COMPARISON OF DECOMPOSITION RATES BETWEEN AUTOPSIED AND NON-AUTOPSIED HUMAN REMAINS IN CENTRAL TEXAS

by

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DEDICATION

This thesis is dedicated to my grandmother. Without her continuous support I would have never been able to complete it. She will always be remembered with love.

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LIST OF ABBREVIATIONS

FACTS	Forensic Anthropology Center at Texas State
FARF	Forensic Anthropology Research Facility
ADD	Accumulated Degree Days
ARF	Anthropology Research Facility
STAFS	Southeast Texas Applied Forensic Science Facility
PMI	Postmortem Interval
TBS	Total Body Score

ABSTRACT

Human decomposition studies are necessary to understand the processes of degradation that commence upon death and to develop methods for estimating time-since-death. Such studies often take place using human body donations at forensic decomposition facilities. At most of these facilities, both autopsied and non-autopsied remains are accepted for donation, yet no study has examined if autopsied and non-autopsied bodies should be separated for analyses. Consequently, it is necessary to test if the rate of decomposition varies between autopsied and non-autopsied bodies in the same environment. As temperature affects decomposition, it is also beneficial to compare the internal body temperatures of autopsied and non-autopsied remains to see if differences between the two may be leading to differential decomposition.

To compare decomposition rates between autopsied and non-autopsied human remains, 59 non-autopsied and 24 autopsied remains donated to the Forensic Anthropology Center at Texas State (FACTS) from 2010-2013 and placed at the Forensic Anthropology Research Facility (FARF) on Freeman Ranch were studied. All remains were placed in a similar manner, and the day each set of remains reached early, advanced, and mummified decomposition stages were documented. The number of accumulated degree days (ADD) between each stage was then determined and analyzed using t-tests. The results showed that the difference in decomposition rates between autopsied and non-autopsied remains was not statistically significant, though the average ADD was slightly lower for autopsied bodies than non-autopsied bodies in each stage of decomposition.

To compare internal body temperatures between autopsied and non-autopsied human remains, eight non-autopsied and five autopsied bodies were investigated. For each body, internal temperature was collected once a day for two weeks. The ambient temperature was subtracted from the internal temperature to determine the degrees above or below ambient temperature for each of the 14 days. The difference between body temperature and ambient temperature for the autopsied and non-autopsied bodies was compared using t-tests. In general the body temperature changed rapidly, especially in the non-autopsied bodies, in the first three days but then leveled off. Internal temperature did not statistically differ between autopsied and non-autopsied remains.

In conclusion, no statistically significant difference was observed in the rate of decomposition between autopsied and non-autopsied remains; therefore, it is unnecessary to separate these two types of remains when studying gross stages of human decomposition in Central Texas. Nevertheless, the decomposition pattern of autopsied remains should be examined to ensure that these findings apply to other environments.

CHAPTER I

Introduction

Numerous researchers have conducted studies on decomposition of human remains (Mann et al., 1990; Galloway, 1997; Ubelaker, 1997; Anderson, 2001; Higley and Haskell, 2001; Vass, 2001; Megyesi et al., 2005; Nawrocki, 2009; Simmons et al., 2010a,b; Parks, 2011; Suckling, 2011). While several studies have examined decomposition rates based on medicolegal death investigations with known postmortem intervals (i.e., the time-since-death for human remains) (Galloway et al., 1989; Megyesi et al., 2005), much of the more recent research on human decomposition is conducted at forensic decomposition facilities such as the Forensic Anthropology Research Facility (FARF) at Texas State University, the Anthropology Research Facility (ARF) at the University of Tennessee, and the Southeast Texas Applied Forensic Science (STAFS) facility at Sam Houston State University (Bass, 1997; Ayers, 2010; Aitkenhead-Peterson et al., 2011; Parks, 2011; Shirley, 2011; Suckling, 2011). When determining the rate of decomposition in various environments, researchers at these facilities seldom, if ever, separate autopsied and non-autopsied remains when performing analyses. Therefore, there is a need to examine differences in the rate of decomposition between autopsied and non-autopsied remains.

Understanding how autopsy incisions affect human decomposition is important, since gross stages of decomposition are a primary factor in determining the postmortem interval (PMI). The PMI is calculated by taking into account the amount of decomposition that has occurred as well as the average temperature and humidity in the area in which remains are located (Megyesi et al., 2005; Vass, 2011). Differential decomposition between autopsied and non-autopsied remains may affect PMI calculations, which has implications in forensic settings. A correct PMI estimation may aid in eliminating or confirming suspects in medicolegal cases. On the other hand, an incorrect PMI estimation may have damaging effects by implicating innocent or eliminating guilty individuals as suspects. Therefore, it is vital that PMI calculations be accurate. This is only possible if studies establishing PMI formulae are not skewed by differential decomposition of human remains. Any differences in decomposition due to an autopsy incision could affect the results of PMI studies, which will have consequences in forensic cases.

This study aimed to examine the effects of an autopsy incision on decomposition rate in a Central Texas environment. The primary hypothesis for this study was that an autopsy incision would statistically affect the rate of decomposition of autopsied remains when compared to non-autopsied remains. Because the autopsied bodies used in this study contained large abdominal incisions (Adams, 2009), insect succession patterns as well as the internal body temperature of the remains may have differed in autopsied bodies when compared to non-autopsied remains. It was possible that the large incision affected how these remains decomposed, as insect activity and temperature greatly affect the decomposition rate of human remains (Anderson, 2001; Galloway, 1997; Higley and Haskell, 2001; Mann et al., 1990; Megyesi et al., 2005; Nawrocki, 2009; Shirley et al., 2011; Simmons et al., 2010a,b; Ubelaker. 1997; Vass, 2001). In addition, autopsied remains used in this study contained an organ bag inside the abdominal autopsy incision. This may have affected the rate decomposition as the organs were removed from the body, placed in a plastic bag, and sewn into the abdomen upon completion of the autopsy.

For example, the fact that the organs were contained in a plastic bag may have limited insect accession to the organs, thereby, affecting the rate of decomposition.

The secondary hypothesis for this study was that the internal body temperature of autopsied remains would be statistically different from the internal temperature of non-autopsied remains during early decomposition. The autopsy incision may have allowed for heat loss from the abdomen during decomposition, lowering the overall internal temperature of autopsied remains. However, the incision may have also provided a moist area for insects to lay eggs (Greenberg and Kunich, 2002; Dix and Graham, 2000). During the active feeding stage of fly larvae there could have been a localized increase in temperature (Heaton et al., 2014), which would have resulted in differing decomposition between the autopsied and non-autopsied bodies (Vass, 2001; Wells and Lamotte, 2001). Therefore, this study tested for differences in internal body temperature between autopsy and non-autopsied remains during the first two weeks after death.

Ultimately, this goal of this study was to determine whether utilizing both autopsied and non-autopsied human remains would skew the results of decomposition and PMI studies. In addition, this study aimed to gain some insight into possible causes of any differences in decomposition rates. Understanding how an autopsy incision affected the decomposition rate of these human remains would benefit future decomposition studies by making the effects of an autopsy incision on decomposition rates apparent.

Literature Review

Factors Affecting Decomposition: A Brief Overview

An autopsy incision may alter decomposition rate by affecting one or more of the numerous factors influencing decomposition. The variables affecting decomposition are numerous and complexly interrelated. Such factors are discussed briefly below.

Mann and colleagues (1990) outlined and scored the factors they believed would have the greatest effect on decay rates of human bodies. The factors they focused on were based on experience in case studies as well as experiments performed at the ARF in Knoxville, Tennessee. According to the authors, temperature, insect access, and burial conditions had the greatest affect on decay rate followed by carnivore/rodent activity, trauma, and humidity/aridity. The authors also listed rainfall, body size and weight, embalming, clothing, the surface the body is placed on, and soil pH as contributing factors to decomposition rates. The authors pointed out that the factors influencing decomposition have a complex interrelationship and that decomposition was extremely variable.

According to Dix and Graham (2000), the environment is a major variable influencing human decomposition patterns. For instance, bodies will decay differently depending on whether they are buried, submerged, or decompose in varying temperatures. They also point out that soil conditions, trauma, and position of the body affect decay rate and pattern. In particular, in 2010 Ayers (2010) examined the effects of submerging remains in in water. The author compared decay of pigs (*Sus scrofa*) in terrestrial, freshwater, and saltwater environments. The study took place in the decomposition facility at Texas State University. The results of the study showed that freshwater remains decomposed most rapidly, followed by saltwater and the terrestrial remains. This study exhibited that the broader environment (terrestrial versus water) and even the composition of the water affect decay patterns and rates.

Though numerous factors affect decomposition of remains, only the factors that may be altered by an autopsy incision are discussed in depth below. These include, temperature and insect activity. Furthermore, a review of the literature revealed no studies pertaining to the effects of using autopsied remains in decomposition studies. However, several studies (Mann et al., 1990; Dix and Graham, 2000; Kelly, 2006; Smith, 2010) have examined the rate of decomposition associated with sharp-force trauma. Such studies are examined in this literature review. In addition, a few of the methods used to categorize decomposition are reviewed, as decomposition characterization was used in the present study.

Categorization of Decomposition

A few researchers have categorized human decomposition. Galloway and colleagues (1989) outlined five decomposition stages for the arid environment of southern Arizona: fresh, early decomposition, advanced decomposition, skeletonization, and extreme decomposition. This study was retrospective and utilized 189 cases from the Human Identification Laboratory of the Arizona State Museum. The authors examined photographs and other documentation of these remains and presented the temporal distribution of the five decomposition stages for the cases used in the study

Megyesi and colleagues (2005) subsequently developed a modified version of Galloway and colleagues' (1989) stages. With Megyesi and colleagues' (2005) method, the body was divided into three regions: the head and neck, the trunk, and the limbs. These anatomical regions were then scored individually based on varying characteristics of human decomposition. The summation of these three scores was calculated to determine the total body score (TBS), which is then used in a formula created to establish the PMI for the body. Additionally, Vass (2011) described the level of decomposition as a percentage, where a higher percentage represented a greater level of decomposition. For example, a score of 50% meant the body was 50% decomposed.

Clark and colleagues (1997) outlined four categories and ten stages of human decomposition. Each category was associated with a set of stages. They were as follows: putrid (stages 1-3), bloating (stages 4-6), destruction (stages 7-8), and skeleton (stages 9-10). The author stated that such characterization of decomposition was helpful in describing decay and in comparative decay studies.

Bass (1997) outlined stages of decomposition based on remains at ARF in Knoxville, TN and local forensic cases. He described five stages and the time period in which each stage occurred: fresh (first day), fresh to bloated (first week), bloated to decay (first month), dry (first year), and bone breakdown (first decade). These stages were based on observations of bodies decomposing at ARF and the author's numerous years of experience with forensic cases in the area.

Insect Activity and Decomposition Rates

A review of studies pertaining to the affects of insect activity on decomposition is necessary, as an autopsy incision may alter the amount of insect activity by increasing the ease of access to the internal portions of the remains This is especially possible, as flies preferentially deposit eggs in moist areas that provide access to the interior of the body (Greenberg and Kunich, 2002; Dix and Graham, 2000). An autopsy incision provides such conditions for egg deposition.

Numerous studies on insect succession have revealed that the quantity of insects and the accessibility of remains to these insects affect the rate of decomposition. A study conducted by Anderson (2011) compared the decomposition of pig remains exposed to indoor and outdoor conditions. Those that decomposed in the indoor environment had delayed insect succession and decomposed more slowly than those that decomposed in the outdoor environment. The delayed insect succession with the indoor environment was likely due to reduced accessibility of the body to insects.

Similarly, Bachman and Simmons (2010) studied the decomposition of buried rabbit (*Oryctolagus cuniculus*) remains with and without insect access. They used TBS to quantify the decomposition of the rabbits and found a significant difference in the decomposition rates of those with and without insect access. The rabbit remains that were exposed to insects decomposed more rapidly that those without insect exposure, proving that insect activity should be considered when estimating PMI. In a similar study by Simmons and colleagues (2010b), rabbits were buried and laid out on the surface with and without insect access. The remains that had no insect activity (buried and surface remains) showed the same decomposition rate. This rate was slower than the burial and surface remains with insect access. Of those with insect access, the surface remains, which were continually exposed to insects, decomposed more quickly than the buried remains, which were only exposed to insects for a short period time. In addition, Simmons and colleagues (2010a) used previously published data to investigate the effects of insect activity on decomposition in various environments. After performing regression analyses on these data, the authors found that as insect activity decreases so does the rate of decomposition. This holds true for all environments examined.

Comparable results were found with human remains in the 1983 study conducted by Rodriquez and Bass (1983) in Knoxville, TN. In this study four bodies (three males and one female) were placed in a wire coffin. The insect activity and decomposition rates were recorded via photograph and documentation. The authors observed that the amount of insect activity appears to be directly related to the rate of decomposition.

Temperature and Decomposition Rates

Because autopsied bodies have a large opening in the torso, the temperature of the body may differ between autopsied and non-autopsied remains. This incision allows for a release of heat from the abdomen, which changes the internal temperature of the remains. Subsequently, a review of the literature is necessary to understand the possible consequences of an autopsy incision on decomposition rates.

It has been previously observed that temperature is a major factor in the rate of decomposition (Mann et al., 1990). Komar (1998) observed that decomposition of human remains was slower in winter months than in the summer months, even in a cold climate. This study took place in Edmonton, Alberta and relied on 20 medical examiner cases from the area. It should be noted that this study did not control for scavenging, environment, or clothing on the remains. A study conducted by Parsons (2009) reached the same conclusions as Komar (1998). Her study area was the cold, dry Montana environment. She recorded the decomposition of pig (*Sus scrofa*) carcasses and found that, when compared to previous studies of decomposition in warmer climates, decomposition of pigs in this colder climate was slower. Also, Parsons noted that the pig carcass decomposing in the summer decomposed more rapidly than the carcass placed in colder months.

Part of the reason that there is a direct correlation between decomposition rate and temperature is that insect activity increases with temperature. Greenberg and Kunich (2002) assert that the temperature of the remains affects egg deposition and, in turn, future maggot activity. For example, Lopes de Carvalho and Linhares (2001) studied decomposition of pig carcasses in southeastern Brazil. The results of this study showed that during winter months the amount of insect activity was lowest. Furthermore, the study revealed that those bodies decomposing in sunlight also showed a greater amount of insect activity. This suggested that temperature affects insect activity in decomposing remains. Additionally, Rodriquez and Bass (1983) observed that the bodies decomposing in the warmer months had a greater amount of insect activity and decomposed more rapidly than those decomposing in cooler months. It is also important to point out that maggot masses reach temperatures higher than the ambient temperature, which may alter the internal temperature of the remains (Higley and Haskell, 2001). This increase in internal temperature may further increase the rate of decomposition of remains, as it may increase the growth of bacteria and microfauna (Mann et al., 1990; Clark et al., 1997).

Though a temperature increase often results in an increase in insect activity, there are limits. For instance, Defilippo and colleagues (2013) conducted a study on the effects of temperature on the development of the blowfly (*Calliphora vicina*), which is a poikilotherm (i.e., it cannot regulate its body temperature). This study revealed that, though the rate of development increased with temperature, extreme low and high temperatures resulted in the death of the blowfly. A 2009 study by Kelly and colleagues showed concurring results. The study by Kelly and colleagues focused on examining the decomposition of clothed and wrapped pig remains in central South Africa. In particular, the authors were interested in arthropod succession during the warm months in this area. Decomposition of clothed, wrapped, and both clothed and wrapped pigs were observed. The decomposition of these pigs was then compared to control pigs with no clothing or wrapping. The pig carcass with both wrapping and clothing showed high rates of maggot deaths due to the high internal temperature of the pig (approximately 45-50°C).

Trauma and Decomposition

Few studies have examined the consequences of extensive, open-wound trauma on rates of decomposition. These types of studies are of interest to the present study, as decomposition of autopsied remains may mimic that of remains with open-wound trauma. Therefore, a review of studies focused on the effects of open wound trauma on decomposition is necessary.

According to Mann and colleagues (1990) trauma is a major factor in the decomposition rate of human remains. The authors rates various variable on a 1-5 scale where 1 is least effect and 5 is the greatest. Trauma was rated 4, implying it is of great significance to the decay rate. It is important to note; however, that these ratings are based only on observations. Dix and Graham (2000) agree with Mann and colleagues (1990) and claim that decomposition at the site of an open wound will occur more rapidly and that insects will prefer these areas. Subsequent studies, however, do not agree with this high level of significance.

Kelly (2006) examined the effects of penetrative trauma (knife wounds) on decomposition and insect succession. There was no difference in the rate or pattern of decomposition and the insect succession was not altered as a result of the trauma. Cross and Simmons (2010) examined the effect of penetrative, gunshot trauma on decomposition in pig carcasses. This study looked at how this type of trauma affects the rate of decomposition, internal body temperature, soil pH, and insect activity. TBS was used to quantify decomposition. They found that the presence of trauma did not affect the rate of decomposition. If fact, the authors found that no variables examined in this study were affected by the presence of penetrative trauma. In addition, insects seemed to prefer the natural orifices of the body to the penetrative trauma areas. The authors suggested this might be due to the attractiveness of volatile substances located in the natural orifices.

A study conducted by Smith (2010) using pig carcasses assessed the effects of stab wounds on decomposition rate and pattern. Two treatments were performed. The first treatment was a single, 15cm incision that penetrated the thoracic cavity, whereas, the second treatment was a single, 15cm incision that did not penetrate the thoracic cavity. These two treatments were compared to a control group. The authors found no significant difference in the decomposition rates for all three groups of pigs but did note slight differences in the pattern of decomposition. The control pigs began decomposition in the facial region. Conversely, decomposition began at the area surrounding the wound for the thoracic penetrative treatment. For the non-thoracic penetrative treatment, decomposition began at both the wound site and the facial region.

Other Possible Effects of an Autopsy

The vast majority of autopsied remains received by the Forensic Anthropology Center at Texas State (FACTS) contain a plastic bag holding all the organs and tissue removed during the autopsy procedure. This bag is sewn into the abdominal area of the body. It is possible that this aspect of the autopsy may affect decomposition.

In fact, Pakosh and Rogers (2009) showed that bodies placed inside plastic bags were preserved when compared to those not contained in plastic bags. This study examined the effects of submerged remains; therefore, the results may not be applicable to the present research. However, Bell (2013) compared the decomposition rate of three pigs in central Texas. One pig was wrapped in black plastic, the second in a cotton sheet, and the third remained unwrapped as a control. The results of this study showed that decomposition was accelerated in the pig wrapped in black plastic compared to the cotton sheet. This was possibly due to an increase in insect activity with the pig wrapped in black plastic, as the plastic protected the carcass from precipitation and the sun, which may disrupt insect activity. The internal temperature of the carcasses, however, did not greatly differ between the three treatments.

Estimating Postmortem Interval

An autopsy incision may alter decomposition via affecting such factors as insect activity and internal body temperature. This may have repercussions in PMI studies, as the extent of decomposition is a main variable used in PMI estimation. Estimating time-since-death is useful in medicolegal cases, as it may have implications in establishing alibi credibility for suspects in these cases.

The postmortem interval is often estimated by examining insect succession and development (Goff and Win, 1997; Anderson, 2001; Higley and Haskell, 2001; Wells and LaMotte, 2001; Greenberg and Kunich, 2002; Bucheli et al., 2009) For example, Bucheli and colleagues (2009) utilized patterns of insect succession to estimate that an individual had been dead for 7-10 months. This case was found inside a house in southeast Texas. The body was skeletonized and desiccated when found. The pattern of insects found suggested the individual had passed during the cooler months, leading to the PMI estimation of 7-10 months. Goff and Win (1997) did the same type of PMI estimation for a set of remains located inside a metal toolbox. A PMI of 14 months was estimated based on the developmental stages of insects on the body (*Anoplolepis longipes* and *Hermetia illucens*, in particular).

Of greatest interest to this study, PMI formulae have been created based on decomposition rates of human remains. Megyesi et al. (2005) created a formula from documentation of 68 forensic cases from various environments. Their formula ($ADD=10^{(0.002*TBS*TBS*+1.81)}\pm 388.16$) was based on the TBS of the remains. The resulting ADD value represented the PMI. (i.e., the number of ADD needed to reach a particular TBS). Investigators then determined the time-since-death by back calculating the ADD using recorded temperature data for the local area.

In 2011, Vass developed PMI formulae, which took into account the decomposition, temperature, humidity, adipocere formation, and soil moisture (Vass 2011). The formulae were created based on observations of human decomposition at ARF in Tennessee. Vass (2011) created one formula for aerobic decomposition (surface remains) and a separate formula for anaerobic decomposition (buried remains). The formulae are as follows:

$$PMI_{aerobic} = \frac{1285 \times (\text{decomposition}/100)}{0.0103 \times \text{temperature} \times \text{humidity}}$$

And

$$PMI_{anaerobic} = \frac{1285 \times (\text{decomposition}/100) \times .46 \times \text{adipocere}}{0.0103 \times \text{temperature} \times \text{soil moisture}}$$

Note that the aerobic formula took into account humidity and the anaerobic formula did not. Likewise, the anaerobic formula took into account soil moisture and adipocere, and the aerobic formula did not. Both formulae incorporated decomposition and temperature. Decomposition was rated as a percentage and temperature referred to the temperature at the scene.

The aforementioned formulae exhibit the use of decomposition as a variable in PMI estimation and reinforce the importance of understanding how autopsied remains used in such studies may skew the results. This is especially so with the recent increase in body donation programs, which accept both autopsied and non-autopsied human remains

Future of Research in Forensic Anthropology

In the past several years, the increase in body donation programs like those at the University of Tennessee, Texas State University, and Sam Houston State University has allowed for more controlled studies of patterns of human decomposition and the variables affecting the decay process. Recently, other decomposition research facilities have been developed at Colorado Mesa University (Connor and France, 2013) and the University of Southern Illinois (Dabbs and Martin, 2013). An increase in such facilities will allow for a better understanding of decomposition patterns in varying environment across the United States (Parks, 2011; Shirley, 2011; Suckling, 2011); however, such an increase comes with certain concerns. For example, Christensen (2006) discussed the moral considerations of body donation programs. The author stated that the key to alleviating any moral issues was to maintain the autonomy associated with body donation and to treat the body donations with the utmost respect at all times. Additionally, often times bodies donated to such facilities have come from medical examiners offices and have been autopsied. This gives rise to the research issue that is discussed in the present study.

In addition, as the ease and financial feasibility of DNA analysis increases, the focus of forensic anthropology may begin to direct its focus away from the biological profile (Dirkmaat and Cabo, 2012). Forensic anthropologists must be prepared to embrace taphonomic and trauma analysis as part of their repertoire (Ubelaker, 1997; Beary and Lyman, 2012; Dirkmaat and Cabo, 2012). Body donation programs provide the ideal settings for furthering such research. These programs reduce the reliance on case studies where confounding variables are incontrollable, providing for more structured research in trauma and taphonomy, as with the current study.

CHAPTER II

Methods

<u>Decomposition Rates: Autopsied vs. Non-Autopsied Human Remains</u>

<u>Study Population and Sample Size for Decomposition Rates Comparison</u>

The sample population for this study consisted of individuals donated to the Forensic Anthropology Center at Texas State (FACTS) from 2010 to 2013 and placed on the surface at the Forensic Anthropology Research Facility (FARF) on Freeman Ranch in San Marcos, TX. This included 83 individuals: 59 non-autopsied and 24 non-autopsied. A donation was considered autopsied if it contained an abdominal autopsy incision. All autopsied remains contained a "Y" incision (Figure 2.1) except D45-2012, which had a "V" incision, and D15-2013, which had a straight-line incision. Also, for the autopsied remains used in this study there was variation in how tightly the autopsy incisions were sewn closed. Some were closed with only a few stitches, leaving the internal portions of the body more exposed. Others were tightly sutured so that the internal portions were barely visible. Autopsied donations were used in this study without regard to the state of suturing, as most tightly closed incisions loosened after a few days of decomposition.

Donations were considered non-autopsied if they contained no abdominal autopsy suture. Any remains with sutures from a cranial autopsy alone were considered non-autopsied, as the incision from the cranial autopsy was much smaller and was assumed not to greatly affect the rate of decomposition. The sample was analyzed without regard to differences in sex, ancestry, age, cause of death, or body size. All remains represented unclothed, surface burials placed in the supine position.

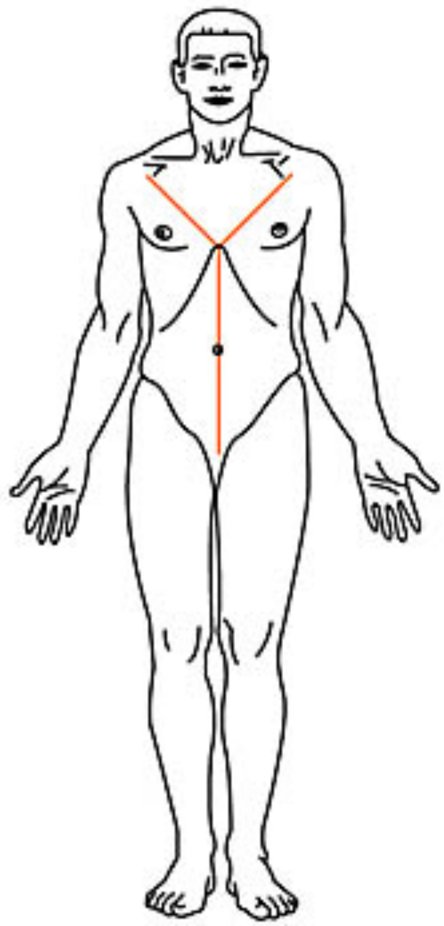

Figure 2.1. Depiction of "Y" Incision Typical of an Autopsy. (Indiana University)

Donations that were decomposing prior to being donated to FACTS, were tissue donors, or were autopsied but contained no organ bag were not used in this study. In addition, photographs and notes were used to examine stages of decomposition (see below). If there was a greater than 5-day gap in the photos and notes between stages of decomposition, then that donation was not used in statistical analysis for that stage of decomposition. As living subjects or live animals were not used in the study, neither IRB or IACUC approval were required.

Decomposition Stages

All the donated human remains used in this study were placed while still fresh. The day each set of remains reached early, advanced, and mummified decomposition stages was determined following a modification of the criteria outlined by Galloway and colleagues (1989). Galloway and colleagues (1989) also described the decomposition stages of skeletonization and extreme decomposition; however, as these stages were seldom reached in the donations that decomposed at FARF, they were not utilized in this study (Suckling, 2011). Galloway and colleagues' decomposition stage criteria are presented in Table 2.1. The criteria utilized in this study are listed in Table 2.2. Galloway and colleagues' (1989) stages, rather than other methods of decomposition characterization, were utilized due to their flexibility when applied to different environments. The day the donations reached each stage of decomposition was determined by examining photographs and notes taken at FARF. At this facility, notes and photographs were recorded daily (on weekdays) for two weeks after placement and then every other weekday until the bodies mummify. Remains were classified as fresh if they showed no discoloration or insect activity. A body was considered in the early decomposition stage when it showed signs of bloat, skin slippage, and green discoloration (Figure 2.2-A). The remains were considered in the advanced stage of decomposition when high maggot activity, sagging of the flesh, and caving in of the abdominal cavity occurred (Figure 2.2-B). For this study, the remains were considered mummified when the soft tissue was completely dried out and skin was leathery and had a "tattered" appearance (Figure 2.2-C). See Appendix A for a full list of donated bodies used in this study as well as the dates that these donated remains reached each stage of decomposition.

Table 2.1. Description of Galloway and Colleagues' Five Stages of Decomposition (Reproduced from Galloway et al., 1989; Table 1)

Decomposition Stage	Description
Fresh	• No discoloration or insect activity • Fresh buried
Early Decomposition	• Pink-white appearance; skin slippage; hair loss • Gray to green discoloration; some flesh still fresh • Brownish shades of discoloration, especially in fingers, nose, and ears • Bloating with green discoloration • Post bloating; discoloration going from green to dark • Brown to black discoloration of arms and legs; skin is leathery
Advanced Decomposition	• Decomposition of tissues with sagging of flesh; caving in of abdominal cavity; extensive maggot activity • Moist decomposition; bone exposure • Mummification with some retention of internal structures • Mummification of outer tissues with internal organs lost through autolysis or insect activity • Mummification with bone exposure of less that one half the skeleton • Adipocere formation
Skeletonization	• Bones with greasy substances and decomposed tissue; sometimes body fluids still present • Bones with desiccated tissue or mummified tissue covering less than one half the skeleton • Bones largely dry; still retaining some grease • Dry bone
Extreme Decomposition	• Skeletonization with bleaching • Skeletonization with exfoliation • Skeletonization with metaphyseal loss, with long bones and cancellous exposure of the vertebrae.

Table 2.2. Stages of Decomposition Used in the Current Study (Adapted from Galloway et al. 1989)

Stage	Description
Fresh	No discoloration, no insect activity
Early	Skin slippage, green discoloration, bloat
Advanced	Sagging of the flesh following post-bloat, caving in at the abdominal cavity, high maggot activity,
Mummification	Complete drying out of soft tissue, retention of skin in leathery, tattered state.

(A)

(B)

(C)

Figure 2.2. Examples of Decomposition Stages. All photographs are of D23-2013. (A) Skin slippage, bloat and discoloration associated with early decomposition. (B) Sunken chest and aftermath of high insect activity [high insect activity was beginning in (A)] associated with advanced decomposition. (C) Desiccated, tattered skin associated with mummification. (Photographs courtesy of FACTS)

Accumulated Degree Days

The relationship between the beginning of each decomposition stage and the accumulated degree days (ADD) was examined. ADD take into account the thermal energy units accumulated by the body (Megyesi et al., 2005). Therefore, by using ADD rather than calendar days, temperature differences due to time of year were accounted for.

For determination of ADD, the temperature data were obtained for the time frame corresponding to the dates each donation was placed for decomposition at FARF. This data came from the forest site weather data recorded by Texas A&M Weather Station, which was recorded every 30 minutes for 24 hours a day 7 days a week. Texas A&M has two weather station sites: the grassland site and the forest site. The grassland site, which is in closer proximity to FARF, is normally used as a representation of weather at FARF; however, the forest site was used as a proxy, in this case, due to ease of access. The present study required many months of weather data, and Texas A&M was not able to provide the grassland site weather data in a timely manner, as it has yet to be archived. The grassland weather data have been archived; therefore, it was easier to acquire and was used in the present study. The forest and grassland data strongly correlate (R^2=0.9811) and do not differ significantly in temperature (Figure 2.3) (Ray H. Kamps, personal communication on July 29, 2013**)** making the forest site weather data an acceptable substitution for the grassland site weather data.

To ensure the forest site data provided an accurate representation of the daily ambient temperatures at FARF, ambient temperature at FARF was recorded once a day for a month using a Thermoworks TW-USB-TC thermocouple data logger, and compared to the corresponding forest site temperature data. A t-test was performed on the temperature data. The temperatures at FARF and the forest site were not significantly different (t-score= 0.6327, CV= 2.042); therefore, the use of the Texas A&M forest site temperature data was acceptable.

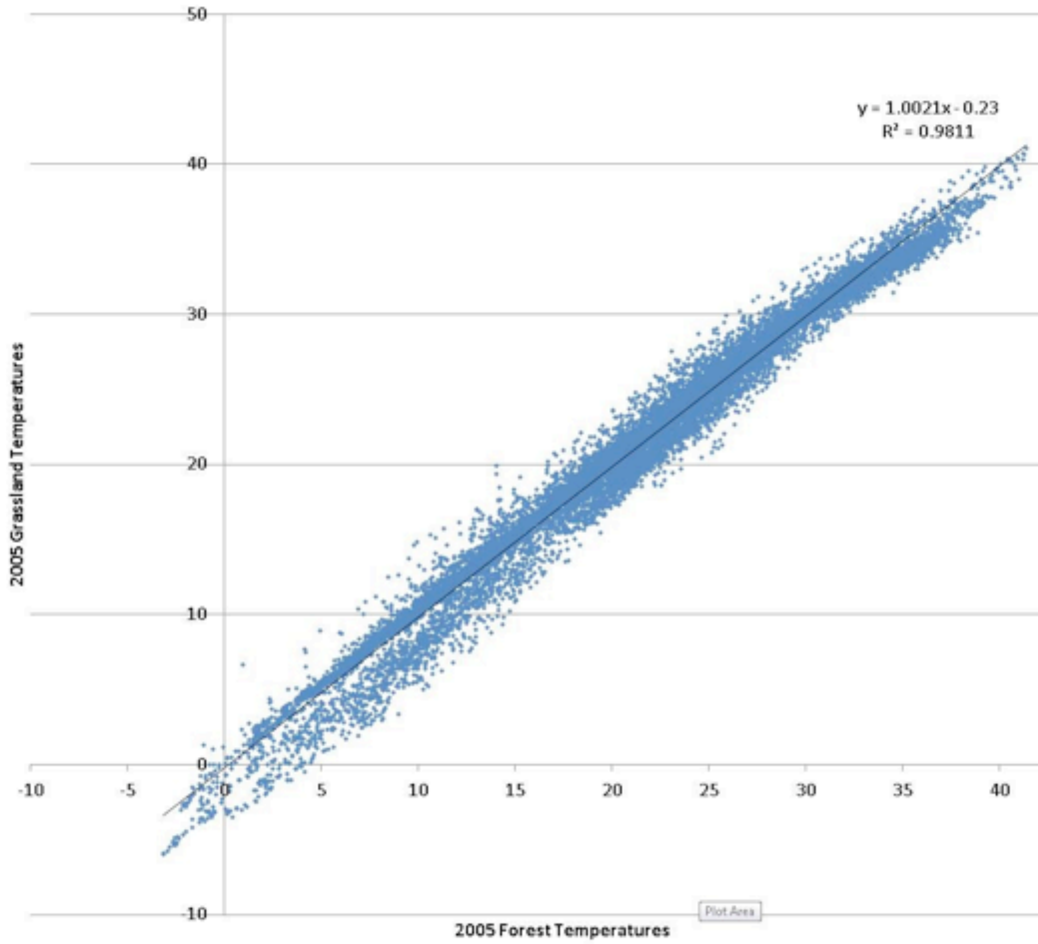

Figure 2.3. Correlation between the Texas A&M Forest Site Temperature Data and Grassland Site Temperature Data. This graph shows the strong correlation (R^2 =0.9811) for 2005. (Graph courtesy of Ray H. Kamps)

After acquiring the temperature data, ADD for each day was calculated by averaging the highest and lowest daily temperatures and subtracting this average from the minimum thermal threshold:

$$ADD = [(Max + Min /2)\text{-threshold}]$$

The resulting value represented the number of degree days accumulated throughout the day. The minimum threshold was set at 0°C, as decomposition slows down significantly at this temperature (Megyesi et al., 2005). Any temperature reading below 0°C was considered 0°C. No upper threshold was set.

Combining ADD and the Decomposition Stages

For every donation, the number of degree-days that accumulated between placement of the body at FARF and early, advanced, and mummified decomposition stages was determined by summing the ADD for each day between placement and the date these stages were reached. The same was done for the time frame between early and advanced decomposition stages and between advanced and mummified decomposition stages.

Statistical Analyses

After data collection, statistical analyses were utilized to determine if there was a statistically significant difference between the rates of decomposition in autopsied and non-autopsied remains. An α–level of 0.05 was used to determine significance. First, the ADD between placement and each decomposition stage and between decomposition stages was determined for all autopsied and non-autopsied remains. These ADD values were then averaged for the autopsied and non-autopsied remains, separately. Next, five different t-tests were performed on the average ADD data. A separate t-test was conducted for the average ADD between placement and each stage of decomposition and for the ADD between stages. In other words, a t-test was performed for the average ADD between (1) placement and early decomposition stage, (2) placement and advanced decomposition stage, and (3) placement and mummification. A t-test was also conducted for the ADD between (4) early and advanced decomposition stages as well as between (5) advanced and mummified decomposition stages. These five t-tests were performed with the aim of understanding in what stage, if any, the decomposition rates differ between autopsied and non-autopsied remains.

In addition, the donations were split according to time of year. This was done because, when the donations were ordered by increasing ADD to mummification, a trend emerged. The higher ADD to mummification values occurred during the fall and winter months (October to March) and the lower ADD to mummification values occurred during the spring and summer months (April to September). This suggested that decomposition differed between seasons and it was necessary to separate the donations by time of year. Therefore, t-tests were performed on the ADD between placement and each stage of decomposition and for the ADD between stages for the fall/winter months and spring/summer months, separately.

Overall, 15 t-tests were performed: five for all donations together, five for fall/winter donations, and five for spring/summer donations. In addition, an f-test for equal variances was performed for the data used in each of the 15 t-tests. If the variances were not equal between the samples, a t-test for samples with unequal variances should have been performed; however, this was not an issue in this study.

In addition to performing t-tests on the data, the average ADD for each stage of decomposition was determined for autopsied and non-autopsied remains in order to compare the ADD between the two. This was done for all donations together and after splitting them by time of year.

Internal Body Temperature: Autopsied vs. Non-Autopsied Human Remains

Internal body temperature (in degrees Celsius) was also recorded on donations received between April and November of 2013 to determine if the internal temperature during decomposition differed between autopsied and non-autopsied bodies. If a significant difference occurs this would help explain the difference in decomposition rates**.** As FACTS received approximately three to four donations per month, I was able to monitor internal temperature on 13 donations. Five were autopsied and eight were non-autopsied. One donation (D22-2013) contained an abdominal autopsy incision as well as incisions in the legs due to tissue donation prior to donation to FACTS. This was included with the autopsied donations due to the low sample size of this treatment. It was assumed that the leg incisions did not alter the internal body temperature of the abdomen. Internal body temperature was also recorded for D31-2013; however, this donation was not classified as autopsied or non-autopsied, as the donation had no abdominal autopsy incision but did have incisions on both legs due to tissue donation.

Using an ice pick, a hole was created at the left lower abdomen just medial to the left anteriosuperior iliac spine at the time of body placement at FARF. This hole was used for the Thermoworks TW-USB-TC thermocouple data logger temperature probe. To prepare for recording the internal body temperature, the USB data logger was inserted into a laptop loaded with the Thermoworks data logger program, EasyLog USB (Figure 2.4). The program was used to start the data logger and set it to record temperature every second. Next, the data logger was removed from the USB port, and the probe was inserted into the data logger (Figure 2.5). Notes were recorded on the sampling procedures and state of the remains each day for the two weeks that temperature was collected.

Figure 2.4. EasyLog USB Program Start Up Page. Note the options to set up and start the logger and to stop the data logger.

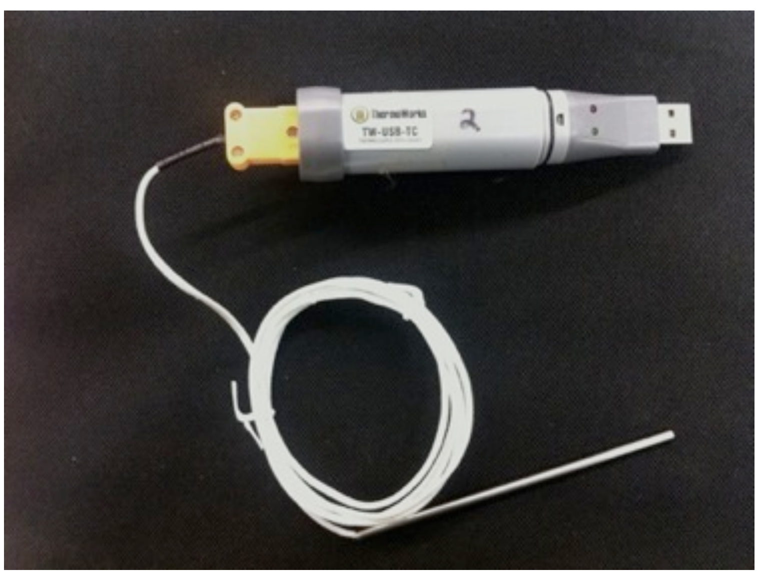

Figure 2.5. Thermoworks TW-USB-TC Thermocouple Data Logger. Temperature probe is attached.

Data collection was performed in the same manner on each body. First, the data logger was used to record ambient temperature for three minutes, ten feet from each donation, as to avoid heat interference from the body (Figure 2.6). The logger probe was then inserted into the hole on the left side of the donation for two minutes to record the body temperature to the nearest degree Celsius (Figure 2.7). This procedure was repeated for each donation (autopsied and non-autopsied). As the logger collected temperature data continuously, an ice pack was placed on the temperature probe for 30 seconds after each temperature-recording episode to differentiate between these episodes.

Figure 2.6. Recording Ambient Temperature. Temperature is recorded ~10 feet from the remains (D29-203). Note the data logger being held in the right hand.

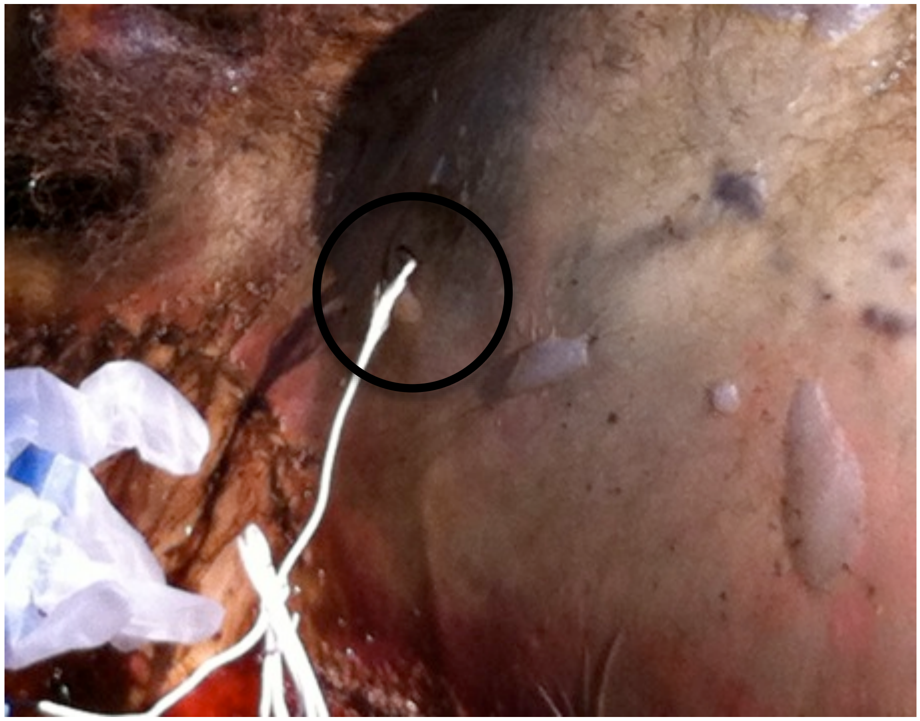

Figure 2.7. Collecting Internal Body Temperature. Circle indicates location of data logger probe inserted into left side of the lower abdomen for internal body temperature recording on D31-2013.

The hole created in the body for the temperature probe was then closed using adhesive tape to prevent gas release. After approximately a week of decomposition it was impossible for the tape to remain on the body due to high maggot activity and/or moisture on the skin. This small open hole likely did not alter the decomposition of the remains as the tape stopped sticking well after the bloat had dissipated and insect activity had created numerous other holes in the skin of the abdomen.

The temperature data were recorded between 8:00 A.M. and 10:00 A.M. each day, unless extenuating circumstances prevented this. Temperature data were recorded every day from the date of placement until the body had been decomposing for at least two weeks. Internal temperature data for the first body used in this study (D20-2013) were recorded for just over a month in order to establish how many days of temperature data should be recorded for each donation. This revealed that the body reached ambient temperature within two weeks of placement; therefore, data were collected for only two weeks on the remaining donations.

After temperature data collection, the USB data logger was inserted into the laptop, and the EasyLog USB program was used to stop the data logger. After saving the data, the EasyLog USB program generated a graph of the temperature data recorded (Figure 2.8). This graph and the associated data were then exported to Excel. For each donation, the ambient temperature was subtracted from the internal body temperature to evaluate how many degrees the body was above or below ambient temperature. This difference was used in statistical analyses (discussed below). The highest ambient and internal body temperature recorded by the data logger during a single recording episode was used to calculate this difference. A complete list of the temperature data can be found in Appendix B.

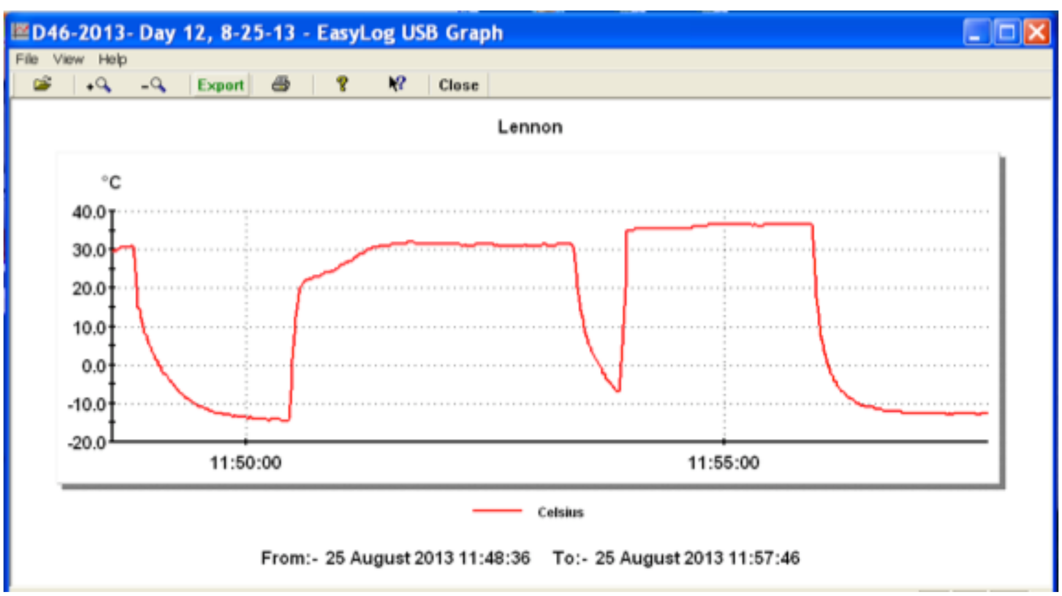

Figure 2.8. Thermoworks USB Data Logger Temperature Graph. The graph was generated by the EasyLog USB program. Temperature is measured in degrees Celsius. Dips in temperature represent times when probe was placed on an ice pack.

Statistical Analyses

Statistical analyses were used to determine if there is a statistical difference between the internal body temperatures of decomposing autopsied and non-autopsied human remains. This was done using t-tests comparing the internal temperature of autopsied and non-autopsied remains. A t-test was utilized for the day of placement and each day of the two weeks that internal body temperature was recorded, resulting in a total of 15 t-tests. The difference between the ambient temperature and the internal body temperature was used in these analyses.

Next, the data were analyzed using multiple regression analyses, and r^2 values were determined. This was done for the autopsied and non-autopsied remains, separately. In addition, the average difference between ambient and internal body temperature for the two groups was determined for the first 2 weeks of decomposition and compared graphically, along with the temperature data for donation D31-2013. This donation had incisions along the length of both legs with no autopsy incision. By graphically comparing this donation with the autopsied and non-autopsied averages it was possible to get a better idea of whether any large incision would cause temperature differences or if the incision must be at the abdomen, like with autopsy incisions.

CHAPTER III

Results

Decomposition Rates: Autopsied vs. Non-Autopsied Human Remains

The ADD were calculated for non-autopsied and autopsied human remains at each stage of decomposition (Appendix C). Descriptive statistics for this data are presented below in Table 3.1. For all decomposition stages the autopsied bodies had a lower mean and standard deviation than the non-autopsied, but the difference is not significant for any stage of decomposition. The results of the five f-tests performed using the ADD for all autopsied and non-autopsied remains are presented in Table 3.2. The f-tests for equal variances show that the variances for these two groups were equal; therefore, t-tests assuming equal variances were used. After performing five t-tests comparing all autopsied and non-autopsied bodies between placement and each stage of decomposition and the ADD between stages, it was evident that there was no significant difference in the rate of decomposition between autopsied and non-autopsied human remains at any stage of decomposition.

Table 3.1. Descriptive Statistics for the ADD at Each Stage of Decomposition for Non-Autopsied and Autopsied Remains
***Note: all values are in units of ADD**

	Placement to Early	Placement to Advanced	Placement to Mummified	Early to Advanced	Advanced to Mummified
Non-Autopsied					
Mean	116.8	297.6	175.9	741.3	412.4
Standard Deviation	87.3	187.2	137.5	510.8	315.8
Median	95.0	262.0	130.6	688.3	387.7
Range	580.9	956.9	858.0	2754.9	1192.8
Variance	7624.8	35047.1	18913.3	260941.2	99736.8
Autopsied					
Mean	100.6	258.2	157.6	587.9	324.5
Standard Deviation	54.6	115.9	95.0	263.2	194.7
Median	99.3	252.6	118.0	529.2	324.1
Range	201.9	419.5	356.1	850.5	703.4
Variance	2,985.1	13,437.0	9,033.0	69,264.9	37,923.8

Table 3.2. T-tests Comparing All Autopsied and Non-Autopsied Remains

Period of Decomposition	n Autopsied, Non-Autopsied	f-test Score	p-value (f-test)	Equal Variances (α=0.05)?	t-test score	df	p-value (t-test)
Placement to Early Decomposition	24,59	0.0153	1	Yes	0.4031	81	0.6879
Placement to Advanced Decomposition	24,57	0.0139	1	Yes	0.3424	79	0.6967
Placement to Mummification	21,58	0.0019	1	Yes	0.1940	77	0.7796
Early to Advanced Decomposition	24,56	0.0634	1	Yes	0.5565	78	0.5484
Advanced Decomposition to Mummification	21,54	0.0285	1	Yes	0.2388	73	0.7194

Next, the donations were split into spring/summer and fall/winter categories depending on the time of year that they decomposed. The average ADD for each stage during these two times of year is presented in Figure 3.1. It was evident that the donations decomposing in the spring/summer months had lower ADD values for all decomposition stages when compared to fall/winter months (Figure 3.1). This was true for both autopsied and non-autopsied remains.

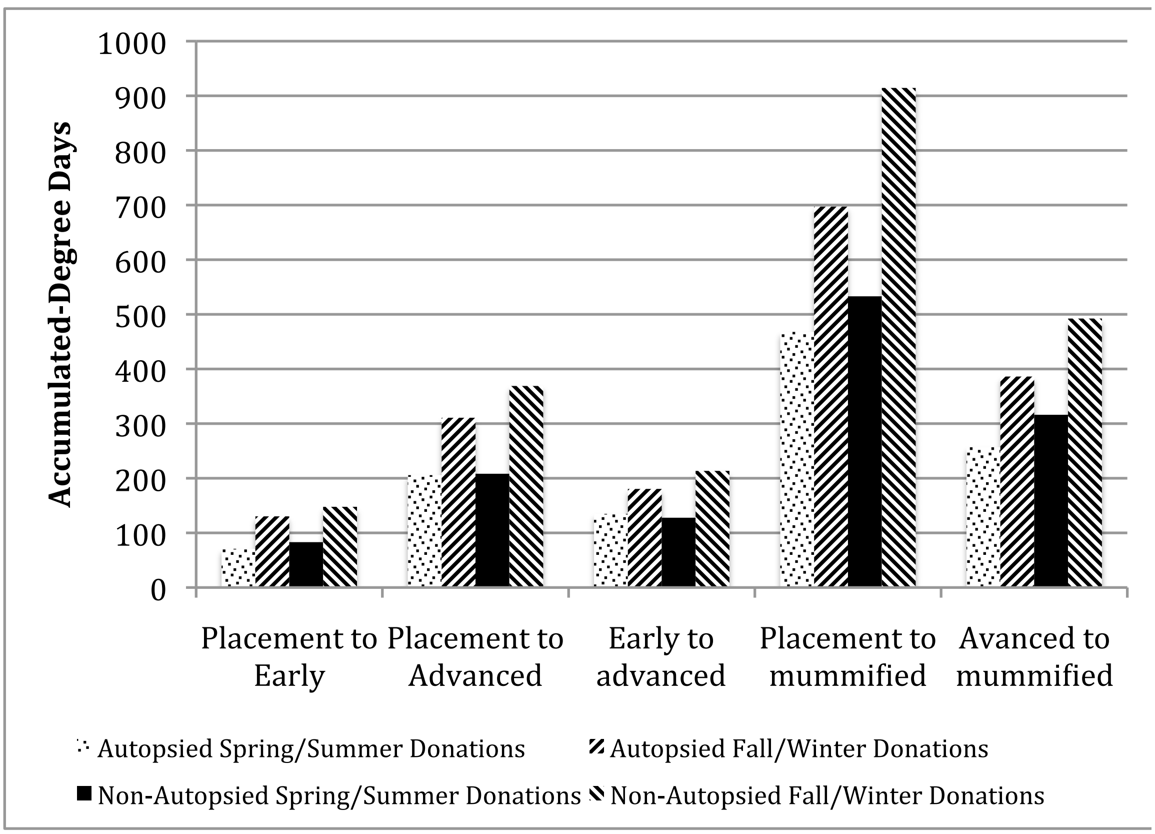

Figure 3.1. Comparison of Average ADD between Autopsied and Non-Autopsied Remains when Separated by Time of Year.

When the donations were split by time of year (spring/summer and fall/winter) the results of the ten f-tests (five for spring/summer donations and five fore fall/winter donations) show that the variances for autopsied and non-autopsied remains are equal

(Tables 3.3 and 3.4); therefore, t-tests assuming equal variances were used. The t-tests show that there is no significant difference in the rate of decomposition between autopsied and non-autopsied human remains. This is true for all 10 t-tests performed: five for spring/summer donations and five for fall/winter donations. There was no statistically significant difference in the rate of decomposition of autopsied and non-autopsied human remains when the donations were split by time of year and analyzed.

Table 3.3. T-tests Comparing Autopsied and Non-Autopsied Remains Placed in Spring/Summer Months

Period of Decomposition	n Autopsied, Non-Autopsied	f-test Score	p-value (f-test)	Equal Variances (α=0.05)?	t-test score	df	p-value (t-test) (α=0.05)
Placement to Early Decomposition	28,12	0.8716	0.6338	Yes	0.5140	38	0.6102
Placement to Advanced Decomposition	26,13	0.6874	0.7931	Yes	0.9361	37	0.3553
Placement to mummification	27,10	0.1541	0.9999	Yes	0.5409	35	0.5920
Early to Advanced Decomposition	26,12	0.8103	0.6834	Yes	0.7566	36	0.4542
Advanced decomposition to Mummification	25,10	0.2770	0.9943	Yes	0.1264	33	0.9002

Table 3.4. T-tests Comparing Autopsied and Non-Autopsied Remains Placed in Fall/Winter Months

Period of Decomposition	n Autopsied, Non-Autopsied	f-test Score	p-value (f-test)	Equal Variances (α=0.05)?	t-test score	df	p-value (t-test) (α=0.05)
Placement to Early Decomposition	32,12	0.0041	1	Yes	0.5585	42	0.5795
Placement to Advanced Decomposition	32,12	0.0325	1	Yes	0.3755	42	0.7092
Placement to Mummification	32,11	0.0183	1	Yes	0.2373	41	0.8136
Early to Advanced Decomposition	31,12	0.0054	1	Yes	0.2805	41	0.7805
Advanced Decomposition to Mummification	30,11	0.0002	1	Yes	0.0042	39	0.9967

Though all t-tests showed there was no significant difference in decomposition rates between autopsied and non-autopsied remains, after determining the average ADD for each stage of decomposition, a trend became evident. In general, the average ADD for autopsied bodies was lower than for the non-autopsied bodies. Figure 3.2 shows the average ADD for all autopsied and non-autopsied remains. The largest difference in average ADD occurred for placement to mummification. The same trends were seen with donations that decomposed during the fall/winter months. Figure 3.3 depicts the average ADD of autopsied and non-autopsied remains that decomposed during fall/winter months.

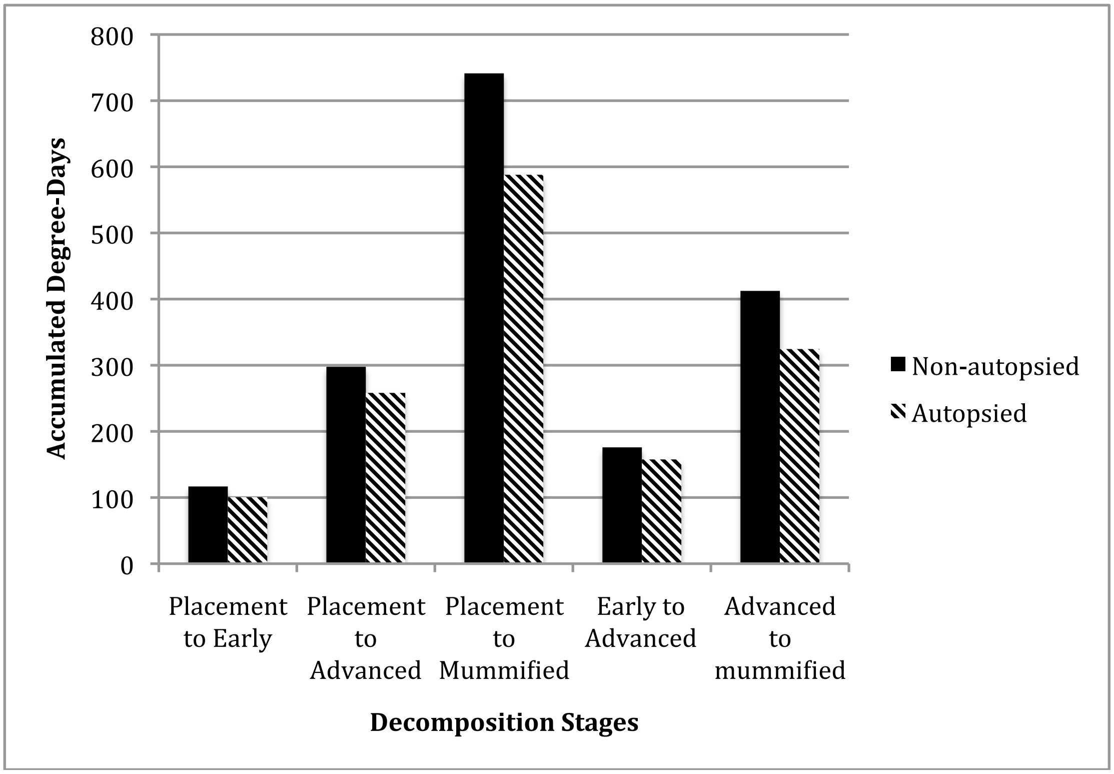

Figure 3.2. Comparison of Decomposition between Non-Autopsied and Autopsied in Mean ADD.

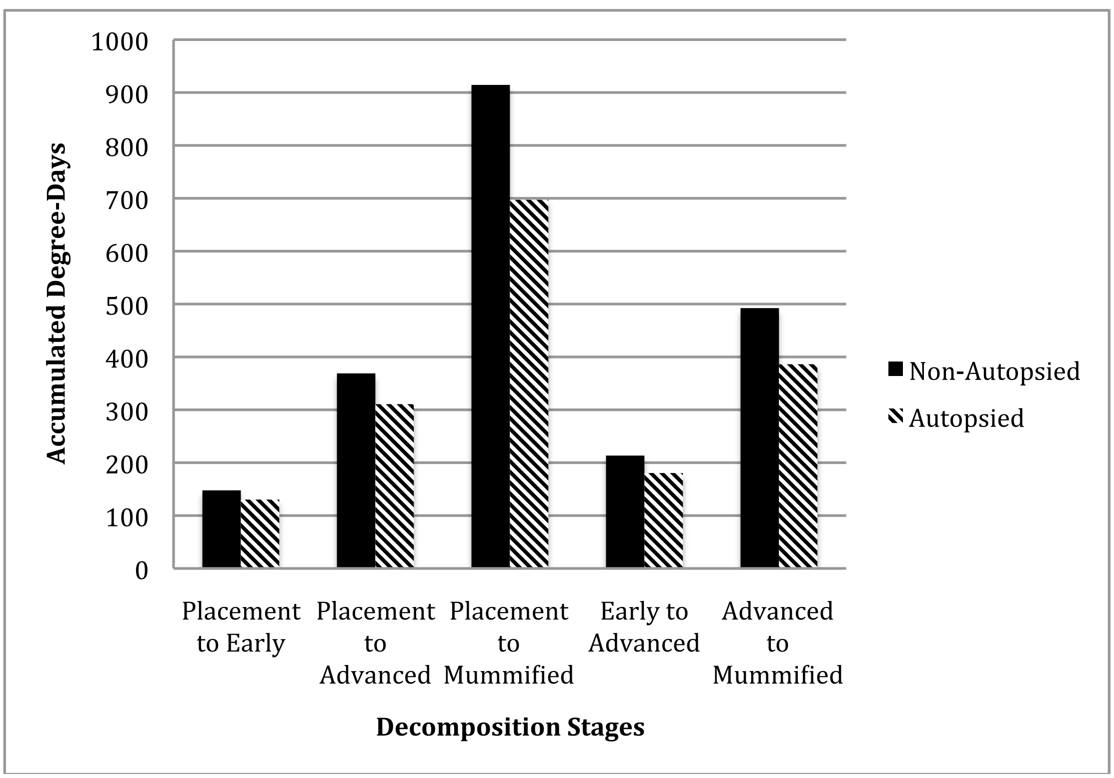

Figure 3.3. Comparison of Decomposition between Non-Autopsied and Autopsied in Mean ADD for Fall/Winter Months

The trend seen with donations that decomposed during the spring/summer months was slightly different. For almost all stages of decomposition the autopsied remains had slightly lower mean ADD than the non-autopsied with one exception (Figure 3.4). The mean ADD between early and advanced decomposition stages was marginally higher for autopsied remains when compared to non-autopsied remains. For all other stages, the difference in ADD between autopsied and non-autopsied was less pronounced than with the fall/winter donations and when all donations were considered together.

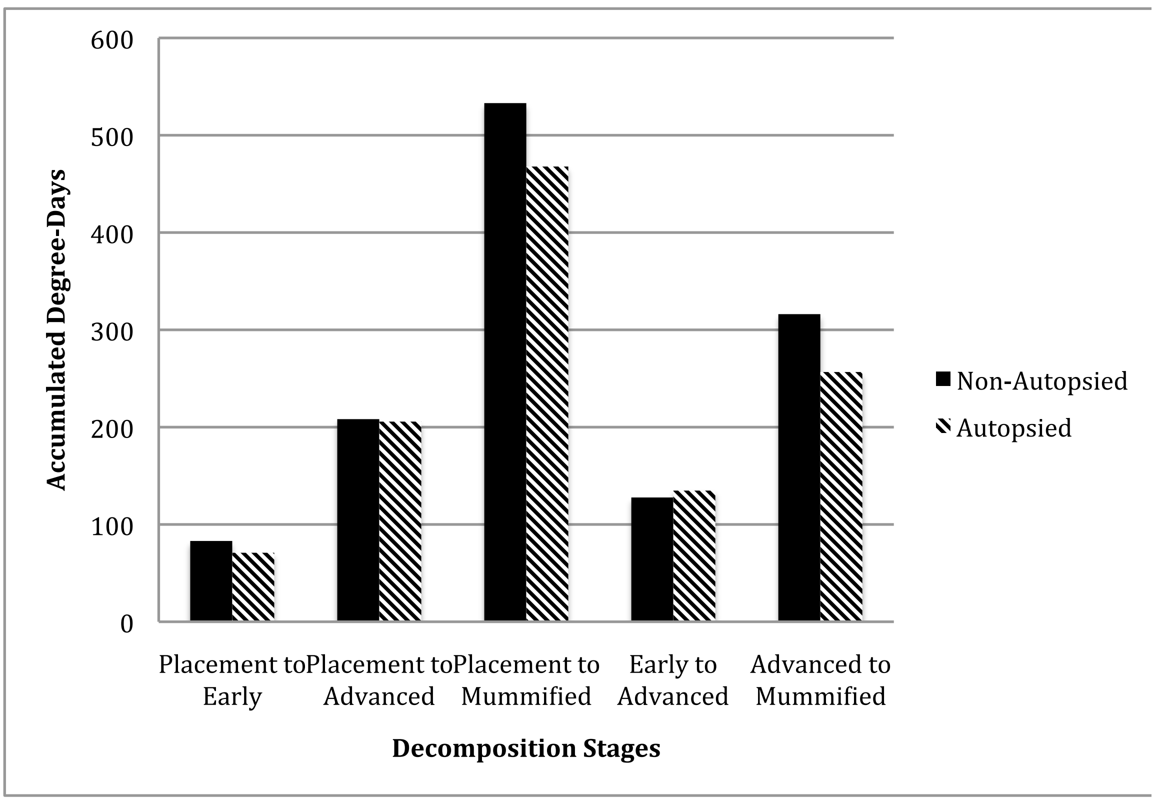

Figure 3.4. Comparison of Decomposition between Non-Autopsied and Autopsied in Mean ADD for Spring/Summer Months

Internal Body Temperature: Autopsied vs. Non-Autopsied

The results of the fifteen f-tests performed using the degrees Celsius from ambient temperature on the 14 days after placement for autopsied and non-autopsied remains are presented in Table 3.5. The results showed that the variances for these two groups were equal for placement and the following 14 days; therefore, t-tests assuming equal variances were used. A total of 15 t-tests were performed comparing autopsied and non-autopsied remains using the difference between internal temperature and ambient temperature (°C). All t-tests showed that there was no significant difference between autopsied and non-autopsied remains (α=0.05) (Table 3.5)

Table 3.5. T-tests Comparing Internal Body Temperature of Autopsied and Non-Autopsied Remains for Placement and the Following 14 days of Decomposition

Day	n Autopsied, Non-Autopsied	f-test score	p-value (f-test)	Equal Variances (α=0.05)?	t-test score	df	p-value (t-test) (α=0.05)
0	4,7	0.8989	0.9178	Yes	0.8878	9	0.3977
1	5,8	0.7253	0.7368	Yes	0.0971	11	0.9244
2	4,8	0.7297	0.7750	Yes	0.1752	10	0.8644
3	4,8	0.9936	0.9966	Yes	0.2041	10	0.8424
4	5,8	0.9791	0.9861	Yes	0.2522	11	0.8055
5	5,8	0.6068	0.6072	Yes	0.0559	11	0.9565
6	5,8	0.9050	0.9211	Yes	0.0741	11	0.9423
7	5,8	0.9980	0.9990	Yes	0.3191	11	0.7556
8	5,7	0.5284	0.5228	Yes	0.1430	10	0.8891
9	5,7	0.5289	0.5410	Yes	0.1047	10	0.9187
10	5,8	0.9798	0.9898	Yes	0.4584	11	0.6556
11	5,8	0.6963	0.7255	Yes	0.3210	11	0.7542
12	4,8	0.5299	0.5553	Yes	0.2349	10	0.8190
13	5,8	0.7551	0.7687	Yes	0.0835	11	0.9350
14	5,8	0.7154	0.7288	Yes	0.0056	10	0.9956

Polynomial (quadratic) regression analysis was also performed for this temperature data to compare the internal temperature progression for autopsied and non-autopsied remains over 14 days of decomposition (Figure 3.5). It took approximately one day longer for the autopsied remains reach ambient temperature, but once they did they stayed closer to ambient than the non-autopsied remains. Overall, the non-autopsied remains appeared to generate more heat than the autopsied remains. The quadratic regression for the non-autopsied bodies explained more of the variability in temperature than the autopsied remains. The R^2 values were 0.496 and 0.356 for the non-autopsied and autopsied, respectively. The multiple regression model explained 49.6% of the variability in the non-autopsied data and only 35.4% of the variability in the autopsied data.

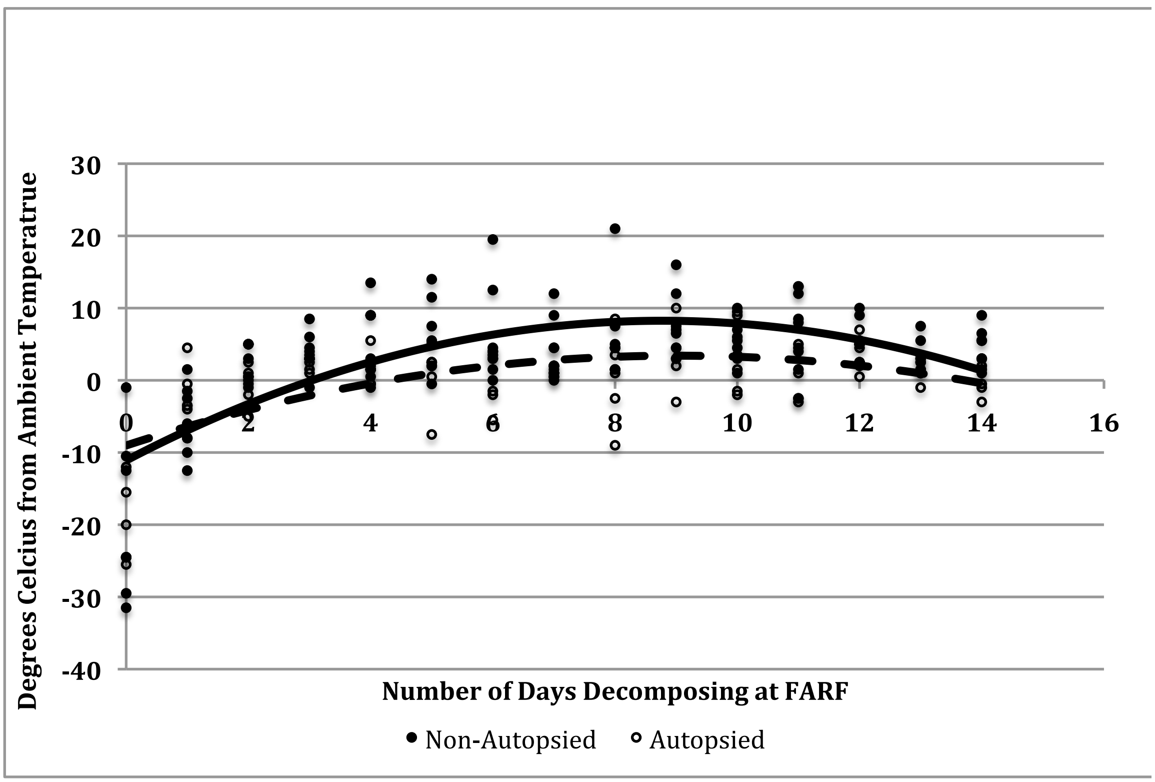

Figure 3.5. Multiple Regression for Internal Body Temperature of Non-Autopsied and Autopsied Remains. The solid line represents non-autopsied remains and the dashed line represents autopsied remains. The R^2 values are 0.496 for the non-autopsied and 0.356 for the non-autopsied remains.

The average temperature data for autopsied and non-autopsied are represented in Figure 3.6 along with the temperature data for donation D31-2013. D31-2013 contained no autopsy incision but did have large leg incisions due to tissue donation. It was also apparent that, with the exception of the peak at Day 8 and the slight peak at Day 13, D31-2013 stayed closer to the ambient temperature than both the autopsied and non-autopsied remains. This donation was closer, overall, to the autopsied remains in terms of the heat generated during decomposition. It is important to note, however, that D31-2013 was only a single observation.

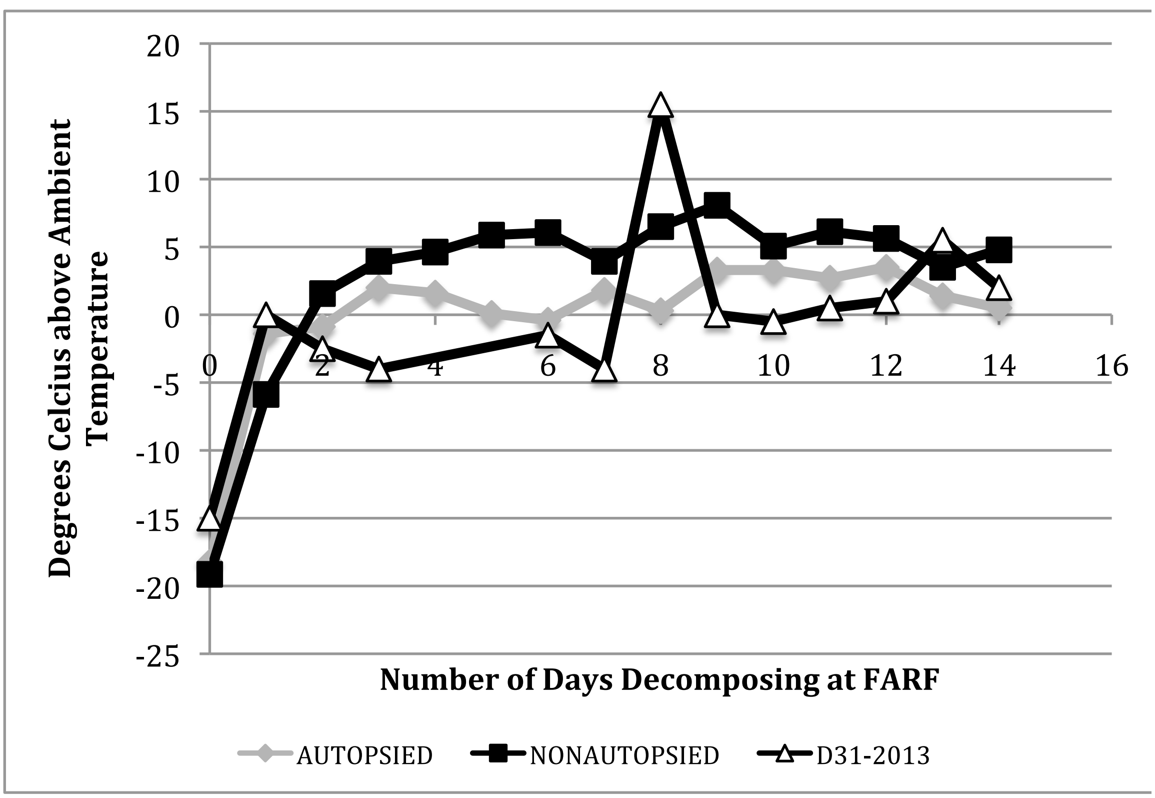

Figure 3.6. Internal Body Temperature: Non-Autopsied, Autopsied, and D31-2013. Comparison of mean internal body temperatures for non-autopsied, autopsied, and the internal temperature for donation D31-2013 for the first two weeks of decomposition.

CHAPTER IV

Discussion and Conclusion

Research in forensic taphonomy has changed significantly in the past several decades. In the past, researchers were primarily restricted to retrospective examinations or investigations using animal models and small sample sizes (Rodriquez and Bass, 1983; Mann et al., 1990; Shean et al., 1993; Komar et al., 2006; Bucheli et al., 2009; Parsons, 2009). However, in the last decade several universities have started decomposition research facilities designed to examine specific scientific question in a relatively controlled environment using donated human remains (Vass, 2001; Parks, 2009; Connor and France, 2013; Dabbs and Martin, 2013). Since current facilities accept both autopsied and non-autopsied remains, recognizing if and how autopsied and non-autopsied human remains differ in their decomposition patterns is important to past and future human decomposition studies. It is possible that the inclusion of autopsied bodies in decomposition studies could skew the results of decay rate and estimations of PMI. Since the determination of the PMI is often essential in medicolegal death investigations, skewed results due to utilizing both autopsied and non-autopsied remains in PMI research may have considerable consequences. Thus, it is important to understand how an autopsy incision affects decomposition of human remains.

Decomposition Rate: Autopsied vs. Non-Autopsied Human Remains

This study showed that the presence of an abdominal autopsy incision did not statistically affect the rate of decomposition of autopsied remains in this Central Texas environment. Even so, when all donations were considered together rather than being split by time of year, the mean ADD values were consistently lower for autopsied bodies when compared to non-autopsied bodies. The same could be said for the donations that decomposed during the fall and winter months. These statistically insignificant, yet consistent, differences in decomposition rates may have been influenced by an increase in insect activity, as insects are attracted to dark, moist areas that give them access to the internal portions of the body in order to lay eggs (Greenberg and Kunich, 2002). An abdominal autopsy incision provides such an environment and likely allows for more insect activity by encouraging egg deposition. In fact, with donations decomposing at FARF, maggot masses concentrated at the autopsy incision area, as seen in Figure 4.1. This may have increased decomposition rates marginally yet not enough to be considered significant.

Figure 4.1. Maggot Masses Concentrated at the Autopsy Incision of Donation D59-2013. (Photograph courtesy of FACTS)

For the donations that decomposed in the spring and summer months, there was no significant difference in the rate of decomposition between autopsied and non-autopsied remains. In general, the mean ADD values were lower for the autopsied bodies when compared to non-autopsied; however, the mean ADD between early and advanced decomposition stages was slightly higher with autopsied remains than non-autopsied. In addition, there was a less substantial variation in mean ADD between autopsied and non-autopsied remains for all other periods of decomposition. This may have been due to the increased temperatures in Central Texas during the spring and summer months. Higher temperatures may have increased the rate of insect succession and decomposition (Vass, 2001; Weatherspark Beta, 2012; Wells and Lamotte, 2001) in all bodies so that the difference between the two was less substantial.

Even with the slight trends seen with mean ADD between stages of decomposition, it is important to remember that there was no significant difference in the rate of decomposition. In fact, the lowest p-value from all t-tests performed for decomposition rate was only 0.3553 (see Table 3.3), which was far from the 0.05 significance level. Therefore, using both autopsied and non-autopsied remains in human decomposition studies for Central Texas does not produce skewed results. Nevertheless, as this study included only 24 autopsied bodies while there were 59 non-autopsied remains, it is possible that a larger sample size of autopsied remains would have produced different results.

Of interest, for both the spring/summer donations and the fall/winter donations, the greatest p-values were seen with the t-tests for the advanced to mummification decomposition period ($p=0.9002$ and 0.9967, respectively). This period of decomposition exhibited relatively the same rate of decomposition when donations were split by time of year. Therefore, the differences in weather throughout the year dis not affect autopsied remains any differently than non-autopsied remains with regard to how quickly the remains move from advanced decomposition to mummification. With all other periods of decomposition examined, the spring/summer donations and fall/winter donations did not exhibit similar p-values.

Also of note, when comparing fall/winter donations and spring/summer donations, there appeared to be a trend in which the average ADD between all stages of decomposition was greater for fall/winter donations. This was true for both autopsied and non-autopsied remains. It is important to note that no statistical analysis was performed to determine if these differences were statistically significant. All that can be said for certain is that there was a trend where, even when temperature differences due to time of year are accounted for through ADD, remains tended to decompose more slowly in the fall/winter months than during the spring/summer months. This may have been due to differences in dew point and precipitation. The dew point is higher in the spring/summer months meaning the air is muggier when compared to the dry winter air. Also, there is more precipitation during the fall/winter months (Weatherspark Beta, 2012). These weather differences may have effected decomposition, resulting in slightly slower decomposition during the fall/winter months. Humidity may have also affected the rate of decomposition of human remains; however, in this Central Texas environment the humidity only slightly varies throughout the year (Weatherspark Beta, 2012). Consequently, it was unlikely that differences in humidity led to differing decomposition due to time of year.

Of interest, the differing rates of decomposition between the spring/summer and fall/winter donations were not consistent with the assumptions outline by Megyesi and colleagues (2005). They stated that ADD and decomposition could be used together to estimate PMI more effectively. The current study showed that even when differences in temperature are taken into account by using ADD days, time of year still affected the rate of decomposition of human remains. Therefore, other factors (e.g., insect and microbe activity) besides temperature were at work. It is important to remember; however, that the differences between decomposition between times of year was not tested statistically in this study.

Internal Body Temperature: Autopsied vs. Non-Autopsied

According to the 14 t-tests performed, internal body temperature was not significantly different between autopsied and non-autopsied human remains for the first 14 days of decomposition. Thus, any loss of heat due to an autopsy incision was not enough to cause significant temperature differences. It is important to note that, if the autopsy incision led to an increase in maggot activity in the abdomen it is possible that the increased heat generation for the maggot masses canceled out the heat loss from the incision itself. Such a situation may result in differences in internal body temperature between autopsied and non-autopsied remains that are not significant. Of note, internal temperature was not significantly different between the two for the day of placement, meaning that the autopsied and non-autopsied remains did not have drastically different body temperatures at placement. Therefore, body temperature at the time of placement did not skew the results of the t-tests.

Though the t-tests showed no significant difference in internal body temperature, a multiple (polynomial) regression analysis revealed that the autopsied bodies remain closer to ambient temperature throughout the 14-day period. This was likely due to much of the heat produced during decomposition being released through the abdominal autopsy suture. This slight, yet consistent, difference in internal body temperature between autopsied and non-autopsied remains may have been the cause of the trend in average ADD between stages seen between the two conditions. However, a decrease in temperature is usually associated with slower decomposition rather that more rapid (Mann et al. 1990; Komar 1998; Parsons 2009). Therefore, it may in fact have been an increase in insect activity that was causing the difference. This is something that should be investigated as part of future research.

When comparing the average internal body temperatures, the same trend was seen. The autopsied stayed closer to ambient temperature. D31-2013, the non-autopsied body with leg incisions, remained closer to ambient than both the autopsied and non-autopsied remains. This suggests that an incision need not be at the abdomen to lower the internal body temperature. There was a spike in the internal temperature at day eight that was possibly due to the temperature data being collected late in the day (6:00 P.M.) rather than the morning, allowing the body to accumulate more heat. It is important to note that this was only one donation; more non-autopsied bodies with large incisions should be studied to determine if these incisions affect the internal body temperature during decomposition.

The autopsied remains in this portion of the study included one donation (D22-2013) with both autopsy incisions and leg incisions. This donation was included with the autopsied remains due a lack of autopsied bodies in the study; however, the temperatures of D31-2013 (discussed above) may suggest that the body should not have been included with the autopsied remains, as the internal temperatures may have been affected by the leg incisions. Conversely, after reviewing the internal temperatures for this body, they do not appear to differ from the temperatures of other autopsied remains. Therefore, the body likely did not skew the results of the internal temperature analyses.

Three of the autopsied bodies used in the internal temperature portion of this study where placed during the fall/winter months. Previous studies have showed that decomposition slows down during these months due to decreased ambient temperature; therefore, these remains did not reach the same levels of decomposition in 14 days as those that decomposed during the spring/summer months (Mann et al., 1990; Komar, 1998; Parsons, 2009). This may have skewed the internal temperature results obtained. Even so, this was unavoidable, as FACTS only received two fresh, autopsied bodies during the spring/summer months. Future studies will benefit from using bodies that decompose during similar times of year.

Though there was no difference in the decomposition rates of autopsied and non-autopsied remains, it is possible that the factors leading to the similar rates were different for the two types of remains. For non-autopsied remains, the internal temperature was able to rise without loss of heat through an autopsy incision. Though the autopsied remains contained a large abdominal incision that may have released the heat produced during decomposition, increased maggot activity due to this same incision may have driven up the internal temperatures. It is possible that the temperature rose high enough to reduce the ADD to each stage of decomposition to that of the non-autopsied remains.

Effects of Trauma on Decomposition Rates

While examining the effects of trauma on decomposition rates was not a goal of this study, the results do provide some insight into this topic since the autopsy incision represents major sharp-force trauma. Trauma that penetrates the skin is often accepted as a factor in the rate of decomposition (Mann et al., 1990), but some studies have contradicted this premise. Smith (2010) examined differences in the rate and pattern of decomposition between pigs with penetrating thoracic incisions, non-penetrating trauma, and a control group with no trauma. She found that penetrating trauma influenced the pattern of decomposition but not the rate. In the control group decomposition began in the face, while in the pigs with traumatic injuries decomposition was observed at the trauma site first. However, the rate of decomposition did not differ in the three groups. The results of this study were consistent with those of Smith (2010). The rate of decomposition does not differ significantly between autopsied and non-autopsied remains suggesting that penetrating trauma does not have a significant influence on the rate of decomposition. However, the consistent trend, in terms of lower mean ADD in the autopsied bodies, may suggest that penetrating trauma has a small effect on decomposition rates by providing another means of access for insects.

Conclusion

Understanding how the decomposition rates of autopsied and non-autopsied remains differ is important to previous and future human decomposition studies, especially if the study is not separating the two. Any differences in decomposition between the two could affect the results of decomposition studies. An autopsy incision may alter the insect activity and internal temperature of the remains when compared to non-autopsied remains. Therefore, it is important to examine if there is a difference in the rate of decay between autopsied and non-autopsied remains.

The primary hypothesis for this study was that an autopsy incision would statistically affect the rate of decomposition of autopsied remains when compared to non-autopsied remains. The secondary hypothesis for this study was that the internal body temperature of autopsied remains would be statistically lower that the internal body temperature of non-autopsied remains. The results of this study showed that decomposition rates and internal body temperatures did not differ significantly between autopsied and non-autopsied human remains; therefore, using both in decomposition studies in a Central Texas environment will not skew the results. The original hypotheses were not supported.

Future Research

Though decomposition rates did not differ between autopsied and non-autopsied remains in this study, the decomposition pattern of autopsied remains should be examined to ensure that these findings apply to other environments. In addition, differences in insect activity between autopsied and non-autopsied remains should be examined in the future, as it is possible that the autopsy incision leads to differing insect activity. With regard to comparing internal body temperature between autopsied and non-autopsied bodies, future research would benefit from using bodies that decompose during similar times of year. It is possible that the fact that the autopsied bodies used in this portion of the study have decomposed during different times of year skewed the results.

APPENDIX SECTION

APPENDIX A: DATES THAT DONATIONS REACHED EACH STAGE OF DECOMPOSITION

A=autopsied; NA= non=autopsied;
Light Grey=1-5 day gap in photos/notes (used in analysis)
Dark Grey= >5 day gap in photos/notes (did not use in analysis)

Donation	Placement (Day 0)	Early	Advanced	Mummification
2010				
D10 A	June 14, 2010	June 16, 2010	June 22, 2010	No photos available
D13 NA	Nov. 5, 2010	Nov. 16, 2010	Dec 15, 2010	May 14, 2011
D15 NA	Dec. 20, 2010	Feb. 21, 2011	Mar. 15, 2011	Apr. 30, 2011
2011				
D03 NA	Feb. 17, 2011	Mar. 11, 2011	Mar. 24, 2011	Apr. 23, 2011
D04 NA	Mar. 3, 2011	Mar. 12, 2011	Mar. 23, 2011	Apr. 6, 2011
D05 NA	Mar. 7, 2011	Mar. 17,2011	Mar. 23, 2011	Apr. 22, 2011
D06 NA	Mar. 28, 2011	Mar. 30, 2011	Apr. 4, 2011	May 6, 2011
D07 NA	Apr. 1, 2011	Apr. 6, 2011	Apr. 20, 2011	May 11, 2011
D09 NA	July 5, 2011	July 9, 2011	July 15, 2011	Aug. 14, 2011
D11 NA	July 19, 2011	July 23, 2011	July 27, 2011	Aug. 13, 2011
D19 NA	Nov. 17, 2011	Nov. 26, 2011	Dec. 20, 2011	Jan. 30, 2012
D20 A	Nov. 28, 2011	Dec. 12, 2011	Jan. 22, 2012	Apr. 20, 2012
D21 NA	Nov. 30, 2011	Dec. 15, 2011	Mar. 1, 2012	May 1, 2012
D22 A	Dec. 5, 2011	Dec. 17, 2011	Jan 25, 2012	Feb. 28, 2012
D23 NA	Dec. 19, 2011	Jan. 9, 2012	Feb 10, 2012	Mar. 15, 2012
2012				
D01 A	Jan. 2, 2012	Jan. 9, 2012	Jan. 17, 2012	Feb. 21, 2012

D02 NA	Jan. 6, 2012	Jan. 22, 2012	Mar. 1, 2012	Mar. 12, 2012
D03 NA	Jan. 28, 2012	Feb. 17, 2012	Feb. 27, 2012	Mar. 6, 2012
D04 NA	Jan. 28, 2012	Feb. 20, 2012	Mar. 7, 2012	No photos available
D06 A	Feb. 13, 2012	Feb. 21, 2012	Mar. 6, 2012	No photos available
D07 NA	Feb. 19, 2012	Feb. 25, 2012	Mar. 3, 2012-	Mar. 12, 2012
D08 NA	Mar. 17, 2012	Mar. 22, 2012	Mar. 27, 2012	Apr. 27, 2012
D09 NA	Mar. 26, 2012	Mar. 29, 2012	Apr. 2, 2012	Apr. 4, 2012
D10 NA	Mar. 30, 2012	Apr. 3, 2012	Apr. 16, 2012	June 2, 2012
D11 NA	Mar. 30, 2012	Apr 9, 2012	Apr. 20, 2012	May 18, 2012
D12 NA	Apr. 10, 2012	Apr. 16, 2012	Apr. 18, 2012	May 18, 2012
D13 A	Apr. 26, 2012	Apr. 30, 2012	May 3, 2012	May 27, 2012
D14 NA	Apr. 30, 2012	May 2, 2012	May 8, 2012	May 15, 2012
D15 NA	May 7, 2012	May 14, 2012	May 19, 2012	May 23, 2012
D16 NA	May 9, 2012	May 13, 2012	May 22, 2013	No photos available
D19 A	May 23, 2012	May 25, 2012	May 28, 2012	June 10, 2012
D20 A	June 1, 2012	June 3, 2012	June 8, 2013	July 2, 2012
D22 NA	June 14, 2012	June 16, 2012	June 23, 2012	July 12, 2012
D23 NA	June 17, 2012	June 22, 2012	June 25, 2012	July 11, 2012
D24 NA	June 21, 2012	June 25, 2012	June 28, 2012	July 4, 2012
D27 A	July 10, 2012	July 17, 2012	July 20, 2012	July 24, 2012
D28 NA	July 31, 2012	Aug. 6, 2012	Aug. 14, 2012	Aug. 22,2012
D29 NA	July 13, 2012	July 17, 2012	July 21, 2012	July 23, 2012
D30 NA	July 27, 2012	July 29, 2012	Aug. 6, 2012	Aug. 24, 2012

D31 *A*	July 27, 2012	July 31, 2012	Aug. 3, 2012	Aug. 6, 2012
D32 *NA*	Aug. 20, 2012	Aug. 24, 2012	Aug. 28, 2012	Aug. 30, 2012
D33 *NA*	Sept. 13, 2012	Sept. 20, 2012	Sept 28, 2012	Oct. 22, 2012
D35 *A*	Sept 6, 2012	Sept. 11, 2012	Sept. 21, 2012	Oct. 5, 2012
D36 *A*	Sept. 13, 2012	Sept. 21, 2012	Oct. 3, 2012	Oct. 19, 2012
D37 *A*	Sept. 25, 2012	Sept. 27, 2012	Oct. 2, 2012	Oct. 17, 2012
D38 *NA*	Oct. 18, 2012	Oct. 23, 2012	Oct. 26, 2012	Nov. 6, 2012
D41 *A*	Oct. 31, 2012	Nov. 7, 2012	Nov. 15, 2012	Dec. 6, 2012
D42 *NA*	Nov. 3, 2012	Nov. 20, 2012	Dec. 3, 2012	Dec. 17, 2013
D43 *NA*	Nov. 3, 2012	Nov. 9, 2012	Nov. 22, 2012	Dec. 17, 2012
D44 *NA*	Nov. 9, 2012	Nov. 19, 2012	Nov. 29, 2012	Jan. 16, 2013
D45 *A: "V" incision autopsy suture*	Nov. 27, 2012	Dec. 5, 2012-	Dec. 14, 2012	Jan. 7, 2013
D46 *A*	Nov. 30, 2012	Dec. 5, 2012	Dec. 21, 2012	Jan. 18, 2013
D47 *A*	Dec. 6, 2012	Dec. 24, 2012	Jan. 9, 2013	Feb. 12, 2013
D49 *A*	Dec. 18, 2012	Jan. 2, 2013	Jan. 18, 2013	Mar. 5, 2013
D50 *NA*	Jan. 1, 2013	Jan. 15, 2013	Feb. 6, 2013	Feb. 28, 2013
2013				
D02 *A*	Jan. 15, 2013	Jan. 28, 2013	Feb. 4, 2013	Mar. 29, 2013
D04 *NA*	Jan. 16, 2013	Jan. 28, 2013	Feb. 4, 2013	Apr. 5, 2013
D05 *A*	Jan. 21, 2013	Jan. 30, 2013	Mar. 1, 2013	Apr. 3, 2013
D06 *NA*	Jan. 26, 2013	Feb. 4, 2013	Feb. 11, 2013	Mar. 20, 2013
D07 *NA*	Jan. 28, 2013	Feb. 5, 2013	Feb. 19, 2013	Mar. 28, 2013
D08 *NA*	Feb. 1, 2013	Feb. 6, 2013	Feb. 19, 2013	Mar. 25, 2013

D09 *A*	Feb. 8, 2013	Feb. 21, 2013	Mar. 5, 2013	Apr. 4, 2013
D10 *NA*	Feb. 13, 2013	Feb. 22, 2013	Mar. 12, 2013	Mar. 26, 2013
D11 *NA*	Feb. 13, 2013	Mar. 4, 2013	Mar. 8, 2013	Apr. 12, 2013
D12 *NA*	Feb. 18, 2013	Feb. 27, 2013	Mar. 12, 2013	Mar. 21, 2013
D13 *NA*	Feb. 18, 2013	Mar. 4, 2013	Mar. 13, 2013	May 2, 2013
D14 *NA*	Feb. 19, 2013	Mar. 7, 2013	Mar. 14, 2013	Mar. 26, 2013
D15 *A: straight line autopsy suture*	Feb. 27, 2013	Mar. 12, 2013	Mar. 18, 2013	Mar. 27, 2013
D16 *NA*	Feb. 27, 2013	Mar. 13, 2013	Mar. 18, 2013	Apr. 10, 2013
D17 *NA*	Apr. 5, 2013	Apr. 15, 2013	Apr. 19, 2013	Apr. 24, 2013
D18 *NA*	Mar. 28, 2013	Apr. 8, 2013	Apr. 15, 2013	Apr. 22, 2013
D19 *A*	Apr. 5, 2013	Apr. 10, 2013	Apr. 16, 2013	Apr. 22, 2013
D20 *NA*	Apr. 19, 2013	Apr. 25, 2013	Apr. 30, 2013	May 2, 2013
D23 *NA*	May 6, 2013	May 10, 2013	May 12, 2013	May 14, 2013
D24 *NA*	May 7, 2013	May 12, 2013	May 15, 2013	June 3, 2013
D26 *A*	June 3, 2013	June 5, 2013	June 11, 2013	June 17, 2013
D29 *NA*	June 14, 2013	June 16, 2013	June 18, 2013	June 24, 2013
D32 *NA*	July 1, 2013	July 3, 2013	July 6, 2013	July 12, 2013
D33 *NA*	July 3, 2013	July 5, 2013	July 8, 2013	July 12, 2013
D34 *NA*	July 5, 2013	July 8, 2013	July 10, 2013	July 19, 2013
D35 *NA*	July 11, 2013	July 13, 2013	July 17, 2013	July 22, 2013
D36 *NA*	July 15, 2013	July 17,2013	July 24, 2013	July 26, 2013
D37 *NA*	July 18, 2013	July 22, 2013	July 24, 2013	July 26, 2013
D39	July 18, 2013	July 24, 2013	July 31, 2013	Aug. 18, 2013

NA				
D46 A	Aug. 13, 2013	Aug. 15, 2013	Aug. 19, 2013	Sept. 27, 2013
D47 NA	Aug. 12, 2013	Aug. 14, 2013	Aug. 19, 2013	Sept. 18, 2013

APPENDIX B: INTERNAL TEMPERATURE DATA FOR NON-AUTOPSIED BODIES, AUTOPSIED BODIES, AND D31-2013

Values represent the difference between ambient and internal temperature for each donation

Non-Autopsied: Days of Decay	**D20-2013**	**D23-2013**	**D24-2013**	**D29-2013**	**D32-2013**	**D33-2013**	**D34-2013**	**D35-2013**
Day 0 (Placement)	-12.5	-1	-10.5	-24.5	-29.5	-24.5	-31.5	no data
Day 1	-8	-1.5	-2.5	1.5	-12.5	-10	-8	-6
Day 2	0.5	3	0.5	5	5	0	-1	-0.5
Day 3	4	6	-1	3	3	3.5	4.5	8.5
Day 4	0.5	9	-1	13.5	3	9	1.5	1.5
Day 5	5	2	2	11.5	-0.5	14	5.5	7.5
Day 6	1.5	0	19.5	12.5	3	4.5	3.5	4
Day 7	0.5	12	4.5	9	2	0	2	1.5
Day 8	1.5	4.5	5	4.5	1.5	7.5	21	no data
Day 9	7	6.5	3	7.5	4.5	12	16	no data
Day 10	3	1	3.5	4.5	7	5.5	6	10
Day 11	4.5	1.5	4	12	8	8.5	-2.5	13
Day 12	5.5	5	5	2.5	9	2.5	5.5	10
Day 13	2.5	5.5	3	1	7.5	1.5	3.5	3.5
Day 14	3	1	5.5	9	5.5	3	6.5	
Day 15	5.5	4	8	no data				
Day 16	5.5	2	4	no data				
Day 17	8	1.5		4				
Day 18	-2.5			-2				
Day 19	5							
Day 20	4.5							
Day 21	3							
Day 22	2							
Day 23	0.5							
Day 24	8.5							
Day 25	4							
Day 26	3.5							
Day 27	4							
Day 28	6							
Day 29	4.5							
Day 30	4.5							
Day 31	4.5							
Day 32	4.5							
Day 33	4.5							
Day 34	4							

Autopsied: Days of Decay	D22-2013	D46-2013	D57-2013	D59-2013	D61-2013
Day 0 (Placement)	-20	-25.5	-15.5	-12	
Day 1	-3.5	-0.5	-3.5	4.5	-4
Day 2	-5	2.5	-2	1	no data
Day 3	3	2.5	1.5	1	no data
Day 4	1.5	5.5	2	-0.5	-0.5
Day 5	2.5	2.5	-7.5	0.5	2.5
Day 6	4	-2	-5.5	3	-1.5
Day 7	4.5	2	1	1	0.5
Day 8	8.5	-2.5	1	3.5	-9
Day 9	2	4.5	3	10	-3
Day 10	-1.5	-2	9.5	9	1.5
Day 11	1	-2.5	5	13	-3
Day 12	7	4.5	2	0.5	no data
Day 13	2.5	1	-1	1.5	3
Day 14	-1	2	-3	-0.5	1.5
Day 15	2.5	no data	-4	1.5	no data
Day 16	2.5	no data	2.5	1.5	no data
Day 17	8	no data	0.5	no data	no data
Day 18	10				
Day 19	5.5				
Day 20	5.5				
Day 21	5.5				
Day 22	5				
Day 23	-0.5				
Day 24	4.5				
Day 25	-0.5				
Day 26	3.5				
Day 27	1.5				

D31-2013: Days of Decay	
Day 0 (Placement)	-15
Day 1	0
Day 2	-2.5
Day 3	-4
Day 4	no data
Day 5	no data
Day 6	-1.5
Day 7	-4
Day 8	15.5
Day 9	0
Day 10	-0.5
Day 11	0.5
Day 12	1
Day 13	5.5
Day 14	2
Day 15	4.5
Day 16	3.5
Day 17	5

APPENDIX C: ACCUMULATED DEGREE DAYS TO EACH STAGE OF DECOMPOSITION FOR NON-AUTOPSIED AND AUTOPSIED FACTS DONATIONS

Light Grey= >5 day gap in photos/notes (not used in analysis)
Dark Grey= No photos/notes available for this stage of decomposition

Non-Autopsied Donations					
	Placement to Early	**Placement to Advanced**	**Early to Advanced**	**Placement to Mummified**	**Advanced to Mummified**
D13-2010	146.789	527.303	380.514	2905.3945	2378.0915
D15-2010	596.394	951.131	354.737	2013.2645	1062.1335
D03-2011	348.094	607.517	259.423	1264.9305	657.4135
D04-2011	148.2455	370.9835	222.738	640.3905	269.407
D05-2011	64.0515	286.7895	222.738	593.831	307.0415
D06-2011	15.505	115.081	99.576	854.6495	739.5685
D07-2011	75.811	403.7775	327.9665	926.2535	522.476
D09-2011	91.76	280.405	188.645	1253.425	973.02
D11-2011	93.105	224.735	131.63	784.19	559.455
D19-2011	144.139	401.6995	257.5605	839.7675	438.068
D20-2011	146.7265	573.61	426.8835	2039.791	1466.181
D21-2011	147.147	1044.802	897.655	2279.2365	1234.4345
D23-2011	199.7485	572.2505	372.502	1074.9	502.6495
D02-2012	170.7995	661.196	490.3965	819.7065	158.5105
D03-2012	235.203	371.305	136.102	500.2075	128.9025
D04-2012	247.514	496.762	249.248	N/A	N/A
D07-2012	85.239	194.5805	109.3415	315.921	121.3405
D08-2012	73.181	167.6355	94.4545	845.8205	678.185
D09-2012	83.71	132.64	48.93	177.895	45.255
D10-2012	72.04	358.295	286.255	1503.045	1144.75
D11-2012	205.125	439.735	234.61	1096.125	656.39
D12-2012	111.1	150.76	39.66	848.93	698.17
D14-2012	26.34	189.495	163.155	335.885	146.39
D15-2012	124.22	231.36	107.14	334.25	102.89
D16-2012	62.325	268.63	206.305	782.325	513.695
D22-2012	30.905	232.325	201.42	803.175	570.85
D23-2012	112.765	200.395	87.63	686.89	486.495
D24-2012	87.63	184.685	97.055	361.105	176.42
D28-2012	156.115	405.545	249.43	644.55	239.005

D29-2012	84.435	200.185	115.75	261.895	61.71
D30-2012	30.22	278.53	248.31	823.36	544.83
D32-2013	84.245	205.91	121.665	267.615	61.705
D33-2012	130.45	328.4	197.95	843.67	515.27
D38-2012	92.18	164.445	72.265	351.14	186.695
D42-2012	254.628	465.0505	210.4225	663.145	198.0945
D43-2012	94.9845	291.418	196.4335	663.145	371.727
D44-2012	121.1185	273.728	152.6095	818.841	545.113
D50-2012	104.164	396.383	292.219	689.6625	293.2795
D04-2013	150.846	249.86	99.014	1134.502	884.642
D06-2013	117.969	231.824	113.855	743.6925	511.8685
D07-2013	93.849	287.122	193.273	816.041	528.919
D08-2013	60.8995	237.1975	176.298	737.2025	500.005
D10-2013	104.876	328.995	224.119	570.05	241.055
D11-2013	218.31	273.071	54.761	864.2915	591.2205
D12-2013	105.9255	268.224	162.2985	431.7705	163.5465
D13-2013	157.539	281.2545	123.7155	1199.4155	918.161
D14-2013	186.9325	283.288	96.3555	496.664	213.376
D16-2013	164.273	254.719	90.446	658.4535	403.7345
D17-2013	170.5195	261.9645	91.445	346.3005	84.336
D18-3013	182.331	311.9705	129.6395	447.7515	135.781
D20-2013	83.488	187.983	104.495	236.748	48.765
D23-2013	63.93	108.83	44.9	150.445	41.615
D29-2013	27.14	87.9	60.76	271.825	183.925
D32-2013	25.845	109.635	83.79	289.49	179.855
D33-2013	27.19	115.315	88.125	235.68	120.365
D34-2013	59.49	118.31	58.82	377.975	259.665
D35-2013	31.23	148.05	116.82	282.385	134.335
D36-2013	23.64	217.37	193.73	277.92	60.55
D37-2013	84.265	143.66	59.395	204.21	60.55
D39-2013	112.565	355.295	242.73	917.51	562.215
D47-2013	32.665	160.665	128	1028.39	867.725
Autopsied Donations					
	Placement to Early	**Placement to Advanced**	**Early to Advanced**	**Placement to Mummified**	**Advanced to Mummified**
D10-2010	28.24	196.78	168.54	N/A	N/A
D22-2011	110.412	533.4475	423.0355	946.267	412.8195
D01-2012	75.0555	151.6165	76.561	208.611	56.9945
D06-2012	89.1875	308.5265	219.339	N/A	N/A
D13-2012	77.82	155.88	78.06	739.7	583.82

D19-2012	28.75	113.965	85.215	462.225	348.26
D20-2012	25.465	159.63	134.165	860.245	700.615
D27-2012	165.335	250.52	85.185	373.85	123.33
D31-2012	90.92	157.85	66.93	210.45	52.6
D35-2012	107.76	342.915	235.155	671.815	328.9
D36-2012	152.595	436.75	284.155	778.31	341.56
D37-2012	26.51	140.61	114.1	458.64	318.03
D41-2012	121.3495	255.7595	134.41	579.856	324.0965
D45-2012	121.226	234.0105	112.7845	471.422	237.4115
D46-2012	81.52	302.2415	220.7215	529.215	226.9735
D47-2012	227.3225	338.902	111.5795	786.436	447.534
D49-2012	137.2655	259.1385	121.873	887.4005	628.262
D02-2013	156.576	255.59	99.014	1011.597	756.007
D05-2013	140.5265	533.1925	392.666	1059.1175	525.925
D09-2013	151.408	301.602	150.194	786.527	484.925
D15-2013	151.2425	254.719	103.4765	401.8375	147.1185
D19-2013	87.685	196.6545	108.9695	306.3005	109.646
D26-2013	27.05	184.28	157.23	353.06	168.78
D46-2013	32.665	132.495	99.83	324.075	191.58

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