Chapter 7
Actualistic Experimental Taphonomy of Inhumation Burial

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Abstract Actualistic experimental taphonomy of inhumation burial represents an important research field with a wide range of applications in the forensic sciences, from improving postmortem interval estimation of buried remains to the detection of mass graves using remote sensing. Observational data on these processes and the effects of different variables could potentially be of great value in forensic contexts, e.g., to help determine whether there was postmortem human alteration of remains at a scene.

Keywords Actualistic experimental taphonomy · Funerary taphonomy · Archaeothanatology · Inhumation · Joint disarticulation sequence · Bone displacement · Body treatment

7.1 Introduction

Actualistic studies have a long history in archaeology, taphonomy, forensic anthropology, and paleontology (Bass 1997; Behrensmeyer and Kidwell 1985; Gifford-Gonzalez 1989; Lyman 1994; Pobiner and Braun 2005; Shirley et al. 2011). They are based on the assumption that contemporary knowledge can be applied to understand the past (uniformitarianism) and that there is a relationship between process and product (Rudwick 1971). Actualistic experimental taphonomy has become an important branch of forensic taphonomy, with a growing number of hypotheses being tested under controlled conditions. Important areas of experimental taphonomic research are the postmortem interval and modifying factors to human remains and evidence, for example, scavenger modification. The taphonomy of inhumation burials is an important line of investigation in both forensic and traditional (funerary) archaeology. For both fields, understanding the formation processes of human burials and distinguishing the effects of human manipulation of the body and its

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surroundings from taphonomic processes are key to reconstructing the sequence of events surrounding the death and burial of an individual.

Experimental inhumation burials in forensic studies have focused both on surface placement of bodies and burial, although the majority of the studies has dealt with the former, in order to observe the stages of gross decomposition and to reflect common modes of disposal of remains by perpetrators. To date, experiments on the taphonomy of inhumation graves have made important contributions to knowledge of, i.a., the rate of decomposition in buried bodies (Marais-Werner et al. 2017; Rodriguez and Bass 1985; Wilson et al. 2007), biological alteration of the burial environment and soil (Tibbett and Carter 2008; Thomas et al. 2017), biodegradation of human tissues (e.g., Wilson 2017), degradation of clothing in buried environments (Stuart and Ueland 2017b), differential decomposition in mass graves (Troutman et al. 2014), and detection of mass graves using remote sensing (Kalacska et al. 2009). Body analogues for humans are used in many studies. Most often pigs (*Sus scrofa*) are used, as they are considered anatomically and physiologically similar enough to humans to serve as analogues, although other studies have used rabbit or rat analogues. Acquiring sizable samples of human bodies is a continuing challenge. The use of pigs as body analogues allows researchers to acquire larger samples and provides much greater control over variables such as body size, cause of death, and pathology, as well as speed of placement after death. In addition, pigs can function as human proxies, when the use of human body donation is not an option due to ethical concerns. However, recent research has indicated that nonhuman body analogues do not reflect the range of variation observed in humans. In a study comparing five humans, five pigs, and five rabbits, the researchers found that humans exhibited greater variability in both visual decomposition changes and insect activity than pigs or rabbits (Dautartas et al. 2015; Steadman et al. 2016). In another study comparing decomposition in 17 pigs and 22 humans, Connor et al. (2017) found that the trajectory of decomposition between the two groups diverged in both rate and gross presentation. They conclude that pigs may be useful in studying general trends but are not a substitute for human subjects. They further call for caution when applying data derived from pigs to human subjects in medicolegal investigation.

Data gathered from forensic case reports has also provided substantial information on the taphonomy of inhumation burials, and analysis of datasets large enough to provide statistically significant results offers important insights into the effects of different taphonomic variables, including (plastic) wrapping of the body, burial depth, and soil type (e.g., De Leeuwe and Groen 2017). In addition, such studies may arguably reflect real-world scenarios more accurately. On the other hand, experimental studies provide the important benefit of regulation of variables throughout decomposition and are designed to test specific hypotheses (which in turn can be developed based on forensic casework) (Sorg et al. 2012; Simmons 2017).

Recently, experimental taphonomy has been used to improve the analysis of inhumation burials from (non-forensic) archaeological contexts (Mickleburgh and Wescott 2018). Approaches to the taphonomy of the burial environment in traditional archaeology have been developed with the aim of distinguishing the multitude of taphonomic factors modifying human remains, and to understand past funerary practices and concepts of death and afterlife.

7.2 Funerary Taphonomy

In funerary archaeology, a subfield of traditional archaeology, the taphonomy of the human body within a grave is receiving increasing attention. Funerary taphonomy, recently defined as “the study of how taphonomic changes aid the interpretation of funerary practices” (Knüsel and Robb 2016: 655), uses the principles of taphonomy to reconstruct the sequence of events surrounding death and burial and to distinguish taphonomic alterations from human modification of human remains. The scope of this developing field is broad: in order to understand the social and cultural aspects of burial, it is important to be able to distinguish the effects of a multitude of taphonomic processes on assemblage patterning. These include, inter alia, bone modification (e.g., weathering, rodent gnawing, burning), mode of burial (e.g., single, primary inhumation, commingled deposition), decomposition, and body condition upon deposition (e.g., desiccation/mummification). The primary concern of funerary taphonomy is to identify patterning resulting from human funerary practices.

An important methodological approach used is *archaeothanatology*. This French- developed field methodology uses the spatial patterning of bones in a deposit, along with knowledge of anatomy and human decomposition, to draw inferences on the treatment of the body and its original position upon interment. The principle underlying this field is that the burial mode (e.g., grave shape and size, body position, presence of a body container, stage of decomposition of the body upon burial) will affect how the body decomposes and is preserved (Castex and Blaizot 2017; Duday 2009; Duday et al. 1990, 2014).

Archaeothanatology relies on principles of forensic taphonomy and an understanding of human anatomy, to interpret a human burial within its context. By analyzing individual bone position and using models of decomposition and the order of joint disarticulation, the original conditions of the deposit, the sequence of taphonomic events and human modifications are reconstructed. Skeletal disarticulation patterns can be diagnostic of environmental conditions (e.g., water flow), animal behavior (e.g., scavenging), and/or human action (e.g., ritual displacement of bones), aiding the reconstruction of the events that formed a burial feature. Final bone position is influenced by body position upon interment, open spaces and supporting structures in the grave, human/animal activity, soil conditions, and patterns of natural joint disarticulation. Archaeothanatology has made extensive use of taphonomic models of the natural sequence of joint disarticulation to distinguish natural from anthropogenic or bioturbation/scavenging processes. In archaeological cases, the application of these methods has allowed researchers to establish a timeline and the sequence of events surrounding the death and burial of individuals. In a study of Moche burial practices in pre-colonial Peru, taphonomic analysis of the disarticulation and spatial distribution of parts of skeletal remains demonstrated that bodies were (partially) mummified prior to burial, allowing disarticulation of brittle parts of the body during placement in a tomb. The analysis further indicated that there was a protracted time between death and final burial (Nelson 1998). Taphonomic analysis of medieval single graves in France has demonstrated the presence of perishable structural supports in the grave (wooden shelf, coffin) as well as revealed the shape and dimensions of the original grave pit. Analysis of post-medieval mass graves allowed the detailed reconstruction of the relative chronology of deposits within the feature, demonstrating that while the deposit was composed of several layers of individuals, the mass grave and all individuals within it were deposited in one event (Castex and Blaizot 2017). Archaeothanatological analysis furthermore helps to i.a. (1) determine if burials are primary or secondary; (2) distinguish between intentional and accidental burials, e.g., in paleoanthropology; (3) reveal whether the body was moved/transported before burial; (4) identify whether a burial has been disturbed post-deposition; and (5) infer the presence of containers and/or wrapping of the body upon interment (which have since decayed).

In the absence of actualistic taphonomic data on the factors influencing final bone position in the grave, archaeothanatology has relied on inferences resulting from repeated observation of patterns in the archaeological record. While archaeological burials can provide insights from a broad range of contexts and environments, archaeological contexts do not provide the possibility to control conditions and are the result (a "final snapshot") of a multitude of processes. As highlighted by Appleby (2016: 21), "there is a danger of circular argument: a burial is primary because of the persistence of labile articulations and as secondary if they are absent. At the same time, the articulations are identified as labile due to their frequent preservation in primary burials and absence in secondary ones. This means that lists of labile and persistent articulations are mostly based on inference about the way in which ligaments decompose from repeated experience." In fact, the comparative analysis of a large number of archaeological burials in supine position from different spatiotemporal contexts found little supporting evidence for the existence of a "common" or "natural" joint disarticulation sequence in humans (Peressinotto 2007), underscoring the need to establish how different variables affect disarticulation and spatial patterning of bones within the grave.

Actualistic experiments provide the opportunity to study the effects of specific conditions and taphonomic processes. Recent actualistic taphonomic experiments by the author aimed at collecting observational data on joint disarticulation and bone displacement throughout decomposition, and the effects of body position and condition on final patterning of skeletonized remains, explore the potential of actualistic experiments to improve and further develop archaeothanatology.

7.3 Actualistic Taphonomy Experiments for Archaeology

Decomposition is a continuous process of chemical, physical, and mechanical changes to the body. Decomposition processes such as bloating are known to cause movement of the body, especially the limbs. Once skeletonization and decomposition of connective joint tissues occur, individual bones can become displaced out of anatomical position. Five main factors are known to influence the final position of the skeletal remains: (1) body treatment and body position; (2) grave architecture and furniture; (3) stage of decomposition upon interment, decomposition processes, and the sequence of disarticulation of the skeleton; (4) environment, e.g., soil type; and (5) human and animal activities in and around the grave/body.

Recent experimental research by the author examines skeletal disarticulation and bone displacement during decomposition of five willed, donated human bodies. The pilot study (2015–2019) explores how different variables influence disarticulation and bone displacement, to improve interpretation of archaeological human burials, and aims to set parameters for future experiments with a larger sample. The overarching goal is to gain a better understanding of the formation processes of archaeological human burials through actualistic study under controlled conditions.

The remains were placed at the Forensic Anthropology Research Facility (FARF) managed by the Forensic Anthropology Center at Texas State (FACTS) University in Central Texas. FACTS receives whole body donations for scientific research under the Texas revised Uniform Anatomical Gift Act (National Conference of Commissioners on Uniform State Laws 2009). Body donations are exclusively acquired by Texas State University through the expressed and documented willing of the donors and/or their legal next of kin. Donors and/or their next of kin are aware that body donations are used for taphonomic studies. Demographic, health, and other information are provided through a questionnaire completed by the donor or legal next of kin. The program complies with all legal and ethical standards associated with the use of human remains for scientific research.

Photography and daily observations provided visual evidence to assess soft tissue decomposition, disarticulation of the skeleton, and bone movement. Photography also provided data for the production of 3D models using structure from motion. 3D models were created at weekly intervals to document and quantify movement of the body parts and skeletal elements over time.

7.3.1 Disarticulation Sequence

An important key to archaeothanatology is knowledge of the relative timing of disarticulation of the individual joints in the human skeleton. A model of the relative sequence of disarticulation is used to "distinguish the action of natural processes from those relating to the placement of the corpse as a part of funerary treatment" (Knüsel 2014: 30). The current understanding of the skeletal disarticulation sequence is based on the idea of labile (non-durable) and persistent (durable) joints (Duday 2009; Knüsel 2014). Labile joints are those that are relatively unstable and disarticulate relatively soon after death, and are frequently found out of anatomical position, unless there is supporting soil or burial architecture. These include joints held together primarily by soft tissue attachments (e.g., hyoid, mandible, patellae, scapulothoracic connection, costo-sternal joints) and small bones of the hands and feet (Duday 2009; Knüsel 2014; Roksandic 2002). Persistent joints, on the other hand, are major weight-bearing joints with ligaments that resist disarticulation and frequently maintain their anatomical position. This model of joint durability is based on (1) assumptions on durability during decomposition based on biomechanical function and strength in life and (2) observations of the anatomical relation of bones in archaeological burials. However, the validity of the model has been questioned based on contradictory findings in archaeological burials, suggesting there may not be a predictable disarticulation sequence based strictly on joint type (Peressinotto 2007).

While the potential effects of different body positions and body treatment (e.g., mummification) on the relative order of joint disarticulation have long been acknowledged (Duday et al. 1990; Maureille and Sellier 1996), the recent actualistic pilot study conducted by the author at FARF of five bodies in different positions suggests that the process of disarticulation is highly complex. The case study involved multiple instances of disarticulation followed by re-articulation, a phenomenon that could not be ascertained based on observation of archaeological burials, demonstrating that the current model may not capture the entire process (Mickleburgh and Wescott 2018). While the current disarticulation model is based on an assumed order of decay of the connective tissues of the joints leading to bone displacement, the actualistic study demonstrated that displacement of bones out of anatomical position is not necessarily dependent on complete decomposition of the connective tissues. Displacement was found to occur in joints still retaining (stretched) connective tissue. In addition, it remains unclear whether the strength or biomechanical function of individual joint articulations in life determines their durability during decomposition, which is one underlying assumption of the disarticulation model currently used.

7.3.2 Bone Displacement

The position of the bones can be critical to understanding the original body position, especially when perishable containers or burial architecture are no longer preserved. Gravity plays a major role in the disarticulation of joints and movement of individual bones depending on the position of the body. If the body is situated in a relatively stable position, little to no movement of the bones may occur. However, if the body is in an unstable position, the bones can move within open spaces due to the effects of gravity. This process is known as *necrodynamics* (Wilhelmson and Dell'Unto 2015). Open space can be present upon deposition of the body, e.g., in a coffin (primary open space), or may be created by decomposition of the soft tissues and burial architecture (secondary open space). Previous studies of archaeological burials have indicated that different body positions may affect the order of joint disarticulation (Gerdau- Radonic 2012; Peressinotto 2007; Ortiz et al. 2013; Richter et al. 2010; Rottier 2016). Understanding bone displacement, its relation to the sequence of disarticulation, and the presence or creation of open spaces can be critical to reconstructing the relative chronology of processes within a burial feature, as demonstrated by the analysis of post-medieval mass burials discussed above (Castex and Blaizot 2017).

To examine the effects of primary and secondary open space on disarticulation and bone displacement, two donated bodies were placed in small oval-shaped pits at FARF in upright, seated position. This body position, which is known from various spatiotemporal contexts in archaeology, was expected to lead to greater forces on upper parts of the body and a greater distance of displacement of bones, due to the effects of gravity and the superposition of body parts (Gerdau- Radonic 2012; Ortiz et al. 2013; Richter et al. 2010; Rottier 2016). Of the two donated bodies, one was immediately buried with soil upon placement, while the other was placed in a pit that remained open throughout the duration of the experiment. The experiment was continued until complete skeletonization. 3D models were developed weekly for the open-pit experiment, and upon placement and final excavation for the burial experiment. The sequential models can be overlaid to allow quantification of bone displacement, i.e., the direction and volume of movement, over time. The burial experiment was expected to produce less movement of the bones due to supporting soil. Furthermore, based on archaeothanatological research, the burial experiment was expected to show displacement of bones only within the soft tissue body volume, while the open-pit experiment could produce displacement outside of the soft tissue body volume.

The experiment revealed that the volume and pattern of bone displacement in the buried donation was similar to that of the open-pit donation. Despite the duration of the burial experiment (793 days), secondary open space was very well preserved, leaving a precise impression of the soft tissue volume of the body in the soil. Upon skeletonization, bones were able to move within this secondary space, and the amount of vertical displacement of bones was similar to that in the open-pit experiment. This highlights inferences based on archaeological burials that the formation of secondary open spaces is a major factor in the final distribution of bones in a deposit. The formation and maintenance of secondary open space is dependent on soil type and the weight of overlying soil, with sandy soils known to rapidly or immediately fill newly created voids (hourglass effect), and soils with a clayey texture preserving voids for a longer duration (Duday 2009). In the burial experiment, fine plant roots were also found to be a major factor in the preservation of voids in the burial pit. In addition, displacement outside of the soft tissue body volume was found to be minimal in the open-pit experiment.

These preliminary results indicate that further investigation of the role of soil type in the creation of secondary open spaces, as well as the duration of time in delayed infilling, is necessary. Overall, the results thus far support earlier findings that the upright seated body position leads to greater bone displacement, than in supine burials. Displacement outside of the soft tissue body volume was minimal in the open-pit experiment, and without repetition of the research with a larger sample, it is impossible to assess the efficacy of this observation as a marker to distinguish between the presence of primary and secondary open space throughout decomposition.

7.3.3 Body Condition Upon Interment

The condition of the body or stage of decomposition at burial can affect the final disposition of the bones. As Knüsel (2014: 46) notes, "delay in burial may occur for a number of reasons: corpse preparation, as in mummification or exposure/storage leading to desiccation; death at a distance; political manoeuvring to ensure succession; or disrupted or lacking ceremonies, planned or simply omitted (as with the dead from battle, which were often left exposed on the field of battle for varying periods of time without burial)." The potential volume of secondary open space in the burial pit created by decay of the soft tissues can differ significantly between bodies interred in different stages of decomposition. Fresh bodies, yet to go through bloating, or bloated bodies, will present larger soft tissue volume than desiccated/mummified bodies. As discussed above, the formation of secondary open space, or voids, allowing bone displacement is dependent on the decay of soft tissues or burial architecture and delayed infilling by the surrounding soil matrix. As such, desiccated body interments lacking primary open space would be expected to demonstrate less bone movement upon skeletonization than fresh or bloated body interments, due to the difference in soft tissue volume. In addition, desiccation is thought to affect the order of joint disarticulation. Cases of "paradoxical articulation" have been described in archaeological burials, in which skeletal remains show preserved labile articulations, but persistent joints have disarticulated. Paradoxical articulation has been suggested to be an indication of desiccation of the body, which limits bone movement and in combination with human manipulation of the remains causes deviation from the "normal" sequence of joint disarticulation (Maureille and Sellier 1996).

To examine the effects of desiccation of the soft tissues on the formation of secondary open space and bone displacement, as well as possible "paradoxical articulation," one donated body in fresh decomposition stage and one naturally mummified body were placed in small oval-shaped pits in supine flexed position. The fresh body donation was excavated after 834 days, at which time the body was found to be completely skeletonized. Secondary open space was well preserved, leaving a clear impression of the soft tissue volume of the body in the soil. Overall, the pattern of bone displacement differed from the upright seated experiment described above, as the supine body position allowed less vertical bone displacement. Displacement was most prominent in the lower limbs and thorax, and bones remained within the original soft tissue body volume. The mummified body experiment is ongoing at the time of writing. The state of articulation and bone displacement in this donation will be assessed upon excavation.

7.4 Application in Forensic Contexts

Forensic archaeology and archaeothanatology have two important aims in common: distinguishing taphonomic alterations from human modification of the remains and their context and reconstructing the sequence of events surrounding death and thereafter. This has led to calls within the field of archaeothanatology to apply its methods in forensic contexts (Castex and Blaizot 2017; Duday and Guillon 2006). While verifiable data collected under controlled conditions is highly valuable to the development of archaeothanatology and funerary taphonomy (as discussed above), it can be argued to be essential in order for this methodological approach to be applied in forensic cases. In a legal setting, it is important that forensic archaeologists can support their interpretations of the data with appropriate (robust empiric) evidence. Actualistic experimental data provide a framework of clear data collection protocols and controlled conditions to establish the role of specific variables. However, despite recent research collecting experimental data to support and improve archaeothanatological methods, the potential for its application in forensic contexts is still impeded for a number of reasons. Foremost among these is the lack of large sample sizes in experimental studies. In a forensic context, where information derived from experiments may need to be defensible in court, statistically significant findings are important. For a solid scientific foundation of the experiment design, repetition and replication of experiments, and the use of control groups, are essential. Preferably, the number of controls in any given experiment would be equal to the number in the test scenario (Simmons 2017). Repetition of experiments reduces the role of chance variation in the results, making statistical inferences more reliable. Furthermore, since human decomposition is known to be highly variable depending on environment, replication of the experiments in different locations, reflecting different environmental conditions, is crucial. Human decomposition research facilities throughout the United States, the Netherlands, and Australia provide the opportunity to replicate experiments in different environments and compare results. However, acquiring substantial sample sizes of donated human bodies remains a challenge. The use of body analogues in human skeletal disarticulation studies is not a viable option, since observations of nonhuman disarticulation sequences indicate that they differ per species (Hill 1980).

7.5 Discussion/Conclusion

Actualistic experimental taphonomy of inhumation burial represents an important research field with a wide range of applications in the forensic sciences, from improving postmortem interval estimation of buried remains to the detection of mass graves using remote sensing. For archaeothanatology and the study of past funerary practices in general, actualistic experiments on human joint disarticulation, bone displacement patterning, and the role of a multitude of variables including body condition, body position, and primary and secondary open spaces represent an important opportunity to observe the entire process under controlled conditions, with the ultimate aim of establishing markers to distinguish between (intentional) human actions and natural processes during excavation. Observational data on these processes and the effects of different variables could potentially be of great value in forensic contexts, e.g., to help determine whether there was postmortem human alteration of remains at a scene. However, for both traditional and forensic archaeology, repetition and replication of experiments (in different environments) and the use of control groups are crucial, to allow reliable statistical inferences.