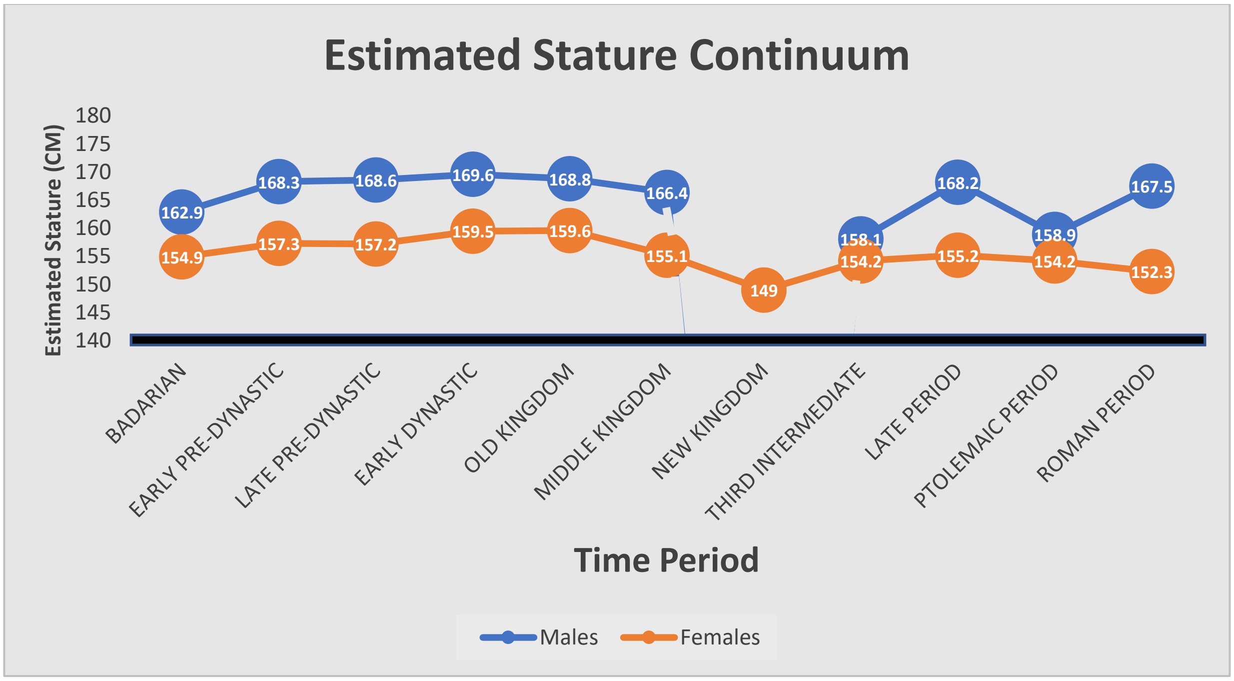


Figure 4.3 **Estimated Stature Continuum Zakrzewski (2003) & This IMPACT Sample**

4.5 Classical Accounts & The Fisher Exact Test

Although simple observations of the data demonstrate the variability of mummification, with most mummies not adhering to the mummification descriptions given by Herodotus and Diodorus Siculus, the Fisher Exact test was administered to treat the descriptions as a testable hypothesis. Using the data from all fifty-four mummies dating from the New Kingdom to the Ptolemaic Period, including those without confident dating, the observed results were tabled and compared to the expected values (Table 4.8). The resulting P-value is <0.0001 and falls well below the set alpha significance level of 0.05, leading to the rejection of the null hypothesis and the hope that the ancient accounts accurately describe the ancient Egyptian practice of mummification.

	Expected	**Observed**	***Total***
YES	**54**	**15**	**69**
NO	**0**	**39**	***39***
Total	**54**	**54**	**108**

Table 4.8 **Fisher Exact Test Table: 54 Mummies Testing the Classical Accounts**

A Fisher Exact test was also administered for the twenty-one Late Period mummies most contemporaneous with Herodotus (Table 4.9). Again, the resulting P-value is P <0.0001 and refutes even further the accounts of Herodotus. Of the twenty-one Late Period mummies in my sample, 81% fall outside Herodotus' descriptions.

	Expected	**Observed**	***Total***
YES	**21**	**4**	**25**
NO	**0**	**17**	**17**
Total	**21**	**21**	***42***

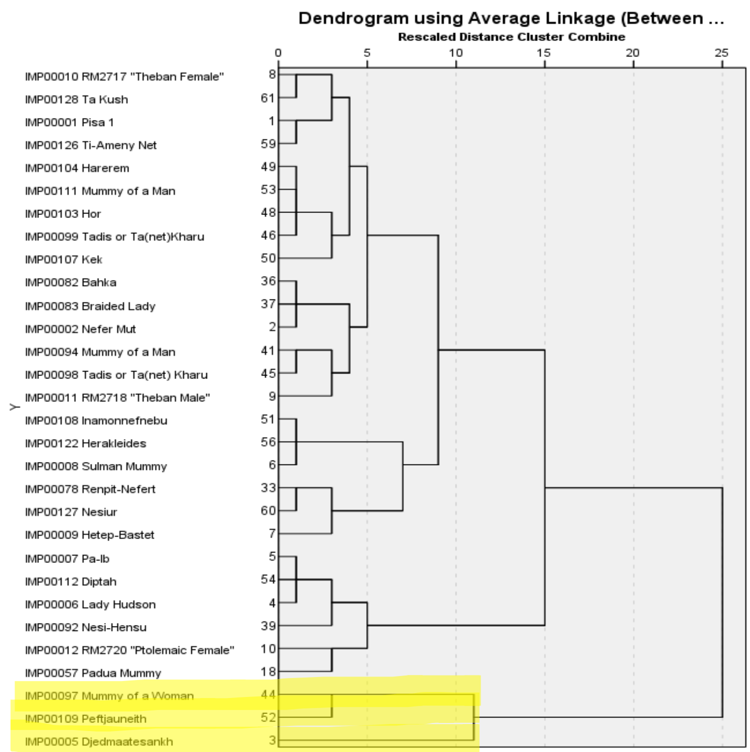
Table 4.9 **Fisher Exact Test Table for 21 Late Period Mummies Testing the Classical Accounts**

4.6 Exploratory Data Analysis Findings

Exploratory data analysis has been used in this thesis for its potential to reveal any connections and links within the dataset. As this sample contains both male and female individuals from different periods with a range of ~3500 years, associations were expected to be arbitrary and nominal at best. What the exploratory data analysis did find, however, was that some of these mummification features have meaningful associations with one another in relation to both social status and time period.

After numerically coding both the demographic data and results of my own mummy assessments in excel (Appendix B), the data was transferred to the statistical analysis software package *IBM SSPS v27*. Once the data were imported, I was able to explore my data using a variety of hierarchical cluster algorithms and varying combinations of my variables. The variables included: sex, time period, age, arm position, amulets, cranial treatment (resin), and estimated stature.

To begin, the four primary variables, the status indicators (arm position, amulets, cranial resin, and estimated stature), were tested together using the squared Euclidian distance method with four different algorithms chosen following the rationales presented in section 3.8; average-linkage (Figure 4.4), single-linkage (Figure 4.5), complete-linkage (Figure 4.6), and Ward's Method (Figure 4.7). In every instance, three individuals clustered together (clusters highlighted for clarity); IMP00005-Djedmaatesankh, IMP00097-Mummy of a Woman and IMP00109-Peftjauneith. As thirty-one individuals were excluded from the analysis because they did not have an estimated stature, this variable was removed, leaving only arm position, amulets, and cranial resin. Upon removing estimated stature, the same three mummies remained clustered, however, they were joined by two individuals (IMP00070-Liverpool 13 & IMP00096 Khonsuemma's (Kherut)) (Figure 4.8). Figures 4.9-4.11 focus on the smaller clustered group. These five mummies remained clustered together through Ward's Method (Figure 4.9). However, IMP00070-Liverpool 13 separated from the group in single-linkage (Figure 4.10), before returning with complete-linkage (Figure 4.11). Djedmaatesankh also left the cluster in Figure 4.11. After analysing these five individuals, it seems that the reason for their linkage is simply the appearance of precious amulets.



<u>Figure 4.4 Average Linkage Dendrogram (Arm Position, Amulets, Cranial Resin, Stature)</u>

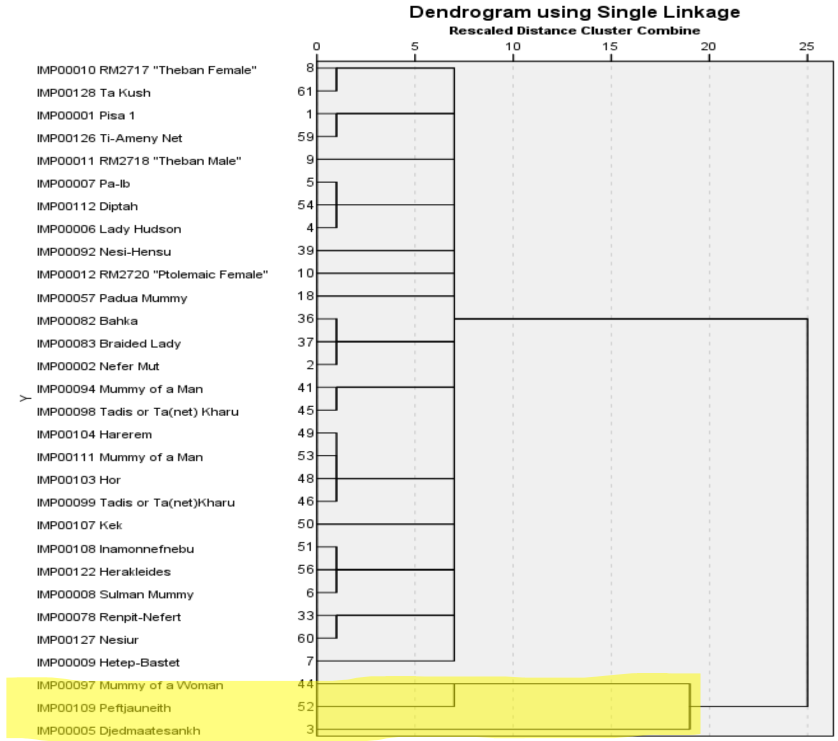


Figure 4.5 **Single Linkage Dendrogram (Arm Position, Amulets, Cranial Resin, Stature)**

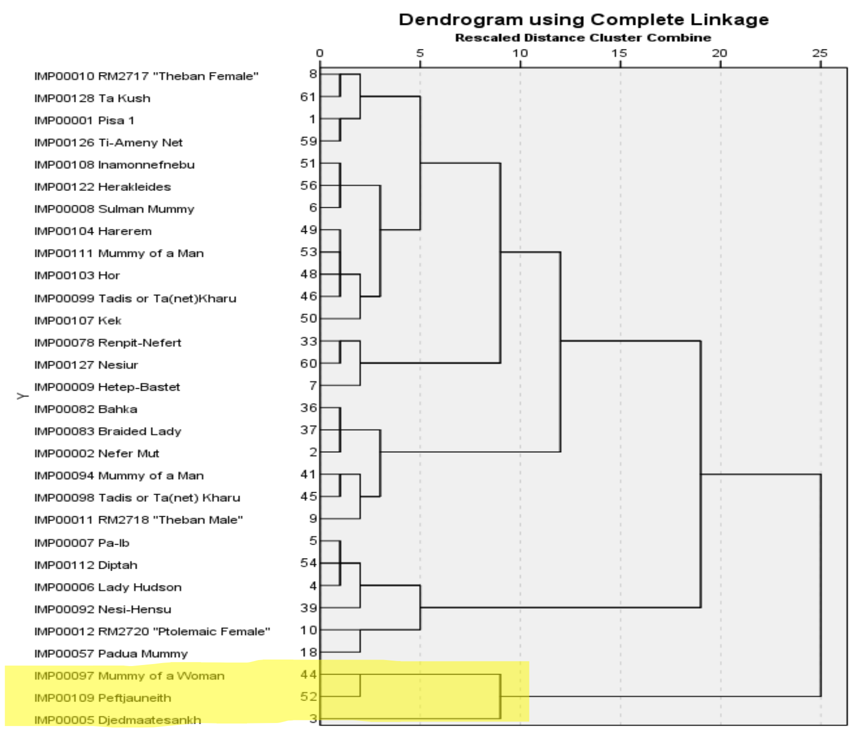


Figure 4.6 *Complete Linkage Dendrogram (Arm Position, Amulets, Cranial Resin, Stature)*

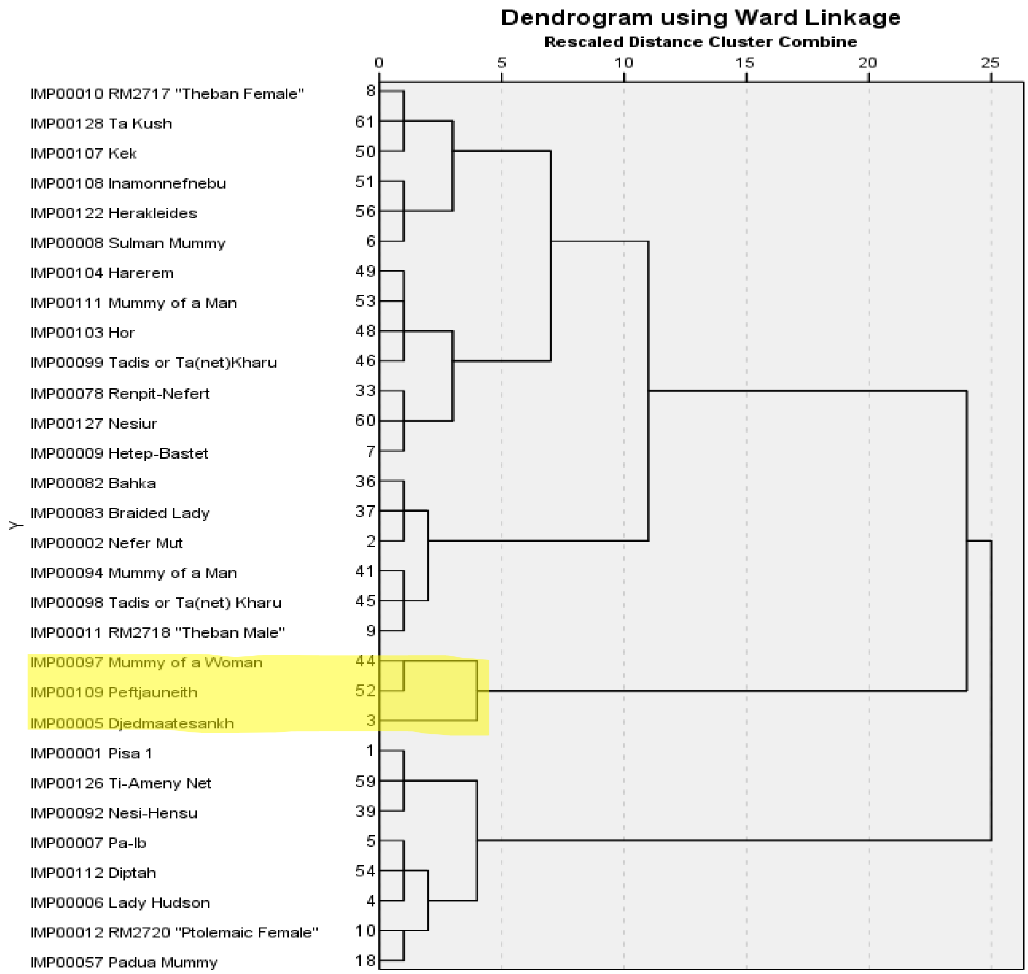


Figure 4.7 **Ward's Method Dendrogram (Arm Position, Amulets, Cranial Resin, Stature)**

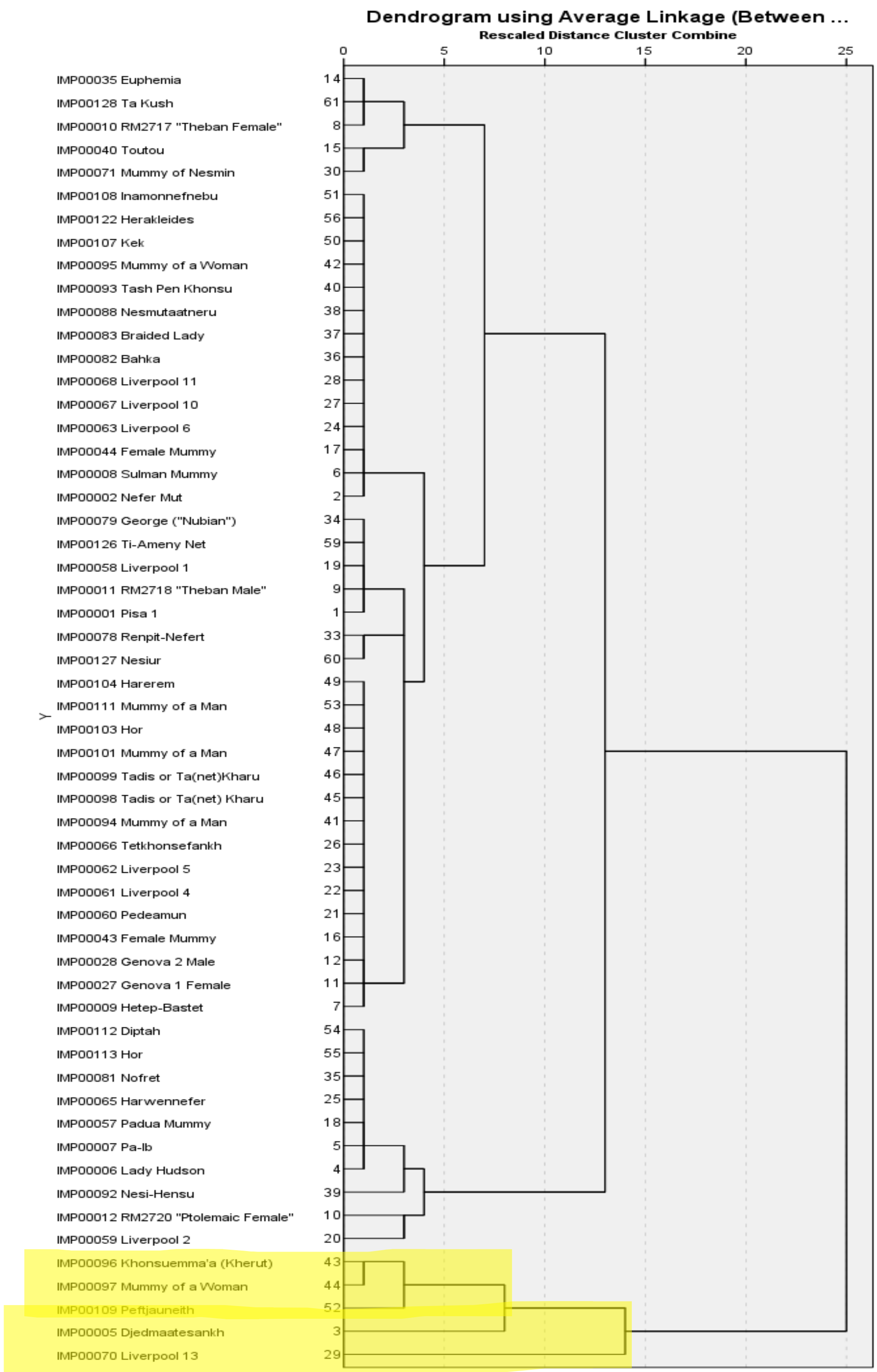


Figure 4.8 **Average Linkage Dendrogram (Arm Position, Amulets, Cranial Resin)**

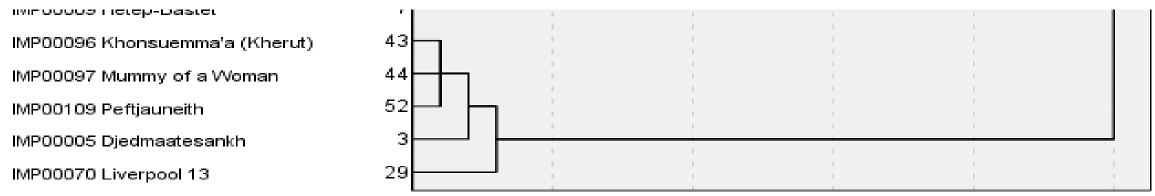


Figure 4.9 **Ward's Method (Arm Position, Amulets, and Cranial Resin)-Small Cluster Only**

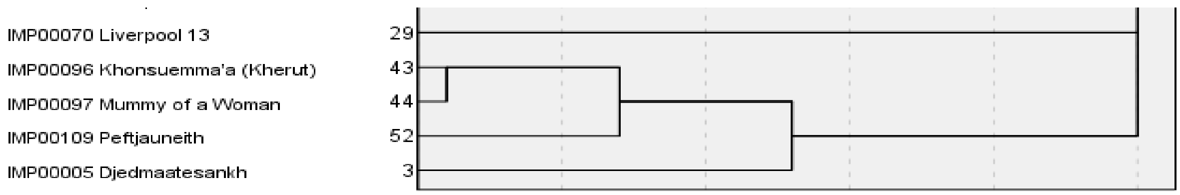


Figure 4.10 **Single Linkage (Arm Position, Amulets, and Cranial Resin)- Small Cluster Only**

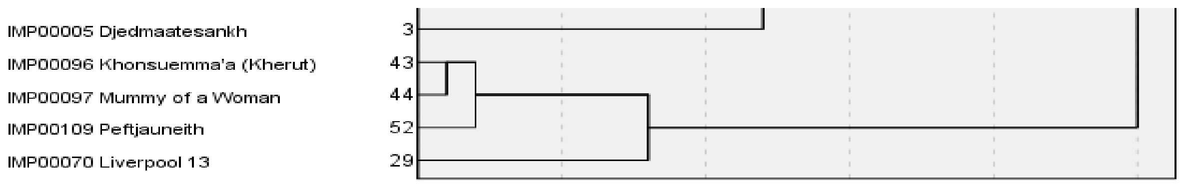


Figure 4.11 **Complete Linkage (Arm Position, Amulets, and Cranial Resin)- Small Cluster Only**

After recognizing that amulets were driving the connection between these mummies, I decided to test the variables separately. I also decided to use time period as a label instead of their IMPACT ID to see if any of these variables exhibited temporal preferences. All four variables were tested by themselves using the four different hierarchical cluster algorithms used above. In every instance, regardless of which algorithm was used (average linkage, single linkage, complete linkage, Ward's Method), the same dendrogram, containing the same clusters of mummies, was created. What these dendrograms revealed was that amulets, stature, and cranial resin were not period dependant (figures presented in Appendix E). Arm positioning, however, does demonstrate period-specific preferences (Figure 4.12), as will be discussed below. In this dendrogram, the top-most cluster represents the "EL" arm position, the center cluster represents the flexed arm position, while the bottom-most, and largest cluster, represents the "EA" arm position.

Outside of the royals, very few New Kingdom mummies have flexed arms, and the two non-royal New Kingdom mummies in this sample have extended arms. As Gray (1972), Elias, Lupton, & Klales (2014), and Loynes (2015) have suggested with their own samples, there is an overwhelming preference for the "EA" arm position during the Third Intermediate Period. All 13

Third Intermediate Period mummies in my sample have this specific arm positioning (Table 4.10). Additionally, my data also confirms the preference for flexed arms during the Ptolemaic Period (Gray, 1972; Aufderheide, 2003; Elias, Lupton, & Klales, 2014; Loynes, 2015) and extended arm positionings during the Roman Period (Aufderheide, 2003; Loynes, 2015). From my sample, nine of fourteen (64.3%) Ptolemaic mummies have flexed arms, while six of seven (85.7%) Roman mummies have extended arms.

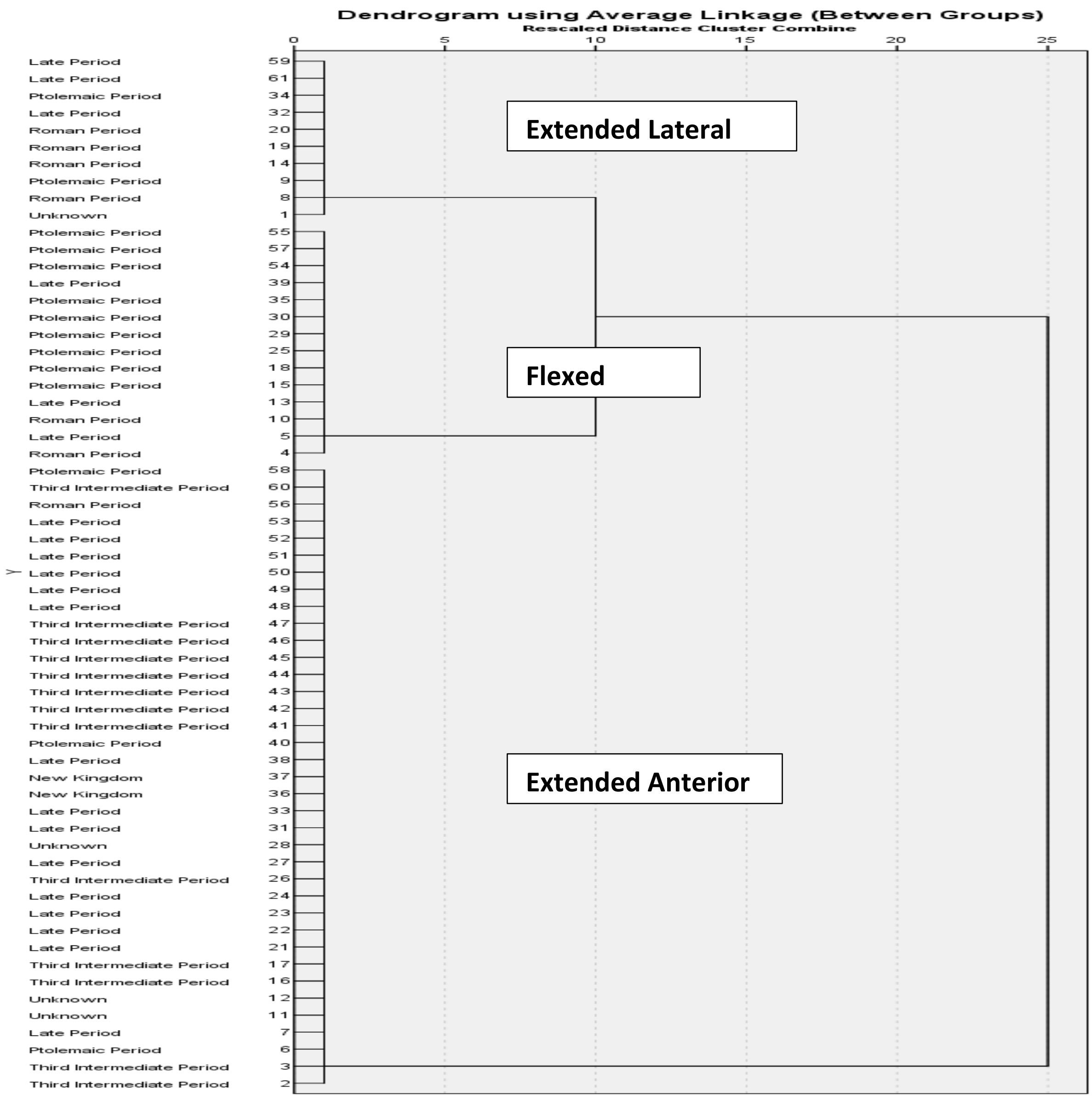


Figure 4.12 **Average-Linkage for Arm Position by Time Period**

IMPACT ID & NAME	SEX	TIME PERIOD	ARM POSITION
IMP00002 Nefer Mut	Female	Third Intermediate Period	EA
IMP00005 Djedmaatesankh	Female	Third Intermediate Period	EA
IMP00043 Female Mummy	Female	Third Intermediate Period	EA
IMP00044 Female Mummy	Female	Third Intermediate Period	EA
IMP00066 Tetkhonsefankh	Female	Third Intermediate Period	EA
IMP00094 Mummy of a Man	Male	Third Intermediate Period	EA
IMP00095 Mummy of a Woman	Female	Third Intermediate Period	EA
IMP00096 Khonsuemma'a (Kherut)	Male	Third Intermediate Period	EA
IMP00097 Mummy of a Woman	Female	Third Intermediate Period	EA
IMP00098 Tadis or Ta(net) Kharu	Female	Third Intermediate Period	EA
IMP00099 Tadis or Ta(net)Kharu	Female	Third Intermediate Period	EA
IMP00101 Mummy of a Man	Male	Third Intermediate Period	EA
IMP00127 Nesiur	Female	Third Intermediate Period	EA

Table 4.10 **Arm Position of 13 Third Intermediate Period Mummies (EA= Extended Anterior)**

Data that conflicts with previously published information on arm position were also found. Elias, Lupton, and Klales (2014) propose that the preferred arm positioning during the Late Period involved crossed arms, however, only three of the fourteen (21.4%) mummies with flexed arms in my sample (Table 4.11) come from the Late Period. Of the twenty-one total Late Period mummies, the largest period-specific grouping in my sample, only three (14.3%) have flexed arms, while eighteen (85.7 %) have extended arms (Table 4.12). Potential reasons for this significant difference in results will be discussed further in Chapter 5.

IMPACT ID & NAME	SEX	TIME PERIOD	ARM POSITION
IMP00006 Lady Hudson	Female	Roman Period	F
IMP00007 Pa-Ib	Female	Late Period	F
IMP00012 RM2720 "Ptolemaic Female"	Female	Roman Period	F
IMP00029 Pasherienaset	Male	Late Period	F
IMP00040 Toutou	Male	Ptolemaic Period	F
IMP00057 Padua Mummy	Male	Ptolemaic Period	F
IMP00065 Harwennefer	Male	Ptolemaic Period	F
IMP00070 Liverpool 13	Male	Ptolemaic Period	F
IMP00071 Mummy of Nesmin	Male	Ptolemaic Period	F
IMP00081 Nofret	Female	Ptolemaic Period	F
IMP00092 Nesi-Hensu	Female	Late Period	F
IMP00112 Diptah	Female	Ptolemaic Period	F
IMP00113 Hor	Male	Ptolemaic Period	F
IMP00123 Thesaberu	Female	Ptolemaic Period	F

Table 4.11 **Flexed Arm Mummies and Time Periods (F=Flexed Arm Position)**

IMPACT ID	SEX	Time Period	ARM POSITION
IMP00007 Pa-Ib	Female	Late Period	F
IMP00009 Hetep-Bastet	Female	Late Period	EA
IMP00029 Pasherienaset	Male	Late Period	F
IMP00060 Pedeamun	Male	Late Period	EA
IMP00061 Liverpool 4	Male	Late Period	EA
IMP00062 Liverpool 5	Female	Late Period	EA
IMP00063 Liverpool 6	Female	Late Period	EA
IMP00067 Liverpool 10	Male	Late Period	EA
IMP00072 Liverpool 15	Male	Late Period	EA
IMP00073 Ta-Enty	Female	Late Period	EL
IMP00078 Renpit-Nefert	Female	Late Period	EA
IMP00088 Nesmutaatneru	Female	Late Period	EA
IMP00092 Nesi-Hensu	Female	Late Period	F
IMP00103 Hor	Male	Late Period	EA
IMP00104 Harerem	Male	Late Period	EA
IMP00107 Kek	Female	Late Period	EA
IMP00108 Inamonnefnebu	Male	Late Period	EA
IMP00109 Peftjauneith	Male	Late Period	EA
IMP00111 Mummy of a Man	Male	Late Period	EA
IMP00128 Ta Kush	Female	Late Period	EL
IMP00126 Ti-Ameny Net	Female	Late Period	EL

Table 4.12 **Late Period Mummies and Their Arm Position (EA=Extended Anterior; EL=Extended Lateral; F=Flexed)**

The clearest potential association within this sample amongst the variables was first seen in Figure 4.13, which uses squared Euclidian distance and the average-linkage algorithm to test arm position, cranial resin, and stature as variables with IMPACT ID as the label. Due to amulets guiding the clusters in Figures 4.4-4.11, they were removed for this analysis. Of note here are five of the six mummies clustered at the bottom: IMP00012-RM2720, IMP00057-Padua Mummy, IMP00007-Pa Ib, IMP00112-Diptah, and IMP00006-Lady Hudson. These five individuals also cluster together with the complete-linkage (Figure 4.14) and Ward's Method (Figure 4.15) algorithms. The qualities these individuals share is the flexed arm position and treatment of cranial resin following excerebration.

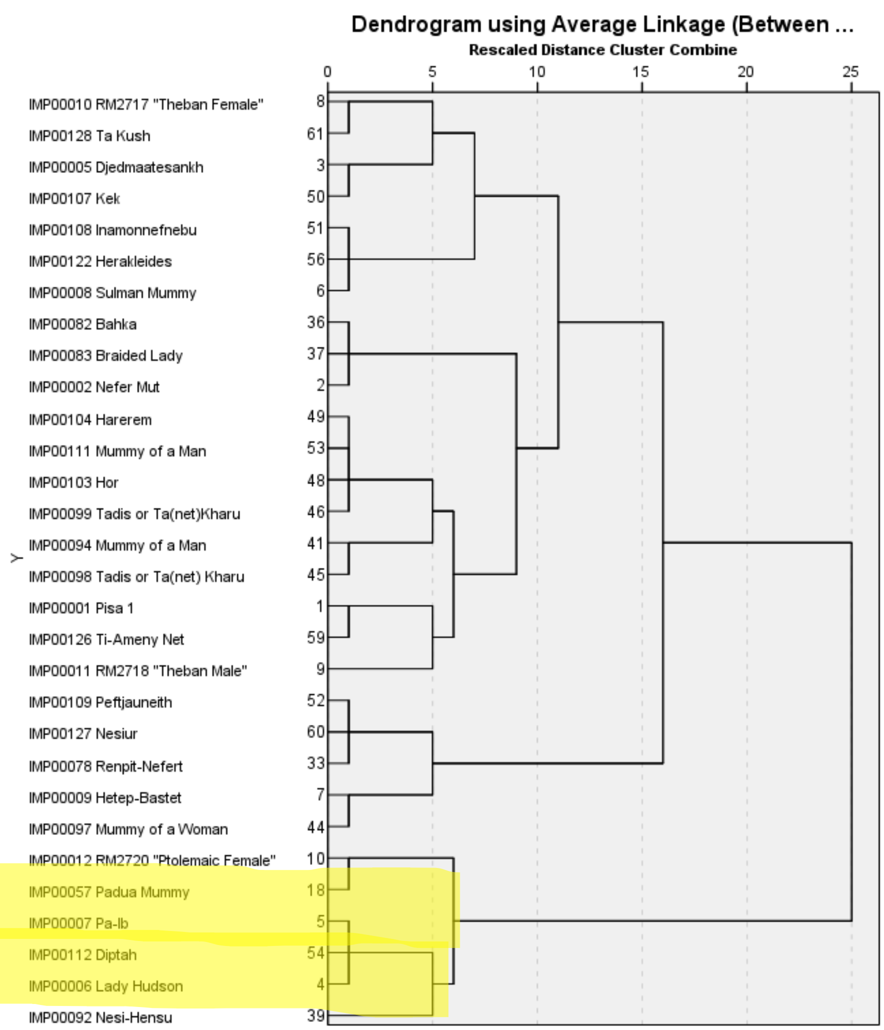


Figure 4.13 **Average Linkage for Arm Position, Cranial Resin and Stature**

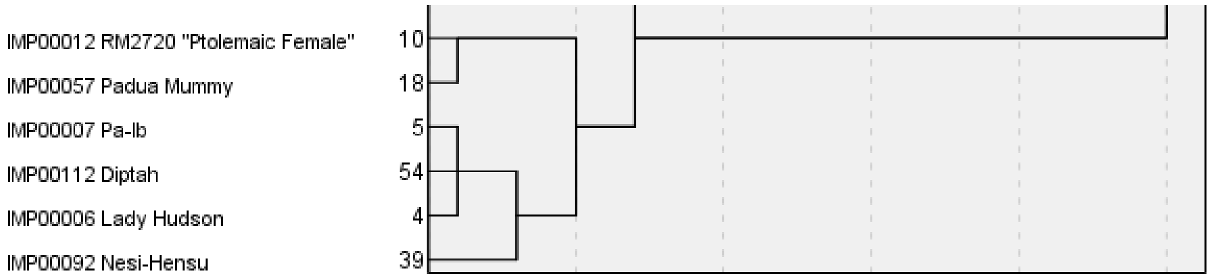


Figure 4.14 **Complete Linkage for Arm Position, Cranial Resin and Stature-Small Cluster Only**

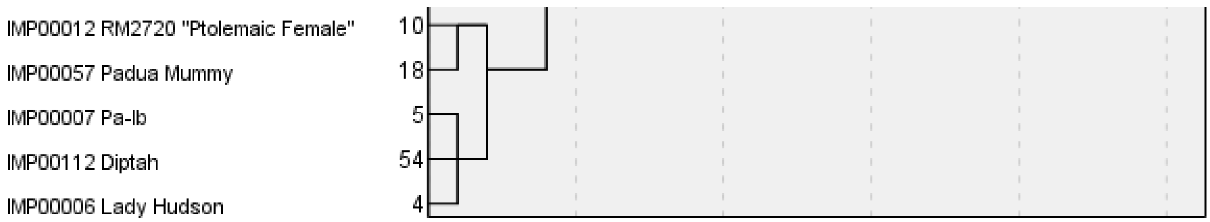


Figure 4.15 **Ward's Method Linkage for Arm Position, Cranial Resin, and Stature-Small Cluster Only**

To further test this association, stature was removed from the analysis, leaving arm position and cranial resin to be tested together. The results of this analysis, using squared Euclidian distance and the average-linkage algorithm, can be seen in Figure 4.16. The five mummies who clustered together above were then joined by an additional four mummies: IMP00113-Hor, IMP00081-Nofret, IMP00070-Liverpool 13, and IMP000065-Harwennefer. These same nine mummies became linked again, and more clearly, when Ward's Method was used with arm position and cranial resin as variables (Figure 4.17). What these nine mummies had in common, and what formed this cluster, was their shared flexed arm position and cranial resin treatment post-excerebration. This prompted further investigation which found that twelve of the fourteen flexed-arm mummies in Table 4.11 could be assessed for brain treatment and that nine of these twelve (75%) individuals were treated with cranial resin (Table 4.13). Furthermore, of the thirteen individuals who were treated with cranial resin, nine (69%) had flexed arms (Table 4.14).

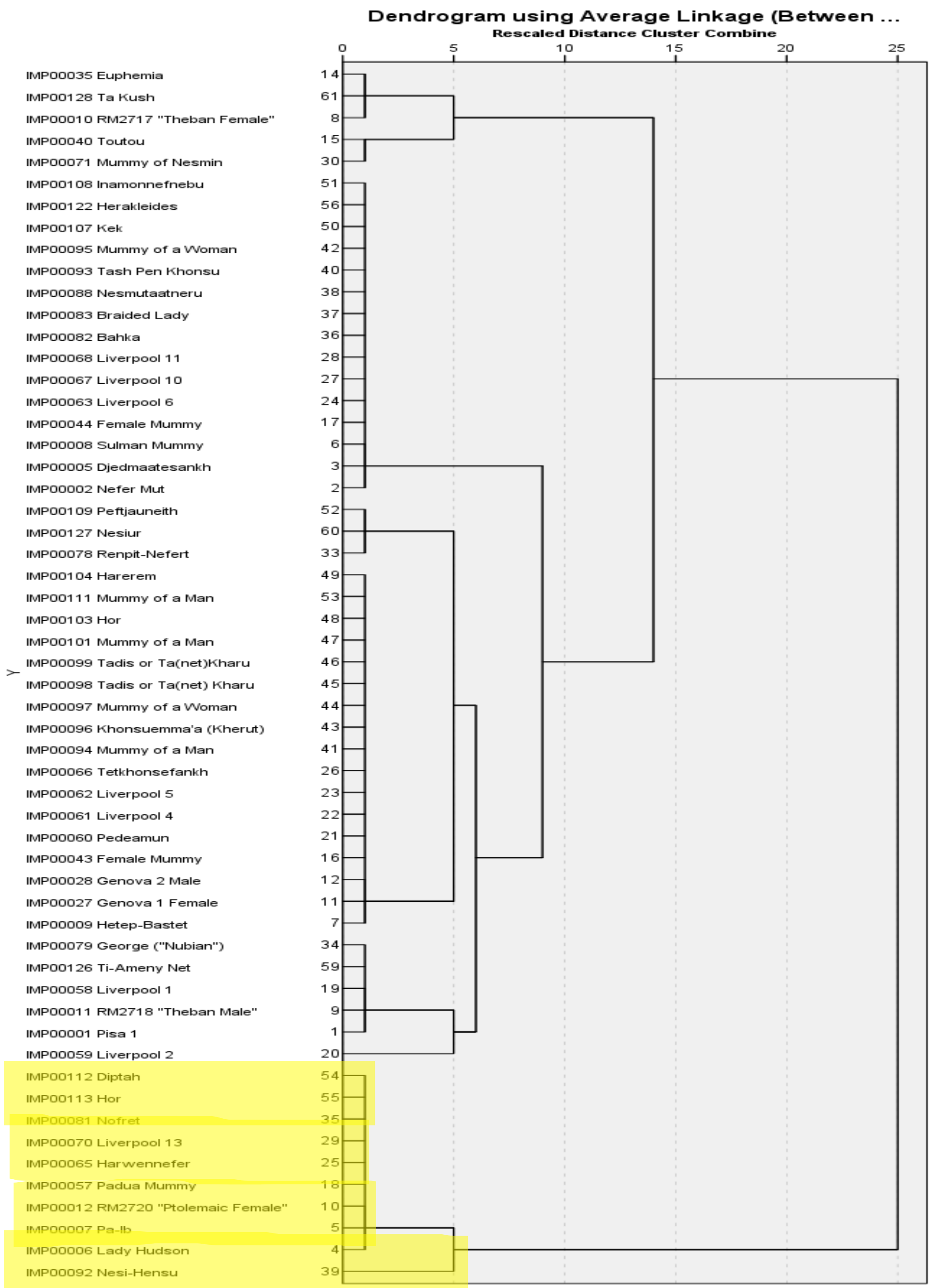


Figure 4.16 **Average Linkage for Arm Position and Cranial Resin**

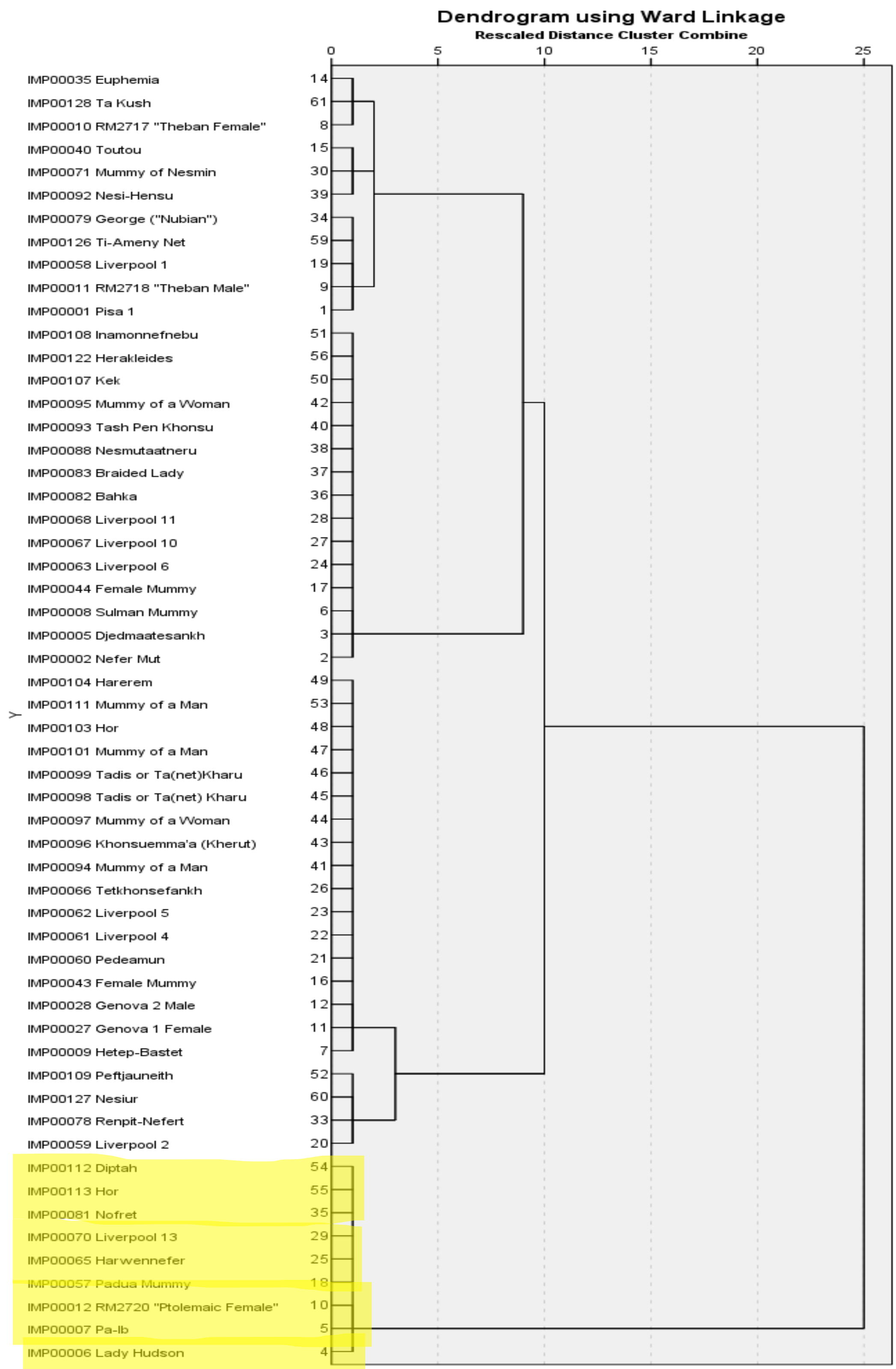


Figure 4.17 **Ward's Method Linkage for Arm Position & Cranial Resin**

IMPACT ID	Sex	Time Period	Arm Position	Cranial Resin
IMP00006 Lady Hudson	F	Roman Period	Flexed	2
IMP00007 Pa-Ib	F	Late Period	Flexed	2
IMP00012 RM2720	F	Roman Period	Flexed	2
IMP00029 Pasherienaset	M	Late Period	Flexed	N/A
IMP00040 Toutou	M	Ptolemaic Period	Flexed	0
IMP00057 Padua Mummy	M	Ptolemaic Period	Flexed	2
IMP00065 Harwennefer	M	Ptolemaic Period	Flexed	2
IMP00070 Liverpool 13	M	Ptolemaic Period	Flexed	2
IMP00071 Mummy of Nesmin	M	Ptolemaic Period	Flexed	0
IMP00081 Nofret	F	Ptolemaic Period	Flexed	2
IMP00092 Nesi-Hensu	F	Late Period	Flexed	1
IMP00112 Diptah	F	Ptolemaic Period	Flexed	2
IMP00113 Hor	M	Ptolemaic Period	Flexed	2
IMP00123 Thesaberu	F	Ptolemaic Period	Flexed	N/A

Table 4.13 **Flexed-Arm Mummies and Cranial Resin Treatment (N/A= Un-Assessable; 0= Brain in tact; 1= Excerebrated without Cranial Resin; 2=Excerebrated and Treated with Cranial Resin).**

IMPACT ID	Arms	Resin
IMP00006 Lady Hudson	F	2
IMP00007 Pa-Ib	F	2
IMP00012 RM2720	F	2
IMP00057 Padua Mummy	F	2
IMP00059 Liverpool 2	EL	2
IMP00065 Harwennefer	F	2
IMP00070 Liverpool 13	F	2
IMP00078 Renpit-Nefert	EA	2
IMP00081 Nofret	F	2
IMP00109 Peftjauneith	EA	2
IMP00112 Diptah	F	2
IMP00113 Hor	F	2
IMP00127 Nesiur	EA	2

***Table 4.14* Mummies Treated with Cranial Resin (2= Excerebrated and Treated with Cranial Resin) & Their Arm Position (EA= Extended Anterior; EL=Extended Lateral; F=Flexed)**

One final note concerning results providing more contextual information on the ancient Egyptians housed within IMPACT involves the Late Period male Peftjauneith (IMP00109) and the Third Intermediate female Mummy of a Woman (IMP00097). Going through different combinations of variables in search of significant clusters eventually led to testing stature and amulets together using squared Euclidian distance and the average-linkage algorithm (Figure 4.18), all of which placed Peftjauneith all by himself. Biological sex was added as a variable as I was interested in seeing if males and females would cluster together, presumably meaning their association went deeper than sex. When cranial resin was added as a variable, Peftjauneith became loosely linked to IMP00097-Mummy of a Woman (Figure 4.19), the tallest woman in the sample at 164.3cm, just as he was in Figures 4.4-4.11. Thus, this cluster included the two tallest individuals in the sample

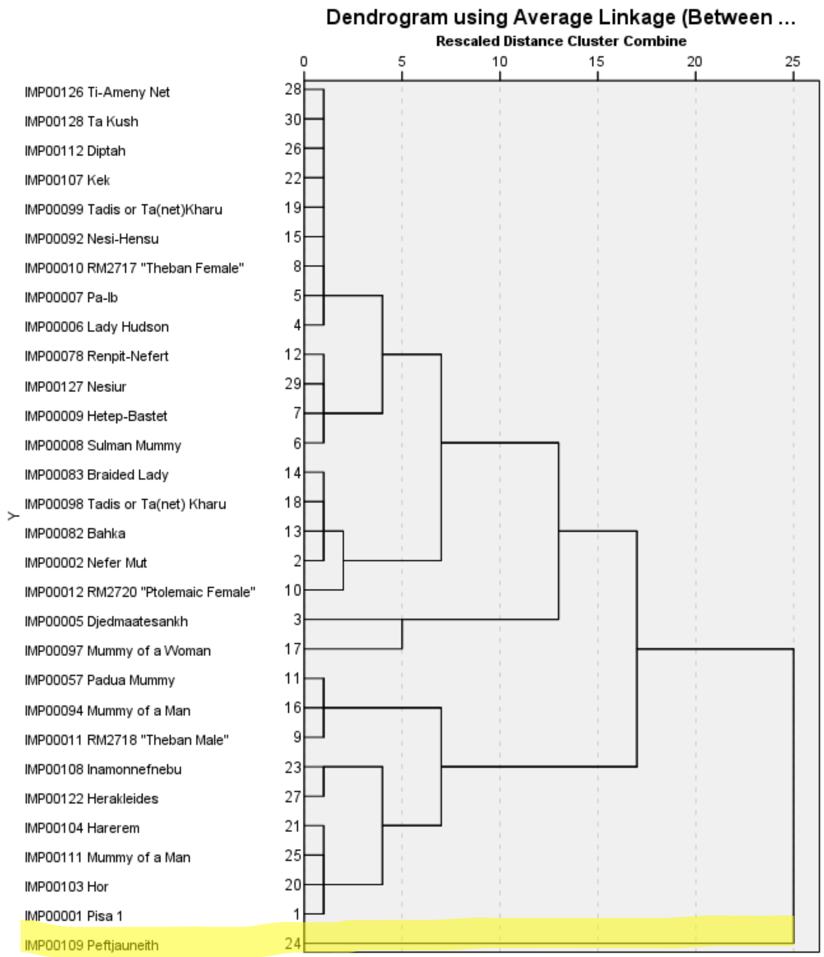


***Figure 4.18* Average Linkage for Sex, Stature, and Amulets**

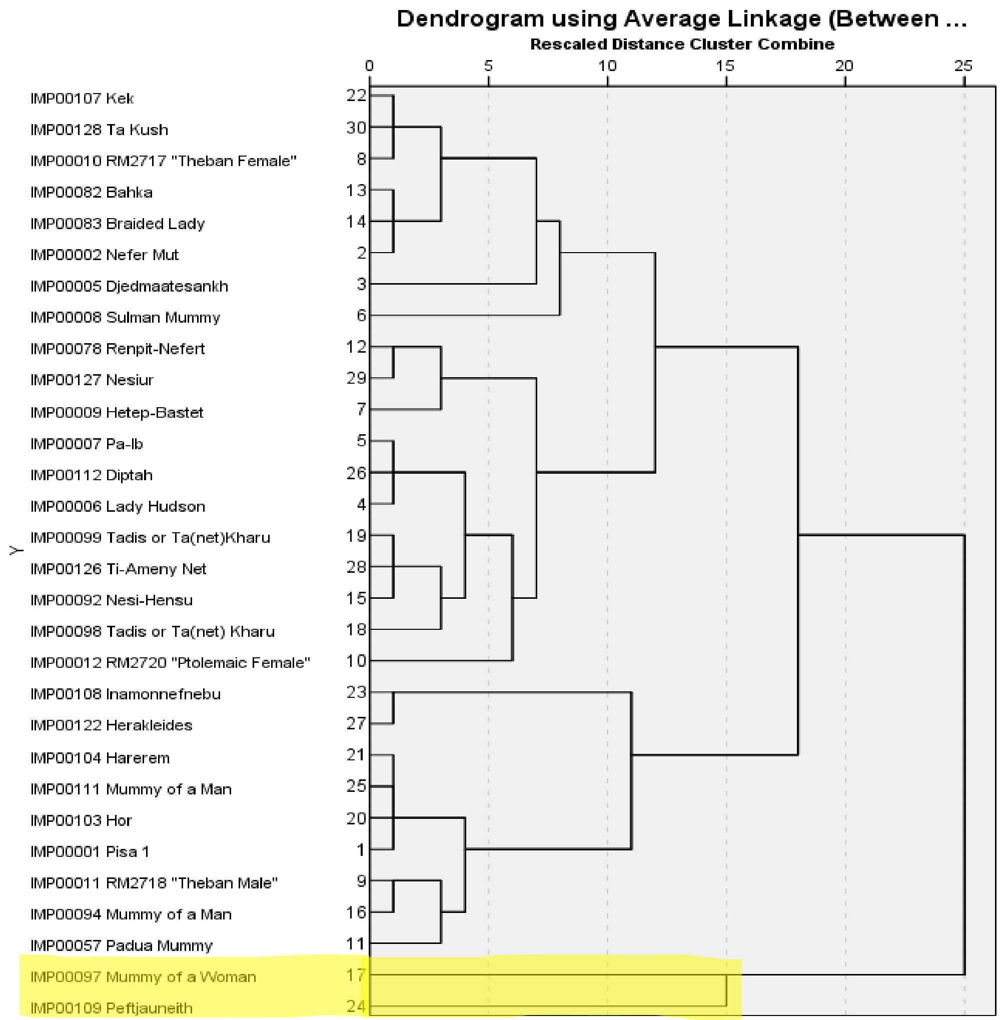


Figure 4.19 **Average Linkage for Sex, Stature, Amulets, and Cranial Resin**

Peftjauneith, in addition to clustering with the groups emphasized in Figures 4.4-4.11, is often a focal point in these cluster analyses for his mummification features indicative of high status. At 179.2cm, Peftjauneith is by far the tallest individual in this sample, who also happens to be one of the individuals with the most amulets. Additionally, he has a large pour of resin in his excerebrated skull and his arms are extended with the hands placed on the hips/pubic area. Due to these facts, there is an argument to be made that Peftjauneith is the individual of highest status within this sample of sixty-one adult ancient Egyptian individuals. Mummy of a Woman (IMP00097) might also be the female of highest status in the sample based on her height and amulets. The case of Peftjauneith, as well as the rest of the results detailed above, will be discussed further in the following chapter.

Chapter 5:

Discussion

This chapter will provide interpretations for the results presented in Chapter 4 and will be organized with respect to the order in which they were given. This discussion will also be informed by the information presented in Chapter 2, the comprehensive literature review, on the trends, features, and evolution of ancient Egyptian society, culture, and funerary practices. This chapter will begin by discussing the simple observations regarding arm position, amulets, cranial resin, and estimated stature. The results of this sample's estimated stature, in relation to the New Kingdom royal sample (Hawass & Saleem, 2016) and Zakrzewski's (2003) pre-Dynastic-Middle Kingdom sample, will also be evaluated further.

Following this will be a discussion on the Fisher Exact tests conducted in Chapter 4. Additionally, an explanation for what these results suggest will be provided. Next, the results of the exploratory data analysis will be evaluated as suggestions are made concerning the role of status in both this particular set of mummies from IMPACT, as well as the general mummification program in post-New Kingdom Egypt.

5.1 Simple Observations: Arm Position

Only fourteen (23%) of the total individuals in this sample had flexed arms. The flexed arm positioning, which had royal connotations during the New Kingdom (Hawass and Saleem, 2016), is generally only described as the preference for one period in post-New Kingdom Egypt, the Ptolemaic Period (Gray, 1972; Aufderheide, 2003; Elias, Lupton, & Klales, 2014; Loynes, 2015). This particular non-royal sample contains fourteen Ptolemaic Period individuals. Of these fourteen, nine had flexed arms (64.3%), confirming the arm position preference of this period and suggesting that the appearance of this arm position, outside the Ptolemaic Period, is rare. A more detailed discussion on arm positioning and temporal preferences can be seen below in section 5.6.

5.2 Simple Observations: Amulets

Precious amulets, in theory, should have been one of the clearest indicators of status. However, as is common in the study of ancient Egyptian mummies, grave-robbing and improper data collection techniques have complicated this analysis. Although I have stated that only eight individuals in this sample (13.1%) currently contain amulets or have overwhelming evidence for now-removed amulets (Gray & Slow, 1968; Lawson, 2016), this number was surely higher originally.

Tomb-robbing was common in ancient Egypt (Shaw, 2000; Aufderheide, 2003) and even influenced significant changes to burial practices and mortuary treatment. In the twenty-first Dynasty, embalmers began trying to make the body seem as realistic, and alive, as possible and some researchers believe this was, at least partially, to deter grave robbing (Aufderheide, 2003). The construction of the Valley of the Kings, and the Valley of the Queens, was also an attempt to protect royals from the grave plundering that was so common in previous periods (Bard, 2005; Shaw, 2000). Also during the New Kingdom, many royal mummies were moved to royal caches by high-priests, hoping to further protect these individuals from being robbed, even though the majority had already been visited and robbed by thieves (Hawass & Saleem, 2016).

Table 5.1 includes the seventeen royal mummies scanned and evaluated by Hawass and Saleem (2016), what was found inside the wrappings/body, and whether they had been robbed and damaged by tomb-robbers prior to being discovered by archaeologists. Thirteen of the seventeen mummies (76.5%) show clear evidence of tomb robbing and only one individual, the nineteenth Dynasty pharaoh Seti I, still contained amulets of metal or stone after being visited by these ancient thieves. The four individuals who were seemingly untouched after being embalmed include Yuya (a royal courtier) and Thuya (noblewoman and wife of Yuya), both of whom had pieces of gold included in their wrappings, the twentieth Dynasty pharaoh Ramses III who had many amulets of metal and stone, and Tutankhamun, the young eighteenth Dynasty pharaoh whose famously lavish burial included over 100 amulets inside the body and wrappings (Hawass & Saleem, 2016). It would be fair to assume that had all seventeen mummies been untouched, many more amulets or items of value would have been uncovered.

In addition to grave robbing, the unwrapping of mummies and early autopsies, as well as inconsistent methods for data recording, made the study of amulets more difficult. Prior to (and even after) the introduction of radiography in mummy studies, destructive unwrappings

Mummy Name (Dynasty)	Items/Amulets Found	Robbed and/or Damaged?
"So-Called" Thutmose I (18)	N/A	YES
Thutmose II (18)	N/A	YES
Thutmose III (18)	2 Bracelets	YES
Hatshepsut (KV60A) (18)	N/A	YES
Yuya (Father of Tiye) (18)	Gold Embalming Plate	NO
Thuya (Mother of Tiye) (18)	4 Items, Stone, Gold…	NO
Amenhotep III (18)	N/A	YES
Queen Tiye (Elder KV65) (18)	Multiple Round/Oval Objects of Stone/Faience	YES
Younger Lady KV65 (Tut's Mother) (18)	N/A	YES
KV55 Skeleton ("Akhenaten") (18)	N/A	YES
Tutankhamun (18)	100+	NO
KV21A (18)	N/A	YES
KV21B (18)	N /A	YES
Seti I (19)	Many Amulets of Metal and Stone	YES
Ramses II (19)	Terracotta Figure in Chest	YES
Merenptah (19)	N/A	YES
Ramses III (20)	Many Amulets of Metal and Stone	NO

***Table 5.1* Robbed and Damaged Royal New Kingdom Mummies. Data from Hawass and Saleem (2016)**

lacking proper data recording methods occurred (Andrews, 1994; Aufderheide, 2003; Andrews, 2004). Andrews (1994) has stated that most early autopsies of Egyptian mummies had incomplete recordings of removed amulets, and almost never included their specific *in situ* positioning, making it nearly impossible to accurately assess amulets and their specific associations (Andrews, 1994).

With both ancient and modern issues surrounding the study of amulets in ancient Egyptian mummies, not much should be read into the fact that only eight individuals in this sample contained amulets. Unfortunately, due to the reality of grave-robbing in ancient Egypt, with individuals trying to easily acquire precious items from the deceased, it becomes quite difficult to accurately determine whether every mummy without amulets in the sample began that way on their thousand(s) year journey to me. The reality of assessing amulets is that their presence can indeed confirm high-status, however, their absence is not necessarily indicative of lower status. It is an unfortunate reality that must be acknowledged by anyone working with Egyptian mummies, especially those interested in status indicators.

5.3 Simple Observations: Cranial Resin

The use of cranial resin by embalmers as an elaboration of the excerebration ritual is one of the more recently suggested features indicative of high-status for ancient Egyptians (Wade and Nelson, 2013). Resin, being made up of exotic, and thus, costly organic materials (Buckley and Evershed, 2001; Buckley, Clark, and Evershed, 2004), already had status implications, and its inclusion post-excerebration further implies high status. This procedure began with New Kingdom royals (Hawass & Saleem, 2016) during the twilight of ancient Egypt (Shaw, 2000; Ikram, 2003; Bard, 2015), but, like most mummification features, would eventually become utilised by non-royal individuals. Likely being one of the harder elaborations to emulate as a lower status individual, due to its cost, it is no surprise that only thirteen of the fifty-six assessable individuals in this sample were treated with cranial resin (23.2%). Furthermore, these thirteen individuals (Table 5.2) only represent 36.1% of all the excerebrated individuals in this sample (N=36).

Nothing out of the ordinary was found for cranial resin in relation to time period and sex. Recently published research has suggested that the use of cranial resin post-excerebration began in New Kingdom royals and peaked during the Ptolemaic Period (Wade, Nelson, & Garvin, 2011; Wade & Nelson, 2013), and most individuals treated with cranial resin in this sample (46.2%) are Ptolemaic. Klales (2014) has also documented the Ptolemaic preference for this treatment as eleven of her thirteen mummies treated with cranial resin are dated to this period. As mentioned in Chapter 2.2, access to resin was likely facilitated due to Egypt's trade relations during the Ptolemaic Period (Lloyd, 2000), while still retaining status connotations.

Of the thirteen individuals treated with cranial resin in my sample, only one is from the Third Intermediate Period (N=1; 7.7%), three from both the Late Period (N=3; 23.1%) and Roman Period (N=3; 23.1%), while six individuals (N=6; 46.1%), the majority, come from the Ptolemaic Period. The haphazard appearance of cranial resin during all four of these periods, in addition to having ties to social status, further demonstrates the variability of the mummification program in post-New Kingdom Egypt.

IMPACT ID	**Findspot**	**Time Period**	**Cranial Resin (0-2)**
IMP00006 Lady Hudson	Unknown	Roman Period	2
IMP00007 Pa-Ib	Unknown	Late Period	2
IMP00012 RM2720	Hawara el-Maktaa	Roman Period	2
IMP00057 Padua Mummy	Unknown	Ptolemaic Period	2
IMP00059 Liverpool 2	Unknown	Roman Period	2
IMP00065 Harwennefer	Abydos	Ptolemaic Period	2
IMP00070 Liverpool 13	Unknown	Ptolemaic Period	2
IMP00078 Renpit-Nefert	Thebes	Late Period	2
IMP00081 Nofret	Akhmim	Ptolemaic Period	2
IMP00109 Peftjauneith	Unknown	Late Period	2
IMP00112 Diptah	Akhmim	Ptolemaic Period	2
IMP00113 Hor	Akhmim	Ptolemaic Period	2
IMP00127 Nesiur	Unknown	Third Intermediate Period	2

Table 5.2 **Findspot of Excerebrated IMPACT Mummies with Cranial Resin**

5.4 Simple Observations: Estimated Stature

Stature estimates of both males and females were available for thirty individuals in this sample, the New Kingdom royal sample (Hawass & Saleem, 2016), and the pre-Dynastic to Middle Kingdom sample published by Zakrzewski (2003). The royal sample (Hawass & Saleem, 2016), while few in number, was expected to give greater averages in height for both males and females. While this was true for males, with the royals having an average height of 165cm versus the IMPACT non-royal average of 163.9cm with a standard deviation of 7.19, the difference is slight. Also, both sample sizes were similar; eleven royal males and ten non-royal males. The average estimated stature for the six royal females was 149.5cm, while the average for the twenty non-royal IMPACT females was 153.8cm with a standard deviation of 4.67. Although the non-royal sample is 4.3cm greater than the royals, which is the opposite of what was expected, the difference is not statistically significant. The Mann-Whitney U test conducted on both males and females with a significance level of .05, comparing royal and non-royal stature averages, confirmed that the differences were not significant.

The tallest non-royal female, IMP00097-Mummy of a Woman (164.3cm) is 5.3cm taller than Hatshepsut (159cm), the tallest female royal, and 10.5cm taller than the royal female average. The tallest non-royal male, IMP00109-Peftjauneith (179.2cm), is 6.2cm larger than the tallest royal male, Thutmose II (173cm), and markedly taller than the royal average (+14.2cm). *Z*-scores acquired for these four individuals (Thutmose II=1.29, Hatshepsut=1.53, Peftjauneith=2.26, Mummy of a Woman=2.31) have also shown that the non-royal differences are more above average and unusual than the royals. Meaning their large stature is out of the ordinary, when compared to others in the non-royal IMPACT sample. Therefore, while these samples differ in time period, these individual non-royal differences may still challenge the expectation that royals were always taller than non-royals. Perhaps this is simply indicative of the consanguineous marriages engaged in by many royals (Habicht et al., 2015), resulting in the stunting of growth, or perhaps, an indicator of a potential diminishing social gap between royals and non-royals in post-New Kingdom Egypt. It is also entirely possible that Peftjauneith and/or Mummy of a Woman were individuals of high status.

Results from testing the non-royals from this sample alongside Zakrzewski's (2003), displayed in Figure 4.3, should be interpreted cautiously as the sample sizes differ tremendously.

With sixty-nine more males and fifty-three more females in her sample, as well as a sample primarily composed of skeletonized individuals, Zakrzewski's (2003) averages are almost certainly more indicative of actual contemporary populations. With that being said, the trends displayed in Figure 4.3 for the pre-New Kingdom sample, are somewhat similar to those from my post-New Kingdom sample. As expected, males are taller than females in every period. Additionally, males and females seem to follow the same upward trajectory, albeit with larger jumps between periods for males, from the Third Intermediate Period until the Late Period. Similar to what Zakrzewski (2003) proposed happened from the pre-Dynastic era into the Dynastic periods, it is possible that after the New Kingdom, a sort of reset occurred. Perhaps the political instability or the influx of foreign rulers led to an overall decline in height before rising in the Late Period. The drop in average stature from the Late Period to the Ptolemaic Period may also mirror the drop from the Old Kingdom to the Middle Kingdom, wherein social complexity was augmented and the gap between royals and non-royals grew. It should be noted that although both my sample and Zakrzewski's (2003) are referred to as "non-royal", the IMPACT sample, solely containing mummified individuals, may all be of higher status comparatively as the Zakrzewski (2003) sample consists primarily of skeletonized individuals, who presumably could not afford to be embalmed. As a result, comparisons and interpretations should be made with caution.

On a final note concerning stature, it is important to reiterate that the regression technique I employed (Raxter et al., 2008) differs from both Hawass and Saleem (2016) and Zakrzewski (2003). Although the underlying equations are the same as those used by Hawass and Saleem (2016), I did not use Raxter et al.'s (2008) extra step for incorporating age into the regression formula for reasons discussed in Chapter 3 (section 3.5). Depending on the age entered, this would presumably result in a decrease of the statures presented in Table 4.4. I suggest that this extra step for age only be used for individuals with a very narrow estimated range for their age-at-death. Although many estimated statures have been published for mummies in the IMPACT sample, for example those in the Liverpool collection (Gray & Slow, 1968) or the Redpath Museum in Montreal (Lawson, 2016), I only used those I was able to personally acquire using the same standardized method. Going forward, the field of mummy studies should ensure that similar methods are used in the pursuit of standardizing data.

5.5 The Fisher Exact Test & the Classical Accounts

The data from Table 4.8 and Table 4.9 present statistical tests that do not support the assertion that the Classical accounts of Herodotus and Diodorus Siculus are completely accurate. As Herodotus wrote his accounts during the Late Period, and Diodorus during the Ptolemaic Period, I removed the seven Roman Period mummies in the sample to ensure the Fisher Exact test was as contemporaneous as possible with the Classical accounts. I also decided to test just the twenty-one late period mummies in the sample to be as fair as possible with Herodotus. In addition to being the period which had the most individuals, this sample subset is the most contemporaneous with the Herodotean accounts. The Fisher Exact test, in both instances, gave P-values of <0.0001, much lower than the 0.05 significance level, emphatically rejecting the null hypothesis that the distribution of observed mummification features in this sample mirrors the accounts of Herodotus and Diodorus.

Even though Wade and Nelson (2013) recently falsified Herodotus and Diodorus' observations on evisceration and excerebration, the results presented here are significant because no statistical testing has been done concerning the entirety of the mummification program. These results offer the academic community and popular literature/media incentive to halt its uncritical acceptance of these mummification accounts (Buckley & Evershed, 2001; Abdel-Maksoud & El-Amin, 2011; Gessler-Löhr, 2012; Jones et al., 2014). These accounts are valuable but should be used primarily as stepping-stones in the analysis of variability in ancient Egyptian mummification, rather than taken as pure fact, as they ignore the inherent variability of the ancient Egyptian mummification program.

5.6 Exploratory Data Analysis: Arm Position, Amulets, Cranial Resin, & Estimated Stature

The testing of these four primary status indicators together did not yield any significant clusters. It did, however, reveal an important issue for those researching ancient Egyptian mummies, especially in relation to status. Firstly, not being able to acquire data for one of the variables would result in the obfuscation of potential links. In this thesis, for example, not being able to acquire stature for the entire sample meant that using this variable eliminated thirty-one individuals from the analysis.

Secondly, as mentioned above in section 5.2, assessing status based on the presence or absence of amulets is problematic. By including amulets as a variable, the clusters seen in Tables 4.4-4.11 were not created by shared sets of mummification features, but rather, a shared lack of features. Amulets were driving the data, and because fifty-three individuals were designated as a "0" on my coding scale, mummies were clustering with 0's in the other categories. Essentially, this meant I was then testing for the opposite of what I had hoped to test for. Whether these amulets were stolen in antiquity, or improperly recorded before their more recent removal, we can again see how this aspect of Egyptian mummy studies affects our present, and future understandings of ancient Egyptian mummification.

5.7 Exploratory Data Analysis: Arm Position and Time Period

After recognizing the issues involved with using estimated stature and the presence of amulets as variables, the four status indicators were tested independently against time period. Appendix E displays the dendrograms related to these tests, and shows that amulets, cranial resin, and estimated stature do not cluster by time period. Arm position, however, does demonstrate clear associations with time period. Consistent with previously published research focusing on this mummification feature, the results for the New Kingdom, Third Intermediate Period, Ptolemaic Period, and Roman Period suggest relatively uniform arm positionings (Table 5.3).

The preferred arm positioning of mummies from the Late Period in this sample, however, differs from Elias, Lupton, and Klales (2014) (Table 5.3). Elias, Lupton, and Klales (2014) propose that the flexed arm position was favoured during this period. However, I found an overwhelming preference for extended positions in this IMPACT sample. The results of Elias, Lupton, and Klales (2014) also conflict with Gray (1972) and Loynes (2015), who also suggest a preference for extended arm positions (Table 5.3).

In their sample of fifteen Late Period mummies, six (40%) individuals had flexed arms (Elias, Lupton, & Klales, 2014). Additionally, two of the three (66.7%) Late Period mummies they had from the region of Akhmim had flexed arms (Elias, Lupton, & Klales, 2014). It should also be noted that Elias, Lupton, and Klales (2014) had fifteen Ptolemaic Period mummies from Akhmim, thirteen (86.7%) of which had flexed arms. In her sample of twenty-five individuals from Akhmim, Klales (2014) had twenty assessable individuals for arm positioning. Of her four Late Period individuals, two (50%) had flexed arms, however, fourteen of the twenty (70%) total individuals had a flexed arm position. Klales (2014) also stated that the higher status individuals in her sample were mostly those with flexed arms.

Elias, Lupton, and Klales (2014) mention that it is entirely possible that differences in arm positioning correspond to traditions that existed in different geographical regions. Although I had no Late Period mummies from Akhmim, I did have six Akhmim individuals from the Ptolemaic Period and of these six Akhmim individuals, five (83.3%) had flexed arms. Perhaps the Late Period discrepancy between my sample (as well as Gray[1972] and Loynes [2015]) and Elias, Lupton, and Klales' (2014) stems from my sample not having any Late Period individuals from Akhmim, which is an area that ostensibly preferred flexed arm positions. It is also possible that the region of Akhmim was innovative and began promoting the preference for flexed arms, which became the dominant position in many regions during the Ptolemaic Period (Gray, 1972; Aufderheide, 2003; Elias, Lupton and Klales, 2014; Loynes, 2015) earlier than elsewhere in Egypt. Regardless of whether there is an actual geographic preference for arm position, our differing results are a testament to the growing variability in the mummification program during post-New Kingdom Egypt and to the composition of the different study samples.

Time Period	**This Study (IMPACT)**	**Gray (1972)**	**Elias, Lupton, & Klales (2014)**	**Loynes (2015)**
New Kingdom	EA	E	E	EA
Third Intermediate Period	EA	EA	EA	EA
Late Period	EA	E	F	EA
Ptolemaic Period	F	F	F	F
Roman Period	EL	EL	N/A	EL

Table 5.3 **Comparing Most Frequent Arm Positions by Period from this sample, Gray (1972), Elias, Lupton, and Klales (2014), and Loynes (2015). (N/A= Unavailable; E = Extended with no clear preference for hand positioning; EA: Extended Anterior; EL: Extended Lateral; F=Flexed)**

5.8 Exploratory Data Analysis: Arm Position and Cranial Resin

After testing the variables independently, I tested several combinations of variables using different algorithms in the search for significant clusters. This led to additional analyses of both cranial resin and arm positioning in conjunction with one another. Although it is possible that this is merely coincidental, having 75% of the assessable flexed-arm mummies (N=9) in the sample being treated with cranial resin, and 69% of mummies with cranial resin having flexed arms (N=9), this association is likely intentional. Additionally, five of the six Akhmim mummies in my sample were able to have their cranial treatment evaluated and it was found that three of the five (60%) had both flexed arms and cranial resin treatment.

Although it is possible that these features cluster together due to regional preferences, as both arm positioning and cranial resin treatment, respectively, may have geographic associations, I suggest another possible reason for their association. As discussed in Chapter 2.2 (section 2.2.5), archaism in ancient Egypt was an "inherent feature of the culture" (Kahl, 2010, 5) that manifested itself in a multitude of ways, from the realm of art to influencing the names and titles of individuals (Taylor, 2000; Redford, 2001a; Kahl, 2010). In post-New Kingdom Egypt, archaism was popularized by foreign rulers attempting to bring legitimacy to their rule (Trigger et al., 1983; Taylor, 2000; Redford, 2001a; Kahl, 2010). This included adopting Egyptian religious beliefs and burial practices, and as a result, Third Intermediate Period mummification is often considered a high point for embalming technologies (Taylor, 2000). Furthermore, it is believed that during the Late Period, specifically during the Kushite and Saite dynasties, "archaism reached full bloom" (Redford, 2001a). With an ambitious building program unseen since the New Kingdom reign of Ramses II, that deliberately emulated the Egyptian past, these foreign rulers were hoping to legitimize their rule (Redford, 2001a). Additionally, as the Kushites built many pyramids in Nubia (modern day Sudan) (Shaw, 2000; Bard, 2015), thousands of years after they were built by Egyptians in the Old Kingdom, it seems that archaism may not target specific time periods, but rather, be more concerned with the most grand, and obvious, royal conceptions. This would mean that both the New Kingdom and the Old Kingdom, the two periods in which pharaonic power was at its height (Shaw, 2000; Ikram, 2003), would be prime candidates for emulation through archaism.

As there are currently no statistical analyses regarding the extent of archaism in ancient Egypt (Kahl, 2010), this is just a suggestion. However, I believe it does merit consideration. Not only because the royal flexed arm position and cranial resin treatment began during the New Kingdom, but also, because archaism was already prominently being employed during the Late Period, with the New Kingdom likely being one of the primary models for emulating the apex of ancient Egyptian culture (Redford, 2001a). If archaism was indeed being practiced by embalmers during post-New Kingdom Egypt, it stands to reason that it would likely result in the emulation of New Kingdom royal mummification, which occurred at the height of ancient Egypt.

Pharaoh Name (Dynasty)	**Sex**	**Arm Position**	**Cranial Resin**
Seti I (19)	M	F	2
Ramses II (19)	M	F	2
Merenptah (19)	M	F	2
Ramses III (20)	M	F	2

Table 5.4 **New Kingdom Royals (Hawass & Saleem, 2016) with Flexed Arms & Cranial Resin**

The New Kingdom introduced cranial resin treatment, as eighteenth Dynasty rulers Amenhotep III and Tutankhamun had generous pours of resin solidified in their cranial vault (Hawass & Saleem, 2016). Furthermore, the nineteenth and twentieth Dynasties saw the adoption of flexed arms as the 'royal arm position' (Hawass & Saleem, 2016). All four pharaonic mummies from the nineteenth and twentieth Dynasties presented by Hawass and Saleem (2016) had both flexed arms and cranial resin treatment (Table 5.4). This includes the reputable ruler Ramses II who, in addition to having a massive building program across Egypt, had the longest documented pharaonic reign, lasting sixty-seven years (Shaw, 2000; Bard, 2015). It should be noted that 18th Dynasty ruler Tutankhamun did have a generous pour of resin in his cranium, however, his arm position was extended.

It is entirely possible that these two features, synonymous with New Kingdom royalty during the nineteenth and twentieth dynasties, became the ideal features wanted by those expecting to be embalmed after death. As they are both associated with royalty at the height of ancient Egypt, these two features could have been regarded as the archetypal and idealized form of mummification. Archaism, imitating New Kingdom Egypt, was already happening during the Late Period within the building programs of foreign rulers, therefore, its appearance in the mummification program would be a rational assumption. As the use of resin during mummification implies some degree of cost associated with status, I am suggesting that some of the more affluent non-royal, but elite, individuals would likely have wanted these two features as a part of their eventual embalming. The democratization of mummification, in conjunction with the potential augmented use of archaism, both occurring in post-New Kingdom Egypt, may in fact explain why these two features often occur together.

5.9 Exploratory Data Analysis: The Case of Peftjauneith (IMP00109)

As was described at the end of Chapter 4, IMP00109-Peftjauneith, a Late Period male from the Leiden University collection (Raven & Taconis, 2005), often occupied his own cluster, separate from others. Peftjauneith appeared to be unique when testing the four status related variables highlighted throughout this thesis. His estimated stature, at 179.2cm, is distinctly greater than any other individual within my sample or even the New Kingdom royal sample (Hawass & Saleem, 2016). Of course his height could simply be the result of family genetics, however, the fact that Peftjauneith has several amulets of gold leaf (Raven & Taconis, 2005) and an extremely generous amount of cranial resin, imply that he is perhaps the highest status individual in the IMPACT sample. Although his arm positioning is extended anteriorly, and not flexed, this is not outside the ordinary as eighteen of the twenty-one (85.7%) Late Period mummies from this sample have extended arms. It is also possible that geographic preferences influenced this aspect, however, Peftjauneith is unfortunately one of many mummies without any known provenience. If Peftjauneith is indeed the highest status individual within the adult Egyptian IMPACT sample, and the simultaneous appearance of flexed arms and cranial resin being indicative of a lavish and idealized form of mummification is true, then the case of Peftjauneith becomes even more significant in demonstrating the variability of mummification in ancient Egypt.

Reasons for having a different arm position, or any combination of these features, could simply be products of specific time periods, geographic regions, or even stylistic choices made by the mummified individual, their family, or the embalmer. Some features are clearly representative of status. However, the variability of the mummification program across time and space, as well as the influence of human agency, implies there is no perfect or ideal grouping, or cluster, of status indicators. Seeing multiple indicators together can be telling, as in the case of Peftjauneith. However, until there is a greater understanding of the variability found within the different Egyptian mummification programs across both time and space, it will be difficult to categorize and interpret status indicators hierarchically.

CHAPTER 6:
Conclusion

As was made clear in Chapter 1, this thesis was conducted to investigate the relationship between ancient Egyptian society, status, and burial practices. By focusing on non-royal mummification in post-New Kingdom Egypt, I have not only evaluated the validity of Classical accounts detailing the supposed processes of Egyptian mummification but tested four mummification features with status connotations for association with one another. These features were also tested for significant associations with specific time periods and geographic regions. More than anything, this thesis has demonstrated that variability in mummification features was pervasive in ancient Egypt. This thesis has also demonstrated that the democratization of mummification in post-New Kingdom Egypt (Aufderheide, 2003) led to the propagation of variability in the practice of mummification, solidifying it as an inevitable aspect of this funerary ritual.

The comprehensive literature review in Chapter 2 delved into a variety of aspects related to ancient Egyptian social stratification and mummification, as well as the necessary tools required by bioarchaeologists to non-destructively and reflexively engage in mummy studies. Chapter 2.1 focused on the primary sources regarding mummification and why Herodotus' accounts have been held in such high regard. Chapter 2.2 presented a brief, but inclusive, chronological history of ancient Egyptian social complexity, while Chapter 2.3 did the same for the mummification program, from its inception, to its banning during the Roman Period. What these three sections made clear is that ancient Egypt, while being well-documented, is still quite enigmatic, especially regarding social stratification and mummification. Ancient Egyptian culture was dynamic and constantly evolving, while still adhering to certain ritualistic aspects across millennia. It was both interested in respecting past traditions and keeping certain aspects in use for thousands of years (for example, through burial rituals or the use of archaism in a variety of ways), while innovations and variability were actively employed on both a macro and micro level. Chapter 2.4 and Chapter 2.5 highlighted the specifics of researching ancient Egyptian mummies in a non-invasive manner, which provides both respect for the dead and respect for the scientific community. This thesis has demonstrated issues within this field of study in terms of both the proper recording of contextual information as well as the mistreatment of these mummified individuals, in both ancient and modern contexts, highlighting the importance and relevance of Chapter 2.4 and Chapter 2.5.

By using the adult ancient Egyptian mummy sample from the IMPACT database (Appendix A), taking into consideration the more than 6000 years of history laid out throughout Chapter 2, this thesis attempted to answer two primary research questions:

Should we continue to rely on the ancient Egyptian mummification accounts of Herodotus?

&

By looking at non-royal mummification, which features indicate differential status, and in which ways, if any, are they correlated?

With the chronological mummification checklist presented in Chapter 2.3 being used as a primary reference, the IMPACT sample was tested in a variety of ways (described in Chapter 3), including being compared to a published New Kingdom royal sample (Hawass & Saleem, 2016) and a published non-royal sample (Zakrzewski, 2003) which focused on earlier time periods. Cultural and historical contexts were informed by Chapter 2.2. Taken as a whole, the results presented in Chapter 4, and discussed in detail in Chapter 5, addressed the primary questions of this thesis and demonstrated further the complexity and variability involved in ancient Egyptian mummy studies. This final chapter will briefly summarize this thesis' most notable findings and suggest future areas of research for both the IMPACT mummy database specifically, and more generally, the study of ancient Egyptian mummification as a whole. The chapter will end by addressing the two primary research questions presented in this work, while final thoughts on this project and how mummy studies and bioarchaeology as a whole should be approached are offered.

6.1 Findings of Note

This section will largely follow the order in which these findings of note were presented in Chapter 4 and Chapter 5, rather than being discussed in order of their significance. To begin, this thesis has highlighted how amulets, and specifically their absence, should be interpreted with caution. As has been demonstrated, amulets were often stolen in antiquity, or improperly documented when removed more recently. Their presence can definitely be indicative of high status, however, their absence does not necessarily imply lower status. As specific associations are nearly impossible to interpret due to poor data recording (Andrews, 1994), amulets must be given additional attention in Egyptian mummy studies going forward. The location of the amulet, its form, and the material it is made of must all be recorded and interpreted in terms of their time period and geographic location.

Cranial resin, being one of the more recently proposed status indicators (Wade & Nelson, 2013), was a central focus this research. What this thesis has brought to light on the subject, in addition to its association with arm positioning (discussed below), is its potential association with the geographic region of Akhmim. Although this sample only had six individuals from the region, half of whom were treated with cranial resin (50%), Klales' (2014) sample of twenty-five Akhmim individuals also had a similar percentage of treatment (52%). Comparatively, only one of the twenty-three mummies from Thebes (4.3%), the largest grouping of region-specific individuals in the sample, was treated with cranial resin. Although the sample sizes are small, and possibly more telling of temporal preferences, this substantial difference in percentage warrants recognition and further investigation into geographic preferences for the treatment of cranial resin post-excerebration.

When compared to the New Kingdom royal sample (Hawass & Sample, 2016), this IMPACT sample provided somewhat surprising results regarding stature. With very similar sample sizes, the New Kingdom royal male average stature of 165cm was only marginally (but not significantly) taller than the non-royal sample (163.9cm). Additionally, for females, the non-royal sample average stature of 153.8cm was actually greater (but not significantly) than the royal average stature of 149.5cm. For females, however, the sample sizes do differ with only six royals and twenty non-royals. IMP00097-Mummy of a Woman and IMP00109-Peftjauneith, the tallest female and male, respectively, in the non-royal sample, were also taller than the tallest royals and taller than the royal averages. Their *Z*-scores, being positive and above 2 (at 2.26 and 2.31 respectively), mean they are above average, and unusual. This means that they are taller than is expected of non-royal individuals (based on this IMPACT sample) and that while these values are not statistically significantly different from the mean (3 *Z*-scores from the mean), they do require detailed examination (Drennan, 1996). These results may challenge the notion that individuals of higher status would be expected to have greater stature than those of lower status (Haviland, 1967; Schoeninger, 1979; Allison, 1984; Angel, 1984; Cohen, 1989; Cook, 1984; Steegman & Haseley, 1988; Zakrzewski, 2003). At the very least, the tall stature of Mummy of a Woman and Peftjauneith distinguish them from the rest of their non-royal counterparts in the IMPACT sample. This is particularly true for Peftjauneith, who, as discussed in section 5.8, demonstrates convincing evidence for being the highest status individual within the adult IMPACT ancient Egyptian mummy sample.

The variation through time of average heights for males and females presented in Figure 4.3, combining averages from Zakrzewski (2003) and my own sample, demonstrates a potential parallel in the rise, and eventual drop, in average stature for pre-New Kingdom Egypt and post-New Kingdom Egypt. Although sample sizes differed, it seems possible that the rising trajectory of average heights for men and women from pre-Dynastic Egypt into the Old Kingdom, followed by a drop during the Middle Kingdom, occurred for similar reasons in post-New Kingdom Egypt. As there is a rise in stature from the Third Intermediate Period into the Late Period for both males and females, before dropping once again during the Ptolemaic Period, perhaps this is indicative of social complexity being in flux after the New Kingdom, before stabilising once again between the Late Period and Ptolemaic Period, mirroring the conclusions of Zakrzewski (2003).

The Fisher Exact tests, conducted on a sample of fifty-four individuals dating from the Third Intermediate Period until the Ptolemaic Period, as well as a Late Period-specific sample of twenty-one individuals, tested the null hypothesis which assumed that the distribution of observed mummification in this sample would mimic the accounts of Herodotus and Diodorus. In both instances, the Fisher Exact test resulted in P-values of <0.0001, categorically rejecting the null hypothesis. Furthermore, as was made clear in Chapter 3 and Chapter 4, the qualifications for mummies in this sample falling outside the Classical descriptions were not small in number. Many prominent and seemingly ubiquitous mummification features not mentioned by either Herodotus or Diodorus were discovered. In many cases, multiple features not mentioned in the Classical accounts occurred within the same individual, further demonstrating the existence of variability throughout the mummification program. It is entirely possible that the accounts of these Classical historians mirrored the geographic region they were visiting, however, this has yet to be explored. Regardless, the fact remains that their accounts should no longer be interpreted as complete or utilised as the ideal standard for ancient Egyptian mummification.

The exploratory data analysis, in addition to highlighting issues surrounding the use of amulets and estimated stature as variables when testing status indicators for association (section 5.5), demonstrated links between arm position and time period (section 5.6) and cranial resin (section 5.7). The first link comes after seeing that arm position preferences documented by other scholars were mostly adhered to for every post-New Kingdom period, except for the Late Period. Elias, Lupton, and Klales (2014) posited that the Late Period preference was crossed arms, however, in my own sample, eighteen of the twenty-one individuals (85.7%) had extended arm positions. Furthermore, the arm positioning assessments of Gray (1972) and Loynes (2015) also suggest a preference for extended arm positions in the Late Period. After further investigation, and looking at individuals specifically from Akhmim, in both the Late Period and Ptolemaic Period, it seems likely that the primary reason for this discrepancy lies in geographic traditions. Concurrently, this discrepancy also further demonstrates the variability present in post-New Kingdom mummification from region to region.

The second link including arm positioning is the association between cranial resin and the flexed arm position. With 75% of flexed arm mummies being treated with cranial resin, and 69% of mummies with cranial resin having flexed arms, this association seems deliberate. After reviewing potential reasons for this association, it seems, once again, that regional traditions (as well as status) may be primarily responsible. However, I have also suggested another potential reason for the association; the practice of archaism within the mummification program. Currently, no systematic analysis exists regarding the use and extent of archaism in any practices during ancient Egypt (Kahl, 2010), let alone mummification, making it an excellent area for future researchers to explore.

6.2 Future Work: The IMPACT Database

In addition to the necessary future work alluded to above, which includes a more sophisticated analysis and recording of amulets, as well as testing for the geographic associations of cranial resin and arm position (both independently and in conjunction with one another), this thesis has proposed a few other areas of future research. This includes suggestions for both the IMPACT database and sample specifically, as well as post-New Kingdom Egypt mummification in general.

In terms of future work that will specifically benefit the IMPACT radiological and contextual database, two primary suggestions are offered. First, as estimated stature has been acquired for this particular IMPACT sample using a regression technique and algorithm offered by Raxter et al. (2008). It would be wise to utilize this formula for any future Egyptian mummies added to IMPACT, however, the extra step which incorporates estimated age-at-death, should be cautiously used. It would also be practical to do this for the Egyptian mummies who did not qualify for inclusion within this thesis. This would include finding a way to acquire proper long-bone measurements for the individuals who only have plain x-ray images available for analysis, which unfortunately may not be possible without them being CT scanned. However, if the raw data for any of the six long bone measurements utilised by Raxter et al. (2008) are available for these mummies from their institution of origin, it could work. This would require, however, collaboration between the IMPACT database moderators and the institutions who have shared their mummy information with IMPACT.

In some cases, estimated stature was offered by the primary researchers working with these mummies from their respective institution of origin (Gray & Slow, 1968; George et al., 1995; Raven & Taconis, 2005; Carrara & Scaggion, 2016; Lawson, 2016), meaning long bone measurements must exist somewhere, if not directly provided in published works. These offered stature estimates were not included in this study as these measurements were taken decades apart, utilising different stature estimation techniques, making it imprudent to try and compare these measurements with one another, or even against the estimated statures acquired for this thesis. Going forward, estimated stature should be acquired in a standardized way, using the same (or similar) techniques for measuring the long bones and calculating the overall stature. This would create an accurate and well-informed scale for the stature of the Egyptian mummies housed in IMPACT to be compared with one another, allowing for assessments related to sex, time period and geographic location. The IMPACT sample could then be more confidently evaluated alongside Egyptian samples also utilising Raxter et al.’s (2008) regression formula.

Second, I believe it would benefit the entirety of the Egyptian IMPACT mummy sample to create a scale of sorts, evaluating, broadly, the social/socioeconomic status of the individuals. Rather than evaluating each individual separately and placing them in a specific position on a scale, this would simply involve grouping the individuals most clearly of higher social status, based on their mummification features and accompanying contextual information, together. Individuals such as IMP00109-Peftjauneith, and possibly IMP00097-Mummy of a Woman, would be included in this specific grouping. As some of these mummies include detailed contextual information and analysis from their institution of origin, other factors could also place individuals amongst this sample's most elite. For example, IMP00012-RM2720 from the Redpath Museum in Montreal, had a gold death mask (Lawson, 2016). Additionally, Lawson (2016) provided an estimated stature of 156.8cm for this female mummy, which would have her designated as "tall" when compared to the rest of this sample.

Although these are not royal mummies, those who are likely of higher status, should be described as such within IMPACT. Mummies like Peftjauneith and RM2720 should have an indication denoting their differential status amongst the other Egyptian mummies housed within IMPACT. This would simplify future research involving social status and mummification. To do this properly, however, more knowledge on which mummification features indicate higher levels of status, rather than simply being a product of time period and/or region, is necessary.

6.3 Future Work: Post-New Kingdom Mummification

This thesis has shed light on aspects of post-New Kingdom mummification in need of further exploration going forward. As was discussed extensively in Chapter 5, and above in section 6.1, a greater knowledge of geographic preferences in relation to mummification features (potentially indicative of social status) is needed. The discovered discrepancy between individuals treated with cranial resin between the regions of Akhmim and Thebes (see section 5.3), as well as the period-specific arm positioning preference which may have also existed at Akhmim (see section 5.6), have proven that additional research on this subject is necessary. This focus should also be broad, rather than merely comparing two regions such as Akhmim and Thebes, allowing for the discernment of which mummification features are truly indicative of status, instead of being a mere geographic preference.

Discussions on the connection between cranial resin treatment and arm positioning (section 5.7), which may also have connections to geographic preference, has uncovered the potential relationship between archaism and the mummification program in post-New Kingdom Egypt. This would be a new avenue to explore in mummy studies as no current analysis evaluating archaism in Egypt exists (Kahl, 2010); let alone its association with the mummification program. Using information presented in this thesis, I believe an analysis of archaism in ancient Egypt would form the basis for an interdisciplinary and collaborative research project that would not only benefit the fields of Anthropology, Bioarchaeology, and Egyptology, but a wide array of disciplines from the art world into the 'hard' sciences.

A final recommendation for future work is a greater focus on cranial resin, one of the most recently suggested mummification features indicative of higher status (Wade & Nelson, 2013). Specifically, evaluating the volume of resin, and the percentage of cranial vault space it occupies, may provide a better understanding of its association with social status. Although mummies in this sample have cranial resin in their skull, overall, they pale in comparison to the generous resin pours seen in New Kingdom pharaohs, such as Tutankhamun and Merenptah (Hawass & Saleem, 2016).

The software packages utilised in this thesis, *Dragonfly 4.1* and *ORS Visual^si^*, allow for the segmentation, and further analysis of internal structures, such as solidified cranial resin. With segmentation, cranial resin can be isolated, removed, and analysed in its own 3D space. For the 2019 annual meeting of the Canadian Association for Physical Anthropology in Banff, Alberta, Canada, I presented an academic poster (Arsenault, 2019) demonstrating how to properly utilize these segmentation features in *Dragonfly 4.1* to evaluate cranial resin. Using IMP00006-Lady Hudson (Figure 6.1), volumetric tools were utilised to isolate a region of interest, the cranial resin, before recreating it as its own entity in a 3D space (Figure 6.2). Further information on this function, including the specific steps to segment cranial resin using *Dragonfly 4.1,* and the results I acquired for Lady Hudson (Arsenault, 2019), are presented in Appendix F.

6.4 Final Thoughts

Returning to the two primary questions posed in Chapter 1, and reiterated above: should we continue to rely on the accounts of Herodotus? And secondly, which mummification features indicate differential status amongst non-royals and in which ways are they correlated? The first question regarding Herodotus, and to a lesser degree, Diodorus Siculus, has been answered quite clearly. Not only have researchers falsified their specific claims regarding evisceration and excerebration (Wade & Nelson, 2013), this research has provided a statistical value allowing for the rejection of the idea that the accounts of Herodotus and Diodorus are completely accurate.

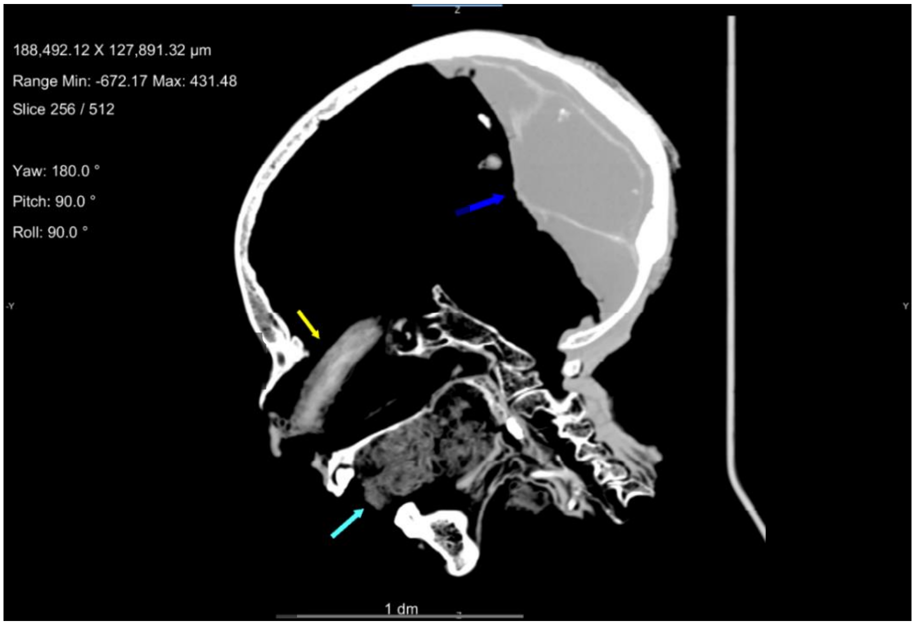


Figure 6.1 **Sagittal View of Lady Hudson (IMP00006)**

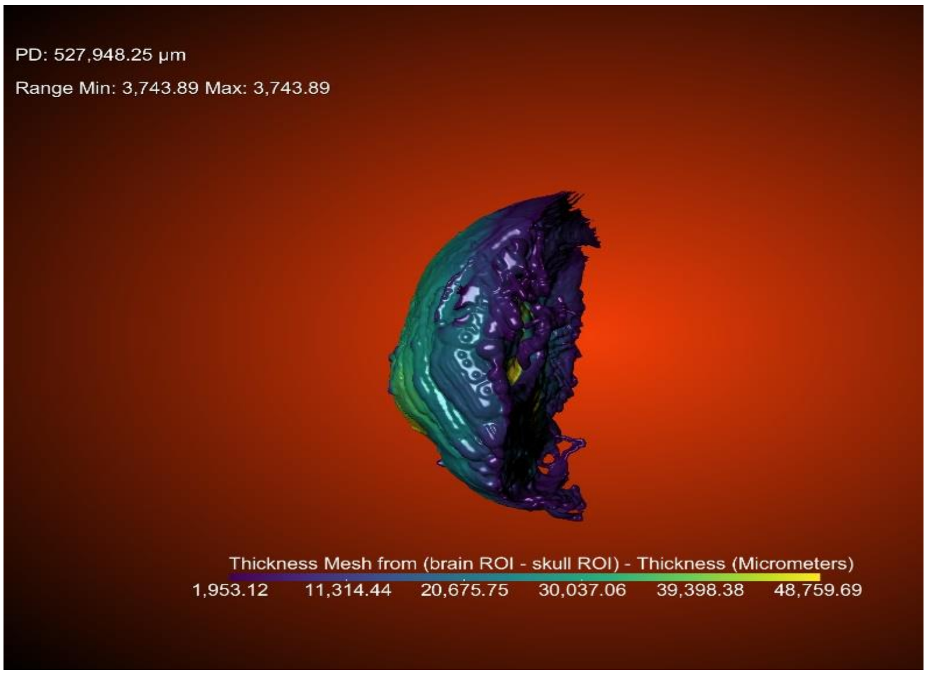


Figure 6.2 **Segmented and Isolated Cranial Resin in *Dragonfly 4.1***

The second question, however, has only been partially answered. From the tests performed on this particular sample, it seems that arm position has associations with both geographic location and the use of cranial resin. However, further research into geographic preferences for many mummification features, not just arm positioning, is necessary for a better understanding of their appearance and use. As seen in Chapter 2.3, some of these preferences have already been discovered. For example, during the Late Period, there existed geographic preferences for the way the body was wrapped, as mummies from the Nile Valley feature far more geometric patterns than mummies discovered in Nubian Egypt (Aufderheide, 2003). It is not unreasonable to assume that many other mummification features are likely products of the geographic region in which they occurred. Researchers have also suggested that some excerebration techniques may be attributed to certain geographic regions (Wade, Nelson, & Garvin, 2011). In terms of arm position clustering with cranial resin, this may also be further explained through research focusing on geographic preference, however, I believe it to be just as likely, if not more, that these features were practiced together in an attempt to emulate New Kingdom royal mummification through archaism. As Kahl (2010) has mentioned, no systematic analyses testing archaism in ancient Egypt exist, especially in relation to mummification, making it a potentially fruitful area of research for future bioarchaeologists and those involved in mummy studies.

Above all, this study has demonstrated the many layers of complexities involved in ancient Egyptian mummy studies. Moreover, these complexities become compounded further when a focus is placed on the intersectionality of social stratification and the practice of mummification, as well as the presence of foreign rulers in post-New Kingdom Egypt. By assessing the non-royal IMPACT sample alongside the information compiled within the comprehensive literature review presented in Chapter 2, it becomes clear that variability was an inevitable property of the mummification program in ancient Egypt, especially after the New Kingdom. Although this intrinsic quality has been explored throughout this thesis, and by many other researchers in the past, much is left to discover. As mentioned in Chapter 1, ancient Egypt is, paradoxically, a well-documented enigma, and this thesis does not change that circumstance. It does, however, explicate the relationship between social status and mummification, while emphasizing the variability, and possible haphazardness, of mummification features. It also provides new avenues to explore in the unrelenting search for novel information regarding the social history and mummification program in ancient Egypt.

On a final note, the work presented in this thesis has also further proven the need for reflexivity within the field of bioarchaeology, and more specifically, ancient Egyptian mummy studies. For the most holistic, and thus, accurate, representation and understanding of ancient Egypt, interdisciplinarity is vital. Furthermore, the use of non-destructive methods, growing ever more abundant due to the technological advancements of the 21st century, should be employed. Not only in the name of conservation and preservation, but primarily, to ensure respect for the dead. The use of non-destructive imaging, like CT scans, in Bioarchaeology calls for collaboration between a multitude of disciplines and fields (Larsen, 2006; Chhem & Brothwell, 2008; Beckett & Conlogue, 2016; Wade et al, 2019; Beckett & Conlogue, 2021) and any researcher interested in conducting proper analyses, should welcome this collaboration with open arms and minds. Not only is this the best approach for a Bioarchaeologist, but the most ethical. Working with mummified Egyptian individuals, whose remains have greatly informed our understanding of the past, means, above all else, implementing the Vermillion Accords (World Archaeological Congress, 1989). Respect for both the dead, and the scientific community, should always be of paramount importance.

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APPENDIX A:

The 61 non-royal adult individuals in this IMPACT sample

IMPACT ID	Sex	Time Period	Institution of Origin
IMP00001 Pisa 1	Male	Unknown	Pisa University
IMP00002 Nefret-Mut	Female	Third Intermediate Period	Royal Ontario Museum
IMP00005 Djedmaatesankh	Female	Third Intermediate Period	Royal Ontario Museum
IMP00006 Lady Hudson	Female	Roman Period	Western University
IMP00007 Pa-Ib	Female	Unknown	Barnum Museum (Connecticut)
IMP00008 Sulman Mummy	Female	Ptolemaic Period	Chatham-Kent Museum
IMP00009 Hetep-Bastet	Female	Late Period	UQUAM (Montreal)
IMP00010 RM2717 "Theban Female"	Female	Roman Period	Redpath Museum (Montreal)
IMP00011 RM2718 "Theban Male"	Male	Ptolemaic Period	Redpath Museum (Montreal)
IMP00012 RM2720 "Ptolemaic Female"	Female	Roman Period	Redpath Museum (Montreal)
IMP00027 Genova 1 Female	Female	Unknown	Civic Museum of Ligurian Archaeology (Genoa)
IMP00028 Genova 2 Male	Male	Unknown	Civic Museum of Ligurian Archaeology (Genoa)
IMP00029 Pasherienaset	Male	Late Period	Civic Museum of Ligurian Archaeology (Genoa)
IMP00035 Euphemia	Female	Roman Period	Brussels Royal Museum
IMP00040 Toutou	Male	Ptolemaic Period	Brussels Royal Museum
IMP00043 Female Mummy	Female	Third Intermediate Period	Brussels Royal Museum
IMP00044 Female Mummy	Female	Third Intermediate Period	Brussels Royal Museum
IMP00057 Padua Mummy	Male	Ptolemaic Period	University Museums of Padua
IMP00058 Liverpool 1	Female	Roman Period	World Museum Liverpool
IMP00059 Liverpool 2	Female	Roman Period	World Museum Liverpool
IMP00060 Pedeamun	Male	Late Period	World Museum Liverpool
IMP00061 Liverpool 4	Male	Late Period	World Museum Liverpool
IMP00062 Liverpool 5	Female	Late Period	World Museum Liverpool
IMP00063 Liverpool 6	Female	Late Period	World Museum Liverpool
IMP00065 Horwennefer	Male	Ptolemaic Period	World Museum Liverpool

IMP00066 Tetkhonsefankh	Female	Third Intermediate Period	World Museum Liverpool
IMP00067 Liverpool 10	Male	Late Period	World Museum Liverpool
IMP00068 Liverpool 11	Male	Unknown	World Museum Liverpool
IMP00070 Liverpool 13	Male	Ptolemaic Period	World Museum Liverpool
IMP00071 Mummy of Nesmin	Male	Ptolemaic Period	World Museum Liverpool
IMP00072 Liverpool 15	Male	Late Period	World Museum Liverpool
IMP00073 Ta-Enty	Female	Late Period	World Museum Liverpool
IMP00078 Renpit-Nefert	Female	Late Period	South Australian Museum
IMP00079 George ("Nubian")	Male	Ptolemaic Period	South Australian Museum
IMP00081 Nofret	Female	Ptolemaic Period	Kulturhistorisk Museum Oslo
IMP00082 Bahka	Female	New Kingdom	Museum of World Treasures (Kansas)
IMP00083 Braided Lady	Female	New Kingdom	Museum of World Treasures (Kansas)
IMP00088 Nesmutaatneru	Female	Late Period	Boston Museum of Fine Arts
IMP00092 Nesi-Hensu	Female	Ptolemaic Period	Archaeological Museum (Zagreb, Croatia)
IMP00093 Tash Pen Khonsu	Female	Ptolemaic Period	Canterbury Museum (New Zealand)
IMP00094 Mummy of a Man	Male	Third Intermediate Period	Leiden University (Netherlands)
IMP00095 Mummy of a Woman	Female	Third Intermediate Period	Leiden University (Netherlands)
IMP00096 Khonsuemma'a (Kherut)	Male	Third Intermediate Period	Leiden University (Netherlands)
IMP00097 Mummy of a Woman	Female	Third Intermediate Period	Leiden University (Netherlands)
IMP00098 Tadis or Ta(net) Kharu	Female	Third Intermediate Period	Leiden University (Netherlands)
IMP00099 Tadis or Ta(net)Kharu	Female	Third Intermediate Period	Leiden University (Netherlands)
IMP00101 Mummy of a Man	Male	Third Intermediate Period	Leiden University (Netherlands)
IMP00103 Hor	Male	Late Period	Leiden University (Netherlands)
IMP00104 Harerem	Male	Late Period	Leiden University (Netherlands)
IMP00107 Kek	Female	Late Period	Leiden University (Netherlands)
IMP00108 Inamonnefnebu	Male	Late Period	Leiden University (Netherlands)
IMP00109 Peftjauneith	Male	Late Period	Leiden University (Netherlands)
IMP00111 Mummy of a Man	Male	Late Period	Leiden University (Netherlands)
IMP00112 Diptah	Female	Ptolemaic Period	Leiden University (Netherlands)
IMP00113 Hor	Male	Ptolemaic Period	Leiden University (Netherlands)
IMP00122 Herakleides	Male	Roman Period	JP Getty Museum (California)

IMP00123 Thesaberu	Female	Ptolemaic Period	Marischal Museum (Scotland)
IMP00125 Lady Ta Khar	Female	Ptolemaic Period	Marischal Museum (Scotland)
IMP00126 Ti-Ameny Net	Female	Late Period	University of Richmond
IMP00127 Nesiur	Female	Third Intermediate Period	Boonshoft Museum of Discovery (Dayton, Ohio)
IMP00128 Ta Kush	Female	Late Period	Maidstone Museum (England)

APPENDIX B:

The 61 non-royal adult individuals in the IMPACT sample and their numerically coded designations for input into *IBM SPSS v27*

IMPACT ID	Sex	Age	Time Period	Arm Position	Amulets	Cranial Resin	Stature	1-Time Period (Label)
IMP00001 Pisa 1	1	1		2	0	1	2	Unknown
IMP00002 Nefer Mut	2	1	2	1	0	0	1	Third Intermediate Period
IMP00005 Djedmaatesankh	2	2	2	1	2	0	2	Third Intermediate Period
IMP00006 Lady Hudson	2	2	5	3	0	2	2	Roman Period
IMP00007 Pa-Ib	2	2	3	3	0	2	2	Late Period
IMP00008 Sulman Mummy	2	2	4	1	0	0	3	Ptolemaic Period
IMP00009 Hetep-Bastet	2	3	3	1	0	1	3	Late Period
IMP00010 RM2717 "Theban Female"	2	2	5	2	0	0	2	Roman Period
IMP00011 RM2718 "Theban Male"	1	1	4	2	0	1	1	Ptolemaic Period
IMP00012 RM2720 "Ptolemaic Female"	2	1	5	3	1	2	1	Roman Period
IMP00027 Genova 1 Female	2	3		1	0	1		Unknown
IMP00028 Genova 2 Male	1	3		1	0	1		Unknown
IMP00029 Pasherienaset	1	1	3	3	2			Late Period
IMP00035 Euphemia	2	3	5	2	0	0		Roman Period
IMP00040 Toutou	1	3	4	3	0	0		Ptolemaic Period
IMP00043 Female Mummy	2		2	1	0	1		Third Intermediate Period

IMP00044 Female Mummy	2	2	2	1	0	0		Third Intermediate Period
IMP00057 Padua Mummy	1	2	4	3	0	2	1	Ptolemaic Period
IMP00058 Liverpool 1	2		5	2	0	1		Roman Period
IMP00059 Liverpool 2	2	1	5	2	1	2		Roman Period
IMP00060 Pedeamun	1		3	1	0	1		Late Period
IMP00061 Liverpool 4	1		3	1	0	1		Late Period
IMP00062 Liverpool 5	2	4	3	1	0	1		Late Period
IMP00063 Liverpool 6	2	4	3	1	0	0		Late Period
IMP00065 Harwennefer	1		4	3	0	2		Ptolemaic Period
IMP00066 Tetkhonsefankh	2		2	1	0	1		Third Intermediate Period
IMP00067 Liverpool 10	1		3	1	0	0		Late Period
IMP00068 Liverpool 11	1	4		1	0	0		Unknown
IMP00070 Liverpool 13	1		4	3	3	2		Ptolemaic Period
IMP00071 Mummy of Nesmin	1		4	3	0	0		Ptolemaic Period
IMP00072 Liverpool 15	1		3	1	0			Late Period
IMP00073 Ta-Enty	2		3	2	0			Late Period
IMP00078 Renpit-Nefert	2	2	3	1	0	2	3	Late Period
IMP00079 George ("Nubian")	1	1	4	2	0	1		Ptolemaic Period
IMP00081 Nofret	2	3	4	3	0	2		Ptolemaic Period
IMP00082 Bahka	2	1	1	1	0	0	1	New Kingdom
IMP00083 Braided Lady	2	1	1	1	0	0	1	New Kingdom
IMP00088 Nesmutaatneru	2	4	3	1	0	0		Late Period
IMP00092 Nesi-Hensu	2	2	3	3	0	1	2	Late Period
IMP00093 Tash Pen Khonsu	2	1	4	1	0	0		Ptolemaic Period
IMP00094 Mummy of a Man	1	2	2	1	0	1	1	Third Intermediate Period

IMP00095 Mummy of a Woman	2	4	2	1	0	0		Third Intermediate Period
IMP00096 Khonsuemma'a (Kherut)	1	2	2	1	3	1		Third Intermediate Period
IMP00097 Mummy of a Woman	2	3	2	1	3	1	3	Third Intermediate Period
IMP00098 Tadis or Ta(net) Kharu	2	4	2	1	0	1	1	Third Intermediate Period
IMP00099 Tadis or Ta(net)Kharu	2	3	2	1	0	1	2	Third Intermediate Period
IMP00101 Mummy of a Man	1	3	2	1	0	1		Third Intermediate Period
IMP00103 Hor	1	1	3	1	0	1	2	Late Period
IMP00104 Harerem	1	3	3	1	0	1	2	Late Period
IMP00107 Kek	2	1	3	1	0	0	2	Late Period
IMP00108 Inamonnefnebu	1	1	3	1	0	0	3	Late Period
IMP00109 Peftjauneith	1	1	3	1	3	2	3	Late Period
IMP00111 Mummy of a Man	1	1	3	1	0	1	2	Late Period
IMP00112 Diptah	2	4	4	3	0	2	2	Ptolemaic Period
IMP00113 Hor	1	1	4	3	0	2		Ptolemaic Period
IMP00122 Herakleides	1	1	5	1	0	0	3	Roman Period
IMP00123 Thesaberu	2	1	4	3	0			Ptolemaic Period
IMP00125 Lady Ta Khar	2		4	1	0			Ptolemaic Period
IMP00126 Ti-Ameny Net	2	2	3	2	0	1	2	Late Period
IMP00127 Nesiur	2	1	2	1	0	2	3	Third Intermediate Period
IMP00128 Ta Kush	2	1	3	2	0	0	2	Late Period

APPENDIX C:

Appendix B SPSS Cluster Analysis Spreadsheet Legend

SEX

Male= 1

Female= 2

TIME PERIOD

New Kingdom = 1

Third Intermediate Period = 2

Late Period = 3

Ptolemaic Period = 4

Roman Period = 5

Unknown = N/A or blank

AGE

Age ranges vary, therefore these classifications are based on the minimum estimated age-at-death for these individuals.

18-29 = 1

30-39 = 2

40-49 = 3

50 and Over = 4

Confirmed Adults but no specific age = N/A or blank

ARM POSITION

EA = 1

EL = 2

F = 3

AMULETS

0 = No Amulets

1 = Clear proof of amulets that have since been stolen/removed (No assumptions)

2 = A few smaller amulets or 1 larger amulet, totaling less than 5.

3 = 5 or more amulets

CRANIAL RESIN

0 = Not excerebrated

1 = Excerebrated

2 = Excerebrated and treated with cranial resin.

STATURE

1= 0-25th Percentile, “Short”

2= 25th-75th Percentile, “Medium”

3= 75th-99th Percentile, “Tall”

Male Stature:

25th Percentile: 152.5 cm

75th Percentile: 165.5 cm

Tallest Individual: 179.2 cm

Female Stature:

25th Percentile: 151.65 cm

75th Percentile: 160.4 cm

Tallest Individual: 164.7 cm

APPENDIX D:

Results of the mummy assessments conducted on the 61 non-royal adult individuals in this IMPACT sample analysing arm position, amulets, cranial resin, and estimated stature

IMPACT ID	Sex	Time Period	Arm Position	Amulets	Cranial Resin	Estimated Stature
IMP00001 Pisa 1	Male	Unknown	EL	0	1	164.7 cm
IMP00002 Nefer Mut	Female	Third Intermediate Period	EA	0	0	146.7 cm
IMP00005 Djedmaatesankh	Female	Third Intermediate Period	EA	2	0	154.9 cm
IMP00006 Lady Hudson	Female	Roman Period	F	0	2	152.5 cm
IMP00007 Pa-Ib	Female	Late Period	F	0	2	154.9 cm
IMP00008 Sulman Mummy	Female	Ptolemaic Period	EA	0	0	160.2 cm
IMP00009 Hetep-Bastet	Female	Late Period	EA	0	1	161 cm
IMP00010 RM2717 "Theban Female"	Female	Roman Period	EL	0	0	152.1 cm
IMP00011 RM2718 "Theban Male"	Male	Ptolemaic Period	EL	0	1	156.2 cm
IMP00012 RM2720 "Ptolemaic Female"	Female	Roman Period	F	1	2	150.2 cm
IMP00027 Genova 1 Female	Female	Unknown	EA	0	1	N/A
IMP00028 Genova 2 Male	Male	Unknown	EA	0	1	N/A
IMP00029 Pasherienaset	Male	Late Period	F	2	N/A	N/A
IMP00035 Euphemia	Female	Roman Period	EL	0	0	N/A
IMP00040 Toutou	Male	Ptolemaic Period	F	0	0	N/A

IMP00043 Female Mummy	Female	Third Intermediate Period	EA	0	1	N/A
IMP00044 Female Mummy	Female	Third Intermediate Period	EA	0	0	N/A
IMP00057 Padua Mummy	Male	Ptolemaic Period	F	0	2	161.6 cm
IMP00058 Liverpool 1	Female	Roman Period	EL	0	1	N/A
IMP00059 Liverpool 2	Female	Roman Period	EL	1	2	N/A
IMP00060 Pedeamun	Male	Late Period	EA	0	1	N/A
IMP00061 Liverpool 4	Male	Late Period	EA	0	1	N/A
IMP00062 Liverpool 5	Female	Late Period	EA	0	1	N/A
IMP00063 Liverpool 6	Female	Late Period	EA	0	0	N/A
IMP00065 Harwennefer	Male	Ptolemaic Period	F	0	2	N/A
IMP00066 Tetkhonsefankh	Female	Third Intermediate Period	EA	0	1	N/A
IMP00067 Liverpool 10	Male	Late Period	EA	0	0	N/A
IMP00068 Liverpool 11	Male	Unknown	EA	0	0	N/A
IMP00070 Liverpool 13	Male	Ptolemaic Period	F	3	2	N/A
IMP00071 Mummy of Nesmin	Male	Ptolemaic Period	F	0	0	N/A
IMP00072 Liverpool 15	Male	Late Period	EA	0	N/A	N/A
IMP00073 Ta-Enty	Female	Late Period	EL	0	N/A	N/A
IMP00078 Renpit-Nefert	Female	Late Period	EA	0	2	158.6 cm
IMP00079 George ("Nubian")	Male	Ptolemaic Period	EL	0	1	N/A
IMP00081 Nofret	Female	Ptolemaic Period	F	0	2	N/A
IMP00082 Bahka	Female	New Kingdom	EA	0	0	147.7 cm
IMP00083 Braided Lady	Female	New Kingdom	EA	0	0	150.3 cm

IMP00088 Nesmutaatneru	Female	Late Period	EA	0	0	N/A
IMP00092 Nesi-Hensu	Female	Late Period	F	0	1	154.1 cm
IMP00093 Tash Pen Khonsu	Female	Ptolemaic Period	EA	0	0	N/A
IMP00094 Mummy of a Man	Male	Third Intermediate Period	EA	0	1	154.3 cm
IMP00095 Mummy of a Woman	Female	Third Intermediate Period	EA	0	0	N/A
IMP00096 Khonsuemma'a (Kherut)	Male	Third Intermediate Period	EA	3	1	N/A
IMP00097 Mummy of a Woman	Female	Third Intermediate Period	EA	3	1	164.3 cm
IMP00098 Tadis or Ta(net) Kharu	Female	Third Intermediate Period	EA	0	1	149 cm
IMP00099 Tadis or Ta(net)Kharu	Female	Third Intermediate Period	EA	0	1	153 cm
IMP00101 Mummy of a Man	Male	Third Intermediate Period	EA	0	1	N/A
IMP00103 Hor	Male	Late Period	EA	0	1	162.8 cm
IMP00104 Harerem	Male	Late Period	EA	0	1	165.2 cm
IMP00107 Kek	Female	Late Period	EA	0	0	151.9 cm
IMP00108 Inamonnefnebu	Male	Late Period	EA	0	0	165.6 cm
IMP00109 Peftjauneith	Male	Late Period	EA	3	2	179.2 cm
IMP00111 Mummy of a Man	Male	Late Period	EA	0	1	161.9 cm
IMP00112 Diptah	Female	Ptolemaic Period	F	0	2	152.1 cm
IMP00113 Hor	Male	Ptolemaic Period	F	0	2	N/A
IMP00122 Herakleides	Male	Roman Period	EA	0	0	167.5 cm
IMP00123 Thesaberu	Female	Ptolemaic Period	F	0	N/A	N/A
IMP00125 Lady Ta Khar	Female	Ptolemaic Period	EA	0	N/A	N/A

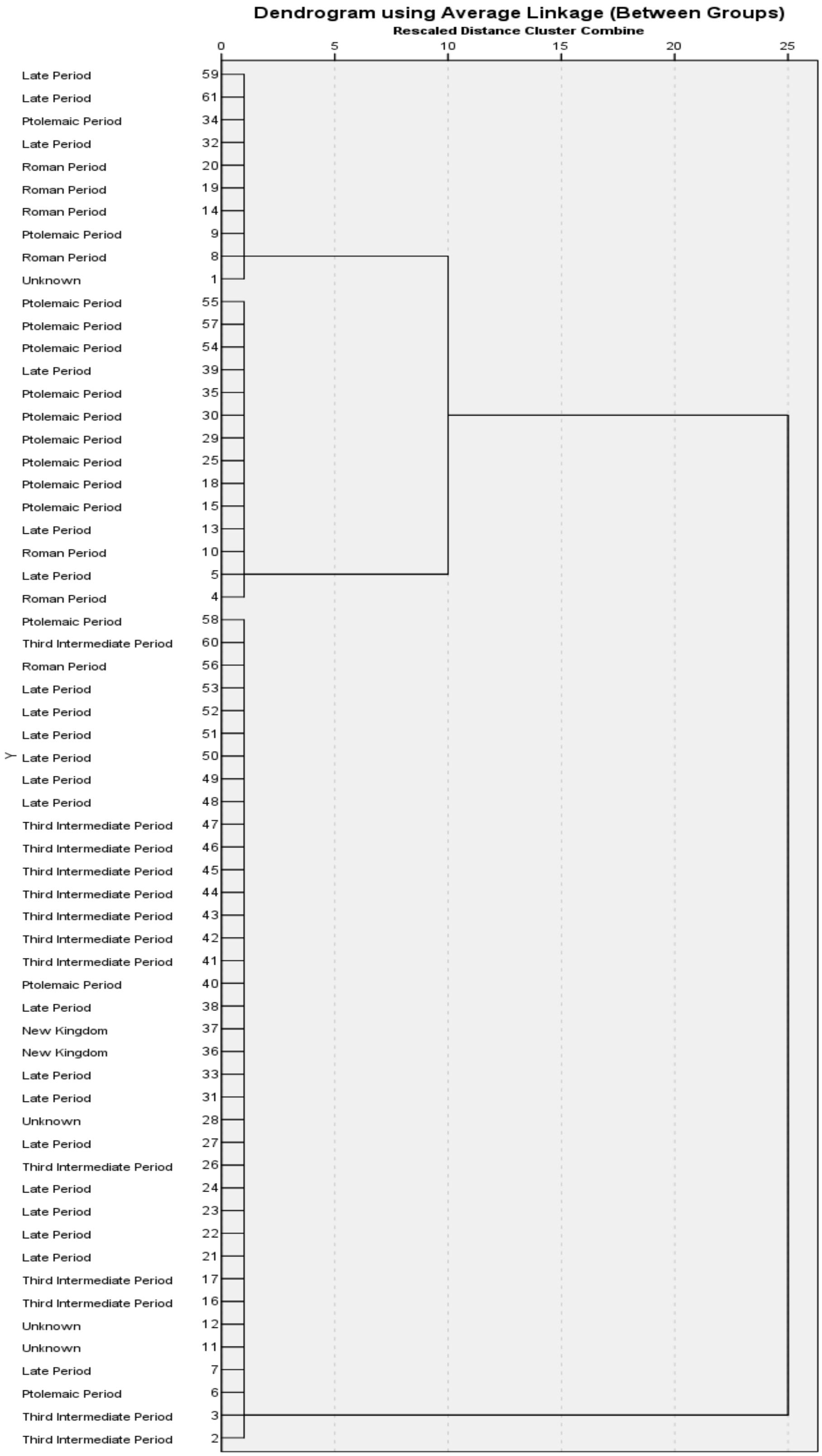
IMP00126 Ti-Ameny Net	Female	Late Period	EL	0	1	151.7 cm
IMP00127 Nesiur	Female	Third Intermediate Period	EA	0	2	157.4 cm
IMP00128 Ta Kush	Female	Late Period	EL	0	0	153.7 cm

Appendix E:

Exploratory data analysis dendrograms demonstrating how this IMPACT sample clusters when the four primary variables (arm position, amulets, cranial resin, and estimated stature) are tested independently against "time period"

It should be noted that although there is only one dendrogram displayed for each of variables, all four algorithms used (average linkage, single linkage, complete linkage, Ward's Method) produced the exact same dendrogram. These EDA tests demonstrated that amulets, cranial resin, and estimated stature do not cluster by time period (based on this IMPACT sample)

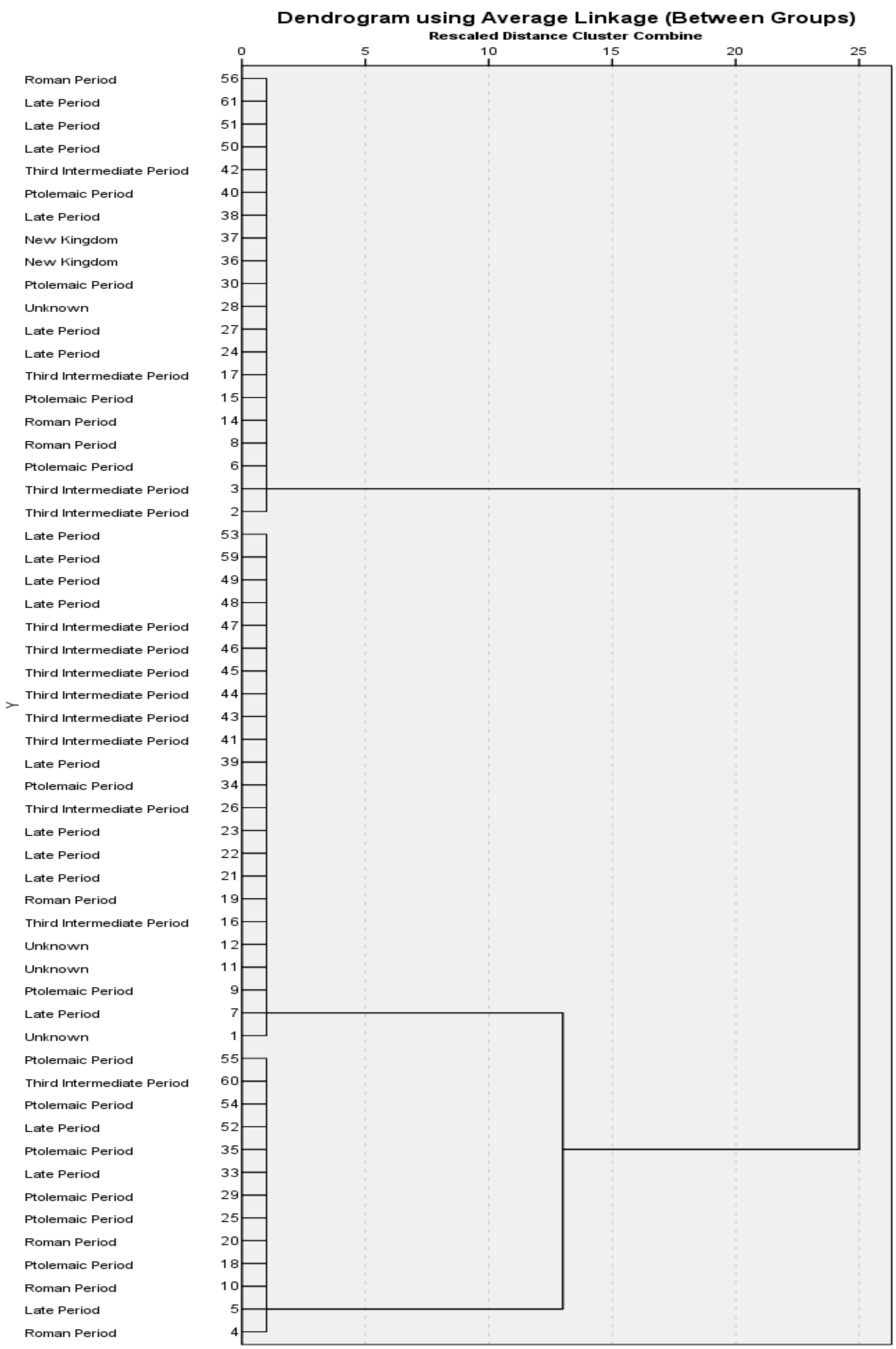
ARM POSITION:



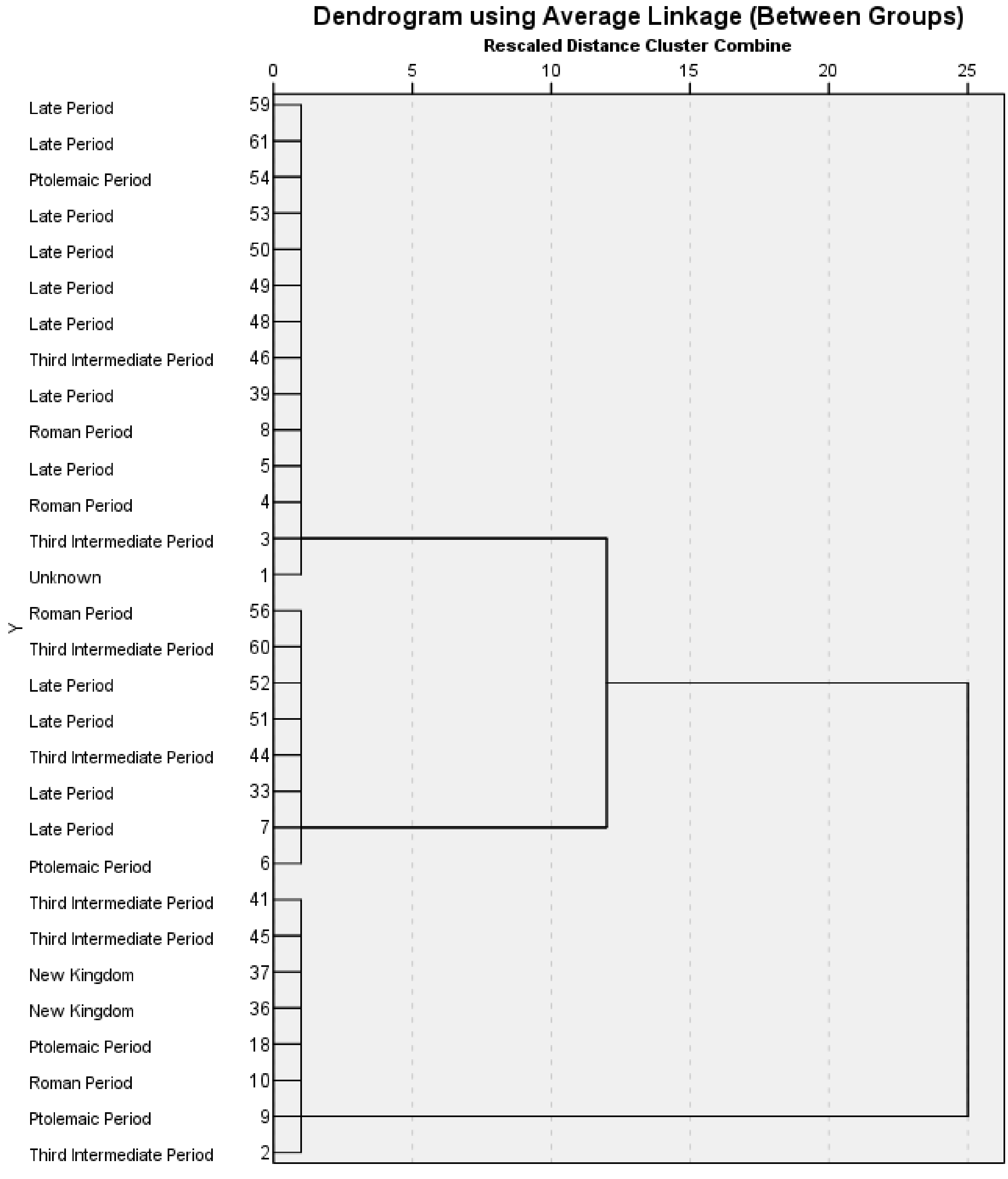
AMULETS:


Dendrogram using Average Linkage (Between Groups)
Rescaled Distance Cluster Combine
0
5
10
15
20
25
Y
Third Intermediate Period 60
Late Period 61
Late Period 59
Ptolemaic Period 58
Ptolemaic Period 57
Roman Period 56
Ptolemaic Period 55
Ptolemaic Period 54
Late Period 53
Late Period 51
Late Period 50
Late Period 49
Late Period 48
Third Intermediate Period 47
Third Intermediate Period 46
Third Intermediate Period 45
Third Intermediate Period 42
Third Intermediate Period 41
Ptolemaic Period 40
Late Period 39
Late Period 38
New Kingdom 37
New Kingdom 36
Ptolemaic Period 35
Ptolemaic Period 34
Late Period 33
Late Period 32
Late Period 31
Ptolemaic Period 30
Unknown 28
Late Period 27
Third Intermediate Period 26
Ptolemaic Period 25
Late Period 24
Late Period 23
Late Period 22
Late Period 21
Roman Period 19
Ptolemaic Period 18
Third Intermediate Period 17
Third Intermediate Period 16
Ptolemaic Period 15
Roman Period 14
Unknown 12
Unknown 11
Ptolemaic Period 9
Roman Period 8
Late Period 7
Ptolemaic Period 6
Late Period 5
Roman Period 4
Third Intermediate Period 2
Unknown 1
Roman Period 10
Roman Period 20
Third Intermediate Period 44
Late Period 52
Third Intermediate Period 43
Ptolemaic Period 29
Third Intermediate Period 3
Late Period 13

CRANIAL RESIN:



ESTIMATED STATURE:



Appendix F:

Detailed information regarding the segmentation function in *Dragonfly 4.1* for isolating and analysing cranial resin. Lady Hudson (IMP00006) is used as the subject in this example

The software packages utilised in this thesis, *Dragonfly 4.1* and *ORS Visual^{si}*, allow for the segmentation and further analysis of internal structures, such as solidified cranial resin. With segmentation, cranial resin can be isolated, removed, and analysed in its own 3D space. For the 2019 annual meeting of the Canadian Association for Physical Anthropology in Banff, Alberta, Canada, I presented an academic poster (Arsenault, 2019) demonstrating how to properly utilize these segmentation features in *Dragonfly 4.1* to evaluate cranial resin. Using IMP00006-Lady Hudson (Figure 6.1), volumetric tools were utilised to isolate a region of interest (ROI), the cranial resin, before recreating it as its own entity in a 3D space (Figure 6.2).

Segmentation is the process of assigning pixels on an image slice or volume to different structural units, such as bone, resin or air. The pixels belonging to each of those units then get assigned to a separate region of interest. As discussed in Chapter 3, the most basic way to segment a CT image is on the basis of pixel brightness, which indicates the attenuation of the x-ray beam by the different components of the object, expressed in HU (Hounsfield Units). Resin often falls around 71 HU (Gostner et al., 2012). In Lady Hudson's case, her cranial resin ranges from 53-78 HU depending on which area is probed.

To assess resin in the skull, there are three structural units of interest: the cranial vault, the resin and the air inside the cranial vault. The process of segmentation involved creating an ROI for each unit where the resin was differentiated from the other units on the basis of pixel brightness, or attenuation, using the "define range" function in *Dragonfly*. Resin is more dense than air, but less dense than bone (Gostner, 2012), so a narrow range can be defined between the two, highlighting the resin pixels. The pixels were then selected using the "point & click" tool in 3D mode, creating a "resin" ROI. However, this included resin in the mouth and resin-soaked tissues outside the skull (Figure 6.1), so the ROI had to be refined manually, slice by slice, using the ROI painter tools to deselect pixels. This became the "brain" ROI, which is a misnomer because it is not the brain, but resin. This process can be quite arduous as this Lady Hudson example had 512 separate slices for both the coronal and sagittal planes, along with another 384 for the axial/transverse plane. After this, a second ROI was created that consisted of the skull bones and everything else (including the air). This was done, once again, by using the "define range" function, with the range moved to include everything in the scans. The pixels were again selected using the "point & click" tool in 3D mode creating what I named the "skull" ROI (which is a misnomer as it encompasses everything).

The image (and new ROI) created in Figure 6.2 was done on the basis of thresholding. Essentially, thresholding creates two categories, the foreground (which is the ROI you want to focus on, in this case, the “brain” ROI) and the background (everything else and in this case, the “skull” ROI). Using thresholding and the “thickness mesh” tool in Dragonfly, everything in the “skull” ROI was removed, leaving just the “brain” ROI. After using the refinement tool a couple of times and the "Boolean Operations" tool on the selected ROIs, I was left with a “thickness mesh” of my ROI, ultimately giving me access to an accurate digital representation of Lady Hudson’s cranial resin without physically opening the skull of this mummy, which would cause irreparable damage.

To assess the volume and overall cranial space taken up by the resin, a few more steps were necessary. To get the overall percentage of the space taken up by the cranial resin, I followed the above steps. However, instead of highlighting the cranial resin as the foreground and primary ROI, I created an ROI for the empty space in the cranial vault. After this new ROI was created, the properties for each ROI were examined in the "statistical properties" window in *Dragonfly*, looking specifically for volume. The total volume of resin was then recorded, and the percent resin volume was calculated by dividing this cranial resin volume (*100) by total Endocranium volume. Once this was completed, Lady Hudson was found to have 312.4cm^3 of hardened cranial resin, while the rest of her cranium was 891.9cm^3, for a total of 1204.3cm^3. Therefore, the hardened resin at the back of her cranial vault occupies 26% of the total space. If a scale were to exist on this basis of cranial resin amount, further levels of social status could perhaps be inferred from assessing the cranial vault of excerebrated and cranial resin-treated mummies.

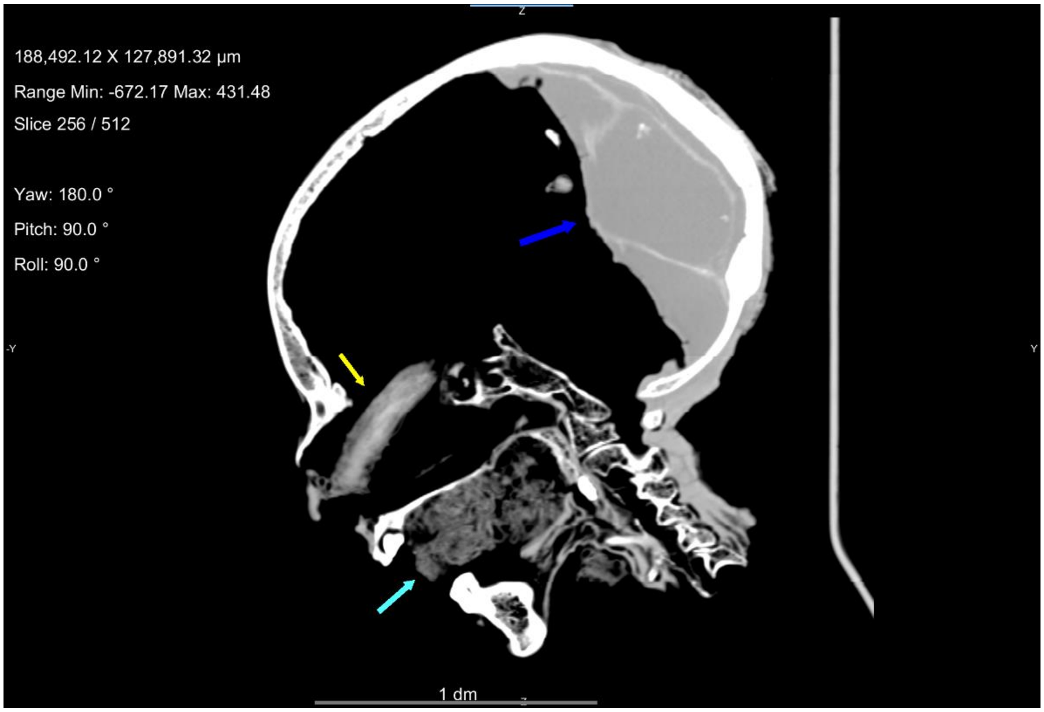


Figure 6.1 **Sagittal View of Lady Hudson (IMP00006)**

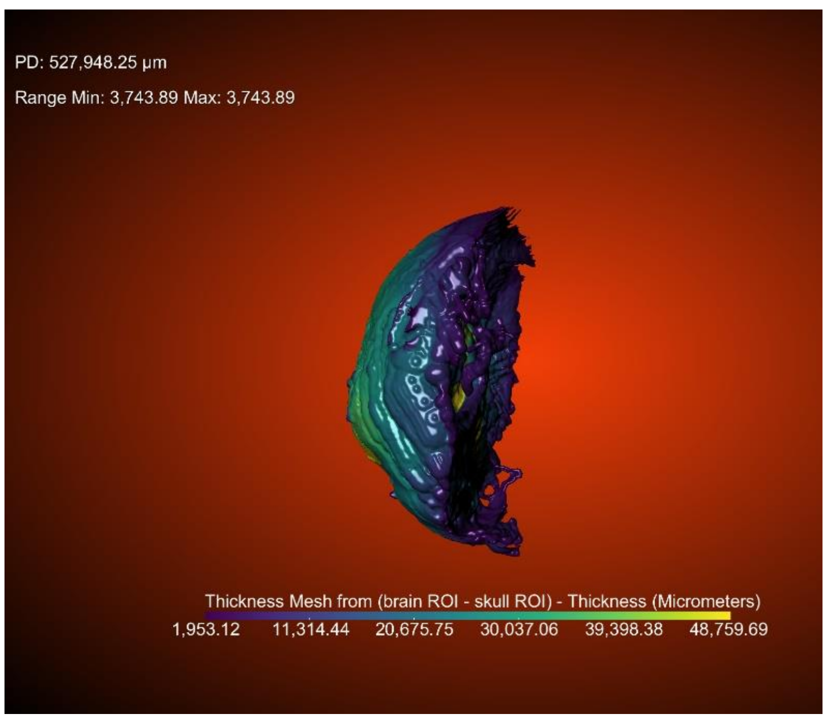


Figure 6.2 **Segmented and Isolated Cranial Resin in *Dragonfly 4.1***

Andrew Arsenault
CURRICULUM VITAE
January 2021

EDUCATION

2018- 2021	M.A., The University of Western Ontario, Anthropology: Bioarchaeology
2012-2018	Honours B.A., Concordia University, Major: Anthropology, Minor: Classical Archaeology
2016	Argilos Archaeological Field School, Macedonia, Greece.
2010-2012	D.E.C., Dawson College, Social Sciences with Honours

SCHOLARSHIPS

2019	SSHRC (Social Sciences and Humanities Research Council of Canada). 17 500$ CAD.
2019	OGS (Ontario Graduate Scholarship). (Declined). 15 000$ CAD.
2018	OGS (Ontario Graduate Scholarship). 15 000$ CAD.

AWARDS AND HONOURS

2019	University of Western Ontario Graduate Conference Travel Fund Award
2016 - 2017	Scholar of the Year Award, Faculty of Arts & Science, Concordia University
2017	Dean's Honour List, Concordia University
2016 - 2018	Golden Key International Honour Society
2011	Awarded Honours in several semesters, Dawson College

RESEARCH INTERESTS

Bioarchaeology, mummification, Archaeology, Biological Anthropology, radiography and digital imaging, Egyptology, Classical Archaeology and History (Egypt, Greece, Rome), paleopathology, hominid/hominin evolution, archaeological theory and methodology, interdisciplinary work, subcultures, cultural Anthropology

CONFERENCE PARTICIPATION

2019	"Computed Tomography & The Social Stratification of Ancient Egyptian Mummification" 2019 Canadian Association for Physical Anthropology Annual Meeting, Banff, AB, Canada, October 23-26.
2017	"Alienation in Heavy Music: Understanding its Creation & Elimination" 2017 Concordia Department of Sociology and Anthropology Honours Conference, Montreal, QC, Canada, April 18th.

ACADEMIC VOLUNTEERING

2018	CAPA 46th Annual Meeting, London, Ontario
2017	Concordia Department of Sociology & Anthropology Honours Conference

OUTREACH

2019 - 2020	President for the Western Anthropology Graduate Society
2018 - 2019	Anthropology Ambassador for the Society of Graduate Students

ARCHAEOLOGICAL EXPERIENCE

2016	Field Labourer, Argilos Archaeological Field School

TEACHING EXPERIENCE

2020	Teaching Assistant/Lab Instructor, ANTH 1020: The Many Ways of Being Human, The University of Western Ontario
2019	Teaching Assistant, ANTH 3311: Advanced Bioarchaeology, The University of Western Ontario
2019	Teaching Assistant, ANTH 2239: Mummies: Scientific & Cultural Analysis, The University of Western Ontario
2018	Teaching Assistant/Lab Instructor, ANTH 1020: The Many Ways of Being Human, The University of Western Ontario
2018	Bioarchaeology Instructor, High School Outreach Day: The University of Western Ontario

LANGUAGES

English and French (Spoken & Written)

ACADEMIC AND PROFESSIONAL AFFILIATIONS

Archaeological Institute of America (AIA)

Canadian Association for Physical Anthropology (CAPA)

Concordia Classics Student Association (CCSA)

Society for American Archaeology (SAA)

Western Anthropology Graduate Society (WAGS)

RECENT EMPLOYMENT

2013 - 2018	HMV/Sunrise Records, Store Keyholder/Head of Staff
2017	Maison des Jeunes (Non-Profit Youth Centre), Youth Worker
2012 - 2015	Touring Musician/Vocalist.
2011 - 2013	Village Des Valeurs, Store Keyholder/Supervisor

SOCIAL VOLUNTEERING

2017 - Present	Maison des Jeunes (Non-Profit Youth Centre), Fundraising