DIFFERENTIAL DECOMPOSITION RATES OF REFUSE COVERED HUMAN REMAINS

by

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Abbreviation **Description**

PMI - Post-mortem interval

TBS - Total body score

I. INTRODUCTION

Estimation of the postmortem interval is one of the main questions often posed to forensic anthropologists in medicolegal investigation contexts. Knowing the postmortem interval (PMI) of a cadaver can help law enforcement recreate the circumstances surrounding the crime or assist in narrowing the list of suspects. PMI can be estimated via an understanding of the environment the remains are found in, as well as the variety of taphonomic factors and agents affecting the decomposition process. However, PMI estimation is complicated by the fact that remains will decompose differently under different depositional conditions. Climate, humidity, access to scavengers, and insect activity all have the ability to alter the rate of decomposition. Due to this fact, it is important that decomposition research focuses on studying the wide array of possible scenarios that human remains are found in an attempt to better estimate PMI.

This research project will investigate the effects that five different types of refuse coverings have on the human decomposition sequence of surface remains. The refuse coverings used in this project represent the kinds of materials perpetrators might use to hide human remains deposited on the surface, and include a mattress, wooden pallets, cardboard, tires, and brush. This research is intended as a pilot study to begin looking at these depositional factors and how they might influence the decomposition sequence. The goal of this research project is to add to the body of research that has been developed concerning human decomposition and to assist medicolegal investigators, law enforcement agents, and forensic anthropologists with an understanding of how refuse coverings may alter the decomposition process and in turn, how the PMI estimate might be affected.

There are a host of variables that can potentially alter the decomposition rate of human remains. The two main variables affecting decomposition are temperature and humidity (Galloway et al. 1989, Mann et al. 1990) and insect accessibility and activity (Rodriguez and Bass 1983, Simmons et al. 2010a,b, Sharanowski et al. 2008). Higher temperatures accelerate the decomposition process by providing an environment that is suitable for bacteria and insects to colonize and breakdown body tissue (Bass 1997, Simmons et al. 2010a, Roberts and Dabbs 2015). Additionally, the more accessible a body is to insects and other scavengers also accelerates decomposition. Scavengers and insects breakdown the body by using it as a source of nutrients and physically removing body tissues.

Taphonomic factors such as insect activity (Rodriguez and Bass 1983, Simmons et al. 2010a,b, Campobasso et al. 2001), scavenger activity (Rippley et al. 2012, Young et al. 2015, Beck et al. 2015), and surrounding soil chemistry (Swann et al. 2010, Tamsin et al. 2009, Meyer et al. 2013) commonly encountered at outdoor death scenes and other criminal investigation cases have provided insight into rates and timing of the human decomposition sequence, which is useful to investigators in determining the postmortem interval. Other researchers have investigated the effects of additional variables on the decomposition sequence of human cadavers under different conditions including burials (Rodriguez and Bass 1985, Troutman et al. 2014), clothing and body wrappings (Card et al. 2015, Kelly et al. 2009, Notter and Stuart 2012), and access to sunlight (Sharanowski et al. 2008, Shean et al. 1993).

Research on the differences between decomposition of human remains on the surface and burials below the surface indicate that surface depositions tend to decompose more rapidly (Mann et al. 1990; Rodriguez et al. 1985, Schotsmans et al. 2011). Mann et al. (1990) state that the depths of the burials play an important role in the speed of the decomposition process with deeper burials decomposing at a slower rate than shallower burials. Rodriguez et al. (1985) believe that this decreased decomposition rate is due to restricted access to the body by insects and lower temperatures below the surface. Troutman et al. (2014) had similar findings in cases of mass burials.

The effects of clothing and other body wrappings on the human decomposition process have also been investigated. Kelly et al. (2009) found that pig carcasses that were unwrapped and unclothed reached the advanced stage of decomposition quicker than carcasses that were wrapped in bed sheets or clothed. Card at al. (2015) found similar results between the decomposition of clothed and unclothed pig carcasses. Those that were clothed decomposed at a slower rate than those that were unclothed and exposed. The authors believe that this is due to the limited access to the body caused by the clothing that restricts insects from colonizing the body. Meanwhile, Notter and Stuart (2012) found that bodies that were covered formed adipocere quicker than bodies that were exposed.

The role that access to direct sunlight plays on the decomposition process has also been explored. Using pig carcasses, Shean et al. (1993) found that access to direct sunlight accelerates the decomposition process. This could be due to the higher temperatures that were associated with the pig in direct sunlight and the larger maggot masses that were found on this body. Sharanowski et al. (2008) performed a similar study with a larger sample size and found that access to direct sunlight was only a factor for the first few weeks of decomposition and that temperature and insect activity played a much more important role in the process.

These studies reveal information concerning the timing and nature of human decomposition and some of the processes involved. Human decomposition research has led to the development of a Total Body Score system (Megyesi et al. 2005) that assesses the decomposition stage of human cadavers by assigning an individual into a decomposition stage based on the appearance of three regions of the body: the head/neck, the trunk, and the limbs. Using accumulated degree days (ADD, described below) and a Total Body Score (TBS), the system calculates a postmortem interval for the individual that should reflect the time period that the individual was deposited at the scene.

Recent trends in decomposition research have involved the use of accumulated degree days (ADD) as a comparative temperature measure to monitor heat units in a specific area that contribute to the decomposition processes (Megyesi et al. 2005, Michaud and Moreau 2010, Lynch-Aird et al. 2015, Suckling et al. 2016, Parks 2010). Since temperature is the major variable that impacts the rate of decomposition (Troutman et al. 2014, Roberts and Dabbs 2015, Meyer et al. 2013, Heaton et al. 2013), ADD reflects the average temperature that a cadaver is exposed to in each 24-hour day, and has become a critical gauge used to better understand the broad chronology and depositional environment in which a body decomposes. Due to its reliance on temperature and not time, ADD is a useful comparative tool that can be used across varying geographic regions and climates. ADD is only factored in when temperatures are above 0°C, or freezing, as this is considered the baseline necessary for decomposition agents such as bacteria and insects to be active (Megyesi et al 2005, Suckling et al. 2016).

While these studies have revealed much about the decomposition sequence of human cadavers, there is still more information that can be learned about how other environmental factors and taphonomic agents affect the decomposition sequence. One area of research that is relatively unexplored is the effects that different types of refuse coverings have on the timing and sequence of the human decomposition process. Often, bodies are found decomposing under refuse as a result of the perpetrator's attempt to conceal the body (Drury 2014, Johnson 2014, Ortiz 2012, Ziezulewicz 2012, Associated Press 2003). Refuse coverings may potentially alter the decomposition process of the victim's body, and this alteration could possibly lead to an incorrect postmortem interval estimate and thus have detrimental effects on the investigation. This study was designed to investigate the effects that refuse coverings can have on the decomposition process, and how it influences the timing and nature of the decomposition sequence.

Five different types of refuse coverings were used in this study including brush, wooden pallets, tires, cardboard, and a mattress. My expectation is that covering the body will significantly alter the decomposition process by accelerating the expected sequence, since the coverings will trap heat and potentially conceal the remains from scavengers. Since decomposition occurs at a faster rate at higher temperatures (Troutman et al. 2014, De Jong et al. 2010, Komar 1998), trapped heat should accelerate the decomposition process. Therefore, any material that traps more heat (i.e. a mattress) should accelerate the decomposition process. The null hypotheses are that covering the body in refuse will have no significant effect on the expected decomposition sequence, alternatively it may actually slow down the decomposition process by deterring other taphonomic agents such as scavengers from influencing the decomposition rate.

The determination of the postmortem interval may be significantly altered by refuse coverings on the body. Estimating the PMI of a victim without taking into account any material that is covering the body could lead to an erroneous time-since-death estimate, potentially leading to complications with trying to pinpoint the whereabouts of a potential suspect during the time that the crime was committed. Understanding the manner in which these types of coverings may alter the normal decomposition process could provide investigators with a means of adjusting their PMI estimate and more accurately determine the time the crime occurred. As a result, a more accurate suspect list can be formed, or suspected perpetrators may be excluded.

In the following chapter, I will outline the materials that were used in this study, as well as the ways in which data were gathered and analyzed. Additional chapters will outline the results of the study and the associated statistical analyses will be presented. Finally, a discussion of the interpretation of the results and the implications of these findings will be provided, concluding with a summary of this project and suggestions for future research.

II. MATERIALS AND METHODS

Materials

Human cadavers that have been donated through the Forensic Anthropology Center at Texas State's Willed Body Donation Program were used for this study. While many studies have focused on decomposition, the majority of them utilize animal carcasses for experiments (i.e., Roberts and Dabbs 2015, Card et al. 2015, Lynch-Aird et al. 2015, Sharanowski et al. 2008, Shean et al. 2008, etc.). Although some animal remains can mimic the decomposition of human bodies, they are not always analogous to human decomposition (Mann et al. 1990). Stokes et al. (2013) found that while decomposition is mostly similar between humans, ovines, porcines, and bovines, there is a significant difference in the microbial activity, nutrient concentrations, and soil chemistry between humans and their animal counterparts. Therefore, it is more appropriate to use human cadavers for decomposition research whenever possible.

Since individuals (or their next of kin) who donate their remains to the Willed Body Donation Program sign release forms that acknowledge their bodies will be used in scientific research, IRB approval was not needed for this project (Wescott, personal communication 2016).

Five different types of refuse material and a total of six donated individuals were utilized in the study. Five individuals were placed at the Forensic Anthropology Research Facility (FARF) laying supine on their back and covered with one type of refuse. The sixth individual was left uncovered and caged (in order to avoid scavenging activities by the local vulture population) to act as the control sample that the experimental individuals will be compared to for analysis. Each of these five experimental individuals were left uncaged but covered head to toe in one of the following refuse materials: brush, mattress, tires, wooden pallets, and cardboard boxes. However, coverage discrepancies occurred due to the nature of the materials being used (e.g. tires and wooden pallets allowed for some bare space on the body due to gaps in these materials, while cardboard and the mattress completely covered the cadaver with no bare space at all). The refuse materials selected were those commonly found at refuse and trash dump sites and are composed of different elements that could variably affect decomposition rates. While the control individual was caged, the other five individuals were left uncaged in order to more accurately mimic real-world circumstances, and also to observe if these refuse coverings would conceal the remains sufficiently enough to prohibit access by vultures and other terrestrial scavengers. It should be noted that FARF is an enclosed space that limits the access of larger terrestrial scavengers (such as deer, pigs, raccoons, and coyotes, etc.), but not avian scavengers (i.e. vultures, hawks, caracara, etc.). In real world circumstances, such limited access due to fencing may not exist and additional scavengers could have the ability to come in contact with the body and accelerate decomposition.

In an attempt to minimize disturbance to both the remains and to the refuse coverings when making observations, flexible large welded wire fencing with 2 in. × 3 in. openings was placed directly over the body, with the refuse covering placed on top of the fencing (Figures 1-5). The flexibility of the fencing allowed it to conform to the body and still allowed for direct contact between the body and the refuse coverings. The flexible fencing was attached to metal frames in order to allow it to be raised using a hand powered chain hoist attached to a gantry crane from each of the four corners in order to make observations, and then placed back down in the exact same spot and orientation each time (Figure 6). This was done in order to standardize the way materials are lifted off the body each time, and minimize the alteration of the microenvironment that is created during decomposition.

The five individuals were placed at FARF between August 19, 2016 and January 31, 2017, with observations occurring from August 19, 2016 to April 6, 2017. Specifics of each donated body used for the research such as age and weight can be found in Table 1. When a donation was received, FACTS standard operating procedures were followed to perform intake and placement, with the only change being in the placement of the refuse coverings on top of the body.

In order to increase the control sample, a larger subset of the individuals used in the longitudinal decomposition study at FARF were also used as controls. Donated bodies placed between August 19 and January 31 from 2014/2015 were also scored via photographs (taken routinely as part of FARF documentation protocols) following the same guidelines outlined by Megyesi et al. (2005). These individuals were placed at FARF under the same conditions as the control individual in this study (i.e. under a cage and on their backs). In total, 22 additional individuals were used from the late summer to winter months of the 2014-2015 season (see Appendix A for control sample summary).

Table 1. Sample Summary

Donation #	Age	Weight (lbs)	Covering	Date of Placement
D38-2016	89	110	Uncovered	8/19/2016
D45-2016	87	144	Mattress	9/27/2016
D51-2016	77	105	Palletts	10/31/2016
D52-2016	55	158	Cardboard	11/3/2016
D04-2017	64	180	Tires	1/19/2017
D08-2017	103	83	Brush	1/31/2017

Figure 1. Mattress placed on body (note chain hoist attached to the gantry crane).

Figure 2. Wooden pallets placed on body.

Figure 3. Cardboard placed on body.

Figure 4. Tires placed on body.

Figure 5. Brush placed on body.

Figure 6. Example of refuse material being lifted off body for observations.

Methods

A daily photo and note log were kept of the decomposition process of all six individuals for the first two weeks after placement, since this is the timeframe that encompasses the period with rapid changes seen in the early portion of the decomposition sequence. Photographs were taken using a Canon EOS 70D (W) camera. Photographs included pictures of: the identifying stake with donation number, anterior face, lateral of right and left sides of head (when possible), anterior of both arms and legs, lateral of right and left sides of the torso, overall of the trunk, and mid-range of the trunk for more detail to use when scoring (Figure 7). If a complete overall photo could not be taken due to the overhanging refuse and frame, an overall of the head, torso, and arms were taken in one photograph and an overall of the legs was taken in another. These specific photographs were taken in order to accurately score each region of the body in accordance with Megyesi et al. (2005). Other pictures were also taken of skeletonized elements, insects, and evidence of scavenging. I documented different aspects of the decomposition process including characteristics such as bloat, body discoloration, loss of hair mat, skin slippage, insect activity, mummification, and skeletonization similar to data currently being collected at FARF for ongoing longitudinal research.

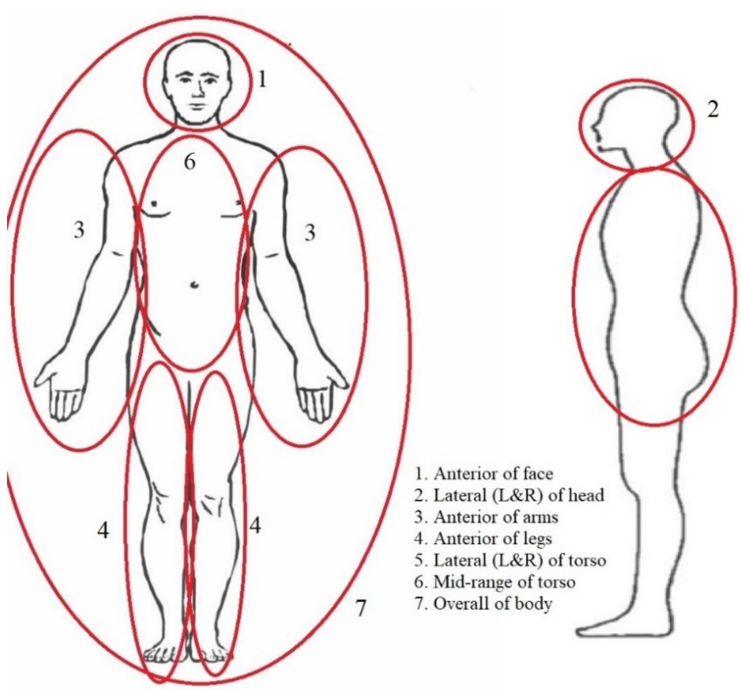

Figure 7. Description of photographs taken during each observation.

After the initial two week period of daily observations ended, photos and notes were taken for each body every 300 ADD. Since ADD are a reflection of the amount of heat a body is exposed to, the number of calendar days that observations were made varied between the summer and winter months. The average time that it took to reach 300 ADD during September and October was 13 days and during November through February it was 20 days. Therefore, it took a body about a week longer to reach 300 ADD during the late Fall/Winter months when compared to the Summer/early Fall months. Accumulated degree days (ADD) were calculated in accordance with Megyesi et al. (2005) by averaging the high and low temperatures of the day. High and low temperatures were obtained from Weather Underground, an online weather recorder with thermometers at the San Marcos Municipal Airport. While weather data was not taken directly from FARF, a review of the temperature readings from the airport did not significantly differ from those on site at FARF, varying only by one or two degrees, and thus were deemed sufficient for use.

Using ADD to assess decomposition allows for a standardized manner of data collection rather than simply using time. This is because a body that has been decomposing for two weeks during the summer may not decompose at the same rate (i.e., take the same length of time) as a body that has been decomposing for two weeks in the winter due to differences in exposure to heat; a driving force behind decomposition. Using ADD solves this issue because accumulated degree days record the amount of thermal energy that a body has been exposed to rather than the time that has passed.

While ADD is a better tool to estimate the PMI than calendar days, there is still some variation of the effect of accumulated degree days on the decomposition process. Bates and Wescott (2016a) state that individuals that die in the Fall/Winter months require more ADD to advance through the decomposition stages than individuals that die during the Spring/Summer months, indicating that ADD is also sensitive to seasonality. This could be due to the higher prevalence of insects during the Spring/Summer months when compared to the Fall/Winter months due to the consistently higher temperatures that are conducive to insect activity. Bates and Wescott (2016b) also stated that there were discrepancies between the number of ADD needed to reach each stage of decomposition between autopsied and non-autopsied remains, with autopsied remains requiring slightly less ADD on average to progress. The authors state that this could also be due to the ability for insects to access the body due to the incisions in the cadaver.

The Total Body Score system developed by Megyesi et al. (2005) was used to assign individuals into a specific decomposition stage for the duration of the study. The Total Body Score system assigns an individual into a decomposition stage based on the appearance of three main areas of the body: the head/neck, the trunk, and the limbs. Bodies were assessed and scored off site from photographs taken from each day. This was done in an attempt to take careful consideration of the notes and appearance of the body rather than assigning a score at the site. Once an individual maintained a consistent TBS for three straight recordings, or 900 ADD, no further data was collected for that individual.

The number of ADD required for each refuse covered sample, as well as all controls from 2014 -2015, was then calculated. The three stages of decomposition that were used in this study included: initial placement to early decomposition, early decomposition to advanced decomposition (found by subtracting the number of ADD needed to reach the advanced decomposition stage by the number of ADD needed to reach the early decomposition stage), and an overall period spanning from initial placement to advanced decomposition. The characteristics of each of these stages of decomposition are outlined in Table 2. Since the early-to-advanced stage of decomposition is simply the amount of ADD to reach advanced decomposition minus the amount of ADD to reach early decomposition, there is no specific TBS range for this phase and the body's appearance can have a mixture of early and advanced decomposition features.

Table 2. Corresponding TBS and Descriptions of Decomposition for Each Stage of Decomposition

Stage	TBS Range	Description of Decomposition
Early	3 - 16	Pink/white to brown/black discoloration of skin, purging of decompositional fluids, bloating and release of gases from torso, skin beginning to dry out
Early-to-Advanced	-	Mixture of early and advanced stages. Body may appear to be early stage with some skeletonized elements, or heavily skeletonized in two regions with one region still displaying early characteristics
Advanced	17 - 24	Caving in/sagging of tissue, moist decomposition to mummification of flesh, bone exposure less than half

Due to the tendency for individuals at FARF to mummify rather than skeletonize, the skeletonization stage of decomposition was not included in this study. A body was determined to be in a decomposition stage when all three scoring areas (head/neck, trunk, and limbs) were scored in a range that corresponded to that stage by Megyesi et al. (2005). For example, a body was determined to be in the early decomposition stage when the head/trunk area scored between two and six, and when the trunk and limbs were scored between two and five. Examples of each decomposition stage starting from placement for each experimental individual can be found in Appendix B.

The amount of ADD required for each individual to reach early and advanced stages of decomposition were compared between refuse covered and control individuals. The amount of ADD required for an individual to progress from early to advanced decomposition was found by subtracting the amount of ADD from placement to early decomposition from the amount of ADD from placement to advanced decomposition with initial placement being considered the zero point of the experiment. This early-to-advanced phase was also used for comparison between covered and control individuals.

Statistical Analysis

The ADD data from both the experimental sample and the control sample from 2014/2015 was first tested for normality using a Shapiro-Wilk's test. This step was performed first in order to determine whether parametric or non-parametric statistical tests would be more appropriate for the data. Six Shapiro-Wilk's tests were performed; three on the control sample for each decomposition stage (early, early-to-advanced, and advanced) and three for the test sample at the same three stages. All six of the Shapiro-

Wilk's tests indicate that the data was normal, and therefore parametric statistical analyses were most appropriate for this study.

First, t-tests were performed to test for any significant differences between the refuse covered individuals and the control individuals in regards to the amount of ADD required to progress to each stage of decomposition. For the t-tests, the averages of the number of ADD at each stage of decomposition were calculated for all covered individuals and again for all control individuals. Three t-tests were conducted; one for each stage of decomposition process (early, early-to-advanced, and advanced) to determine if and during what stage of decomposition there was any significant difference in the amount of ADD.

Second, the ADD of each refuse covered individual was compared to the averages of the control sample at each stage of decomposition using a z-test. The z-test compares the ADD of each refuse covered individual against the normal distribution of the control sample at the same stage to test for significant differences. This test shows if a certain covered individual differs from the controls and at what stage it does so. Z-scores and p-values were calculated for each test individual at each stage of decomposition for a total of 15 z-scores and p-values.

Finally, the ADD at the early and advanced stages of decomposition was log-transformed. A Shapiro-Wilk's test was conducted again to determine if the log-transformed data was normally distributed. Then, a Kendall's rank correlation test was used to test for the type and magnitude of the relationship between the log-transformed ADD and the corresponding Total Body Score (TBS). To test for correlation, the amount of ADD at the early and advanced stages of decomposition for each refuse covered individual was compared to the corresponding TBS at that stage. Due to the relationship between temperature and decomposition, a positive correlation is expected between the amount of ADD an individual has been exposed to and the resulting TBS.

III. RESULTS

Accumulated degree days (ADD) data were tested for normality using a Shapiro-Wilk's test at each of the decomposition stages (early, early-to-advanced, advanced) for both the uncovered control and covered samples. Results of the Shapiro-Wilk's tests indicate that the data is normally distributed at each stage for both samples (Table 3), meaning that normal, parametric statistical tests can be used to analyze the data.

Table 3. Results of Shapiro-Wilk's test for normality

Uncovered (Control) Sample			
Stage	W	df	p-value
Early	0.941	22	0.185
Early - Advanced	0.941	22	0.184
Advanced	0.958	22	0.432
Covered (Experimental) Sample			
Stage	W	df	p-value
Early	0.846	4	0.181
Early - Advanced	0.856	4	0.214
Advanced	0.874	4	0.284

First, to determine if there were any significant differences in the amount of ADD at each stage between the covered and uncovered control samples, three t-tests were used; one for each stage of decomposition (early, early-to-advanced, advanced). The results of these tests indicate that there are no significant differences between the amounts of ADD at any of the three stages of decomposition between the refuse covered and control samples at the 0.05 level (Table 4).

Table 4. T-tests comparing refuse covered vs. control ADD at each stage

Stage	t Stat	p-value
Early	-0.572	0.588
Early - Advanced	0.671	0.539
Advanced	0.649	0.552

Second, ADD for each covered individual was compared to the uncovered control sample at each stage of decomposition to determine if there were any significant differences for a specific covered individual. This was achieved by running a z-test for each covered individual using the distribution (mean and standard deviation) of the uncovered control sample. All z-scores were not significant at the 0.05 level, with the exception of the cardboard covered individual at the early-to-advanced and advanced decomposition stages (Table 5). The results were then graphed to visually represent how each covered individual compared to the distribution of the uncovered control sample (Figures 8-10).

Table 5. P-values of z-test for each covered individual
*Significant if less than 0.025 or greater than 0.975

Cover	Early	Early - Advanced	Advanced
Mattress	0.278	0.068	0.067
Pallets	0.199	0.044	0.041
Cardboard	0.115	1.000	1.000
Tires	0.389	0.955	0.940
Brush	0.928	0.528	0.614

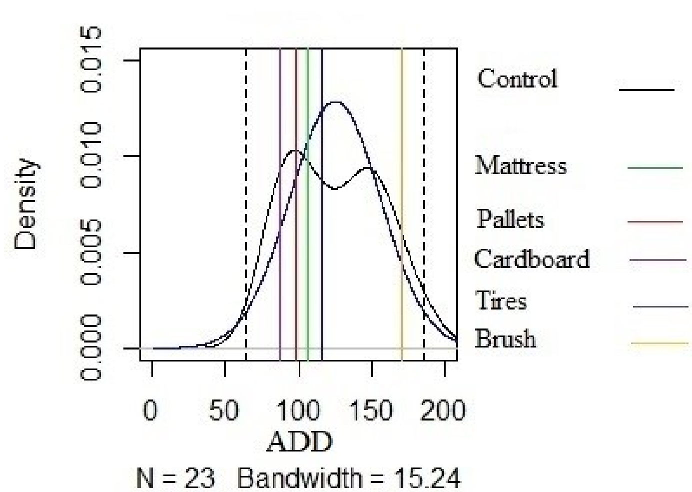

Figure 8. Density plot of ADD for each covered individual and the uncovered control sample at the early decomposition stage.

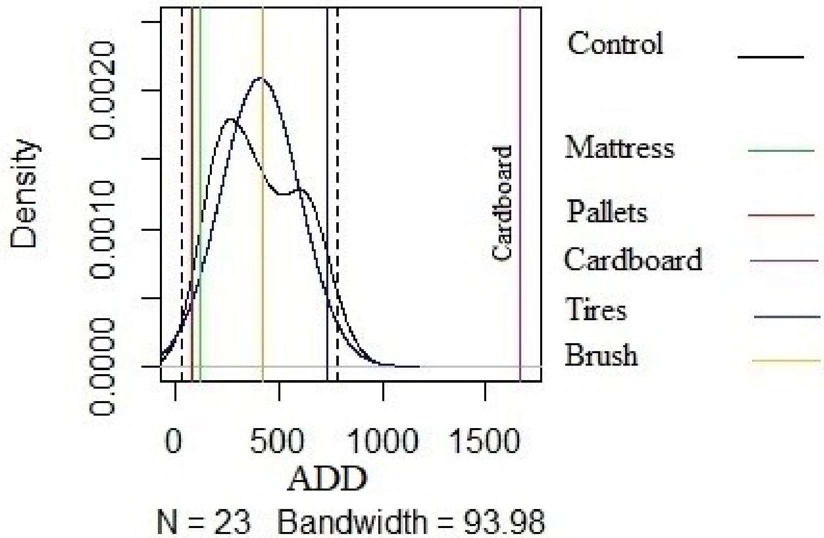

Figure 9. Density plot of ADD for each covered individual and the uncovered control sample at the early-to-advanced decomposition stage.

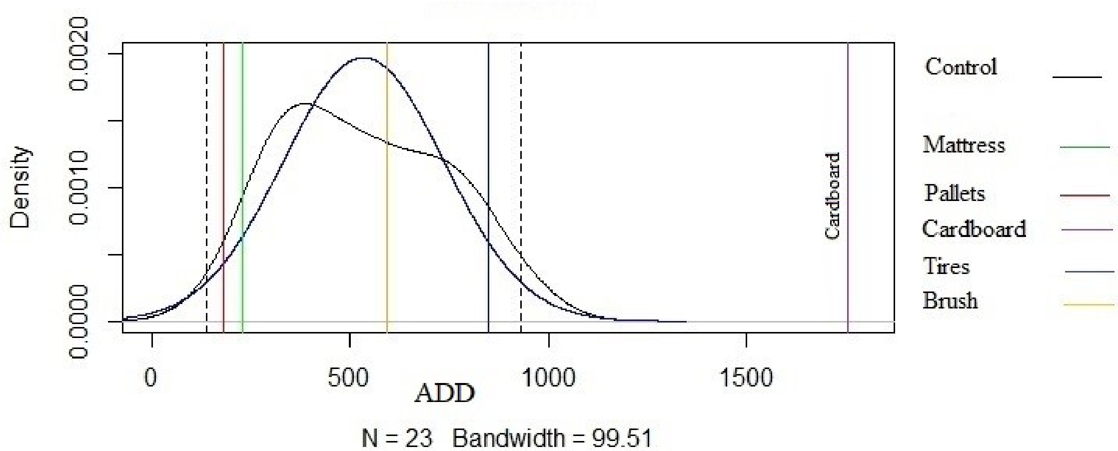

Figure 10. Density plot of ADD for each covered individual and the uncovered control sample at the advanced decomposition stage.

Finally, the ADD data at the early and advanced stages of decompositon was log-transformed and again tested for normality using a Shapiro-Wilk's test. The Shapiro-Wilk's test resulted in a p-value of 0.001, meaning that the log(ADD) data was not normally distributed. A Kendall's rank correlation test was used to determine the type and magnitude of the relationship between ADD and TBS and resulted in a tau value of 0.7207. The slopes for the trendlines of the early and advanced stages of decomposition were also calculated to show the rate of change in TBS with respect to ADD (Figure 11).

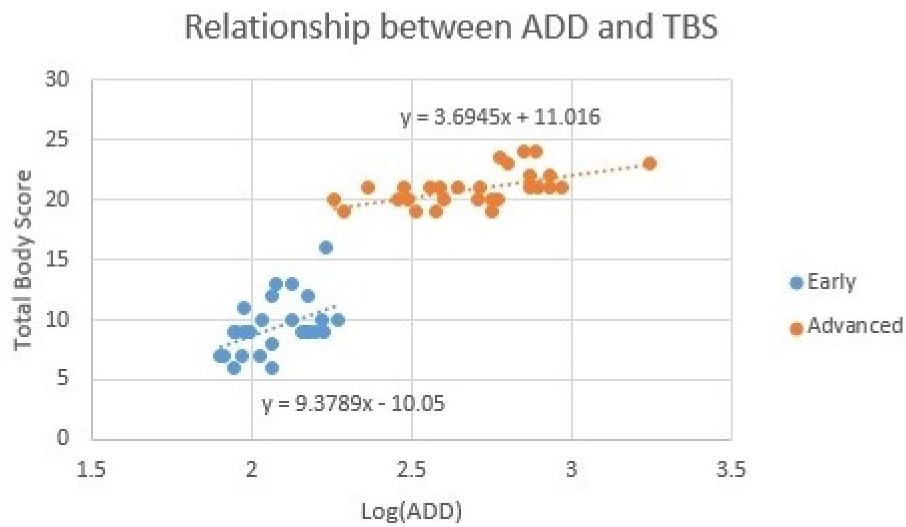

Figure 11. Rate of change (slope) between ADD and TBS at the early and advanced stages of decomposition.

IV. DISCUSSION

Results indicated that there were no significant differences between the amount of ADD required for a body to progress to either the early, early-to-advanced, or advanced stages of decomposition between the refuse covered individuals and the uncovered controls, with the exception of the individual covered with cardboard. This could be due to the fact that, with the exception of the bodies covered by the mattress and cardboard, there wasn't complete coverage of the body with the other refuse materials in this study. The wooden pallets, tires, and brush all had gaps that prevented complete coverage, while the mattress and cardboard completely covered the anterior surface of the body, but had exposed areas on either side. These gaps may have allowed heat to escape from under the coverings, and thus not accelerated decomposition as previously anticipated.

There were some significant differences when it came to comparing each covered body to the control sample through a z-test. The results indicated that the only significant difference in ADD was with the cardboard-covered individual. The body covered by the cardboard was significantly different from the control sample at the early-to-advanced and advanced stages of decomposition (Table 4). This means that after the early stage of decomposition, this body required more ADD to progress to the advanced stage of decomposition than the uncovered control body and the 22 retrospectively scored control bodies from 2014/2015.

After showing early signs of decomposition (a pink/white appearance on all regions of the body), the cardboard-covered individual showed no signs of bloat or purge shortly thereafter. In fact, there was little bloating of the abdomen throughout the study and only a small amount of skeletonization of the humeri. This decelerated decomposition process is in contrast to the decomposition of all other individuals, both covered and control. This is unusual given that the cardboard covered most of the body and should have trapped heat more effectively than the wooden pallets, tires, or brush. There was a relatively comparable level of insect activity on the cardboard-covered body and the other bodies, therefore insect access should not have been substantially different or limited.

Upon review of the willed body donation paperwork, one potential reason for the decelerated decomposition process of the cardboard covered individual might have been found. This individual was given a dose of antibiotics prior to their death (likely due to pneumonia). Since the goal of antibiotics is to cure infections in the body, antibiotics kill bacteria almost indiscriminately. A side effect of this is that beneficial bacteria in the body are also killed. While there are currently no studies investigating the relationship between antibiotics and the decomposition process, antibiotics are likely to play some role in the deceleration of decomposition and the results of this research project hints at this possibility. Macrolides are the most common treatment against pneumonia (Gamache and Soo Hoo 2017). However, there is currently no research investigating the effects of these drugs postmortem.

Bacteria play an important role in the breakdown of tissues in the body after death, thus providing the means for decomposition (Butzbach 2009). Paterson (1993) states that drugs have the ability to spread from one area of the body to others postmortem. Given that this individual had pneumonia, the antibiotic that was originally intended for the lungs could have spread to other areas and may explain why decomposition of the whole body was significantly decelerated. It is also of interest to note that the torso of this individual did not drastically change throughout the decomposition process and little to no bloating was seen throughout the duration of the study.

Antibiotics may also have a profound effect on the surrounding soil chemistry during decomposition. Soil composition and the microbial communities associated with them can affect the rate of skeletal muscle tissue decomposition (Haslam and Tibbett 2009). If antibiotics leach from the body and into the soil, they could also affect these microbial communities, further altering the decomposition rate. Given the relationship between bacteria and decomposition, killing some of this bacteria likely removed one of the driving forces behind the decomposition process.

The donation paperwork of the 22 control individuals from the 2014/2015 year was investigated following these findings and no recent antibiotic treatment was noted. While there were two cases of individuals who suffered from bacterial infections, since no antibiotic treatment was reported, no assumptions were made about the occurrence of any treatment. The effects of antibiotics on the decomposition process and on the soil surrounding decomposing human remains should be studied in order to understand this potential relationship. Overall, more research should be conducted on the relationship between antibiotics and decomposition, including replicating this study with a cardboard-covered individual who is antibiotic-free.

The effects of antibiotics on the human decomposition process could have important implications for forensic anthropologists and law enforcement. If antibiotics do have the ability to slow down decomposition, it could lead to an erroneous PMI estimation. Antibiotics may give the body a “fresher” or earlier appearance and lead investigators to make a PMI estimation that is short of the true perimortem time frame, potentially hindering investigations.

Another proposed explanation for the decelerated decomposition of the cardboard covered individual is the pH of the cardboard boxes themselves. Cardboard boxes can vary in pH from neutral to slightly acidic. The pH of the shipping boxes used in this study were not tested. However, if the cardboard boxes were acidic, this could have affected the surrounding soil chemistry, and thus the decomposition process. Therefore, the pH of refuse coverings and any potential effects they may have should be considered when conducting similar experiments.

The refuse coverings appear to have deterred large terrestrial and avian scavengers. The only body that showed signs of scavenging was the brush covered individual around both hands. This could be due to the fact that the brush did not conceal the body as efficiently as the other refuse materials and left bare areas on the body. The brush would have also been the easiest material for scavengers to move in order to access the body.

The results of this study indicate that refuse coverings do not alter the decomposition process in the same manner as burials. This is likely due to the restriction of insects and the lower temperatures under the surface. Covering the bodies with refuse likely did not lower temperatures significantly or severely restrict insect access.

This study's findings are more closely aligned with previous research on differences between sun and shaded decompositions. While there are small discrepancies between shaded/refuse covered individuals when compared to sunlit/uncovered individuals, the decomposition process as a whole is not significantly changed. This mimics the relationship between refuse covered individuals and the uncovered sample. It is possible that refuse coverings could act as shading agents that block the bodies from the sun and affect the decomposition process in the early stages, however this was not found in this study.

The Kendall's rank correlation test showed that there was a strong positive correlation between ADD and TBS (*tau* = 0.7207). This means that as ADD increases, TBS also increases. This is expected given the relationship between temperature and decomposition (Megyesi et al. 2005; Galloway et al. 1989; Mann et al. 1990). Additionally, calculating the rate of change in TBS with respect to ADD shows that there is an almost threefold increase in rate of decomposition at the early stage (slope = 9.38) when compared to the advanced stage (slope = 3.69). This means that decomposition progresses almost three times faster during the early phase and then slows down towards the advanced phases. These results indicate that temperature and heat play a much larger role in the decomposition process than any of the coverings used in this study. With the exception of the cardboard-covered body described above, all of the bodies (both uncovered control and refuse covered), followed a consistent pattern in terms of the amount of ADD required to reach specific stages of decomposition.

Additionally, scoring the decomposition stage of the body may also have affected the results of this study. The Total Body Score system may not appropriately describe the physical changes that a body is undergoing. Distinguishing between one score and another can be difficult and leaves room for error. Often, a region of the body could be described as two or three different scores which introduces a substantial level of subjectivity to the scoring process. Interobserver error is a possibility when following the guidelines outlined by Megyesi et al. (2005) and could affect the timing of the progression from one stage of decomposition to another, especially as decomposition advances and when a body shows signs of multiple decomposition stages (Nawrocka et al. 2016). While these discrepancies in scoring may not drastically alter the results of this study, it should still be taken into consideration that any two observers may not describe the same body with the same score. Therefore, multiple observers should be used when replicating this study or any other that utilizes the Total Body Score system.

The Total Body Score system could potentially be problematic for accurately estimating PMI in Central Texas as well. A study by Suckling et al. (2016) at FARF indicates that there are significant differences between the ADD calculated by the Total Body Score system and the observed ADD even when other confounding factors such as scavengers were controlled for. These discrepancies can lead to an erroneous PMI estimate. The authors also report that the Total Body Score system may only be suited to the environment and climate that it was developed on. Additionally, Myburgh et al. (2013) found that of their 16 test pig carcasses, only one fell within the 95% interval for PMI estimation using ADD and the Total Body Score system. It has been suggested that a universal system for estimating PMI is not possible and regional PMI formulae should be created for best results (Cockle and Bell 2015).

Intraobserver error could also pose a problem for consistent scoring from one day to the next or between different bodies. However, repetitive scoring should solve this problem as the observer becomes comfortable with the scoring system and with their ability to identify certain characteristics of the decomposition process. In this study, photographic scoring of bodies in the first few months was reassessed at the end of the study to account for inexperience in the beginning. While scores did not change drastically during this process, some scores were changed by a point.

In order to further investigate the effects of refuse coverings on the decomposition process, this study should be replicated with the same refuse materials using larger sample sizes. If possible, individuals with similar demographic and physical characteristics should be utilized in an attempt to control as many confounding factors as possible. Individuals without a recent history of antibiotic treatments should also be used since it is unknown how this may affect the decomposition process. Additionally, this study should also be replicated with other types of coverings to investigate whether the lack of significant difference in decomposition was simply due to the five types of materials used in this study.

The position of the body in relation to the refuse may also alter the decomposition process. Another study performed at FARF found that bodies decomposed slower when placed on top of surfaces other than the natural ground (Shattuck, 2009). If this is true, then placing the bodies on top of the refuse may change the rate of decomposition in a manner that doesn't correspond to placing the refuse on top of the body.

It is also possible that the repeated disturbance caused during observations could have altered the rate of decomposition. The frames and refuse were lifted and removed from the body on a regular basis throughout the study. This movement has the potential to disrupt the microenvironment that develops during decomposition and potentially releases heat that may be trapped beneath the refuse. However, Adlam and Simmons (2007) conducted research that shows that there are no significant differences when it comes to decomposition stages and ADD between samples that are repeatedly disturbed by observers and those that are not.

Given the results, the refuse coverings used in this study did not significantly alter the amount of ADD needed for an individual to advance to the early, early-to-advanced, and advanced stages of decomposition. While it is possible that other types of refuse coverings may significantly alter the decomposition process, it is more likely that temperature and insect access still play more impactful roles when it comes to the rate of decomposition. As long as temperature and access to insects are held relatively equal between demographically similar individuals (e.g., those of similar age and size), they should decompose at similar rates with small discrepancies. However, further research should be conducted to investigate the role that coverings and other taphonomic factors may have on the decomposition process.

Overall, refuse coverings did not have any significant effect on decomposition stages and PMI estimates, with the possible exception of bodies covered in cardboard. With the role that antibiotics play in the decomposition process in question, further research should be conducted with cardboard covered bodies to determine any possible effects. Otherwise, PMI estimations can be formulated for refuse covered bodies in the same manner that uncovered bodies are, taking the temperature of the environment and accessibility of insects into consideration.

V. CONCLUSION

There is a variety of research that focuses on the decomposition process of human and non-human remains, as well as some of the surrounding potential confounding factors in an attempt to understand the postmortem interval. While temperature and humidity are two of the most important factors, other variables such as insect access and scavenger activity have also been shown to play a role in accelerating the decomposition process. Conversely, low temperatures, particularly below freezing, slows the decomposition process by limiting insect and bacterial activity. Factors like these have the potential to alter the rate of the decomposition process and have real world implications, in terms of understanding time since death in scenarios that include factors such as freezing the body after death, limiting insect and scavenger activity, and burying the body in a grave.

This study investigated the effects of five different refuse coverings on the decomposition process of human remains. The amount of ADD needed for a covered body to advance to the early and advanced stages of decomposition was assessed using the Total Body Score system (Megyesi et al. 2005) and then compared to one contemporaneous uncovered control and 22 control individuals from the ongoing longitudinal study. Keeping in mind the small sample size, after comparison of the covered and uncovered bodies in terms of ADD, results indicate that there were no significant differences with the exception of the body covered in cardboard. This lack of a difference in all but the cardboard covered body could be because the temperature, humidity, and insect access were not significantly altered by the refuse coverings. The cardboard covered individual did differ significantly from the other covered individuals as well as the controls at the early-to-advanced and advanced stages of decomposition, but whether this is due to the cardboard covering or to the dose of antibiotics received by the individual prior to death is not yet known, and further research should be conducted to investigate this discrepancy.

Scoring the bodies using the Total Body Score system could have led to inconsistencies and result in both inter- and intraobserver error that could have an impact on the final results. While studies suggest that the TBS method has high scoring agreeability between multiple observers (Dabbs et al. 2016, Wescott et al. 2018), multiple observers and multiple observations per observer should be utilized when undertaking any research involved in scoring decomposition due to the subjectivity involved in the process. Further research with larger sample sizes is needed using both the same refuse coverings and others to determine if any potential differences were due to sampling error or other confounding factors (i.e., antemortem antibiotic treatment).

This study and others like it help researchers understand the postmortem decomposition process. Results of this study highlight the need for further understanding of exactly how certain coverings may alter the rate and nature of the decomposition process and how other factors, such as antibiotics, confound this process. Studying the postmortem decomposition process allows biological anthropologists to contribute to a vast multidisciplinary field of science, and to more accurately and effectively assist law enforcement in the criminal justice process.

Results of this pilot study indicate that there may not need to be an adjustment for refuse covered bodies when estimating the PMI. This means that PMI estimations for victims covered with mattresses, wooden pallets, tires, and brush can likely follow the same guidelines that are applied to bodies with no coverings, (with perhaps the possible exception of bodies covered in cardboard, or individuals that may have been given a dose of antibiotics shortly before death). Forensic investigators working death scenes where bodies are covered in refuse may be able to use these initial findings when considering the postmortem interval, when narrowing down suspected perpetrator lists, or when considering other components of the criminal investigation that rely on time since death estimations.

APPENDIX SECTION

Appendix A. 2014/2015 Control Sample Summary

2014/2015 Control Sample Summary

Donation #	Age	Weight (lbs.)	Date of Placement
D43-2014	73	230	9/2/2014
D44-2014	73	130	9/1/2014
D45-2014	65	145	9/5/2014
D46-2014	81	NA	9/5/2014
D47-2014	69	240	9/12/2014
D49-2014	56	195	9/23/2014
D50-2014	75	120	10/1/2014
D51-2014	74	170	10/3/2014
D52-2014	63	250	10/3/2014
D55-2014	62	190	10/17/2014
D56-2014	69	160	10/30/2014
D58-2014	69	200	10/31/2014
D59-2014	60	160	10/23/2014
D60-2014	59	179	11/6/2014
D61-2014	59	120	11/11/2014
D62-2014	53	180	11/11/2014
D64-2014	89	90	12/2/2014
D65-2014	43	220-230	12/3/2014
D66-2014	59	150	12/3/2014
D67-2014	60	185	12/4/2014
D68-2014	84	180	12/5/2014
D04-2015	78	275	2/12/2015

***All weights are measured or estimated antemortem, and therefore may not be accurate.**

APPENDIX B. Examples of Each Stage of Decomposition

Control (D38-2016)

Figure B1a. Placement

Figure B1b. Early stage


Figure B1c. Early-to-Advanced stage


Figure B1d. Advanced stage

Mattress (D45-2016)

Figure B2a. Placement

Figure B2b. Early stage


Figure B2c. Early-to-Advanced stage


Figure B2d. Advanced stage

Wooden pallets (D51-2016)

Figure B3a. Placement

Figure B3b. Early stage


Figure B3c. Early-to-Advanced stage


Figure B3d. Advanced stage

Cardboard (D52-2016)

Figure B4a. Placement

Figure B4b. Early stage

Figure B4c. Early-to-Advanced stage

Figure B4d. Advanced stage

Tires (D04-2017)

Figure B5a. Placement

Figure B5b. Early stage


Figure B5c. Early-to-Advanced stage


Figure B5d. Advanced stage

Brush (D08-2017)

Figure B6a. Placement

Figure B6b. Early stage


Figure B6c. Early-to-Advanced stage


Figure B6d. Advanced stage

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