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Controlled experimental observations on joint disarticulation and bone displacement of a human body in an open pit: Implications for funerary archaeology

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ABSTRACT

The study of death and burial in prehistoric populations is fundamental to understanding the human past. In recent years increasing attention has been given to methods and techniques to understand important aspects of funerary ritual such as body treatment, and concepts of death and decay of the human body. The French-developed methodological approach archaeothanatology aims to understand how the dead body was treated, and which factors influenced the final condition and position of the skeletal remains. A core part of the approach is assessing the anatomical articulation of the joints of the skeleton. Sequences of the relative order in which the joints of the body naturally disarticulate are used to reconstruct body position and condition upon interment. These disarticulation sequences are largely based on observations of archaeological skeletons, in which distinguishing the effects of different variables is highly challenging. Experimental studies (actualistic taphonomy) allow observation of disarticulation and bone movement under controlled conditions.

This paper discusses the actualistic experimental study of a willed donated human body to examine the process of decomposition and skeletal disarticulation under controlled conditions. The results support earlier indications that burial environment and variations in body position can greatly affect patterns of disarticulation and bone displacement. Furthermore, the process of disarticulation observed in this study was complex, involving multiple instances of displacement of bones out of anatomical position prior to loss of the connective tissues, as well as cases of disarticulation followed by 're-articulation'. This demonstrates that sequences based largely on archaeological data may not capture the entire process. Further actualistic studies are needed to better understand the effects of different variables on disarticulation and final bone position. Such studies provide the opportunity to refine and improve the existing framework used to assess body treatment. Understanding body treatment in the past contributes to the wider conceptualization of human death and burial.

1. Introduction

In recent years, studies in funerary archaeology have increasingly focused on how the body of the deceased was treated by the living, and which taphonomic processes influenced the final condition and position of the skeletal remains in an archaeological burial. Body treatment is an important part of meaningful and ritualized funerary behavior and is intimately associated with concepts of death and decay, the afterlife, and agency of the deceased (Nilsson Stutz, 2016; Nilsson Stutz and Tarlow, 2013; Robb, 2013).

To accurately interpret a static mortuary deposit it is necessary to understand the dynamic formation processes that created the spatial distribution of the bones and artifacts in the grave. A notable methodological approach aimed at reconstructing the natural and human factors involved in the formation of a burial feature is the French-developed *archaeothanatology*. Archaeothanatological research has shown that the position of the skeletal remains in the grave does not always reflect the original body position, and is influenced by the mode of body treatment (e.g. wrapped, placed in a container, desiccated/mummified) before and during burial. Key to inferring the post-depositional movement of skeletal remains within a burial feature is an understanding of soft tissue decomposition, the sequence of disarticulation of the joints, and how a multitude of factors and taphonomic processes contribute to in situ displacement of the bones observed in archaeological investigations (Duday, 2009, 2012; Duday et al., 1990; Harris and Tayles, 2012; Knüsel, 2014; Knüsel and Robb,

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2016; Nilsson Stutz, 1998, 2003; Nilsson Stutz and Larsson, 2016; Roksandic, 2002; Valentin et al., 2010). The movement of bones out of anatomical relation – also referred to as 'necrodynamics' – occurs through the combined factors of soft tissue decomposition and joint disarticulation, the presence of open space for the bones to move in, the effects of gravity on the bones, soil type and conditions, and/or natural (e.g. animals, plant roots) or human agents (Dirkmaat and Passalacqua, 2015; Ortiz et al., 2013; Wilder, 1923; Wilhelmson and Dell'Unto, 2015). Rotation and movement of bones can occur due to normal decomposition processes if empty space is present in the burial chamber ('primary open space') and as empty space is created due to the decomposition of soft tissues and structural elements such as wrappings ('secondary open space') (Duday, 2009).

Since archaeological burials represent a 'final snapshot' resulting from the combined effects of numerous factors, understanding the taphonomy of the burial environment, and therefore interpreting funerary behavior, is challenging. Experimental studies (actualistic taphonomy) provide the opportunity to study the effects of specific conditions and taphonomic processes under controlled conditions. This study examines skeletal disarticulation and bone displacement during decomposition of a willed donated human body placed in a seated position within a small open pit. The goal is to gain a better understanding of the formation processes of archaeological human burials. This case study is part of an ongoing larger study of willed donated human remains, aiming to establish how different variables influence disarticulation and bone movement. The ultimate aim of such experimental research is to improve interpretation of archaeological human burials and our understanding of concepts of death and decay in the past.

1.1. Sequence of disarticulation

Archaeothanatology uses the relative sequence of joint disarticulation of the human skeleton 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 method seeks to explain indications for deviation from the natural sequence in any given human burial, through either natural processes of decomposition or human treatment of the body. A detailed assessment of the state of articulation/disarticulation of each joint of the skeleton is - used among - others to: 1) determine if burials are primary or secondary, 2) establish whether a burial was disturbed post-deposition, 3) infer the presence of containers and/or wrapping of the body upon interment (which have since decayed), 4) to understand if a body decomposed in an open or filled (e.g. covered with soil) space, or 5) to ascertain the stage of decomposition of the body upon interment (e.g. fresh, mummified). The disarticulation sequence is based largely on observations of disarticulated skeletons in archaeological burials as well as assumptions on the relative durability of joints during decomposition based on their strength and size in life (Duday, 2009, 2012; Duday et al., 1990; Knüsel, 2014).

Based on observations of joint articulation in archaeological burials, as well as the volume of soft tissues and the biomechanical function of the joint in life, researchers have constructed two primary types of articulations – persistent (durable) and labile (non-durable) (Duday, 2009; Duday et al., 1990; Knüsel, 2014; Peressinotto, 2007; Sellier and Bendezu-Sarmiento, 2013; Table 1). Persistent articulations (Table 1) are those that connect bones with important biomechanical functions of weight bearing and locomotion. Persistent articulations are joints with large and tough ligaments such as the sacro-iliac (pelvic girdle) joints, the knees, the ankles, the atlanto-occipital joint, and the humero-ulnar (elbow) joint (Knüsel and Robb, 2016). Labile articulations include the smaller bones of the cervical (neck) vertebrae, hands, toes, hyoid, costosternal (rib-breastbone), and others lacking (intricate) boney articulation such as the scapulothoracic (shoulder blade-thorax) joint and patella (kneecap) (Duday, 2009, 2012; Duday et al., 1990; Knüsel, 2014; Knüsel and Robb, 2016; Sellier and Bendezu-Sarmiento, 2013).

Table 1
Labile and persistent joints of the human skeleton based on sequences described in archaeothanatological literature (Duday et al., 1990; Duday, 2009; Knüsel, 2014; Peressinotto, 2007; Sellier and Bendezu-Sarmiento, 2013).

Labile joints	Persistent joints
Hyoid, temporomandibular, phalanges, metacarpals, metatarsals, carpals, tarsals, cervical vertebrae, scapulothoracic, glenohumeral, costosternal, costovertebral, acetabulofemoral, femoro-patella	Atlanto-occipital, humero-ulnar, thoracic and lumbar vertebrae, lumbosacral, sacro-iliac, tibiofemoral, talocrural, talocalcaneal

The labile articulations in particular are used to assess whether a burial is primary or secondary, because if these articulations are preserved, it is assumed that burial occurred rapidly after death (Duday, 2009). Notable exceptions to the labile/persistent distinction have been identified. The wrist, for example, is considered to be a strong joint in life, due to the numerous ligaments connecting the carpal bones. Yet, these ligaments are thought to decompose rapidly after death. Similarly, the acetabulofemoral (hip) joint was originally assumed to be persistent due to its important weight-bearing function, but is now considered to be labile as the joint is maintained by thin capsular ligaments which can decay rapidly (Duday, 2009; Knüsel, 2014; Knüsel and Robb, 2016). These exceptions indicate that the relation between joint strength and function in life and durability after death is not straightforward.

The validity of the labile/persistent joints distinction in different conditions and contexts has been drawn into question, since a comparison of a large sample of supine burials from different spatiotemporal contexts found little evidence for a 'common' or 'natural' disarticulation sequence (Peressinotto, 2007). Archaeological studies have indicated that patterns of joint disarticulation and final bone position vary with original body position as well a body treatment, but distinguishing the effects of different variables using archaeological data has proven highly complex (Gerdau-Radonic, 2012; Ortiz et al., 2013; Peressinotto, 2007). Next to factors such as soil characteristics and burial depth, Peressinotto (2007) argues that even very subtle differences in body position can affect the order of disarticulation. The potential effects of environmental conditions on the speed of decomposition of different types of connective tissues are also unknown. In addition, the danger of circular argument has been noted by Appleby (2016: 21): "*a burial is primary because of the persistence of labile articulations and 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.*"

The few existing actualistic observations of human skeletal disarticulation have suggested that disarticulation proceeds in a generally cephalic-caudal direction, and from the periphery to the centre. Though based on small samples, these studies also suggest deposition type and environment affect the process (Dirkmaat and Sienicki, 1995; Haglund, 1993; Rodriguez and Bass, 1985).

1.2. 'Seated' burials

The majority of archaeological burials that currently form the basis of our understanding of disarticulation and bone displacement consist of bodies in extended supine positions. In order to examine the effects of body position, this experiment used an upright seated position. Seated burials are known from many different spatiotemporal contexts across the globe. This position describes the placement of the body with the vertebral column in a vertical position, usually flexed anteriorly, and with the lower limbs flexed at the hip and at the knees toward the torso (Knüsel, 2014: Fig. 6). The frequency of this practice varies, although seated burial tends to occur alongside various other body positions and funerary treatments (e.g. Gerdau-Radonic, 2012;