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Forensic Anthropology and Archaeology in Denmark

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Abstract:
In this paper, we provide a brief overview of the status of forensic anthropology and forensic archeology in Denmark, as well as related information about education, research, and skeletal collections. Forensic anthropologists mainly deal with the examination of unidentified skeletal remains. Some special tasks include cranial trauma analysis of the recently deceased, advanced 3D visualization from CT scanning of homicide cases, and stature estimation of perpetrators using surveillance videos. Forensic anthropologists are employed at one of Denmark's three departments of forensic medicine (in Copenhagen, Odense, and Aarhus) and have access to advanced imaging equipment (e.g., CT and MR scanning, surface scanners, and 3D printers) for use in both their requisitioned work and their research. Extensive research is conducted on different topics, such as the health and diseases of past populations, age estimation, and human morphology. Research is based on skeletal material from the archeological collections housed in Copenhagen and Odense or on CT data from the recently deceased. There is no full degree in forensic anthropology in Denmark, but elective courses and lectures are offered to students at different levels and to people from different professional backgrounds.
Forensic archaeology is a relatively new field of expertise in Denmark, and relevant cases are rare, with only one or two cases per year. No forensic archeologists are officially employed in any of the departments of forensic medicine. Until recently, the Special Crime Unit of the police handled crime scene investigations involving excavations, but with the option of enlisting the help of outside specialists, such as archaeologists, anthropologists, and pathologists. An official excavation work group was established in 2015 under the lead of the Special Crime Unit of the police with the aim of refining the methods and procedures used in relevant criminal investigations. The group is represented by five police officers from the Special Crime Scene Unit, a police officer from the National Police Dog Training center, the two archaeologists from Moesgaard Museum, a forensic anthropologist from the Department of Forensic Medicine (University of Copenhagen), and a forensic pathologist from the Department of Forensic Medicine (University of Aarhus).

Keywords:
bones, CT scanning, 3D models, identification, trauma, skeletal collections

INTRODUCTION

In Denmark, there are three departments of forensic medicine situated in Copenhagen, Odense, and Aarhus. Forensic medicine includes several disciplines: forensic pathology and clinical forensic medicine, forensic toxicology, forensic genetics, forensic odontology, and forensic anthropology. The departments perform forensic examinations for the police, the courts, and other authorities in Denmark, Greenland, and the Faeroe Islands. The departments are part of three universities (University of Copenhagen, University of Aarhus, and University of Southern Denmark), and thus, together with the requisitioned work, research and teaching are important tasks.

All three departments are equipped with advanced laboratories, including a hard tissue laboratory in Aarhus, which is used for the microscopy of undecalcified bone in the recently deceased. In particular, Denmark is at the forefront in terms of medical imaging facilities. Danish forensic medicine departments are among the few in the world with in-house CT scanners dedicated to bodies and human skeletal remains. An in-house MR scanner is available in Copenhagen, while access to the scanner in Aarhus is granted through collaboration with a nearby hospital. X-ray planar radiography, surface scanners, photogrammetry equipment, and 3D printers can also be found in all three departments. Through collaboration, access to instruments such as micro-CT scanners and electron microscopes is possible. These imaging technologies play an important role in forensic anthropology, both for requisitioned work and research.

In this paper, we provide a brief overview of the status of forensic anthropology and forensic archeology in Denmark, paying particular attention to the different types of forensic cases in which we are involved and some of the methods we apply in our work. Information about education, research, and human osteological collections is also mentioned.

FORENSIC ANTHROPOLOGY

Forensic anthropology units are part of the section of the forensic pathology in all three departments and are under the supervision of the chief pathologist (statsobducent). As such, all forensic anthropological examinations are conducted in cooperation with a forensic pathologist, and all reports are countersigned by the chief pathologist or deputies. The three forensic departments are accredited by the International Organization for Standardization (ISO).

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Forensic anthropologists typically deal with bones from completely skeletonized remains or highly decomposed bodies. However, looking at the international context, forensic anthropologists have increasingly been requested to handle the identification and age estimation of living individuals. In particular, they have been responsible for estimating stature, performing gait analysis, matching bodily features among suspects and perpetrators (e.g., in homicides or robberies recorded by security cameras systems) [1-7], and estimating the age of juvenile perpetrators, asylum seekers, or victims of child pornography [8-11].

In Denmark, forensic anthropologists mainly deal with the examination of unidentified skeletal remains (burned and unburned). At the department in Copenhagen, forensic anthropologists also perform cranial trauma analysis of the recently deceased, advanced 3D visualizations from CT scanning in homicide cases, and stature estimation of perpetrators or suspects using surveillance images and videos.

EXAMINATION OF UNIDENTIFIED SKELETAL MATERIAL

Skeletal remains (e.g., bones found on beaches and forest floors or uncovered during construction and gardening) are brought to our departments by the police for investigation.

Human skeletal remains, often anatomical teaching specimens or acquired archaeological human bone material (most often skulls) [12], surface in attics, etc. are delivered to us.

Our first steps are to 1) assess whether the remains are human or nonhuman and 2) determine whether they are recent (i.e., of interest to the police) or archeological bones. If these initial questions about the nature and age of the bones have been answered and the findings are of police interest, we will provide information about the individual's sex, age at death, stature, and ancestry—the so-called biological profile—as well as information about special characteristics and signs of disease and trauma. There are around 50 cases per year in Denmark, of which 25–30 are investigated in Copenhagen, 10–12 in Aarhus, and 5–10 in Odense. The majority of these cases turn out to be animal remains or archeological human bones.

In all three institutes, we apply traditional anthropological methods [13-16], but we might supplement our analysis with CT scanning or X-rays when we suspect ante-mortem trauma or bone disease [14,17,18]. In Odense, forensic anthropologists also use experience-based age assessments [19], and "Transitional Analysis 3" [20], if enough bones are available for analysis.

CRANIAL TRAUMA ANALYSIS

In cases of complicated cranial trauma, we may assist forensic pathologists with their analyses [21-24]. Due to their research and case studies, forensic anthropologists have a deep understanding of bone and its response to trauma. We examine the skull macroscopically and, in some cases, we use CT scanning and stereo microscope as supplementary tools. We describe the anatomical position and characteristics of each fracture line as well as their extension. We estimate the impact areas and the possible impact order based on the pattern of the fracture lines [25].

Recently, 3D-printed skulls with traumatic injuries have been used in court trials; they have been used by forensic pathology experts to explain fractures and lesion mechanisms. A running project in collaboration between the Copenhagen and Aarhus departments involves investigating the performance and utility of 3D-printed skulls in court (C. Villa, personal communication).

BURNED BONE

Our work also includes an analysis of thermally damaged bodies. In cases of cremation, we provide biological profiles and identify traits, such as previous fractures, disease, or anatomical variants, that can help in the identification of the remains. We assist the pathologist in differentiating peri-mortem trauma from postmortem trauma, and we may help forensic odontologists identify dental fragments and dental work (which are vital for identification) among other burned/cremated debris.

ADVANCED 3D VISUALIZATIONS FROM CT SCANNING IN HOMICIDE CASES

In Denmark, postmortem CT scanning (PMCT) is performed routinely on all bodies before autopsy [26]. The PMCT images can be examined by a forensic pathologist before an autopsy, and sometimes, in homicide cases, 3D-advanced visualization of injuries can be generated from the PMCT images. 3D models of bones, internal organs, and bullet paths can be generated from PMCT data using imaging post-processing software, such as Mimics or 3D Slicer. Blender is another software used to visualize and manipulate 3D models; in particular, it is used in Aarhus to illustrate a case of dismemberment (L.W.T. Boel, personal communication). This ensures accurate documentation of medical findings and generates reports in a more intuitive manner. Furthermore, 3D models of victims, including their lesions, are permanent datasets that can be reviewed at any time, if needed [27-29].

STATURE ESTIMATION OF PERPETRATORS USING CLOSED-CIRCUIT TELEVISION (CCTV)

Stature might be an important factor when identifying a criminal using surveillance cameras [1,7,30]. This is especially true when the perpetrator's stature is above or below the population's average. At the Department of Forensic Medicine in Copenhagen, we can estimate a suspect's stature using video frames by applying the photogrammetry technique. 3D models of the area of interest are created using photogrammetry [31]; then, the video frame showing the suspect(s) can be oriented and scaled based on the information from the 3D models of the scene, and measurements of the suspect's stature can be extracted. We can provide an estimate of the suspect's height, expressed as an interval that can vary from ± 4 cm to ± 15 cm. The interval considers the many factors that can influence stature, such as 1) technical uncertainties in the 3D models of the scene due to the quality of the video and the precision in the orientation of the video frames; 2) uncertainties resulting from the suspect's posture (a person's stature is their vertical height from the floor to the top of their head when they are in an upright position with their feet together and knees extended, but this position rarely occurs in our natural movement

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patterns, so it must be estimated); and 3) uncertainties due to the presence of headwear or footwear on the suspect.

The police may be interested in estimating a suspect's height in cases of robbery, homicide, attempted murder, or assault. In the last couple of years, we have dealt with around four to five cases annually. The amount of time needed to complete the workup can vary greatly, from two (e.g., one suspect and one crime scene) to seven days (e.g., four suspects and two crime scenes).

SPECIAL TASKS

As forensic anthropologists, some of us are members of the Danish Disaster Victim Identification (DVI) team. This means that our skills and competences can be requested in situations such as mass disasters (natural, terror-related, or accidental) or genocide investigations (mass graves) [32-34]. The presence of forensic anthropologists on DVI teams has proven to be a valuable asset [35], as we can assist, for example, in identifying bone and tooth fragments from among other materials, separating human and nonhuman remains, identifying and managing comingled remains, constructing biological profiles, and identifying other traits (e.g., previous fractures, disease, or anatomical variants) that can help in the identification of human remains [35-37]. To date, forensic anthropologists in Copenhagen have been involved in several international missions to, for example, Kosovo and Iraq and in national tasks involving mass disaster investigations.

Forensic anthropologists with expertise in forensic imaging can also play a key role in the interpretation of radiological images (e.g., by distinguishing bone and tooth fragments from other materials or assisting in reconstructing bullet trajectories) [35,38-40]. Indeed, imaging methods such as radiographs and PMCTs are increasingly used during DVI operations [41].

FORENSIC ARCHEOLOGY

Forensic archaeology is a relatively new field of expertise in Denmark, and relevant cases are rare. Until now, there have been only one or two cases per year. Historically, crime scene investigations involving excavations have been, and to some degree still are, handled by crime scene investigators from the Special Crime Unit or local police districts without formal archaeological training. The former has a dedicated support function in relation to criminal investigations in police districts. They supply specialist competences and possess the methods, tools, and techniques that are necessary for investigative work. It is the local police district that finances the investigation; this includes any use of outside specialists (e.g., archaeologists, anthropologists, and pathologists), even though the request is made through the Special Crime Unit. However, there is a standard agreement between the three forensic departments and the National Police that a forensic pathologist should provide support when required by the local district police.

In the early 2000s, the first use of archaeologists at a crime scene in Denmark was initially characterized by personal contacts, but since 2010, there has been a formal collaboration between two archaeologists from the Moesgaard Museum in Aarhus and Special Crime Unit [42]. The decision to have a forensic anthropologist attend a recovery site is not left up to the police; rather, it depends solely on the forensic pathologist/supervisor on call. Participation in a scene of recovery involving skeletal remains or burned remains has, until recently, traditionally been handled by forensic pathologists. This has been the case in part due to tradition but also due to a lack of awareness among forensic pathologists of what and how anthropologists and archeologists can contribute to the recovery scene. This tradition is slowly changing due to knowledge sharing and teaching, and archaeologists and anthropologists are now more often involved in recovery scenes.

An official excavation work group was established in 2015 under the leadership of the Special Crime Unit. The group is represented by five police officers from the Special Crime Scene Unit, a police officer from the National Police Dog Training Center, two archaeologists from Moesgaard Museum, one forensic anthropologist from the Department of Forensic Medicine, University of Copenhagen, and a forensic pathologist from the Department of Forensic Medicine, the University of Aarhus. The group aims to refine the methods and procedures used in relevant criminal investigations. However, it also seeks to encourage knowledge sharing through excavation exercises and lectures to ensure that both police, archaeologists, anthropologists, and pathologists are better equipped professionally and qualified to handle these cases. The group has also joined the European forensic archaeology network, the European Network of Forensic Science Departments (ENFSI), and it has hosted forensic archaeological courses and meetings (e.g., the European Meeting of Forensic Archeology [EMFA]) to further develop the field of forensic archaeology in Denmark and strengthen related interdisciplinary collaborations [42]. Throughout the years, the group has participated in numerous "hands-on" training excavations all over Europe under the auspices of the ENFSI Scene of Crime – Subgroup Forensic Archaeology and is working together with the other members of the organization to create a best practice manual for forensic archaeology. Concurrently, the ENFSI is working on a European accreditation protocol to further strengthen the quality of archaeological fieldwork [43].

SKELETAL COLLECTIONS

The departments in Copenhagen and Odense curate large human osteological collections for Danish museums. The majority of archaeologically excavated remains end up at these two departments for analysis and curation. The collections provide the basis for comparative studies, and new research methods, such as isotope analysis [44-47] and DNA analysis, are helping to reveal Denmark's prehistory [48,49]. The collections are also used for training students during the courses in biological anthropology (see below session "education and research").

The anthropological skeleton collection in Copenhagen

The collection consists of around 30,000 skeletal remains found at Danish archaeological sites, but it also contains materials from other countries, including Greenland, the Faroe Islands, Egypt, and the near East. The

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collection covers the entire geography of Denmark and represents all of Denmark's prehistoric and historic periods, from the Mesolithic to the 18th century. Its globally recognized uniqueness is partly due to its scope and partly due to the thoroughness of its archaeological documentation. The anthropological skeletal collection is managed by the Laboratory of Biological Anthropology at the Department of Forensic Medicine in Copenhagen.

The anthropological skeleton collection in Odense

This collection consists of more than 16,500 skeletons from all periods, although primarily from the Danish Middle Ages to the preindustrial period, and it contains material mostly from Funen and Jutland. It is managed by the Biological Anthropology Unit at the Department of Forensic Medicine, University of Southern Denmark in Odense, called Antropologisk DataBase Odense Universitet (ABDOU).

EDUCATION AND RESEARCH

There is no academic degree in forensic anthropology or forensic archaeology in Denmark. The extant practitioners in forensic anthropology (of which there are six in Denmark) come from different educations, which can include a biological, medical, or archaeological academic degree from a Danish university or a degree in natural sciences or physical anthropology from a non-Danish university. Three forensic anthropologists are employed at the Department of Forensic Medicine in Copenhagen, two in Odense, and one in Aarhus. In Aarhus, the person responsible for the anthropological examinations is the chief pathologist.

The University of Copenhagen offers lectures in human osteology, forensic anthropology and archaeology, and 3D imaging technologies to students of medicine, archaeology, and biology, as well as to medical doctors specializing in forensic pathology. We also offer introductive courses on this topic to the public under the framework of the Folkeuniversitetet. A book on basic osteology and biological anthropology written in Danish and Swedish was published in 2008 as part of the Nordic effort to produce a book on the topic in Scandinavian languages [14].

The University of Southern Denmark (SDU) offers an extended (two-term) BA elective course and training in biological anthropology to students from different academic backgrounds, mainly archaeological, biological, or historical studies. ADBOU provides individual scientific lectures on forensic anthropology to medical students, and, as in Copenhagen, more general introductions to the topic are provided to the public. Until now, ADBOU has held three international summer or field schools. The first field school, held in 2015, focused on the topic of age estimation using skeletal remains (in cooperation with the Max Planck Institute for Demographic Research, Rostock), while the Hågerup Bioarchaeology Field Schools in 2018 and 2019 (together with Øhavsmuseet in Fåborg) taught students how to excavate skeletons and establish biological profiles. These courses encouraged several participants to choose a career in forensic anthropology. Since 2019, several workshops on the new age estimation technique Transition Analysis 3 have been conducted at American forensic science conferences or at SDU in Odense.

All three institutes offer dissertation projects in several aspects of forensic and biological anthropology and forensic imaging to undergraduate and master's students. Ph.D. projects are also available.

Research is largely based on skeletal material from collections and data acquired during requisitioned work (CT scanning). In many cases, our research has been inspired by the needs we encounter in our daily work (e.g., the improvement of existing methods). We also collaborate with national colleagues, and institutions outside our field of expertise, such as those related to veterinary [50], human evolution [51,52], paleontology [53-55], and cultural heritage [56,57].

Based on archeological skeletal material, we conduct research into, for example, health and diseases of past populations [58-67], trauma [68] dietary habits of the past [46,47], migrations [44], human morphology [69,70]. Based on PMCT scans, we also conduct research into, for example, age estimation [11,71,72], cranial trauma [21-23], 3D documentation and virtual reconstruction [27,73,74], 3D printing [75]. We are often involved in the study of mummies [76-79].

In Odense in particular, research has focused mainly on two areas: method development and the health of past populations. For more than 20 years, testing and developing methods to estimate the age at death of skeletons has been one of the cornerstones of ADBOU's work. This has resulted in the development of three different methods, all of which have proved to be more precise than older procedures [20,80-85]. A method for estimating sex from the humerus and femur head diameter was also published [86]. Work on the health of past populations is centered on infectious diseases and changing mortality patterns [64,87,88]. However, it also includes aspects of forensic interest, such as the risks of cranial vault trauma or interpersonal violence [89-91]. ADBOU has a long tradition of cooperating with universities abroad, and large parts of its forensic research, especially regarding age and sex estimation, were conducted with Penn State University (the United States), the University of Manitoba (Canada), and the Max Planck Institute for Demographic Research (Germany). These projects received funding from the U.S. National Institute of Justice, the U.S. National Institute of Health, and the U.S. National Science Foundation. ADBOU hosts international scientists on a regular basis, a collaboration that has resulted in several Ph.D. theses and articles in forensic anthropology.

CONCLUSION AND FUTURE PROSPECTS

There are relatively few forensic anthropology and archeology cases in Denmark. To continue to deliver cutting edge content in the future, we should continue to conduct high-quality research. Our research ideas are mostly prompted by the demands related to requisitioned work or have been inspired by them. We should develop unbiased, precise, and accurate methods, testing inter- and intra-observer variation and statistical variance. We need to redefine methods based on population-specific standards and test existing methods on the Danish population. We can do this both by using archeological skeletons and, more importantly, by using data from the recently deceased. PMCT data should be used for the development of varying aspects of biological profiles and trauma analyses. Finally, we

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should continue our professional training by attending scientific meetings and courses offered by, for example, the Forensic Anthropology Society of Europe (FASE), a subsection of the International Academy of Legal Medicine, and the network of forensic archaeologists in Europe (EMFA/ ENFSI) mentioned previously.

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