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The importance of Human Anatomy in Forensic Anthropology

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SUMMARY

How important is anatomy in forensic anthropological analysis and caseworks? This basic question needs to be addressed in a monograph on forensic anthropology, especially if it is published in an anatomical journal, as is this case. Therefore, the main objective of this study is to analyse the importance of human anatomy in forensic anthropology. This is done by a literature review taking into account two perspectives: a historical perspective and a practical perspective. The historical perspective refers to the evaluation of the common history of human anatomy and forensic anthropology. The practical perspective refers to the evaluation of three practical points: (i) the role of forensic anthropology, (ii) the ten basic questions to be answered in any osteological study firstly defined by Ubelaker (1988), and (iii) five practical forensic anthropological cases. Results showed an intrinsic historical relationship between human anatomy and forensic anthropology. This inherent relationship between forensic anthropology and human anatomy is evident in the analytical procedures and the development of any forensic anthropological case. In fact, the relationship between both scientific fields is indubitable. Human anatomy is basic in forensic anthropology. A forensic anthropologist must have a wide and sound understanding of human anatomy, embracing foetus, new-born, infantile, juvenile and adult individuals. This is extremely important to resolve each case. Therefore, universities, which offer a degree in forensic anthropology, whether medical, biological, humanities and social sciences, should provide students with an extensive foundation in human anatomy.

Key words: Human morphology – Osteology – Non-adults – Adults – Forensic anthropology

INTRODUCTION

How important is anatomy for forensic anthropologists? This is a basic question that needs to be addressed in a monograph on forensic anthropology, especially when the monograph is published in an anatomical journal, as is this case. This question points directly to the current discussion of how a forensic anthropologist should be educated academically, which has been formulated by Sue Black and Soren Blau (Blau, 2016a). This paper starts posing the aims and scopes of both disciplines as a basis to discuss the relationship between forensic anthropology and anatomy.

Strictly speaking, forensic anthropology is the application of biological anthropology knowledge to legal cases (Black, 2008). Biological

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anthropology is the new term for physical anthropology. Currently, textbooks and academic departments mostly use the term biological anthropology instead of physical anthropology. The term of physical anthropology evokes antiquated focuses of the discipline, as for example racial typology. This is what caused the American Association of Physical Anthropologists to vote in favour of changing its name to American Association of Biological Anthropologists, in 2019. Therefore, biological anthropology is the scientific field that studies the human being from a biological perspective. Biological anthropology includes: the study of human and non-human primate morphology and evolution, human morphological development, human morphological variability and adaptation to different environments, human genetics and the biological bases of human behaviour (Valls, 1985; Ellison, 2018; Sanabria, 2019). The study of past populations of fossil hominins and non-human primates are basic to understanding: (i) the diversity within and between human populations; (ii) the course that human evolution has taken; and (iii) the processes that have brought about human evolution (Washburn, 1951; Valls, 1985; Ellison, 2018; Sanabria, 2019). Consequently, forensic anthropology refers to the study of living or dead humans, or what remains of the human, for medico-legal purposes (Black, 2008; Black et al., 2010; Wilkinson and Rynn, 2012; Cummaudo et al., 2014). In 2004, Red Cross developed the concept of humanitarian forensic actions (forensic humanitarianism) to guarantee that those who die in war, disaster and other complex emergencies are treated with dignity and do not become missing persons (Cordner and Tidball-Binz, 2017, Parra et al., 2020). Humanitarian cases (humanitarian forensic actions) are also included within the term of forensic anthropology (Cordner and Tidball-Binz, 2017, Parra et al., 2020). The terms of forensic osteology and forensic anthropology are often confused and interchanged (Black, 2008). Forensic osteology, as its name indicates, refers to that information recovered from the skeleton (Black, 2008). Forensic osteology is a sub-area of forensic anthropology, which in turn is a sub-specialty of biological anthropology.

Anatomy is a branch of biology. Anatomy focuses on the study of animal morphology and their variations (Rosse and Gaddum-Rosse, 1997). It provides a universal language for understanding how and why form supports function. Anatomy is intrinsically tied to developmental biology, embryology, comparative anatomy, evolutionary biology, and phylogeny, as these are the processes by which anatomy is generated over immediate (embryology) and long (evolution) timescales (Rosse and Gaddum-Rosse, 1997). The discipline of anatomy is divided into macroscopic and microscopic anatomy. Macroscopic anatomy, or gross anatomy, is the examination of animal body parts with the naked eye. Gross anatomy also includes the branch of surface anatomy (the study of the external features of the body of an animal). Microscopic anatomy or histology involves the study of the tissues of various structures and cells by optical instruments (Rosse and Gaddum-Rosse, 1997). Gross anatomy can be divided in systematic anatomy and regional anatomy. Systematic anatomy examines the body taking into account systems separately such as skeletal, vascular, digestive, lymphatic, etc. Regional anatomy examines the different systems as a whole located in a particular region of the body such as the head, chest, upper limbs and foot, etc. Human anatomy is of special interest within human biology, corresponding to a great conceptual framework that furnishes information to understand the human living or dead body. A general understanding of the systems of the body aids in an appreciation of a more detailed interrelationship between parts and regions. Consideration of the functional and clinical aspects of the human anatomy provides a better background on which to build human body knowledge. In current anatomical journals, there can be seen different published papers on cell biology, tissue architecture, neuroanatomy, evolutionary developmental biology, comparative functional morphology, evolutionary morphology, forensic anthropology, integrative vertebrate palaeontology, and palaeoanthropology, among others (see the web pages of different anatomical journals such as the European Journal of Anatomy, Journal of Anatomy, Anatomical Record, and Journal of Anatomical Science and Research, among others).

The objective of this paper is to evaluate the importance of anatomy in forensic anthropology using two different perspectives: a historical perspective and a practical perspective. The historical perspective refers to the common history of both sciences. The practical perspective refers to the analysis of three practical points: (i) the forensic anthropologist role; (ii) the 10 basic questions to be answered in any skeletal study firstly described by Ubelaker (1988); and (iii) the analysis of some forensic anthropological cases.

MATERIALS AND METHODS

A literature review of the history of human anatomy and physical (biological) anthropology, of the role and techniques of forensic anthropologists and of all published forensic anthropological cases was undertaken in bioanthropological, anatomical and forensic publications such as anthropological reference books as those of Brothwell (1962), Scheuer and Black (2000), Klepinger (2006), Ubelaker (1988), Komar and Buikstra (2008), Drikmaat and Cabo (2012), and Barone and Graen (2018), among others, and scientific journals such as American Journal of Physical Anthropology, American Anthropologist, Journal of Forensic Sciences, International Journal of Legal Medicine, Clinical Anatomy and Journal of Anatomy, among others. The search was structured from two perspectives: a historical perspective and a practical perspective. The historical perspective consisted of a review of the common history between forensic anthropology and human anatomy. The practical perspective included a search of forensic anthropology methodological/research papers. In these last papers, three types of assessment were done, which are: (1) the analysis of the role of forensic anthropologists; (2) the analysis of the 10 basic questions to be answered in any skeletal study firstly defined by Ubelaker (1988); and (3) the analysis of five forensic anthropological cases in which the importance of human anatomy in their resolution is evidenced. In fact, every forensic anthropological case is useful to evaluate the importance of human anatomy in their resolution. However, because of the great quantity of cases found in the anthropological literature, only five of the most engaging cases were chosen.

RESULTS

For a better comprehension of the text, the findings of this study have been split into four different sections, according to the different areas of search and discussed topics, and these are set up below.

Historical relationship between forensic anthropology and human anatomy

Physical (biological) anthropology had its origin in the 18th century with George-Louis Leclerc (Buffon) in France and Johann Friedrich Blumenbach in Germany, who created, respectively, the French and German Schools of physical anthropology (Varéa and Tomás, 2014). Buffon introduced the concept of "race" in the study of human variability and was the author of the *Histoire Naturelle, générale et particulièr,* which had a great influence among Naturalists. Blumenbach used the term anthropology in a non-philosophical sense, but as a naturalistic study of the human being for first time. He applied his comparative anatomical methods to his classification of human "races", of which he claimed there were five: Caucasian, Mongolian, Malayan, Ethiopian, and American. At this point, it is necessary to remark that, currently, the term "race" is not biologically accepted, because genetic differences between both sexes are greater than the genetic differences between different human populations (Lewontin, 1972; AAPA, statement on race, 1996; Relethford, 2003). Nowadays, to refer to different human groups, we use the terms populations or ancestry. After this clarification, and continuing with the historical relationship between forensic anthropology and anatomy, in the 19th century the French anatomist Paul Broca was awarded the first Chair in Physical Anthropology in the University of Paris. In the same century, a Spanish disciple of Broca, Federico Olóriz, was awarded the Chair in Human Anatomy in the Complutense University of Madrid and was responsible for introducing physical anthropology research in Spain (Valls, 1985; Reverte-Coma, 1991). Olóriz is well known

for his studies on the Spanish cephalic index and the creation of a Spanish cranium collection consisting of 1900 individuals. He is also famous for introducing fingerprint analysis as a human identification technique in Spain. At the end of the 19th century, in Europe, physical anthropology had crystalized enough to be recognized as a scientific field of research, and because of this, in this period, different publications and associations in physical anthropology were created. In 1865, the Spanish Anthropological Society was founded by the Spanish anatomist Pedro González; and in 1874, he also created the first Spanish anthropological journal called *Revista de Antropología* (Arquiola, 1981). Other names that are renowned in this period in Spain are Ángel Pulido Fernández and Manuel Antón Fernández, both from the Central University of Madrid (Márquez-Grant et al., 2011). In the rest of Europe, important names are Retzius, from the Karolinska Institutet (Sweden), de Quatreforges, from the Museum National d'Histoire Naturelle in Paris, and Topinard, from l'École d'Anthropologie also in Paris. In America, Hrdlička, educated in medicine and disciple of Topinard, created in 1918 the American Journal of Physical Anthropology and, in 1920, the American Association of Physical Anthropology (Shapiro, 1959, Brickley and Ferllini, 2007).

Current forensic anthropology originates from these first USA physical anthropologists such as Hrdlička, Dorsey and Tood (among others), who were intermittently asked to provided human identification services for the police (Kerley, 1978). In addition, the Second World War and Korean War gave the opportunity for trained physical anthropologists and anatomists to contribute to the recovery, identification, and repatriation of USA soldiers' remains (Dirkmaat and Cabo, 2012). In this period, research on different identification indicators were also developed by physical anthropologists such as Troter and Gleser (1952), McKern and Stewart (1957), and others, increasing skeletal knowledge (Dirkmaat and Cabo, 2012). In 1970, forensic anthropology was recognised as a new scientific field in the USA. This was influenced by Krogman's series of papers published in the *FBI Law enforcement Bulletin* (Dirkmaat and Cabo, 2012). In 1972, the American Academy of Forensic Sciences opened the Physical Anthropology Section (Dirkmaat and Cabo, 2012). In the eighties, forensic anthropology was increased with caseworks of human rights and abuses. Two examples of this are El Equipo Argentino de Antropología Forense (Argentine Forensic Anthropology Team) and forensic anthropologists international missions involved in the international criminal tribunal for the former Yugoslavia war crimes. At the end of the 20th century, forensic anthropology was well known in the world. Educational and training courses in forensic anthropology were asked in the different universities of the different countries, and the forensic anthropologist's skills were increased from bones to decomposed, burned, and fully fleshed remains, and even occasionally the living (Dirkmaat and Cabo, 2012). At this point, it is necessary to say that, sometimes, forensic anthropology is also called forensic physical anthropology to avoid confusing it with other anthropological actuations related to social anthropology and that sometimes are also called forensic anthropology (Márquez-Grant, 2018).

Nowadays, in Europe, physical (biological) anthropology, including forensic anthropology, is mostly located in Biological Sciences Faculties such as in the University of Barcelona (Spain), Pompeu Fabra University (Spain), the Autonomous University of Barcelona (Spain), University of Athens (Greece), University of Liverpool (UK), Durham University (UK), Bournemouth University (UK), Universität Hildesheim (Germany), and Masaryk University (Czech Republic), among others. There are also some groups focused on forensic anthropology (and human osteoarchaeology) in archaeological or anthropology schools such as the University of Leicester (UK) and Kent University (UK). There is also the Cranfield Forensic Institute in Cranfield University, which is a Defence Academy of the United Kingdom. In Canada, USA and Australia, departments of biological anthropology are in the anthropology school along with cultural anthropology (Blau 2016b), such as Simon Fraser University (Canada), University of Toronto (Canada), University of Nevada (US), University of

Illinois (US) and Australian National University (Australia), among others. In South America, the forensic anthropological groups are also in social anthropology departments; however, in these last cases, the objective is usually the study of archaeological human remains, except in some universities where forensic anthropology is closely related to victim identification (Sanabria, 2019). In all these countries, most forensic anthropologists are academically educated in social anthropology, and for this reason they are asked to be accredited by Forensic Anthropological institutions (Blau, 2016b; Sanabria, 2019). In the world, there are also some departments or units of forensic anthropology located at medical or health sciences schools such as the University of the Basque Country (Spain), the University of Granada (Spain), Loughborough University (UK), Centre Universitaire Romand (Switzerland), Boston University (US) and Antonio Nariño University (Colombia), among others. According to the American Association of Physical Anthropology, currently, around one in eight physical anthropologists have some professional affiliation with a medical school, usually in a department of anatomy. Some examples of current anatomists working on forensic anthropology or osteology in Europe are Sue Black from Lancaster University (UK), Francisco Pastor from the University of Valladolid (Spain) and myself from the Rovira i Virgily University (Spain), among others. Nowadays, there is the discussion about what discipline offers the best basis to form forensic anthropologists. The question is whether forensic anthropologists should be educated in medical or biological schools with a focus on anatomy or in humanity schools, which can offer relevant technical and social skills (Blau, 2016a).

It is clear that there is an intimate historical relationship between biological anthropology (and forensic anthropology) and human anatomy, and that the discipline of biological anthropology in part originates from human anatomy. However, biological anthropology also has the historical influence of zoology through naturalists. This last relationship is evidenced by both (1) the importance of human variability in biological anthropology and (2) the location of biological anthropological units in zoology departments when it is in a biology school, in Europe. On the other hand, zoology is in part animal anatomy. Zoology studies the animal form and structures, a part of their physiology, and this is included in the definition of anatomy, as it has been seen in the introduction.

The role of a forensic anthropologist

While a forensic pathologist applies his/her medical knowledge to establish the manner and cause of death through necropsies and the analysis of the corpse at the crime scene, the task of the forensic anthropologist mainly focuses on searching, recovering and identifying human remains. The objectives of a forensic pathologist are to know the types and cause of wounds, and causes of unexplained death, whether suicide, accidental, natural or violent. The objectives of the forensic anthropologist are to: (i) assist in the location and recovery of human remains, (ii) seek to provide an opinion on post-mortem interval, (iii) evidence of any foul play and (iv) analyse the human remains. They look for the morphological particularities of the individual, dead or alive, intact or fragmented, to determine the biological profile (anatomical parts which are present; age, sex, ancestry, and height, etc.), as well as to contribute to the reconstruction of the facts by means of the taphonomic principles and techniques, to answer legal questions (Velho et al., 2012). Taphonomy is the science that reconstructs past events or processes that lead to the formation of associated biological remains (Lloveras et al., 2016; Pokines and Baker, 2013). The contribution of taphonomy in forensic anthropological cases is seen in the third (Cultural factors influencing the identification) and fourth (Córdoba kids) cases exposed in the Forensic Cases as Evidence section in this paper. Currently, new trends in forensic anthropology are developing, due to the increasing role of forensic anthropologists in crime scenes. There is an increasing role of: DNA analysis, forensic archaeology, forensic taphonomy and trauma; and the human remain analysis can be done directly on bone or indirectly through imaging and remotely. These developing trends and techniques led to the creation of

new specialisations. In past times, one forensic anthropologist may have analysed all the human remains of a case. Currently, different forensic anthropologists with a variety of specialisations such as histology, trauma, taphonomy, age at death, craniofacial reconstruction, etc. can be found working on the same case.

In live individuals, forensic anthropology can be applied in complex cases, as for example in ambiguous genitalia (França, 2011) and in cases where there are doubts on the age of criminal responsibility of the criminal subject, when it is necessary to estimate the age of the individual (Silva et al., 2008). These methods of age estimation can also be applied in cases of border control, migration and human trafficking (Scheuer and Black, 2000; Doyle et al., 2019). This is necessary, because the law is different for minors and adults. For forensic cases, as in our social structure, a minor is one who is younger than 18 years of age. However, from a biological point of view a sub-adult individual (a non-adult) is one who is younger than 21 years of age (Rissech, 2016).

In dead individuals, and depending on the police necessities, forensic anthropologists can be asked to estimate the biological profile of skeletonized, mummified, decomposed, mutilated or burned bodies with the objective to identify the individual and to contribute to the determination of the cause of death, identification of the circumstances that caused the death (Silva et al., 2013). However, they can also only be asked to perform trauma analysis, craniofacial reconstruction, etc. or just DNA sampling. Corpses can be classified as fresh (or recent) and complex corpses (Muñoz-Silva, 2019). A fresh corpse is one that has all its soft tissues, and its biological profile is relatively easier to obtain. A complex corpse is one that shows alterations that hinder its identification as a body in advanced decomposition, skeletonization, carbonization or a dismembered body (Muñoz-Silva, 2019). The process of identification of complex corpses is different from that performed in fresh corpses, since complex corpses have conservation states in which there is neither external nor internal genitalia, no face, and no fingerprint. Examples of this are the cases of disrupted human remains of recently deceased individuals derived from a massive disaster or fatal accident, intentional dismemberment or fragmentation following a homicide, or, for example, coming from the results of scavenging activities of predators or showing extreme stages of decomposition or preservation. In these cases, previous information on the individual identity does not usually exist, which complicates the resolution of the case. In some cases, when the search is focused on a particular individual because he or she disappeared or can be the victim of a crime, the remains found have a potential identity (this particular individual), which facilitates the investigation. This allows comparing both DNA obtained from the remains and that from the family members of this particular individual (potential identity). The existence of this potential identity also allows comparing the dental pattern of the unidentified remains (if there is a complete mandible or maxillary) with the previous dental records of the individual that corresponds to the potential identity. Both DNA and dental records will indicate whether the remains correspond or not to this possible individual (potential identity). In the cases where there is not potential identity (a possible individual), bone and dental diagnoses are used in order to construct the biological profile of the corpse/remains (sex, ancestry, age, stature, etc.), which will be cross checked with databases of missing persons. If a possible identity is not found, a facial reconstruction can be done to be shown in the media, just in case it is recognised by someone. In the case that, during the search, a possible identity is got and their possible family members exist, a DNA test will be done between possible family members and the remains.

The ten basic questions to be answered in any skeletal study

Usually, the process of identification of a complex body is based on its bones and teeth because of the lack of soft tissues or because of the advanced state of decomposition. In these anthropological analyses, forensic anthropologists must respond to the 10 basic questions related to those bones and teeth, which are the following (Ubelaker, 1988): (1) Is it a bone? (2) Is it human? (3) Is it modern? (4) How many bones are there? (5)

How many people are there? (6) What biological population does it belong to? (7) Which sex is it? (8) How old is it? (9) How tall is it? (10) What are the individual characteristics of the remains? What pathologies, traumatisms, stress markers and enthesopaties does it have?

The identification of isolated, fragmented or commingled remains, which are habitual in mass disasters and violent conflicts (Mundorff and Vidoly, 2018), can be difficult even for a specialist. Burned plastics and small stones can look like a bone and they can be confused with a bone. The damage to remains can be great, thus making them small and hard to identify. Sometimes, human remains may be commingled with faunal remains and they may have been sufficiently altered by weather elements, cultural practices, or exposed to extreme temperatures, so that anatomical features are not readily appreciated.

Usually, one of the first difficulties to resolve is the differentiation between human and non-human bones. The faunal bones that more frequently are wrongly identified as human are those from deer, bear, pig and dog, and young cow and horse (Ubelaker, 1988). Particularly, and as examples, bear carpal and tarsal bones can be confused with human carpal and tarsal bones. Pig teeth (Fig. 1) can also be confused with human teeth, particularly molars, and some chicken bones can be confused with human perinatal bones (Fig. 2) - A perinatal individual is one who is around birth, between 30 and 42 weeks of gestation. For recognizing human bones, anthropologists use gross bone morphology; however, in these cases of human and non-human bone mixture it is useful to remember that the long bones of most adult animals, which are a similar size to humans, have different bone architecture and thicker and more compact cortical bone (Ubelaker, 1988). In those extremely difficult cases, in which bones are fragmented and also morphologically modified due to some disease, surgery or outdoor exposure, bone microscopic morphology (Histology) can be used. In humans, osteons are dispersed and uniformly distributed in the circumferential laminar bone (layer aspect), while in many animals they tend to line up in rows called osteon bands (Andronowski et al., 2017).

Forensic anthropologists usually do not have to deal with very old material because they usually work on modern individuals belonging to forensic cases. Although sometimes the question about the modernity of a bone is usually reduced to distinguishing whether the remains are modern

Fig. 1.- Some molars and a canine from a common pig.

or archaeological, in these cases the forensic anthropologist has to look around the remains observing the context and the stratigraphy of the site. However, the limit between modern/forensic and archaeological can be a small boundary, which varies between different countries in a range of 30 to 100 years, and because of this some remains such as those of the Spanish Civil War are between forensic and archaeological (Márquez-Grant et al., 2011).

When the skeletal remains are indeterminate in that they cannot be associated with any particular skeleton, the forensic anthropologist calculates the minimum number of individuals (MNI). This is done by taking into account the number of repeated bone elements. That is to say, forensic anthropologists classify the bones by taking into account their morphology (joint congruence, same pathological set and symmetry of even bones), colour, sex and degree of maturation. This classification allows one to estimate the MNI present in the sample (Brothwell, 1987; Bradley and Byrd, 2014).

The estimation of sex and age-at-death is based on the morphological differences observed between men and women at different ages (sex differences) and on the morphological differences in each maturational stage (age differences) for each sex. In adults, where secondary sexual features have developed, sex estimation is relatively easy. However, in sub-adults, particularly in children, foetuses and perinatal

Fig. 2.- Perinatal human clavicle (at left) and chicken humerus (at right).

individuals, sex estimation is difficult, because in these immature individuals the secondary sexual features (robustness of the bones, muscular insertions and the features that give amplitude to the pelvis) have not developed yet (Scheuer and Black, 2000; Rissech, 2016). Contrarily, in sub-adult individuals age estimation is more precise, because they are growing, and changes occur in predicted times (Scheuer and Black, 2000; Rissech, 2016). In adults, growth (quantitative process expressed by an increase in body size and number of cells) has finished and the maturation process (qualitative process expressed by changes in the structure, composition and functioning of cells, organs and body in their conjunct) continues; however, this maturational process is less genetically controlled than in sub-adults. This contributes to an increase in the variability of the morphological changes due to ageing, which in turn contributes to the increase in the age estimation error (Rissech, 2016). To help to diminish the error of estimation, in 2019 the IDADE2 web page was created. This is a free web, which allows estimating the age at death based on probabilities and Bayesian inference (Rissech et al., 2019). In fact, adult age estimation is a difficulty to be resolved, because our population lives long and the older a person is, the bigger the estimation error. In addition, the best-known adult age estimation methods such as Todd (Todd, 1921), Lovejoy (Lovejoy et al., 1985), Suchey-Brooks (Brooks and Suchey, 1990), Hartnett (Hartnett 2010) and other, are up to 60 or 70 years of age, depending of the methods. This limit of age makes difficult to estimate age of the most elderly individuals, increasing the error of estimation (Rissech, 2016). Therefore, to have an accurate adult age estimation, morphological age changes need to be precisely and meticulously evaluated by the forensic anthropologist. Usually, she/he needs specific training in adult age estimation to be competent in this technique (Rissech, 2016).

The estimation of stature and ancestry is part of the identification process of a non-identified skeleton or of dismembered body parts. Even though measurements of body parts such as a vertebra or a metacarpal bone can be used to estimate the stature, the use of long bones is preferable, because they are intrinsically related to stature, particularly femur (Rissech et al., 2008). Estimation of the stature is done by the application of equations in which the length of the bone is introduced as variable and the equation gives you a result, corresponding to the stature of the individual. There are several equations to be used. The best-known are those of the Trotter and Gieser (1952) based on USA samples. However, these equations systematically overestimate stature in both female and male skeletons from the Spanish and Italian populations (Formicola, 1993; Formicola and Franceschi, 1996; Lalueza-Fox, 1998). In these Mediterranean populations, the equations of Pearson (1899), based on a French sample, perform better. This is probably due to the intertwined biological population history of French, Spanish and Italian populations (Formicola, 1993; Formicola and Franceschi, 1996; Lalueza-Fox, 1998). Ancestry assessment represents an important part of forensic anthropological analysis. Its interpretation, together with the other aspects of the biological profile, can be clues to narrow the search for missing persons and facilitate positive identification of the remains. The skull, particularly the mid region, is universally accepted to be the most informative region in relation to ancestry (Cunha and Hubelaker, 2019). However, there is not a single trait that can be found only in a single population. This is due to human variability. Forensic anthropologists use multiple traits as a guide to the most probable biological origin. The list of skull non-metric traits is particularly large: they can be found in Hauser and De Stefano (1989) and Hefner (2009). In addition, Hefner and Ousley (2014) created OSSA a statistical programme which quantifies the probability of belonging to a given population for a particular individual. Cranial and postcranial metric traits can also be used for ancestry assessment. FORDISC software based on a maximum of 34 cranial and 39 postcranial measurements and through discriminant functions is able to classify individuals according to their ancestral group (Ousley and Jantz (2013).

Pathologies, traumatisms, stress markers and enthesopaties are useful to help to individualise

individuals (Ortner, 2003). They can be like a mark, which differentiates a particular individual from a group of individuals that share similar characteristics such as sex, age, ancestor, stature and skeletal constitution.

In spite of all of these anthropological techniques and methods, sometimes the answer to these ten questions can be obstructed by the influences of several factors such as humans, animals, plants and weather elements. This is the field study of taphonomy.

The influence of taphonomic agents on bones

There are several factors that can morphologically modify the bones such as human (cultural or criminal), animal, plant and environmental influences. Cultural modifications can be intentionally or non-intentionally done in live individuals or after death. The intentional modifications are usually due to cultural or aesthetic reasons such as the cranial deformations (Reina et al., 2016), and incisions and inlays in teeth (Ubelaker, 1988; Ferré, 2013). However, they can be also criminal modifications such as bone cuts and cut marks which can be related to dismemberment, skinning, disarticulation, defleshing or scraping (Botella et al., 1999; Lloveras et al., 2016). The non-intentional modifications are usually related to non-intentional behaviours, as for example the custom of squatting which causes the squatting facets in the distal epiphysis of the tibia (Ubelaker, 1988). The human modifications that originated after death are usually related to the burial process or other rituals. However, they can also be of criminal origin, for example to hide identification of the victim. Particularly, in this last case, lack of knowledge of the morphological results of these processes can lead the forensic anthropologist to an inaccurate interpretation of the bones observations (and thus the sequences of facts that occurred in the crime) and leave, for example, the victim unidentified, favouring the criminal.

Animals, plants, and weather elements can also modify the bones. Animals can usually fragment and move the bones, and crush the epiphyses. They can also leave beak, tooth and digestion marks. Plant activity can importantly affect human remains, causing different types of chemical and mechanical alterations, and affecting the survival of the remains (Lloveras et al., 2016; Pokines and Baker, 2013). Exposure of skeletal remains to weather elements can lead to the gradual decomposition of bone materials as a result of chemical and mechanical transformations supported by different agents such as sun, wind or rain, as well as temperature and humidity variations (Lloveras et al., 2016). The main feature of the actuation of these factors is the whitening of the bone. The appearance of longitudinal and parallel fissures/cracks, the exfoliation of the bone surface (Fig. 3), and the appearance of a fibrous and rough texture are also the result of weather elements (Lloveras et al., 2016; Pokines and Baker, 2013). In addition, pathologic influences can modify the morphology of the bones, hindering the identification of bone type and the species to which it belongs. To know how to interpret all these types of morphological modifications suffered by bones is absolutely necessary to resolve forensic anthropological cases (or to interpret archaeological bone remains). This taphonomic knowledge is necessary to identify correctly the remains and to reconstruct possible sequences of the facts, as will be shown below in the Forensic Cases as Evidence section in this paper.

Forensic cases as evidence

Five forensic cases illustrate the application of these previously exposed concepts and demonstrate the significance of human anatomical knowledge for forensic anthropologists

Case 1 – The bone recognition and inconclusive identification (Modified from Ubelaker 1988)

In a street in Chicago, some small fragments of bone were found in a human blood puddle. Circumstantial evidences suggested that a man had been shot in the head. In addition, the microscopic structure of those small pieces of bones was compatible with human cranial bone microscopic structure. However, the observation of osteons distribution with a similar pattern to other animals made the identification inconclusive.

Fig. 3.- Frontal of adult horse showing the effects of weathering. Whitening and flaking of outer bone layers are observed.

This case evidences the importance of human anatomy (both gross and microscopic anatomy) in forensic anthropological cases. In addition, this case also evidences the difficulty that can exist in the assessment of small pieces of bones and their importance in resolving forensic cases. However, as in this case, sometimes, the difficulty of recognising bones can lead us to an inconclusive identification.

Case 2 – Cultural factors influencing the identification (Modified from Ubelaker 1988)

In Alaska, a bone fragment without epiphyses, displaying a non-consolidated fracture, was found. The fracture had been surgically treated by a metallic plaque. Bone growth around the plaque indicated that the surgery had taken place a long time previously. Therefore, and because of the surgery, it was assessed as human. However, efforts to find the surgeon were fruitless. In the end, a microscopic analysis of the osteon pattern was carried out. Results revealed a band pattern like that of a big dog, indicating that the surgeon was a veterinary.

The conclusion of this case is that we cannot get carried away with the appearances of the case. The most important thing is the anatomy and the anatomical observation, in this case the morphology of the osteons.

Case 3 – Comparative anatomy, documented faunal collection complementing the identification (Modified from Ferreira da Silva et al., 2013)

In 2005, some skeletal remains were found in a desert area of North America. These remains were initially attributed to a missing person who possibly was the victim of a homicide. The skeletal remains consisted of four bones and one tooth. Three of the bones were long bones with fused epiphyses, compatible with upper or lower limbs. These three long bones did not display any point of fracture. The fourth bone was the smallest bone. It was fractured irregularly and was compatible with a vertebra fragment. The

tooth had one root with a curve, compatible with a canine tooth. Through the morphological analysis of these four bones, mainly epiphyses and mussels origin and insertions areas, it was concluded that it was a non-human origin, belonging to an adult animal of medium size. The analysis of the tooth indicated that it had different size and shape from a human adult canine tooth, which reaffirmed the non-human origin.

To determine the animal specimen from which the skeletal elements came from and in order to be sure of their faunal origin, these bones were morphologically compared with a documented faunal collection. Results indicated the compatibility of the forensic material with the tibia, femur and canine tooth of a domestic dog of medium size (*Canis lupus familiars*).

This case, apart from indicating the importance of human anatomy in any forensic anthropological study, also indicates the importance of the comparative anatomy and the documented faunal collections to conclude some forensic cases.

Case 4 – Córdoba kids (Modified from Alvarez (2018) and Bravo-Cuiñas (2012)

The case of the Córdoba kids is well known in Spain. On 8 October 2011, a father reported the disappearance of his two kids in a Park in Córdoba city in Spain. He stated that someone took them in an oversight when he went to his car for a moment. The kids were siblings a 6 year old girl, and a 2 year old boy. The father had taken the two kids to spend the weekend with them at his family farm. He had agreed this with his wife with whom he was in the process of separation. That day, whilst the children were eating lunch in the father's family farm, he took the opportunity to burn memories of his coexistence with his wife. Pursuant to the father's declaration, when the kids woke up from the nap, he took them to play in the park. At 18.40 hours on this day, he reported the disappearance of the children by phone to the police. However, according to the police's investigations, this call was made from the farm, not from the park. In addition, the security cameras surrounding the park recorded the father alone this day. There was not any evidence that the children had ever been in the park in the afternoon of that day.

On 10 October, the Scientific Police made the first search for the kids in the farm. They found the remains of a large bonfire, where the father had allegedly burned memories and photographs of his marriage. In this bonfire, there were also some skeletal remains. The forensic anthropologist of the Scientific Police reported that these bones corresponded to a dog. On October 11 and 12, the search of the kids was intensified in the farm and surroundings. Results were null.

After eleven months of no results, the mother's family asked for a counter-report on the bones found in the bonfire of the farm by an independent forensic anthropologist. This new forensic anthropologist was well known as a judicial expert in many judicial proceedings, inside and outside Spain, including cases of torture by the Spanish law enforcement agencies. In the Córdoba kids case, this new anthropologist analysed about two hundred pieces of bone and nine teeth (Fig. 4). He concluded that they were the remains of two children between two and six years of age. This report resulted in the Police Commission asking for a third anthropological analysis of the farm's bones by another well-known independent anthropologist. This last anthropologist was expert in children's teeth and bones. The conclusion of this third anthropologist was the same as that done by the anthropologist appointed by the wife's family: the farm's bones involve bones of two different infantile individuals, particularly teeth and talus (Fig. 4).

According to the report of the forensic anthropologist hired by the wife's family, the father did not make a simple fire, but practically built an oven with bricks and a metal plate to achieve greater combustion. Both the bone colour and the cracks morphology in the bones were evidence of the fire's very high temperature. When the bones burn at high temperatures, they whiten and the cracks are transversal to the longitudinal axes of the bones (Fig. 5). These higher temperatures usually destroy DNA, because of this, this forensic anthropologist asserted that it was impossible to find DNA in these bone remains, which indicated the intentionality of impeding to check DNA between bones and kid's family and therefore the objective of hiding the victims' identity.

Fig. 4.- Teeth and two tali of different size found in the bonfire of Las Quemadillas made by Bretón. Modified from Bravo-Cuiñas (2012) published in "El Mundo, Andalucia" in *August 28th*.

If the case had been resolved from the first bone analysis on October 10, the family's suffering, the money spent on almost 11 months of searching for the children and subsequent analyses would have been reduced to some days.

Case 5 – Minimal expression of a zygomatic bone (Modified from Black, 2008)

A man announced the disappearance of his wife. According to him, he had not seen his wife for two days. He explained to the police that at 4 pm on 30

Fig. 5.- Example of bones burned at high temperatures. They show white colour. The cracks are transversal to the longitudinal axes of the bones.

November she went shopping at Sainsbury's local, which was located 12 minutes from their house. This couple lived in an apartment building with a door attendant. The police interrogated neighbours and the door attendant. None of them had seen her on 30 November and much less at 4pm of that day. The door attendant said with certainty that she had not left her home that day. The husband responded to this assertion, that perhaps at 4pm on 30 November the door attendant was busy with things of the building, which probably did not allow him to see how and when she left the building. However, apartment building video surveillance cameras showed that she had never gone out of the building that day. In addition, supermarket video surveillance cameras indicated that she never was shopping in the Sainsbury's local on 30 November. The husband insisted that she went shopping at 4 pm on 30 November. He suggested that the apartment building cameras perhaps had some problems that time that day. He also suggested that perhaps she got disoriented and lost, and maybe she never arrived at the supermarket. The police searched in the couple's house with no success. They again asked friends and neighbors about her. There was no evidence of her escaping from home or kidnapped. Later, the police decided to search the couple's flat more thoroughly. They looked for blood or some human remains in each small corner of the flat, as for example the sink, bath, laundry and bathtub drain. Particularly, the police found the wife's blood in the bathtub drain. The husband explained that she got cut when she was having a bath 3 days previously. The police thought that this was logical and possible. Therefore, they did not consider this blood evidence. However, later, they looked into the washing machine filter and found a small piece of bone. After an intense analysis, the forensic anthropologist arrived at the conclusion it was a human bone, concretely it was a small part of a human zygomatic bone. In this case, the husband could not argue that she hit the washing machine by chance, living a piece of a cheekbone in the filter of the washing machine.

This case illustrates again the importance of human anatomy in forensic anthropological cases and the necessity of having a deep knowledge of this scientific field.

DISCUSSION

Throughout this paper, the importance of human anatomical knowledge in forensic anthropology and therefore in forensic osteology has been evidenced. This paper aims to illustrate the inseparable bond between forensic anthropology/osteology and human anatomy thereby justifying the necessity of increasing anatomical knowledge in the academic education of physical (biological) anthropologists, particularly forensic anthropologists/osteologists (and human osteoarchaeologists). In addition, it is crucial to highlight the importance of forensic anthropology along with eliminating the common belief that forensic anthropology is just about a pile of bones.

Although, traditionally, forensic anthropologists worked with dry, complete, and fragmentary bone remains, nowadays they also face a wide range of differentially preserved human remains that include fleshy, decomposed, burned, dismembered and very disturbed remains (Blau, 2016a). In addition, as is shown in this monograph on forensic anthropology, current anthropologists are also asked to assess identification questions in: (i) clinical cases, as for example, the age estimation of an individual (see Black et al., 2010; Doyle et al., 2019); (ii) cases of living individuals, which can involve facial and body measures, craniofacial identification and fingerprint recognition (judicial anthropology); and (iii) cases involving missing persons and victims of crimes, accidents, mass disasters, and crimes coming from periods of violence because of ethnic, political and religious reasons (Blau, 2016a).

The common history between physical (biological) anthropology and anatomy evidences the intrinsic relationship between both disciplines. Most of the first physical anthropologists were human anatomists. This also evidences the inherently close relationship between forensic anthropology/osteology (and human osteoarchaeology) and human anatomy. Each forensic anthropology/osteology (and human osteoarchaeology) study runs within the field of the human anatomy. The forensic anthropologist and osteologist analyse the form, aspects and metrics of every bone to facilitate

the identification of the individuals to whom the remains belongs. Forensic anthropologists and osteologists need a knowledge of human biology in general, together with some chemistry, physics and mathematics, and a sound understanding of human anatomy (Klepinger, 2006). This is observed in each anthropological technique and the detailed knowledge of every bone of the human body that forensic anthropologists must have. This anatomical knowledge is necessary to recognise each tiny part of a bone (as in the zygomatic bone case), avoiding identification being inconclusive. In addition, forensic anthropologists must be able to work indiscriminately on remains of different maturation stages such as foetuses, new-borns, children, juveniles and adults, implying a great and wide knowledge of human anatomy. It is important to recognise human skeletal material and not confuse it with faunal remains (as in the Córdoba kids' case). The definitive and early resolution of the case is of extreme importance (Holobinco, 2012) to avoid the suffering of the victim's family and not waste time, effort and money unnecessarily. The quick resolution of the case mostly depends on the anatomical knowledge of the forensic anthropologist/osteologist. The lack of anatomical knowledge, and particularly the ignorance of the childhood anatomy, was the cause the eleven months delay to the resolution of the Córdoba kids' case. In contrast, the extensive human anatomical knowledge of the forensic anthropologist resulted in the resolution of the extremely difficult case of the tiny fragment of a zygomatic bone which could have slipped past during the search. In addition, histology (microanatomy) helped to overcome the appearances of the third case (cultural factors), in which the presence of a surgery (cultural factors) was influencing the opinion of the anthropologist, who was dubious about the biological origin (species) of the remains. He/she thought that they belonged to a human when in reality the bones belonged to a big dog with a surgery. Therefore, there is no doubt of the importance of anatomy in the full sense and human anatomy in particular, in forensic anthropology.

This unquestionable importance of human anatomy (and human biology) in forensic anthropology points to the current discussion about the academic education of forensic anthropologists. Over the last 20 years the media has contributed to interest in the term "forensic", leading to an increase in the number of courses that start or finishes with this term (Black, 2000; Blau, 2016a, 2016b). Many of the courses on forensic anthropology and osteology offer a superficial introduction to osteology and technical principles of the discipline, but very few provide a thorough education in practical and technical abilities, and much less in human anatomy (Blau, 2016a). It is of vital importance that forensic anthropology students be prepared in anatomy (at least in musculoskeletal system), making them able to interpret every tiny crease or wrinkle of the bones, and preparing them to deal with a wide range of human remains of different ages, sexes and different states of preservation. In addition, they should be prepared to deal with unpleasantness, for example bodies in advanced states of decomposition, semi eaten by animals or remains resulting from the actions committed by criminals to their victims to hide evidences (Wright et al., 2005).

In America, Australia and some European countries, social anthropology and physical (biological) anthropology (and thus forensic anthropology) are in the same school or department of anthropology together with archaeology. In light of the growing role of anthropologists in dealing with life (Black, 2010) and managing the identification of victims of large-scale mass disasters (Blau, 2016a), what discipline offers the best basis for forensic anthropology is under discussion. Should forensic anthropologists be academically educated in medical or biological schools with a focus in human anatomy or should they be educated in humanities schools, which can offer technical and socially relevant abilities? (Blau, 2016a). However, although human anatomy is basic for forensic anthropologists, knowing the different beliefs and behaviours in relation to death in different cultures and peoples and how they deal with it is also important. For example, in Western countries the physical contact with the dead and the dying is avoided (Blaauwn and Lahteenmaki, 2002). In contrast, in some Muslim cultures, prior to burial, the body of the deceased

is washed by a relative. While some cultures do not have any problem to display human remains (Blau, 2016b), as in the case of Capela dos Ossos (Bone Chapel) in Evora (Portugal) and All Saints Cemetery Chapel in Sedlec (Czech Republic), other cultures, such as the indigenous of Australia and Maori communities, are very offended if the remains of their ancestors are displayed (Blau, 2016b). As we have seen in the Results section, the academic education received by forensic anthropologists in different countries varies greatly (Márquez-Grant et al., 2016). In addition, most of the university degrees in anthropology, particularly those of US do not highlight training in physical (biological) anthropology and osteology (Klepinger, 2006). It is true that whatever training one chooses to undertake, the important thing is the anthropological experience that one acquires along one's career in forensic anthropology, the experience in forensic and osteological caseworks and internships (Klepinger, 2006) and different types of remains and different states of maturation. However, as we have also seen along with this paper, human anatomy is basic in any forensic anthropological case. A forensic anthropologist must have a sound anatomical (and biological) basis of the human body (Klepinger, 2006). This is extremely important to resolve each case and help to get a conclusive identification of the analysed remains. Therefore, schools, whether medical, biological or humanities/social, should provide forensic anthropology students with a great foundations in human anatomy, together with some taphonomy, chemical, physics and mathematical knowledge.

CONCLUSION

The information provided by this study furnishes information on the state of current forensic anthropology and demonstrate the close relationship between forensic anthropology and human anatomy. It is clear that historically, there is an intimate relationship between forensic anthropology and human anatomy. Forensic anthropology developed from physical anthropology, and this last science originated, in great part, from human anatomy. Not only is the history of forensic anthropology related to human anatomy, but the role and techniques of forensic anthropologists are also within the human anatomy field. Each forensic anthropology (and human osteoarchaeology) study runs within human anatomy. The forensic anthropologist's tasks include in part focusing on searching, recovering and analysing human remains; they also focus on a detailed and exhaustive analysis of the form, aspects and metrics of the remains to facilitate the identification of the individual to whom they belonged, or the bone, if it is one tiny bone, as we have seen in the Results section of this paper. Forensic anthropologists must be able to work indiscriminately on remains of different maturation stages such as foetuses, new-borns, children, juveniles and adults, implying a great and wide knowledge on human anatomy. In addition, currently, they can also be asked to assess: clinical cases, as for example age estimation; cases of living individuals, which can involve facial and body measures, craniofacial identification and fingerprint recognition; and cases related to missing persons and victims of crimes, accidents, mass disasters, and crimes coming from periods of violence because of ethnic, political or religious reasons. The roles and techniques (DNA analysis, forensic archaeology, forensic taphonomy and trauma) of forensic anthropologists are increasing, which generate new forensic anthropology specialisations. Formerly, one forensic anthropologist may have analysed all the human remains of a case. Currently, different forensic anthropologists with a variety of specialisations such as histology, trauma, taphonomy, age at death, craniofacial reconstruction, etc. can be found working on the same case. Therefore, human anatomy is basic in forensic anthropology. The forensic anthropologist and osteologist must have a sound anatomical and biological basis of the human body to resolve each anthropological case. Consequently, schools, which offer a degree in forensic anthropology, whether medical, biological or humanities/social, should provide forensic anthropology students with powerful foundations in anatomy.

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