VILNIUS UNIVERSITY
FACULTY OF MEDICINE

Medicine

Department of Pathology and Forensic Medicine

Sini Tuuli Selin, 6th year,group 9

INTEGRATED STUDY MASTER'S THESIS

Skeletal Completeness and Its Importance in the Forensic Examination of Skeletal Remains

Supervisor *Lecturer Rokas Šimakauskas*

Head of the Department of Pathology and Forensic Medicine *Professor Dr. Arvydas Laurinavičius*

Vilnius, 2026

sini.selin@mf.stud.vu.lt

Table of contents

1.ABSTRACT

The analysis of human skeletal remains is an important part of forensic medicine, especially when identifying unknown individuals and understanding the circumstances of death. In most of the forensic medicine cases, skeletons are rarely found complete. They are often fragmented, partially preserved, or mixed with other remains. This makes it more difficult to reconstruct a biological profile, such as age, sex, stature and ancestry. Because of this, understanding skeletal completeness and bone recovery patterns is essential.

The aim of this thesis was to examine which bones are most frequently recovered in forensic cases and what factors may influence skeletal completeness. The study is based on data collected from 48 forensic cases in Lithuania between 2023 and 2025, including approximately 100 individuals. The data included information about recovered bones, recovery locations, postmortem damage and whether the remains were single or commingled.

Data was analyzed with Microsoft excel, where all the bones found were marked separately, and further analyzed with R studio.

The results showed that skeletal recovery varies between different bone groups. The most commonly recovered bones were ribs and vertebral bones, followed by skull bones such as the frontal and temporal bones. Pelvic bones and some of the long bones, such as fibula and clavicle, were less commonly recovered. When bones were grouped anatomically, skull bones were the most represented, while pelvic bones were the least represented.

The study also found that the presence of the skull and pelvis, increased the probability of determining sex. However, even when these bones were present, identification was not always possible due to fragmentation and preservation issues. Environmental factors also influenced bone recovery. The highest number of the bones was found in underground contexts, while fewer bones were recovered from surface, indoor or water environments. Fragmentation was very common and was observed in most of the cases.

Commingled remains were relatively frequent and were more often associated with presence of children compared to single burials. Animal bones were found in a smaller number of cases.

Results showed that most frequently found bones are skull bones, ribs and vertebrae and that skeletal completeness is highly variable and influenced by bone type, recovery conditions and postmortem changes.

2. SANTRAUKA

Žmogaus skeleto liekanų analizė yra svarbi teismo medicinos dalis, ypač kai reikia nustatyti nežinomų asmenų tapatybę ir mirties aplinkybes. Daugeliu atvejų skeletai nėra randami pilni. Jie dažnai būna fragmentuoti, iš dalies išlikę arba sumaišyti su kitomis liekanomis. Dėl to tampa sunkiau nustatyti biologinį profilį, pavyzdžiui, amžių, lytį, ūgį ir kilmę. Dėl to svarbu suprasti, kiek pilnas yra skeletas ir kaip dažnai randami skirtingi kaulai.

Šio darbo tikslas yra išsiaiškinti, kurie kaulai dažniausiai randami teismo medicinos tyrimų metu ir kokie veiksniai daro įtaką skeleto pilnumui. Tyrimas paremtas 48 atvejų Lietuvoje 2023–2025 metais, apimančių apie 100 individų, duomenimis. Duomenyse buvo pateikta informacija apie rastus kaulus, radimo vietas, pomirtinius pažeidimus ir tai, ar liekanos buvo pavienės, ar sumaišytos. Duomenys buvo tvarkomi „Microsoft Excel“ programoje, o tolesnė analizė atlikta naudojant „R Studio“.

Rezultatai parodė, kad skirtingi kaulai randami nevienodai dažnai. Dažniausiai buvo randami šonkauliai ir slanksteliai, po jų – kaukolės kaulai, tokie kaip kaktikaulis ir smilkinkaulis. Rečiau buvo randami dubens kaulai ir kai kurie ilgieji kaulai, pavyzdžiui, šeivikaulis ir raktikaulis. Suskirsčius kaulus į grupes, daugiausia buvo rasta kaukolės kaulų, o mažiausiai – dubens kaulų.

Tyrimas taip pat parodė, kad kaukolės ir dubens kaulų radimas padidina tikimybę nustatyti lytį. Tačiau net ir esant šiems kaulams, tai ne visada pavyksta dėl kaulų fragmentiškumo ir blogos išsilaikymo būklės. Taip pat svarbūs yra aplinkos veiksniai. Daugiausia kaulų rasta po žeme, o mažiau – paviršiuje, pastatų viduje ar vandenyje. Daugumoje atvejų kaulai buvo fragmentuoti.

Sumaišyti palaikai buvo gana dažni ir juose dažniau buvo randama vaikų kaulų nei pavieniuose palaidojimuose. Gyvūnų kaulų buvo rasta tik nedaugeliu atvejų.

Rezultatai parodė, kad dažniausiai randami kaukolės kaulai, šonkauliai ir slanksteliai, o skeleto pilnumas labai skiriasi ir priklauso nuo kaulo tipo, radimo sąlygų ir pomirtinių pokyčių.

3. ACKNOWLEDGMENTS

I sincerely thank associate lecturer Rokas Šimakauskas, for his invaluable guidance and support throughout my thesis. His expertise and encouragement were essential to the successful completion of this work.
I would also like to thank my dear friend Rūta Kaškelevičiūtė for her continuous support throughout this thesis.

4.ABBREVATIONS

PMI= Postmortem interval
MNI= Minimum number of individuals
MNE= Minimum number of elements
CT= Computed Tomography
DVI= Disaster Victim Identifications
DCP= Data collection procedure
BRI= Bone representation index
GSI= Gun shot injury
C1-C7= Cervical vertebrae
Th1-Th12= Thoracic vertebrae
L1-L5= Lumbar vertebrae

5.KEY WORDS

Skeletal completeness, forensic medicine, minimum number of individuals, minimum number of elements, osteological analysis, incomplete remains.

6. INTRODUCTION

The recovery and analysis of human skeletal remains are central to forensic medicine and forensic science. One of the key challenges in this field is the variability in skeletal completeness, which directly affects the ability to identify individuals and reconstruct biological profiles. In forensic medicine remains are rarely recovered as complete skeletons; instead, they are often fragmented, dispersed, or partially preserved due to a range of environmental and postmortem factors.

This study aims to investigate the recovery rates of skeletal bones using a data derived from forensic cases in Lithuania. The objectives were to identify the most and least frequently recovered skeletal elements, assess differences between anatomical groups, and evaluate the influence of contextual factors such as recovery environment, fragmentation, and commingling.

7. LITERATURE REVIEW

This literature review is the introduction for the data analysis, which is the main aim of this thesis. It focuses on explaining what skeletal completeness is, how it can be measured, and why it is important in forensic anthropology. It also looks at the challenges that arise when remains are incomplete, especially when trying to estimate the biological profile. By reviewing previous research, this chapter provides the background needed to better understand skeletal recovery patterns and their role in forensic investigations.

7.1. DEFINITION OF SKELETAL COMPLETENESS

Skeletal completeness indicates how much of the total skeletal remains are available for osteological analysis. [1] Skeletal remains can range from incomplete, complete, fragmented, burned or otherwise incomplete. [2]
Preservation and completeness are primary components for osteological analyses in forensic and archaeological field. Documenting skeletal remains is essential for indicating individual's ancestry, sex, age and stature, possible trauma, pathology and unique characteristics of bones. [1] Evaluating the skeletal completeness, visual recording is commonly used. It involves schematic skeletal diagrams, which indicates the presence or absence of bones and completeness or fragmentation of skeletal elements. There also are digital methods and software with virtual applications. [1]
In skeletal examination, remains should be put in anatomical order and skeletal completeness should be checked. It should also be verified that all bones belong to the same individual and make sure that there is no mixing or doubling of elements. [3] In remains recovery context, there could be request from forensic doctor or anthropologist about completeness of remains recovered or is there

possibility to recover additional bone elements or other body portions. [4] Typically, the complete set of 206 bones forming the human skeleton is not present in forensic recoveries. [2]
There are thoughts that lacking disciplinary standards evaluating skeletal completeness may influence to communication about skeletal completeness within forensic anthropologists. [4]
For estimating skeletal completeness, there is possibility to use nine different methods. Three methods evaluate skeletal completeness by individual bones. Five of them evaluate it by skeletal assemblage and one by using commingled assemblage for estimation. [4]
Skeletal completeness can give information is part of the skeleton old example from the exhumed human remains or from the case in mass disasters or acts of war. [5]

7.2. QUALITATIVE AND QUANTITATIVE METHODS FOR ESTIMATING SKELETAL COMPLETENESS

There are multiple ways to estimate skeletal completeness. Standards method, where individual bones are marked, bones are characterized in their completeness in percentage. Zonation method also indicates individual bones, but bones are divided according to their expected postmortem breakage patterns. Individual bones can also be pre-determined by their landmark traits, which is called landmark method. [4]
For skeletal assemblage, there is five different methods, which can be used for skeletal completeness. Bone count method, where bones present are counted and then divided by the number of bones in an average human body. [4]
Data collection procedure (DCP) 2.0 is a detailed inventory method for skeletal assemblage. This data provides basic standards to determine skeletal age, sex, ancestry and stature of unknown remains. [6] Relative bone size method, groups bones according to their body region and each region is assigned weighted percentages. [4]
Skeletal completeness can be also estimated by using bone representation index, where large bones are counted individually, while smaller bones are grouped together as single units. Volumetric approach method evaluates the skeletal assemblage, it uses CT volume render, which standardize percentage values assigned to each bone in the body.
Commingled assemblage can also be used as a method, this is called analytical recovery rate, it determinates the minimum number of elements for select bones that contribute to the biological profile. [4]
Quantitative methods can be used for estimation of skeletal completeness. One of Quantitative methods is percentage of skeletal completeness, where each bone or skeletal element is assigned a percentage value based on its contribution to the complete skeleton. Total skeletal completeness is

calculated by summing the percentages of all present elements and if needed information can be broken down into regions, for example cranial, for more detail. [1] The percentage of completeness of skeletal remains gives information about natural preservation and potential limitations placed on analysis by the condition of the material. Calculated percentage from skeletal remains assess the amount of material representing different areas of the body. Percentage in total is 100%, skull 20%, torso 40 %, arms 20% and legs 20%. Many times, percentage of total completeness of skeletal remains are marked into categories more than 75%, 75-50%, 50-25% and less than 25%. [7]

Minimum number of elements (MNE) measures the number of total elements represented regardless of the side. MNE measures the units required to account for all the fragments in an assemblage that are identifiable as each skeletal category or skeletal portion, so it counts the fewest number of individual skeletal elements necessary to account for all fragments. It could be determined in different ways but always involves the identification of specific elements or element features. The MNE values for various elements can then be compared to determine minimum number of individuals (MNI). Typically, determination is based on a particular section of the bone, proximal, distal or midshaft example. MNE is more accurate than just counting fragments because it takes fragmentation into account. [8]

Minimum number of individuals (MNI) can be determined by using several methods, but they all involve replication. [8] Estimation of the MNI of individuals found is a key point in forensic anthropological analysis. It is usually calculated by counting the number of similar bones. [9] This measurement identifies how many individuals are found from skeletal remains; for example, if two right femurs are found, there should be remains of two different individuals in the assemblage. [8]

After MNE and MNI are evaluated, bone representation index (BRI) can be used. BRI measures how many elements are present compared to how many would be present if each MNI were represented by a complete body. [10]

Unique element identification can be used as a qualitative method. Pathological changes to the bone can be found in the skeletal remains. This could help to identify individual by his past diseases. Some diseases can leave a specific mark to the bone. Pathologies can be congenital, metabolic, infectious, traumatic or neoplastic. For example, arthritis, osteomyelitis, scoliosis. [7]
Medical conditions can be used for identification, as well as surgical procedures, also if there is presence of surgical hardware. Reconstruction of trauma to the skeleton can also be unique element for identification. This includes healed trauma which has happened some considerable time before

death or damage that could be the cause of death. Dental records can be used to identify skeletal information if dental information is still present in remains. [11]

7.3. IMPORTANCE OF ESTIMATING SKELETAL COMPLETENESS

Counting and reporting the number of remains contained in an incomplete, fragmented, and/or commingled assemblage is a basic but essential part of the skeletal inventory process. Describing the number of remains present is critically important because it can influence the progress of postmortem investigations, provide insight into whether further work is needed, can be used to understand clearing and other postmortem effects that have led to the dispersion or loss of material, can influence MNI estimates, facilitate the identification and resolution of commingling, and influence the range of analytical methods to be applied, among other considerations. [4]

In situations where assemblages are complex and have a lot of fragmentation and/or mixing, lists alone may not be enough to resolve the case/skeletal completeness.

One part is the recording of skeletal completeness. This comprises a statement summarizing the presence/absence and completeness/fragmentation of the skeletal elements present to indicate how much of the total skeleton is available for osteological analysis [1]

Accurate reporting of skeletal completeness may be important to assist in bringing closure to the family of the deceased and to respect the cultural and/or religious beliefs of the deceased's family. Knowing the degree of completeness of the recovered skeletal remains may be important to the family of the deceased, as knowledge of exactly how much of their loved one is at rest may contribute to providing a sense of closure with the death. Furthermore, burial customs in some cultures, such as those of Native Americans and Indigenous Australians, believe the soul/ spirit of the deceased wanders in 'limbo' until the body of that deceased individual is laid to rest. [1]

Skeletal completeness is a crucial factor in many research studies, including trauma prevalence studies. It's important to quantify completeness to determine the representativity of a sample and ensure the reliability of research findings. [12]

Incomplete remains can hinder the detection and interpretation of trauma or pathological conditions. For example, determining the cause of death or the presence of specific diseases may be limited by the availability of key skeletal elements. [12]

7.4. CHALLENGES IN BIOLOGICAL PROFILE ACCURACY OF INCOMPLETE REMAINS

The completeness of skeletal remains directly affects the accuracy of estimating the biological profile (age, sex, stature, and ancestry). If only certain skeletal elements are present, the reliability of these estimations can be compromised.

The extent of skeletal preservation influences the ability to draw accurate conclusions about the individual's age, sex, ancestry, stature, and presence of trauma or disease. Assessing skeletal completeness helps researchers understand the postmortem processes that may have led to the dispersal or loss of material. This information can be crucial for interpreting the context of the remains and the circumstances surrounding death. [4]

There are four categories for assessing biological identity. These are sex, age at the death, stature and ethnic origin, all this information can be collected from skeletal remains if all bones are present. State of preservation can also affect the accuracy of biological identity. More fragmentation and poorer completeness of the skeleton results in greater difficulty to realize full identity of the skeletal remains.[11] There are more bones in the skeleton of an infant compared with adult human. At the time of birth, newborn baby has around 300 bones, during the lifetime some bones fuses together and form 206 bones of the adult skeletal system. [13] For estimation of biological identity of the skeleton, metric and/or morphological methods can be used. [14]

7.4.1. SEX

Determination of sex is usually done first because estimation of stature and age are dependent for it. Completeness of the remains and degree of sexual dimorphism inherent in the population from where individual originates effects on reliability of sex determination. These two are also the main morphological differences between female and male skeletal remains. The two most sexually dimorphic elements of the skeleton are the pelvis and the skull. Male's bones are usually larger, longer and more solid compared to female bones because of the higher muscle mass and surface attachment is larger in the bones. [11]
In adult bones skull and pelvis have about 90% accuracy when estimating sex in skeletal remains but also long bones are used for estimation of sex. If the bones are fragmented or incomplete it is less accurate, and the chance to identify the individual decreases. Researchers can use other bones, for example, patella, clavicle, mandible, vertebrae and scapula for sex estimation if pelvis and skull are missing. First most reliable skeletal element for sex estimation is pelvis, because female pelvis is designed for delivering a baby, so it is much wider and gives optimal space for birth canal compared male pelvis. Second most reliable skeletal element for sex estimation is skull, with differences between female and male in postcranial factors. Long bones, especially femur, have been also used for sex estimation if skull and pelvis are missing or severely fragmented; femur has shown up to 89% accuracy at single measurements. Sexual dimorphism in femur is due to weight differences of female and male. Also, high muscle mass in males and wider pelvis in females plays

a role in differences in femur. [13] In the future, the femur cannot necessarily be relied upon for gender assessment in Western countries due to decreased muscle mass and increased obesity in both women and men. [15]

Major differences in the skull appear after puberty. The glabella, supraorbital ridges, mastoid process, the nuchal and malar areas become more prominent compared to female skull. In the female skull orbits are more rounded, features are smaller, and forehead remains vertical. Ethnicity can affect to the determination of sex; greater muscle mass affects to the joint size and can affect to the body durability. Females from the rural area might have robust joints which affects to the prominence of the skull features compared to male from gracile urban area. [13]

7.4.2. AGE-RELATED CHANGES

Age-related changes can be divided in three groups in the person's life cycle, growth and development, stability and aging.

To the first phase, growth and development affects mostly genetics and environment. It mostly includes children and young adults, which skeletal changes are well-documented and predictable.

To the second phase starts when maturity is reached, there is significant variation between skeletons, and they are more individual and population specific.

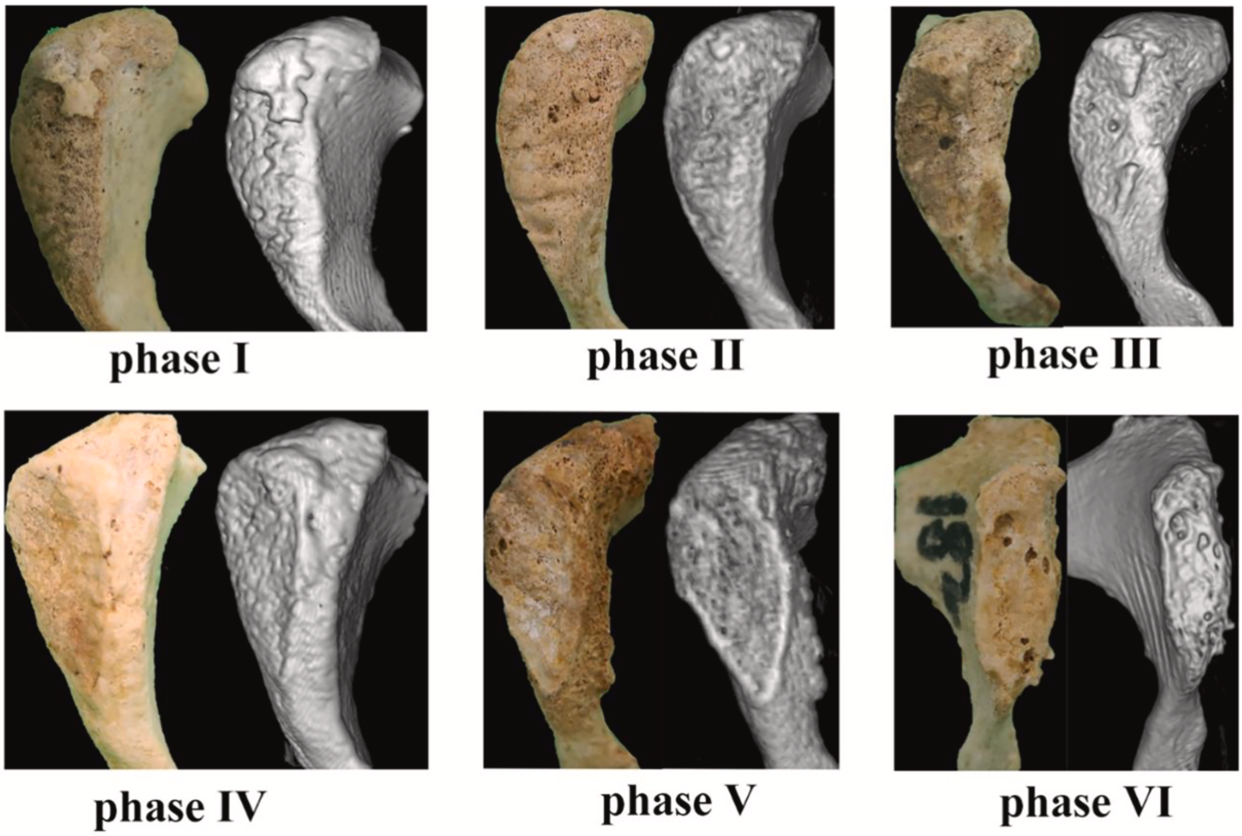
The third phase is influenced by health status, occupation, nutrition and endocrine function. [13]

Methods utilized to estimate age at death in fetal, infant, child and other skeletally immature individuals differ from those applied to the analyze the skeleton from mature skeletal remains. If the preliminary evaluation of the recovered remains reveals complete development of the third molars, fusion of the iliac crest and sternal clavicle epiphyses and complete ossification of the spheno-occipital synchondrosis, then the age estimation techniques are appropriate for mature individuals. [16]

Skeletal aging is referred from morphological features of the skeleton that reflect its ongoing adaptation to biomechanical loading and its involvement in mineral metabolism, growth, remodeling and pathological processes. However, because these biomechanical and physiological changes accumulate in a non-linear and irregular manner over life course, the use of skeletal indicators to estimate chronological age is inherently associated with a degree of error. In adults age estimation is estimated mainly by morphological changes related to degeneration. As previously said, degree of change is dependent on cultural and environmental factors throughout life. Also, individual variations affect the degeneration of bones.

Dental development, skeletal maturation and size and epiphyseal union are mainly used in estimation of juvenile individual. [15] The most accurate method for estimating skeletal age under

18 years old individual is dental development, although malnutrition and extreme metabolic diseases can affect to the dental condition and dental development can be retarded. [17]
In adults, pubic symphysis, auricular surfaces, cranial sutures and sternal end of the fourth ribs are used in the age estimation. [15] The most used method for age estimation from pubic symphysis is Suchey-Brooks method. It is a 6-phase scale method where the pubic symphysis surface is evaluated, and proximal age determined. Phase I is young 18 years old individual and phase VI, older individual 79 years old. [18]



Picture 1. Suchey-Brooks method based on morphological features of pubic symphysis, used for age evaluation in human skeletal remains.[18]

Age estimation methods are limited by the lack of diversity in reference samples. Many traditional approaches were developed using skeletal collections from White/European American and Black/African American populations, which do not reflect the genetic and environmental diversity of modern populations. As a result, applying these methods to other groups may reduce accuracy, particularly because factors such as lifestyle, nutrition, and health can influence skeletal aging. [15]

7.4.3. STATURE

For stature estimation two different methods can be used, these are mathematical models and anatomical method. Stature estimation is commonly performed using mathematical models that regress long bone lengths, such as the femur, against stature to produce predictive formulas with confidence or prediction intervals. Alternatively, the anatomical method estimates stature by measuring skeletal elements from the skull to the foot, summing these values, and applying soft tissue and age correction factors. When a complete skeleton is available, the anatomical method is considered the most reliable approach for stature estimation, as it is not dependent on specific populations or time periods. [19]

The formulas using the femur and tibia provide the lowest estimation error. When preferred skeletal elements are unavailable, stature may be estimated from other bones, though accuracy decreases significantly with incomplete remains. The most reliable estimations are obtained when undamaged skeletal remains from individuals of known sex and ethnic origin are examined, as the height of the individual is both sex and race dependent. [11]

7.4.4. ETHNIC ORIGIN

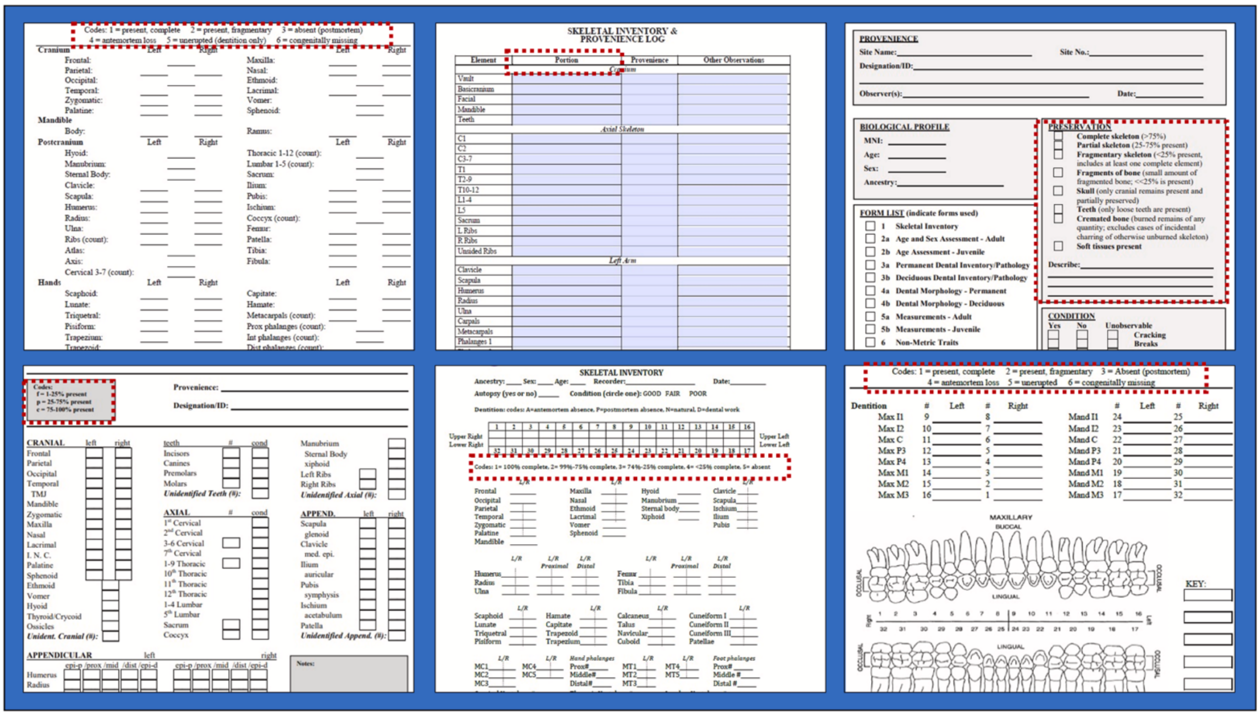
The assessment of ethnic origin is among the most challenging and least reliable attribute in forensic osteology. [11]

Ancestry assessment is essential for selecting appropriate reference populations for age, sex, and stature estimation; therefore, it is often recommended as the first step, as it guides the choice of methods. [20] As key population differences in living individuals are primarily expressed in facial features and integumentary system, so the skull is therefore the most extensively analyzed skeletal element for this purpose. Ethic identity can be calculated from the limb bones, and it uses variation in the intermembral indices. In the upper limb brachial index radial and humeral length are used and lower limb, tibial and femoral lengths are used. [11] Some cultural modifications can be found in the bones, especially in the skull and teeth. This can give crucial information for identification. [20]

8.METHODOLOGY

Before evaluating skeletal completeness, all the bones that are found should be placed in anatomical position on a flat surface, this is recommendation but not necessarily needed. Most important is to recover all elements safely and document them. Different countries use different forms for evaluating skeletal completeness. [4]

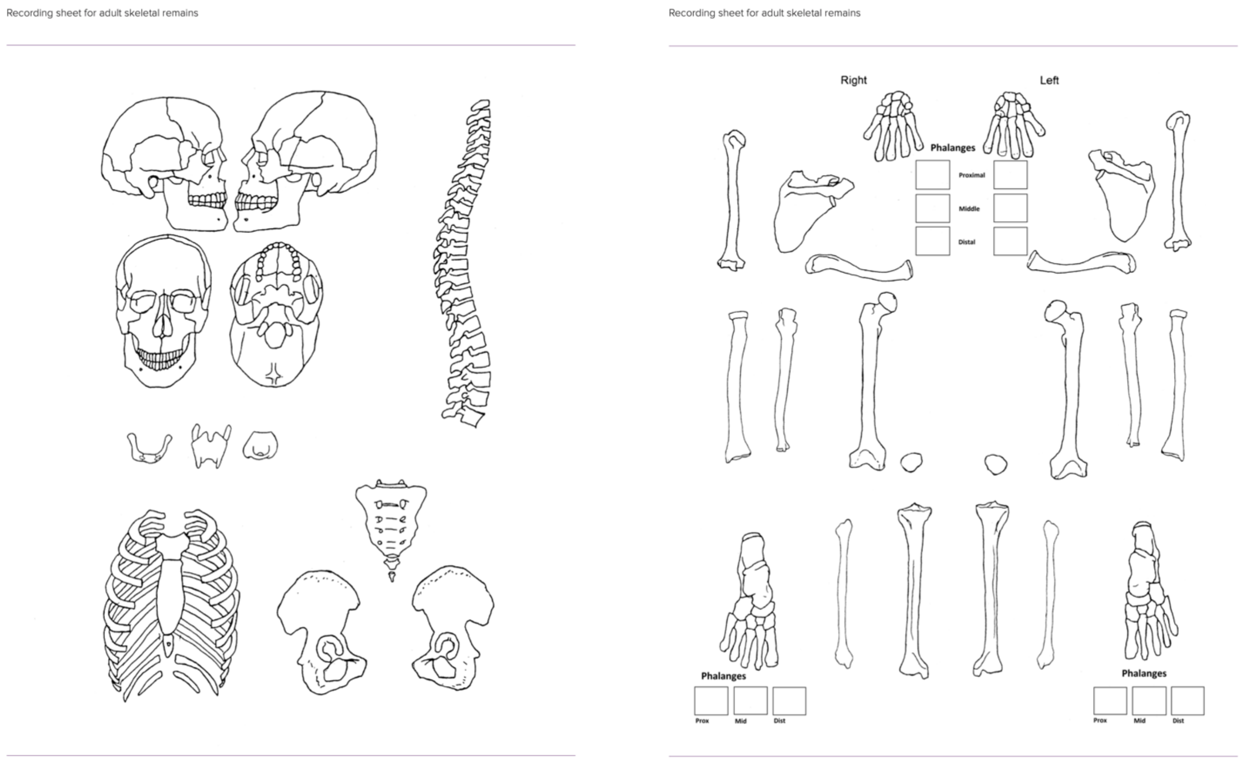
Picture 2. Before forensic evaluation, bones found are usually first placed on a flat surface in anatomical order. [4]



Picture 3. Different forms for recording skeletal remains in forensic medicine. [4]

Several methods exist for recording skeletal completeness, including the system described by Buikstra and Ubelaker (1994). [17] Buikstra and Ubelaker used weighted percentages to score skeletal completeness, categorizing elements as complete, >75% present, 25-75% present, <25% present or single element. [21] After this calculation method, new research exceeded more positive identifications than before. In calculating completeness, these researchers assigned greater weight to larger bones than to smaller ones, with particular emphasis on the cranium and mandible [2]

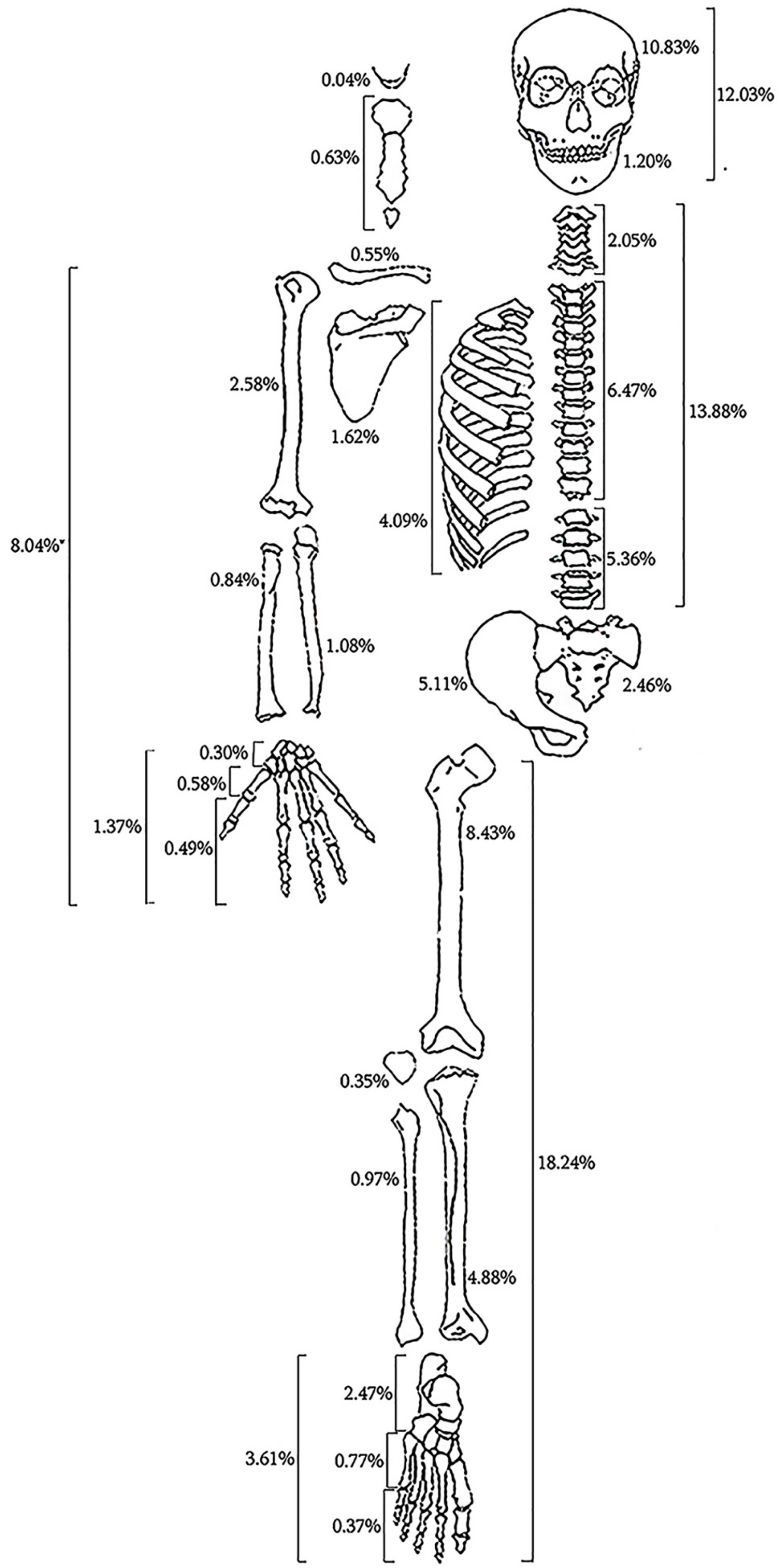
The choice of method should reflect the specific research objectives. At a minimum, the number of each bone type and all major joint surfaces should be documented to allow calculation of pathological prevalence. Any method used must be clearly referenced or fully described if unpublished. Visual recording forms, such as those provided in the 2004 guidelines, facilitate recording both completeness and the degree of fragmentation. [17]



Picture 4. This recording form of skeletal completeness is used and recommended by British Biological Anthropology and osteoarcheology association [17]

Fragmentation significantly affects the quantity of metric data that can be collected. The recording system used should be clearly described and fully referenced where applicable in the final report. For highly fragmented skeletons, provides guidance on relevant aspects to consider. Documenting features such as abrasion, erosion, and the characteristics of broken bone ends can aid in identifying the cause of fragmentation, particularly in articulated remains. For smaller assemblages, spreadsheets/ basic templates may be sufficient for data management. However, for larger or more complex assemblages, it is generally recommended to use a relational database, to ensure efficient and accurate data handling. [17]

In 2017 Rowbotham, Blau and Hislap-Jambrich made new approach for skeletal completeness, they used computed tomography (CT) volume rendering to determine the relative volume of each skeletal element compared to a complete skeleton. By calculating percentage values for each bone, ranging from very small elements (~0.01%) to larger bones example the femur (~8.43%) practitioners can now compute an overall completeness score based on measurable data rather than subjective assessment. This technique provides a scientific, reproducible means to record how much of a skeleton is preserved and can improve the consistency of completeness reporting in osteological analysis. [1]

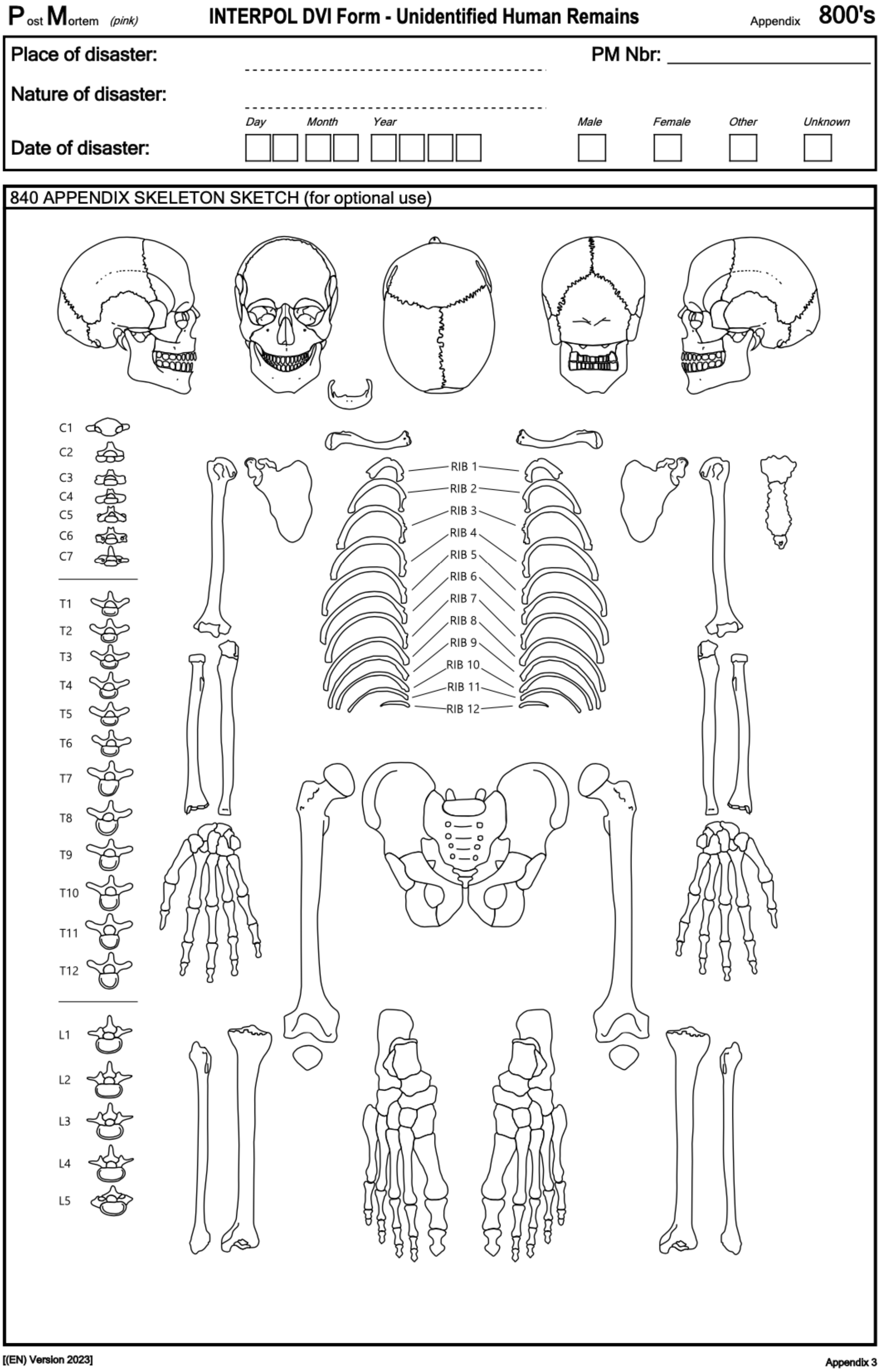


Picture 5. In study made by Rowbotham S. K., Blau S., Hislop-Jambrich J. they calculated percentages for each bone in total, this did not account fragmentation. [1]

In Lithuania bones found are placed to the flat surface in anatomical order. Similar form as in the pictures is used were the bones found are marked and there is added marks of fragmentation or gnaw marks example.

International criminal police organization also called INTERPOL has their own disaster victim identification guide, it is made for disaster victims and suitable for fragmented human remains. The form is primarily designed for more intact remains and may be less effective in cases where are severe fragmentation. [22]

There are many different forms depending on the situation. For founded skeletal remains Interpol post-mortem (PM) form can be used, and it is standardized tool to use in disaster victim identifications (DVI), it enables systematically document findings from unidentified human remains, including presence of completeness and fragmentation of bones. Also, observations which are relevant for biological profile estimations such as age, sex, stature and ancestry. There is a part where trauma, pathological changes and taphonomic alterations of remains can be marked. PM form incorporates detailed odontological section for recording dental status of skeletal remains. It includes tooth presence or absence, restoration and diagnostic features. The dental data is particularly valuable for comparative identification as they can be matched with antemortem dental data. [23]



Post Mortem (pink) INTERPOL DVI Form - Unidentified Human Remains Appendix 800's

Place of disaster: PM Nbr:

Nature of disaster:

Date of disaster: Day Month Year Male Female Other Unknown

840 APPENDIX SKELETON SKETCH (for optional use)

[(EN) Version 2023] Appendix 3

Picture 6. Form for recording skeletal remains, which is recommended to use by Interpol, and it is used for victims of disasters. [23]

9. MATERIAL AND METHODS

9.1. MATERIALS

The material for this thesis and data analysis was obtained from Lithuanian State Forensic Medicine Service data archive. The dataset included the cases from years 2023-2025. There are approximately 100 individuals in the data, and they were found in 48 different locations across Lithuania. Material was given without any identifying information and in excel form. Seven cases of remains where described using separate template and other 41 cases were described in the text form.

In the excel template for each case, the following variables were also provided: place of finding, additional animal bones, minimum number of individuals, approx. skeletal age, sex, PMI, antemortem and postmortem damage.

Skeletal remains were mostly found underground, ground surface, inside some building and water, only in one case the place of finding was unknown. In some cases, place of finding was described more precisely, for example, under the tree roots or construction site.

Additional animal bones were marked only by presence or absence; more information was not provided.

In only few cases there was antemortem damage in the bones, but almost all cases had postmortem damage, mostly causing fragmentation. In one case there was old bone fracture as antemortem damage and in other case GSI was identified. Postmortem damage could also be gnawing marks, which were made by animals.

Minimum number of individuals were from one to 13, which was the biggest MNI. In 13 cases were <18 years old identified, these could also be babies or smaller childrens. But only in eight cases were marked which bones were childrens bones.

The PMI of the cases were mostly more than 50 years or more than 100 years. In the material only nine cases had postmortem interval under 50 years.

Sex was marked female, male or not applicable, there was not marked cases were both female and male remains were found. In commingled cases there was either female or male found, and rest of the remains were marked not applicable.

9.2. METHODS

The main goal was to know what the recovery rate of different parts of the skeleton is and evaluate it with the R studio or in the excel.

First the text format from excel was put in the table form in the excel. In the rows was all the different bones marked and in the columns case numbers. In the data, which was given, some cases were marked in the different sheet. There was seven of these cases. In the excel sheet bones were added to the table like in the skeletal inventory forms like in the annex 2. Bilateral bones were marked left and right sided. All the long bones were divided to the proximal and distal end and diaphysis. Skull bones contained occipital, parietal, temporal, frontal, sphenoid, nasal, zygomatic, maxilla and mandible. Other head bones were not marked on the template. Vertebrae were divided to atlas, axis, C3-C7, Th1-Th12 and L1-L5. Ribs were divided left and right sided. Sacrum and sternum were marked also separately.

Forming the new excel table of founded bones, all the bones mentioned in the data sheet were marked to the new table. Going thought the written material; bones which were mentioned was added. Same list of bones was made for childrens bones.

If the bone was mentioned example 1 humerus is found, all the three parts of the bone were marked, meaning distal and proximal end and diaphysis.

Also, if the bone was fragmented it was marked after the number of amounts, later it was removed because almost all the cases the bones were fragmented, and it is simpler to do analysis.

If some bone was mentioned only in one or two cases, they were left from the table, because the information would not be significant. These bones were example palatine and ethmoid bones, they were mentioned only in one case. They could be present in other cases where total skull was found, but since they were not marked, they were not added separately.

After the whole data were marked to the table it was valuated what could be the most interesting information. Childrens bones were mentioned only in eight cases. In some commingled cases, the age of the skeleton was determined to be under 18 years old, but the bones which belonged to these remains were not determined. So, the bones under 18 years old were added to the main table.

Usually in the cases ankle, metatarsal, metacarpal and carpal bones were identified if they were from sinister or dexter side, but phalanges of foot or hand were just marked, unidentified side, so they were put in one group called both hand phalanges or foot phalanges.

One row was made for pelvis and skull, in this line pelvis was marked to be found if any parts of it was found and skull was counted if more than one part of skull was founded. There were several cases where only mandible was found, so in these cases skull was not marked.

Skull bones were also counted separately, how many of them were found in every case. In this data the full count of one skull could be only 14, since some bones were not mentioned in the data.

Separated rows for each long bone were calculated and their side dexter or sinister. If even some part of the long bone was found and could be identified as this bone, it was marked to be one found bone. There were only few cases in which some long bones were unidentified. These were not marked to the table.

Bones were also divided to new groups similarly as in the study made in Germany by Ohlwärther, Holz, Edler and others. They divided bones in the larger groups and separated fragmented and complete bones. They formed groups for the skull, pelvic bones, vertebrae, flat bones, long bones and not determinable. In the study they did not determine specifically which bones belonged to which group. [24]
In this study group for short bones was formed in place of not determinable. This group contained hand bones, including carpals, metacarpals and phalanges, patella and foot bones, including tarsals, metatarsals and phalanges.
Group was formed from skull bones, which was already counted previously. Long bones which counted, clavicle, humerus, ulna, radius, femur, tibia and fibula. For flat bones scapula, ribs and sternum was marked. Vertebrae counted bones from C1-C7, Th 1-Th12 and L1-L5.
Pelvic bones included ilium, ischium, pubic bone, acetabulum and sacrum.
Even sacrum is part of the vertebrae, it was added to the group of pelvic bones. In the forensic osteology, sacrum is counted as a one part of human pelvis and affects the sex determination. [25]
Bones were counted as total even if some of them were marked fragmented, because the data collector could tell about the bone -which bone it was and from which side it belonged.

9.3. HYPOTHESIS

Main question of this thesis was "What is the recovery rate of different parts of the skeleton?", it was expected that skull bones were most often found in the cases, second most founded would be pelvic bones. Compared to other animal bones these are easiest to identify and recognized as human bones. Smaller bones can be moved by animals, so it was supposed they wouldl not be so frequently founded.
In the article bone finds and their medicolegal examination they found long bones, skull bones and vertebrae were most found. Skull bones were more commonly fragmented compared to vertebral bones, which were most commonly complete. In long bones fragmentation and complete bones were equal. In the study pelvic bones were least found. [24]
In this analysis there will be more bones which are fragmented and the fragmentation rate can be higher. Data which was given didn't separate in all cases which bones were fragmented, in some

cases bones which were fragmented was mentioned in the description and in other cases fragmentation was mentioned in the postmortem damage part.

In the study from Hesse, Germany they had 2781 other bones examined including human and animal bones, from these 1112 were nearly complete and 1669 were fragmented, so in this case also there was more fragmented bones compared to completed ones. [24]

The most accurate bones for evaluating gender of skeletal remains are pelvis and skull bones. Assuming that if the pelvis and skull bones are found, the sex can be determined from the skeletal remains.

Referring to "In adult bones skull and pelvis are about 90% accuracy when estimating sex in skeletal remains but also long bones are used for estimation of sex." [13] Of course conditions of recovered bones can affect the determination.

In the data there were more complete cases and fragmented skeletal remains. The assumption would be that skeletal remains, would be more complete if they are found underground or inside some building. The probability that bones would be transported elsewhere with animals decreases. In the data additional animal bones found with skeletal remains was also marked, there was not mentioned what kind of animal bones was found and how many. It is supposed in some cases they are found but the result is not significant.

In the study from Hasse, Germany made by Ohlwärther, Holz, Edler and others they recovered that half of the cases contained animal bones. Of all the bones and bone fragments only 43.9% were human origin. [24]

It is hypothesized that children are more frequently found in commingled cases than in individual cases. Children skeletal remains are less frequently recovered compared to adult skeletal remains. In the article diagenesis of juvenile skeletal remains, it is confirmed that childrens' bones decompose more rapidly due to smaller size, incomplete mineralization, higher organic content and greater porosity of the bones. [26]

10. RESULTS

Data consisted of 48 cases of skeletal remains. Minimum number of individuals was approximately 100. Recovery rate of all bones was measured, and which bones were mostly found in these cases. After calculating recovery rates of different parts of the skeleton, recovery rates were analyzed how they related to other variables.

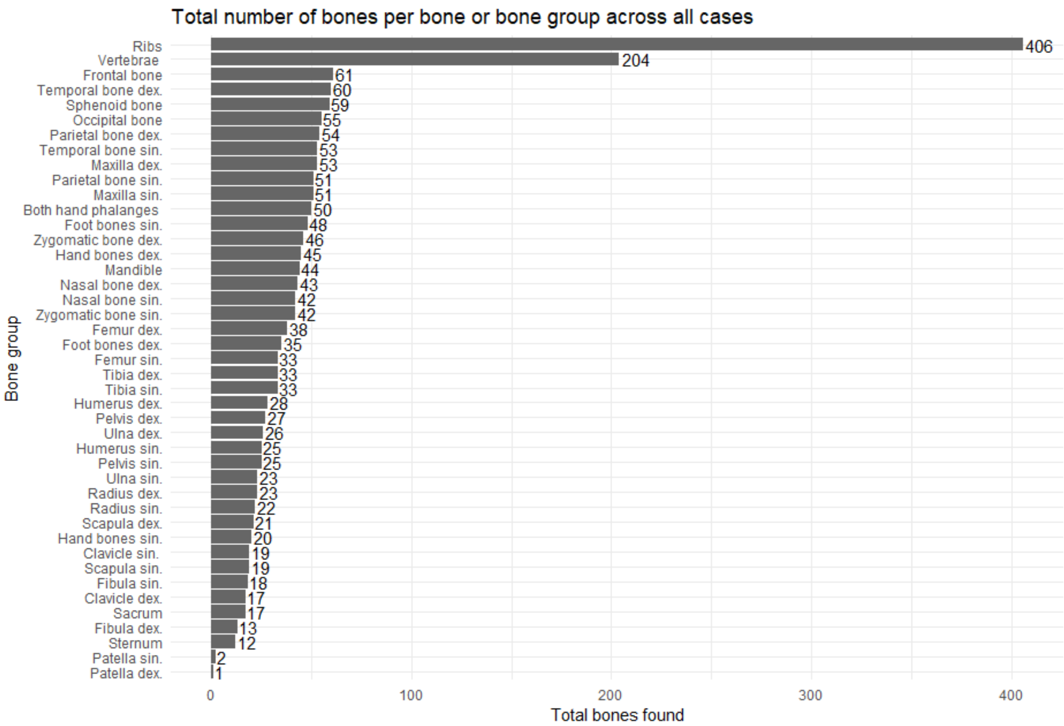
Analysis showed that most frequently found bones or bone groups was ribs (406) and vertebrae (204 pieces). After these two big groups most frequently found were head bones; frontal bone -61, temporal bone (dex.) -60, sphenoid bone -59 and occipital bone -55.

It is interesting that temporal 60 and parietal 54 bones from right side were more commonly found compared to left side, temporal 53 and parietal bone (sin.).

The fewest bones found were patella 3, sternum 12, fibula 13 (dex.) and 18 (sin.), sacrum 17 and clavicle 17 (dex.) and 19 (sin.).

Head bones were more frequently found in this data, including frontal, temporal, sphenoidal, occipital, parietal, maxilla, nasal, zygomatic and mandible bones.

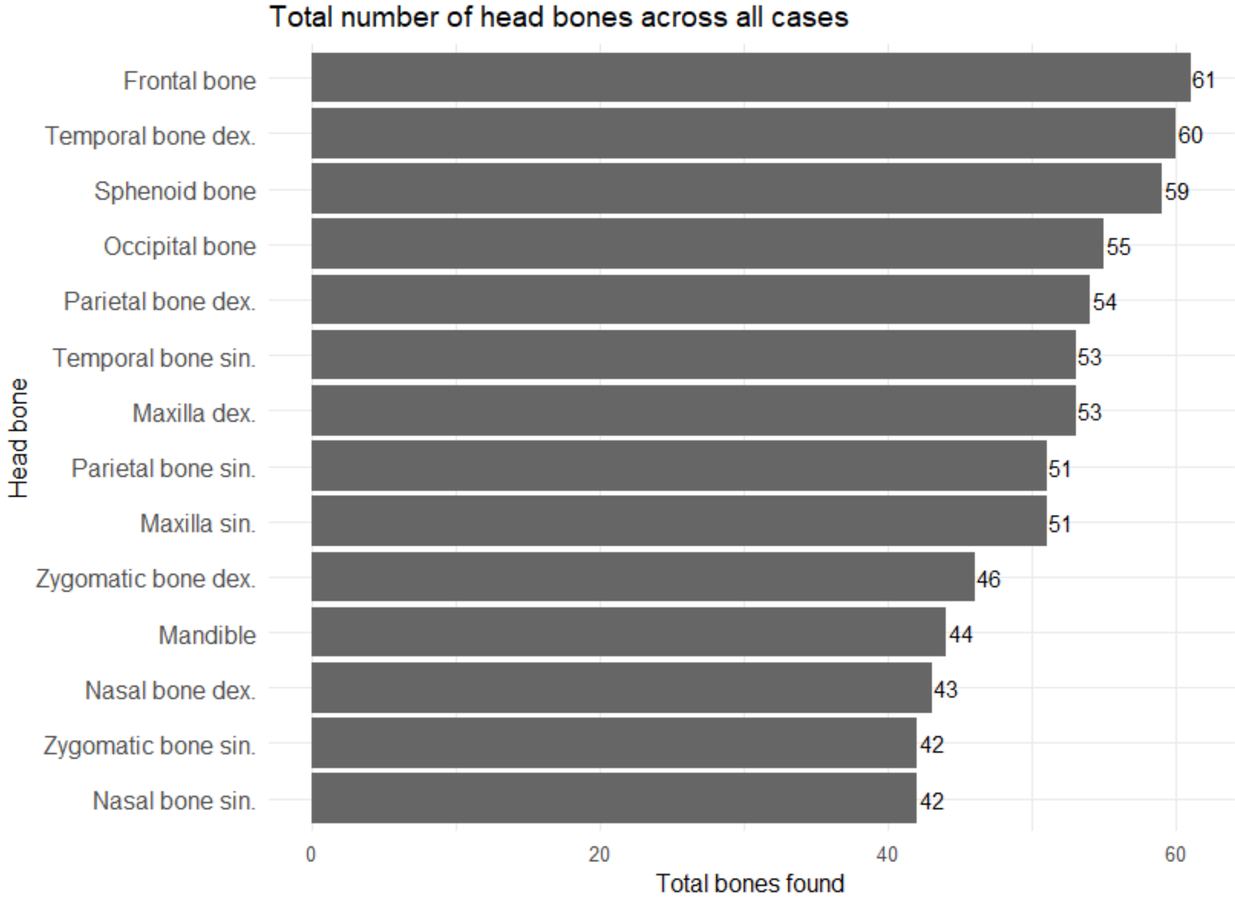
Figure 1. Most frequently found bones or bone groups.



Skull bones were also analyzed separately. Results showed that frontal bone is most often recovered -61 times. Second was temporal bone dex. -60 times, and sphenoid bone -59 times. Nasal bone and zygomatic bones were recovered 42 times.

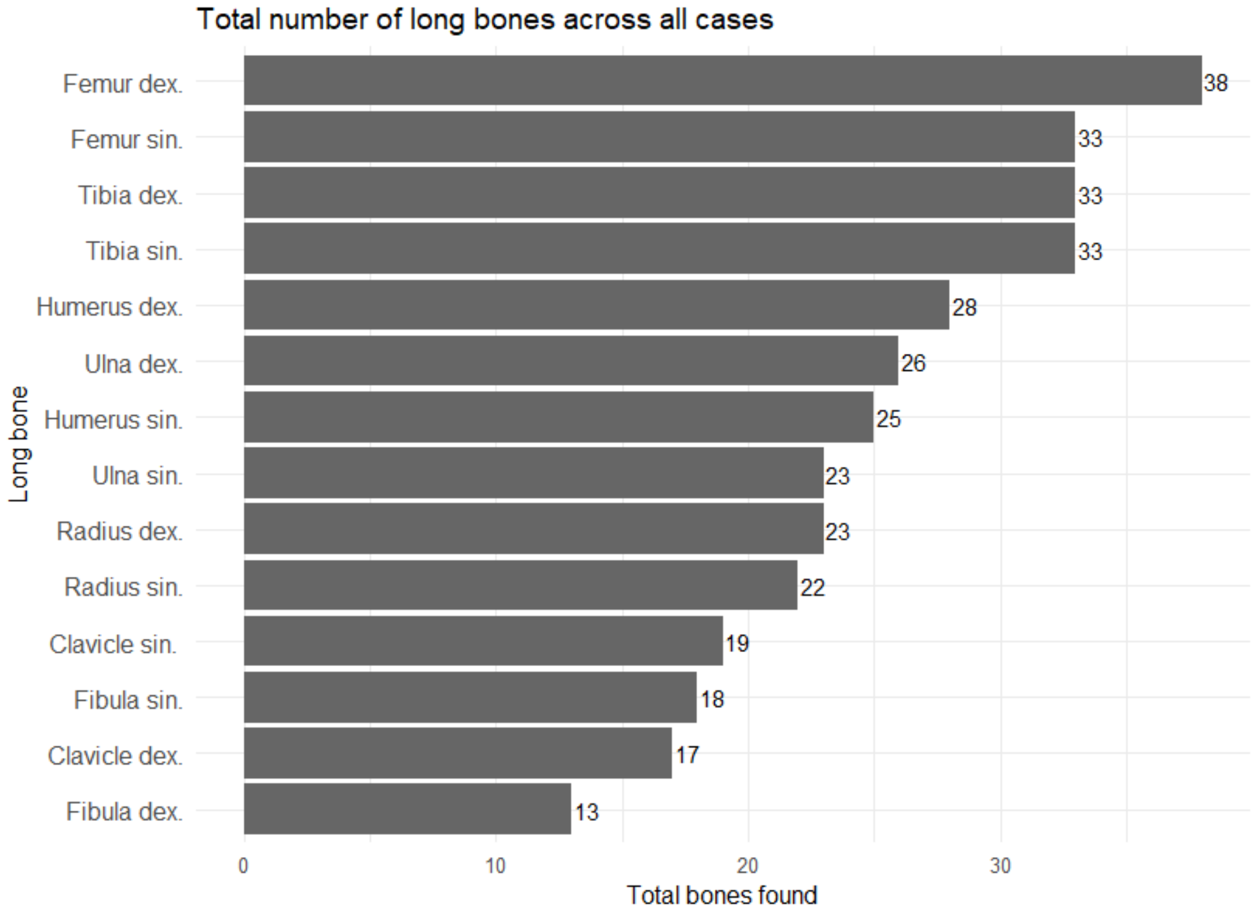
In total, skull bones were found in 37 cases from total 48 cases.

Figure 2. Most frequently found head bones.



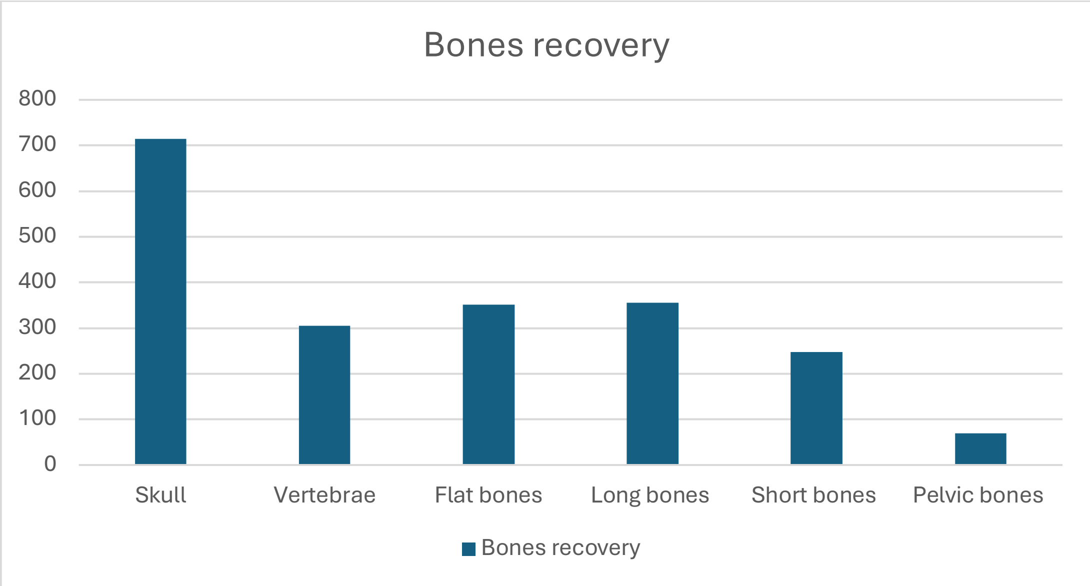
Long bones were divided by bone and their bilateral side, sinister and dexter. They contained clavicle, humerus, radius, ulna, femur, tibia and fibula. Most frequently recovered was right femur 38 times and left femur 33 times. Each tibia was found 33 times. Least founded was fibula right 13 times and left 18 times, right clavicle 17 times and left 19 times.

Figure 3. Most frequently found long bones.



Bones were also marked in the larger groups, skull, vertebrae, flat bones, short bones and pelvic bones. In this division also can be seen that skull bones were more markedly found, containing 714 elements of the skull. Pelvic bones were the least found in this sorting, to be noted it also contained sacrum. There was not that much difference in the number of vertebral bones, flat bones, long bones, and short bones.

Figure 4. Amount of bones divided into larger groups.



Since skull and pelvis can be used to sex determination. Data was analyzed to see if there was any correlation in sex determination if the skull and pelvis was found. In 48 cases, skull was found in 77.1% of the cases (n=37) and pelvis was found in 29.2% (n=14) of the cases, in this analysis condition of the bones and amount of fragmentation was not take account. Also, in all cases all the individual's gender was determined.

If no skull or pelvis was found, in 11.1% of cases sex of skeletal remains was determined and in 88.9% of cases sex wasn't determined.

If skull or pelvis was found 35.5% of cases sex was determined and in 64.1% sex was not determined. Compared if both skull and pelvis is found 27.8% cases sex was determined and 72.2% gender could not be determined.

If skull is not found, 81.8% cases sex was not determined and 18.2% of the cases sex was determined. When skull was present, in 35.1% of cases sex was identified and 64.9% cases it was not.

In cases where no pelvic elements were present, sex could not be determined in 73.5% of cases, while it was determined in 26.5% of cases. In cases where pelvic elements were present, sex could not be determined in 57.1% of cases, whereas sex was determined in 42.9% of cases.

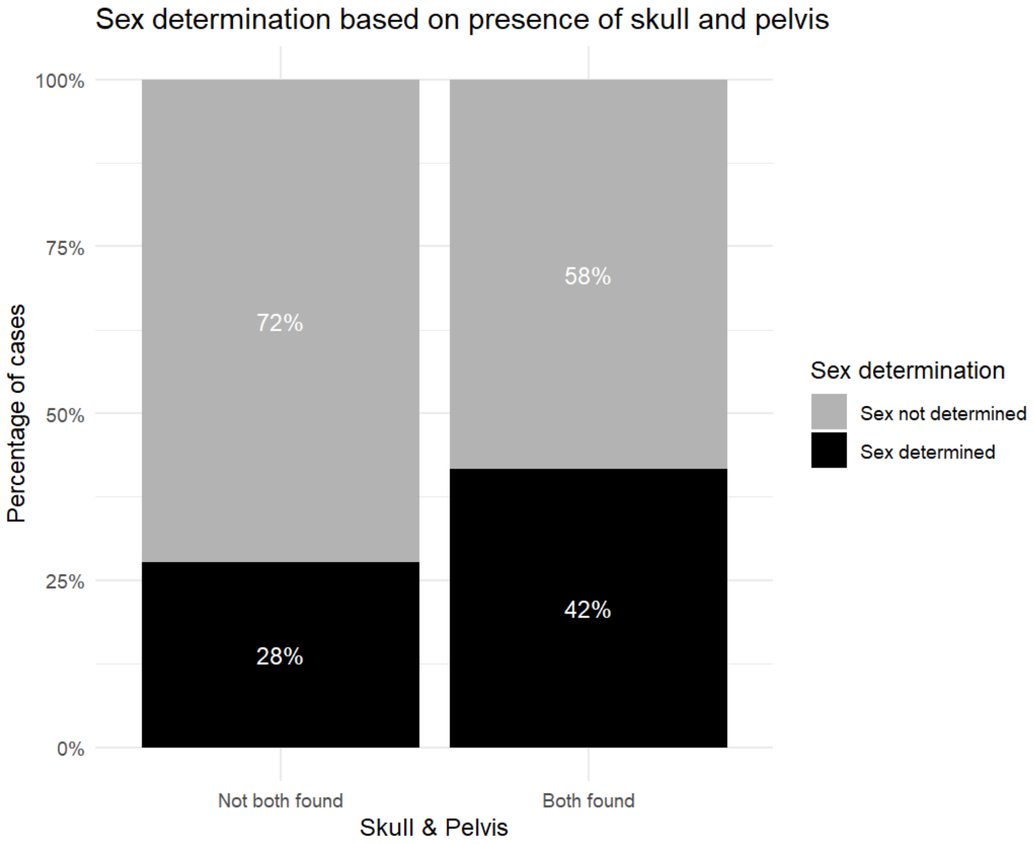
The statistical analysis was conducted to examine whether the presence of specific skeletal elements was associated with successful sex determination. A chi-square test showed no significant association between skeletal element presence (i.e., skull or pelvis found) and successful sex determination χ^2 (1, N = 48) = 1.10, p = .295. However, because one or more expected cell frequencies were below 5, the assumptions of the chi-square test were not fully met. Therefore, Fisher's Exact Test was also conducted. This test likewise indicated no significant association between skeletal element presence (i.e., skull or pelvis found) and successful sex determination (p = .239).

A chi-square test also indicated no significant association between the presence of both the skull and pelvis and successful sex determination $\chi^2(1, N = 48) = 0.29$, $p = .590$. Because some expected cell frequencies were below 5, Fisher's Exact Test was additionally conducted. This test also showed no significant association between the presence of both skeletal elements and successful sex determination ($p = .476$).

Further analysis examined the skull independently. A chi-square test showed no significant association between the presence of the skull and successful sex determination χ^2 $(1, N = 48) = 0.48$, $p = .487$. Because some expected cell frequencies were below 5, the assumptions of the chi-square test were not fully met. Fisher's Exact Test likewise showed no significant association between skull presence and successful sex determination ($p = .462$).

Similarly, analysis of pelvic bones demonstrated no statistically significant association between pelvis presence and successful sex determination, χ^2 $(1, N = 48) = 0.59$, $p = .441$. However, because some expected cell frequencies were below 5, the assumptions of the chi-square test were not fully met. Fisher's Exact Test likewise showed no significant association between pelvis presence and successful sex determination ($p = .315$).

Figure 5. Sex determination based on presence of skull and pelvis.

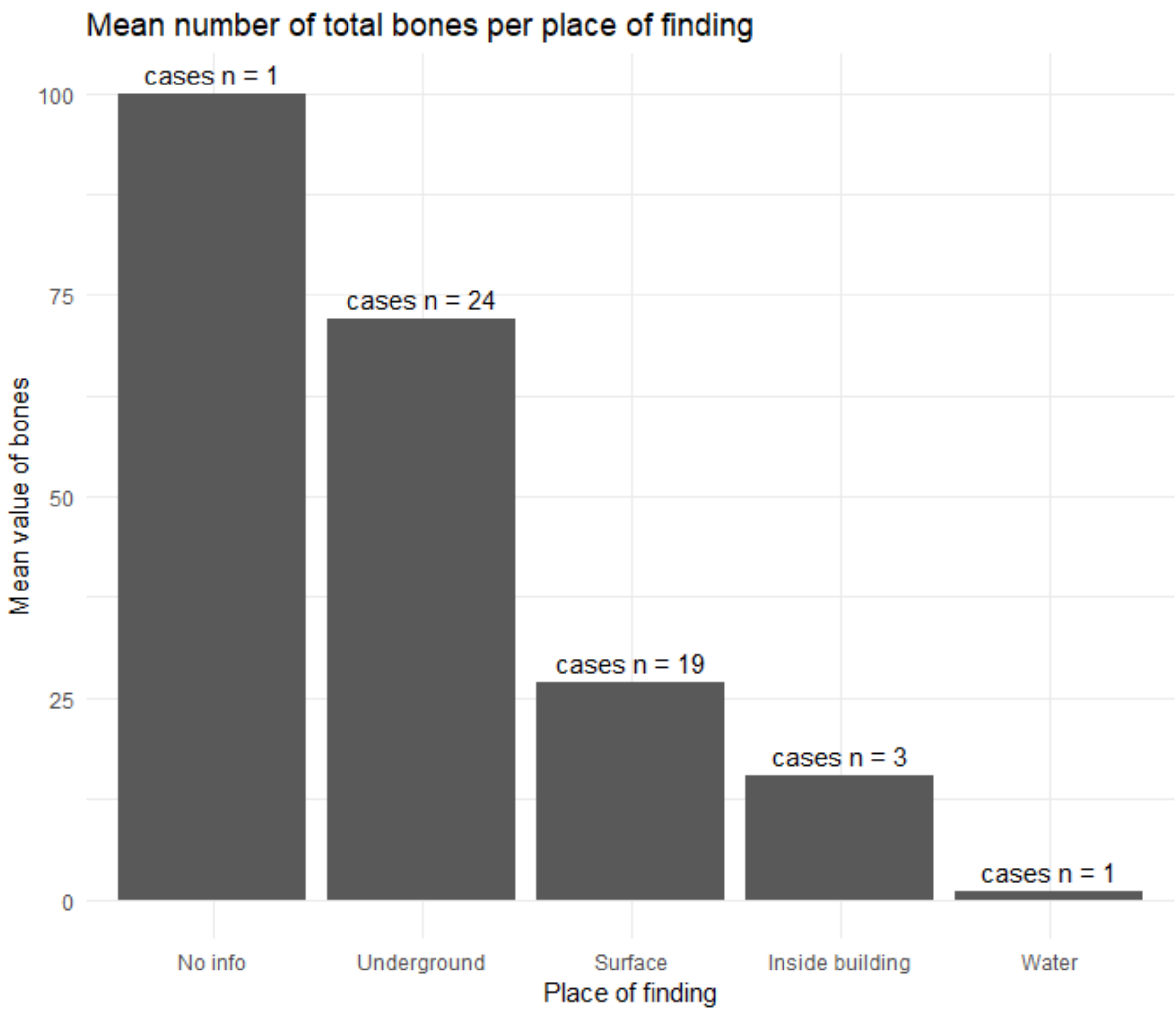


Amount of bones found was assessed based on the total number of bones recorded in each case and examined according to recovery location. A total of five categories were identified: no available information, underground, surface, inside building, and water.

For cases where no information on recovery location was available (n = 1), the total number of recorded bones was 100. In underground contexts (n = 24), the number of recorded bones showed considerable variation, ranging from a minimum of 1 to a maximum of 589. The mean number of bones was 72.0, while the median value was 20. For remains recovered from the ground surface (n = 19), the number of bones ranged from 1 to 79. The mean value was 26.9, and the median was 20. In cases recovered from inside buildings (n = 3), the number of recorded bones ranged from 13 to 20. The mean number of bones was 15.3, with a median of 13. For remains recovered from water (n = 1), only a single bone was recorded.

The number of bones recorded varied notably both within and between recovery locations, with particularly wide ranges observed in underground and surface contexts.

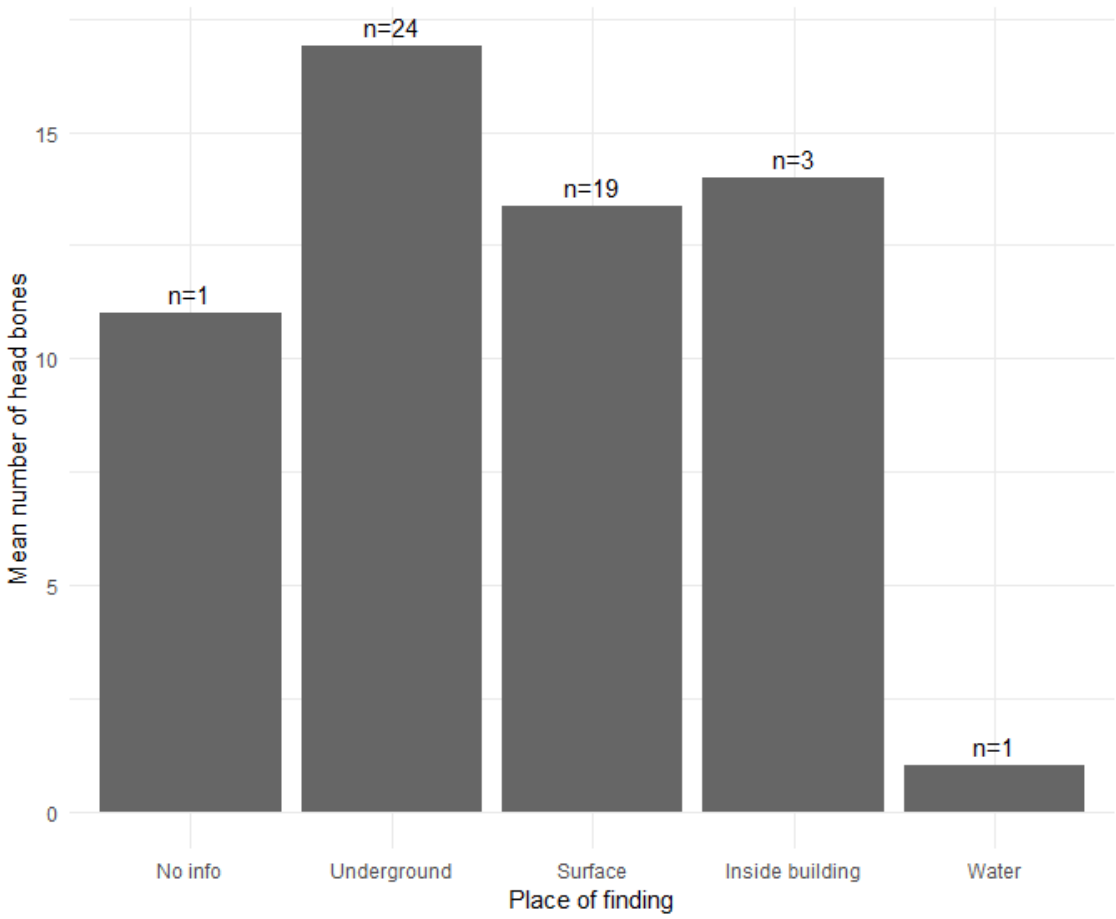
Figure 6. Mean number of total bones found per place of finding.



Similarly to the amount of bones found, we measured how much skull bones were recorded per case across different recovery locations, including underground, surface, inside building, water, and cases with no available location information.

For cases with no available information on recovery location (n = 1), a total of 11 skull bones were recorded. In underground contexts (n = 24), the number of skull bones per case ranged from 0 to 140, with a mean of 16.9 and a median of 7. For remains recovered from the surface (n = 19), the number of skull bones ranged from 0 to 65, with a mean of 13.4 and a median of 7. In cases recovered from inside buildings (n = 3), the number of skull bones ranged from 13 to 16, with a mean of 14 and a median of 13. For remains recovered from water (n = 1), one skull bone was recorded.

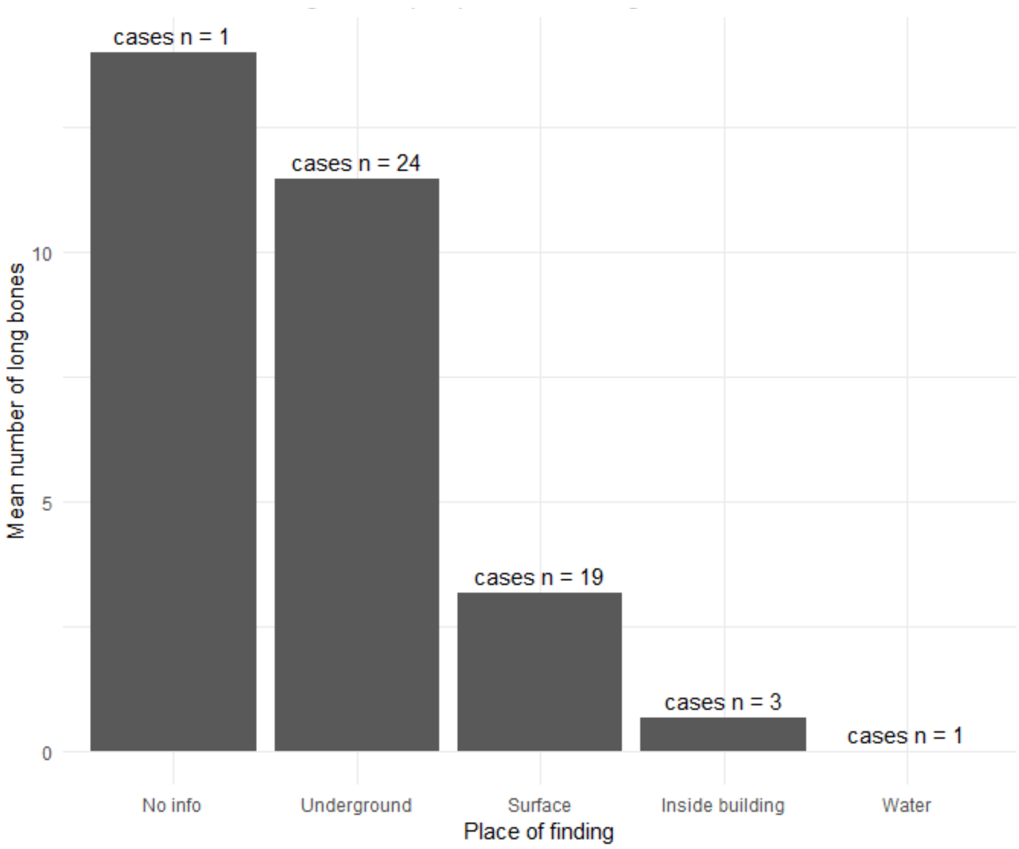
Figure 7. Mean number of skull bones per place of finding.



The distribution of long bones was examined based on the total number of long bones recorded per case across different recovery locations, including underground, surface, inside building, water, and cases with no available location information. Same locations as previously.

For cases with no available information on recovery location (n = 1), a total of 14 long bones were recorded. In underground contexts (n = 24), the number of long bones ranged from 0 to 116. The mean number of long bones was 11.5, with a median value of 4. For remains recovered from the surface (n = 19), the number of long bones ranged from 0 to 13. The mean value was 3.16, and the median was 1. In cases recovered from inside buildings (n = 3), the number of long bones ranged from 0 to 2. The mean number of long bones was 0.667, with a median of 0. For remains recovered from water (n = 1), no long bones were recorded.

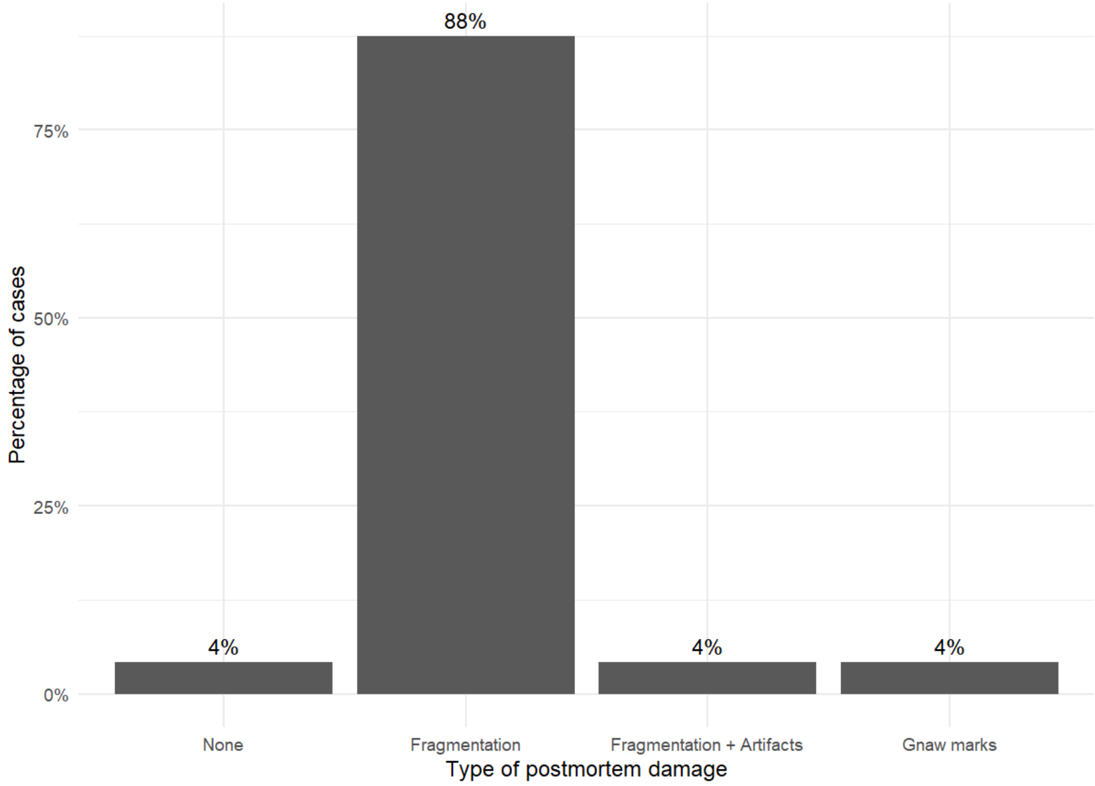
Figure 8. Mean number of long bones per place of finding.



Postmortem damage was assessed in a total of 48 cases and classified into four categories: no observable damage, fragmentation, fragmentation in association with artifacts, and the presence of gnaw marks.

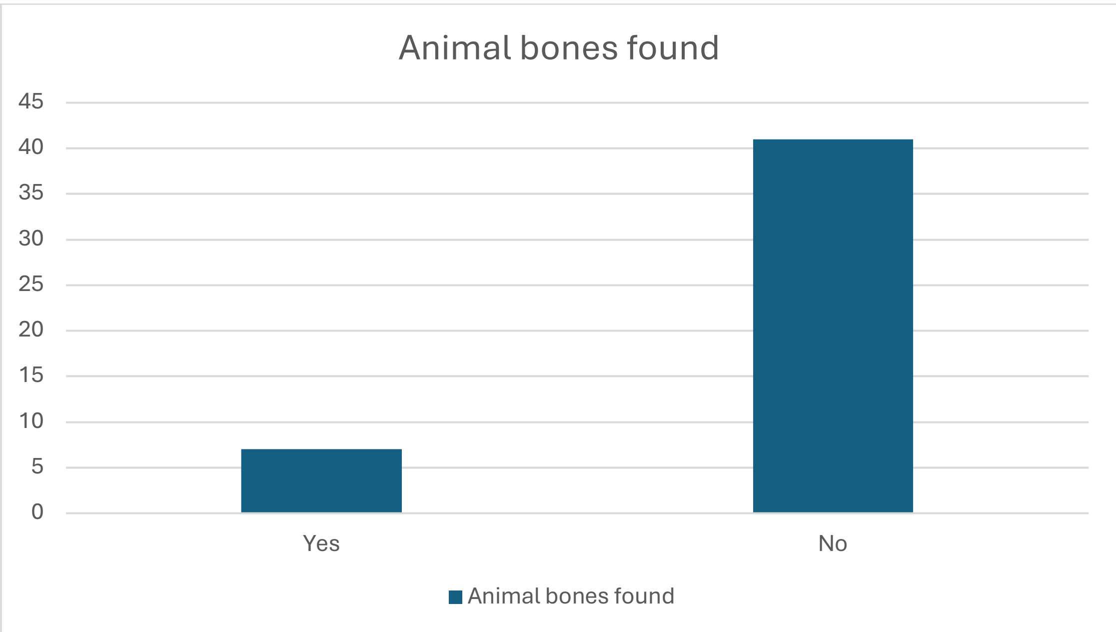
No postmortem damage was recorded in 2 cases, representing 4.2% of the total sample. Fragmentation was the most observed form of postmortem alteration, occurring in 42 cases, which corresponds to 87.5% of all cases examined. In 2 cases (4.2%), fragmentation was observed in conjunction with artifacts. Additionally, gnaw marks were identified in 2 cases, accounting for 4.2% of the sample.

Figure 9. Percentage of cases by typer of postmortem damage.



The presence of animal bones was assessed across a total of 48 cases. Animal bones were identified in 7 cases, representing 14.6% of the sample. In the remaining 41 cases (85.4%), no animal bones were recorded.

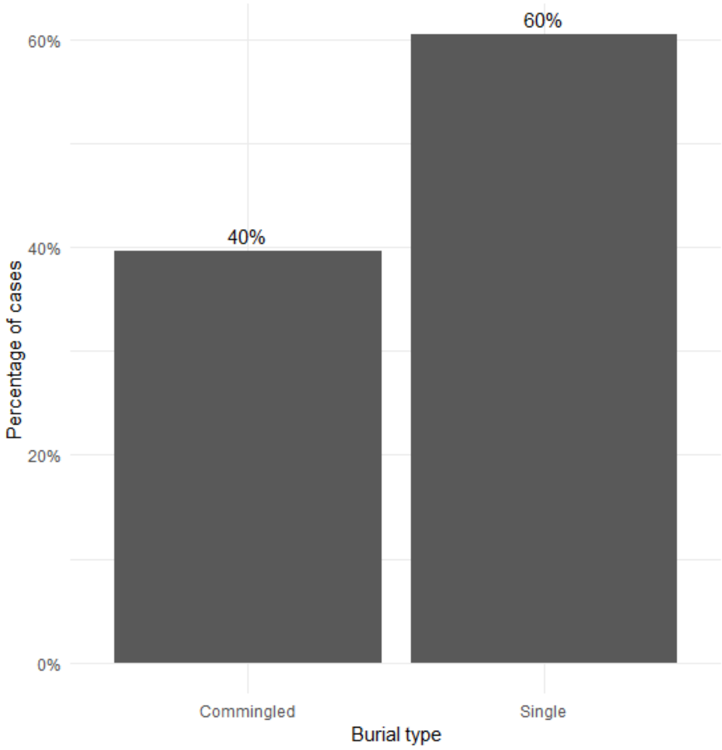
Figure 10. Amount of cases were animal bones were found.



The distribution of burial types was assessed across all cases and categorized into single and commingled skeletons.

Single skeleton cases, representing remains of one individual, accounted for 60.4% of the sample. Commingled cases, defined as containing remains of more than one individual, comprised 39.6% of the total.

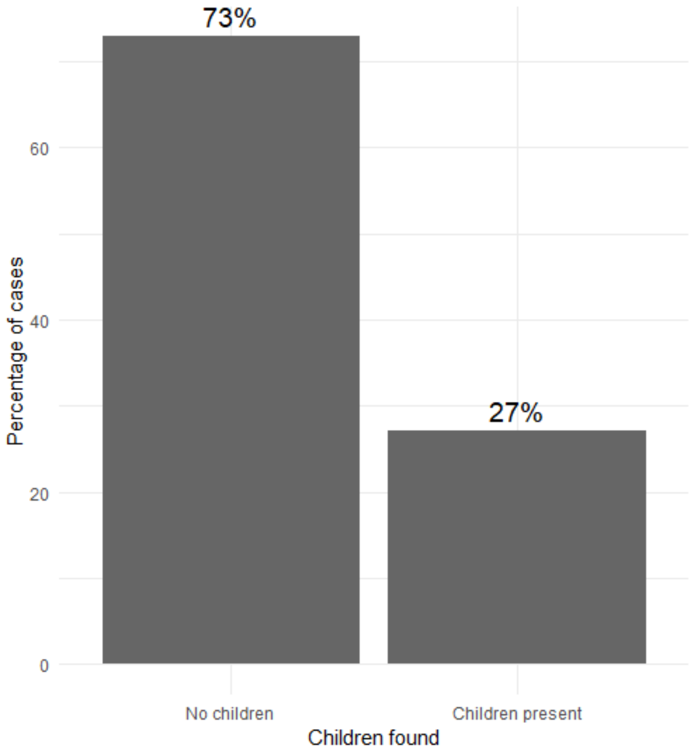
Figure 11. Comparison of skeletal findings; single vs. commingled burials.



The presence of children within the dataset was recorded for all cases and categorized as either present or absent.

Children were identified in 27.1% of the cases. In contrast, no children were recorded in 72.9% of the cases. These values indicate that, within the dataset, cases without the presence of children were more frequently observed than those in which children were identified.

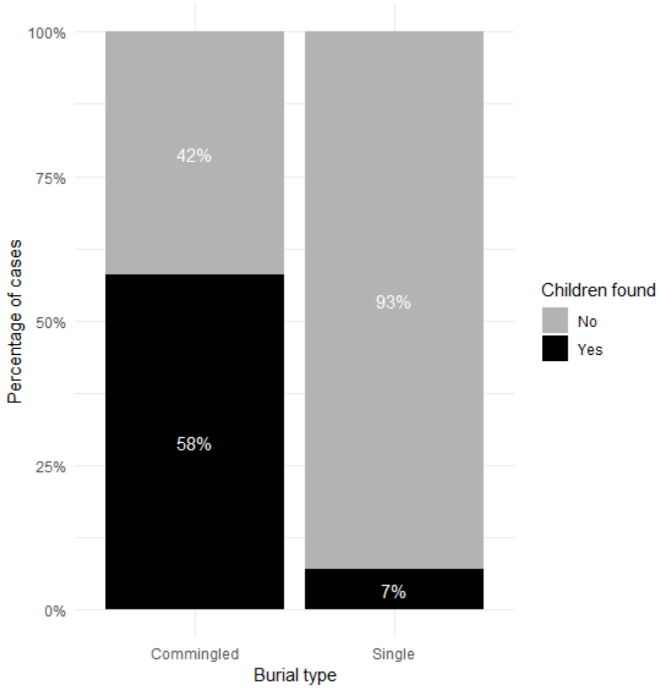
Figure 12. Amount of identified childrens from the data.



The occurrence of childrens were further examined in relation to the type of burial, categorized as either single or commingled skeletons.
In commingled skeleton cases, childrens were present in 57.9 % of the cases, while 42.1 % of cases did not include children. In single skeleton cases, children were present in only 6.9% of the cases, while 93.1% of cases consisted only adults.

A chi-square test showed a statistically significant association between burial type (i.e., commingled vs. single) and the presence of children, χ^2 (1, N = 48) = 12.65, p < .001. The results indicate that children were significantly more frequently recovered in commingled burials than in single burials.

Figure 13. Presence of children in single vs. commingled burials.



11. DISCUSSION

This data analysis examined the degree of recovery of skeletal bones and related variables in 48 cases; the minimum number of individuals was estimated to be approximately 100 remains. The results show clear differences in the recovery of bones in different skeletal groups, as well as differences in recovery context, fragmentation, and burial type.

The most frequently found bones were ribs and vertebrae, followed by skull bones such as the frontal bone, temporal bones, sphenoid bone, and occipital bone. The high prevalence of ribs and vertebrae may be related to their abundance in the human body and the relative durability of vertebral bones in depositional environments. Vertebral bones are easier to identify from animal bones. Although it does not explain the high amount of ribs found, considering ribs are thin and easily fragmented. Similarly, the high prevalence of skull bones suggests that skull bones are relatively well preserved or more easily identified when found. This is further supported by the high overall prevalence of skull bones, as they constituted the largest bone group in the material. Analysis of skeletal grouping further showed that skull bones were the most frequently found group, while pelvic bones were the least represented. This difference has important implications for forensic analysis, particularly in terms of sex assessment. Although both the skull and pelvis are commonly used to determine sex, the results show that the pelvis was present in only a minority of cases.

The relationship between the presence of skeletal bones and sex determination showed that the presence of either the skull or pelvis increased the likelihood of sex determination compared to cases where both were absent. However, even when these bones were present, sex determination was not always possible. So there was no statistically significant association between the presence of the skull and/or pelvis and successful sex determination. This suggests that factors such as preservation, completeness, and fragmentation play a significant role in limiting the applicability of standard osteological methods.

The location of recovery also influenced the number of bones recorded. The greatest variation and maximum number of bones found were observed in underground contexts, while fewer bones were generally found in surface and interior areas. There was one case of water contexts where finds were single bone. Similar patterns were observed for skull and long bones, and again in underground contexts the finds were most variable. These findings suggest that the depositional environment plays an important role in skeletal preservation and the outcome of the finds.

Fragmentation was a dominant feature of the data material and was observed in most cases. This high degree of fragmentation likely contributed to the variation in skeletal completeness and may have affected the identification of some bones. The presence of gnaw marks and fragmentation from violence in a small number of cases further suggests that post-mortem processes, including environmental and possibly biological factors, influenced the condition of the remains.

Animal bones were identified in a minority of cases, suggesting limited but significant interaction between human remains and animal activity or mixing of deposits.

The distribution of burial types revealed that most cases consisted of single individuals, although a significant proportion were commingled. The presence of children was relatively low overall. However, a clear difference was observed between burial types. Children were identified more frequently in commingled contexts than in single-skeletal burials and this showed statistically significant result.

Overall, the findings highlight the complexity of skeletal recovery and analysis and demonstrate that bone preservation, fragmentation, recovery context, and type of assemblage all influence the presentation of skeletal bones and the results of forensic analysis.

11.1. LIMITATIONS

Limitations for the literature review part, was that some of the sources are from archeological studies, and all the sources are not from the medical publications. For forensic anthropology and medicine there is limited sources and only small part from forensic medicine is forensic anthropology only.

In our university outlines, is marked that sources used in the thesis should have been written within 10 years, in this study there was not enough sources from this period.

Some limitations were recovered when interpreting the results of this data analysis.

The dataset consisted of 48 cases and approximately 100 individuals. While it was sufficient to identify general patterns and analyze bone recovery and for skeletal completeness, a larger dataset would likely provide more information for identifying remains, but this was not the purpose of the study.

The quality and consistency of the original data were limited. The storage format varied between cases (Excel templates vs. descriptive text). This required data transformation and standardization, which could lead to interpretation errors or minor inaccuracies during data entry and classification.

Another important limitation is the lack of detailed information on fragmentation. In other hand fragmentation was recorded as postmortem damage in most cases, it was not consistently described at the level of individual bones, although in some bones this was mentioned or described. As a result, fragmentation could not be quantitatively included in the analysis, although it is a critical factor affecting skeletal completeness and identification accuracy.

Additionally, some skeletal bones were excluded from the analysis due to their rare occurrence in the data (e.g., palatine and ethmoid bones). This may have slightly affected the overall representation of skeletal completeness, especially in cases where these bones were present but not explicitly documented.

The study is also limited by incomplete contextual information. For example, data on animal activity ware only recorded as a binary variable (presence/absence), without specifying species or how many animal bones were present. Similarly, recovery conditions were partially documented, but for this data analysis, they were excluded from the analysis, even though these factors may affect bone preservation.

The study is geographically restricted to Lithuania, and the findings may reflect region-specific recovery practices, environmental conditions, and taphonomic processes.

11.2. STRENGTS

One of the main strengths of the study is the use of real forensic case data collected over several years (2023–2025). The data reflects real forensic scenarios, including variation in recovery environments, fragmentation, and commingling. This enhances the ecological validity of the study and makes the findings directly relevant to forensic practice.

Another strength is the relatively diverse material in terms of recovery contexts. The inclusion of remains recovered from underground, surface, indoor, and water environments allows for a broader understanding of how different depositional conditions affects skeletal preservation and recovery rates.

The creation of detailed bone lists, including bilateral bones and subdivision of skull bones, allowed for a more precise assessment of skeletal representation.

A further strength is the comprehensive analysis of skeletal elements at multiple levels. The study not only examined individual bones, but also grouped them into anatomical categories (e.g., skull, long bones, flat bones, pelvic bones, and short bones). This multi-level approach provides both detailed and generalized views of skeletal completeness.

Additionally, the study integrates multiple variables, such as recovery location, postmortem damage, presence of animal bones, burial type (single vs. commingled), and presence of children. This multifactorial approach allows for a more comprehensive understanding of the factors influencing skeletal recovery and completeness.

The use of tools like Excel and R Studio supports reproducibility and transparency in data processing and analysis.

11.3. RECOMMENDATIONS FOR FUTURE RESEARCH

For future research, it is recommended to include larger and more diverse datasets. Expanding the sample size and incorporating material from different countries would improve the generalizability of the results and allow for more robust statistical analyses. Comparative studies across different environmental and forensic contexts would be particularly valuable.

More standardized data collection protocols of skeletal completeness are needed in forensic medicine/anthropology. Consistent recording of skeletal components, fragmentation, and preservation conditions would significantly improve data quality and inter-study comparability.

An important recommendation is to include a detailed fragmentation analysis. Since fragmentation plays a crucial role in skeletal completeness and identification, future studies should quantify fragmentation at the level of individual bones. As mentioned in the methodology section, there is a template for fragmented bones, but it was developed 30 years ago. This would allow for a more accurate assessment of how fragmentation affects recovery rates and the assessment of the biological profile.

Furthermore, future research should further investigate the influence of environmental and taphonomic factors. Variables such as soil composition, climate, burial depth, and animal activity should be systematically recorded and analyzed to better understand their impact on bone preservation and recovery. This type of research has been conducted in Germany, and it would be interesting to know how these variables affect other countries.

This research could be continued by investigating the relationship between skeletal completeness and the accuracy of biological profile assessment. Research could focus on determining the threshold levels of completeness required for reliable assessment of sex, age, and height.

12. CONCLUSIONS

To conclude this data analysis, which examined the recovery rates of different skeletal bones and analyzed factors influencing skeletal completeness. Findings showed that skeletal recovery is highly variable and influenced by many factors, including bone type, depositional environment, fragmentation and burial type.

Data analysis results showed that ribs and vertebral bones were the most frequently found bones, probably because of their high number in the human body, also vertebral corpus is dense bone material and easier to recognize. Although it does not explain the high amount of ribs found, considering ribs are thin and easily fragmented.
Skull bones were also commonly identified, especially frontal bone, temporal bones, sphenoidal bone and occipital bone. In contrast, pelvic bones and some long bones, such as fibula and clavicle, were less frequently recovered. When grouped anatomically, the bones of skull formed the most represented group, while the bones of pelvis were the least represented group.

Results also showed that skeletal completeness affects to the ability to construct a biological profile. The presence of skull and pelvis increased the probability of sex determination. However, even if these elements were present, identification is not guaranteed. This highlights the effects of preservation and fragmentation.
The highest amount of bones was found in the underground, while fewer bones were found in the surface, inside building and water. This showed that the burial type affects to the recovery of the bones.

Fragmentation was found to be a dominant feature in the material, occurring in most cases. This affected to the skeletal completeness and probably to the number of finds and analytical results. Study also found that commingled burials were common and were more often associated with the presence of child remains, compared to single burials.

More studies are needed to improve the standardization of recording skeletal completeness, considering the high fragmentation of the bones.

13. REFERENCES

[1] Rowbotham S. K., Blau S., Hislop-Jambrich J. Recording skeletal completeness: A standardised approach. Forensic Science International. 2017; 275: 117-123. https://doi.org/10.1016/j.forsciint.2017.02.036

[2] Scacciaferro H. R., Skeletons in the database: digitally investigating skeletal completeness using iris. Florida Gulf Coast University. 2025. https://scholarscommons.fgcu.edu/esploro/outputs/graduate/Skeletons-In-The-Database-Digitally-Investigating/99385528927706570#file-0

[3] Iscan M.Y., Steyn M. The human skeleton in forensic medicine. Third edition. Springfield, Illinois. Charles C Thomas. 2013.

[4] Palmitto A., Winburn A.P., Pink G., Brown G.A., LeGarde C.B. Forensic anthropologists and estimates of skeletal completeness: The impacts of training and experience. Science&Justice. 2024: 64:104-116. https://doi.org/10.1016/j.scijus.2023.12.004

[5] Lecomte D., Plu I., Froment A. Modern biology, imagery and forensic medicine: contributions and limitations in examination of skeletal remains. Bulletin de l'Academie Nationale de Medicine. 2012: 196: 1103–1116. https://www.researchgate.net/publication/236226085

[6] Langley N.R., Jantz L.M., Ousley S.D., Jantz R.L., Milner G., Data collection procedures for forensic skeletal material 2.0. Knoxville. The university of Tennessee. 2016 https://fac.utk.edu/wp-content/uploads/2016/03/DCP20_webversion.pdf

[7] Mercian archaeology. Osteological analysis of human remains from the chapter house, Worcester cathedral. 2003 Aug. https://www.ossafreelance.co.uk/PastProjects/WCCH03sk1188.pdf

[8] Osterholtz A.J., Baustian K.M., Martin D.L. Commingled and disarticulated human remains: Working toward improved theory, method and data. New York. Springer Science+Business Media. 2014. https://doi.org/10.1007/978-1-4614-7560-6_3

[9] Parmentier S., Signoli M., Adalian P. Reliability of two methods of estimation of the minimum number of individuals (MNI) from commingled remains. La revue de medecine legale. 2022:2: 46-53. https://doi.org/10.1016/j.medleg.2011.04.002

[10] Robb J. What can we really say about skeletal part representation, MNI and funerary ritual? a simulation approach. Journal of archeological science: reports. 2016: 10: 684-692. https://doi.org/10.1016/j.jasrep.2016.05.033Get rights and content

[11] Thompson T., Black S., Forensic Human Identification: An Introduction. Boca Raton, Florida USA: CRC Press; 2007. Pages ,202-214, 214- 216.

[12] Beier J., Santon M., Rathmann H. Estimating trauma prevalence from incomplete human skeleton remains. Scentific reports. 2024: 14: Article number 27713. https://www.nature.com/articles/s41598-024-76231-1

[13] Cheng P. Forensic examination of skeletal remains. International journal of research and analytical reviews (IJRAR). 2023:10: 240–351. https://www.ijrar.org/papers/IJRARTH00061.pdf

[14] Blau. S. Encyclopedia of forensic sciences: Skeletal analysis.Third edition. Elsevier: 2023; 551-562. https://doi.org/10.1016/B978-0-12-823677-2.00002-7

[15] Appel N.S., Edgar H.J.H. A pilot study of age estimation and cause of death: Insight into skeletal aging. Forensic sciences. 2024: 4: 508-522. https://doi.org/10.3390/forensicsci4040034

[16] Ubelaker D.H., Khosrowshahi H., Estimation of age in forensic anthropology: historical perspective and recent methodological advances. Forensic sciences research. 2019; 4:1-9. https://pmc.ncbi.nlm.nih.gov/articles/PMC6427487/pdf/tfsr-4-1549711.pdf

[17] Mitchell P.D., Brickley M. Updates guidelines to the standards for recording human remains. British association for biological anthropology and osteoarchaeology. 2017. Chapter 2 and 7. https://babao.org.uk/wp-content/uploads/2023/08/14-Updated-Guidelines-to-the-Standards-for-Recording-Human-Remains-digital.pdf

[18] Dubzik B., Langley N., Estimating age from the pubic symphysis: A new component-based system. Forensic science international. 2015: 257: 98-105. https://doi.org/10.1016/j.forsciint.2015.07.047

[19] Spradley M.K., Metric methods for the biological profile in forensic anthropology: sex, ancestry and stature. Acad Forensic Pathol. 2016 Sep; 6 (3): 391-399. https://doi.org/10.23907/2016.040

[20] Cunha E, Ubelaker DH. Evaluation of ancestry from human skeletal remains: a concise review. Forensic Sci Res. 2019 Dec 23;5(2):89-97. doi: 10.1080/20961790.2019.1697060.

[21] Haas J, Buikstra JE, Ubelaker DH. Standards for data collection from human skeletal remains. Fayetteville, AR: Arkansas Archeological Survey Research Series; 1994. https://archive.org/details/isbn_1563490757_t0j9

[22] de Boer HH, Roberts J, Delabarde T, Mundorff AZ, Blau S. Disaster victim identification operations with fragmented, burnt, or commingled remains: experience-based recommendations. Forensic Sci Res. 2020 May 26;5(3):191-201. doi: 10.1080/20961790.2020.1751385.

[23] INTERPOL. Disaster victim identification guide: Post-mortem (PM) forms: INTERPOL; 2023. https://www.interpol.int/content/download/5325/file/PMFormSet_en-GB.pdf

[24] Ohlwärther TEN, Holz F, Edler K, Kölzer SC, Reuss E, Verhoff MA, Birngruber CG. Bone finds and their medicolegal examination: a study from Hesse, Germany. Forensic Sci Med Pathol. 2024 Jun;20(2):480-489. doi: 10.1007/s12024-023-00599-1.

[25] Garg A, Goyal N. Forensic Osteology and Identification [Internet]. Forensic Analysis - Scientific and Medical Techniques and Evidence under the Microscope. IntechOpen; 2021. https://doi.org/10.5772/intechopen.99358

[26] Caruso V, Marinoni N, Diella V, Possenti E, Mancini L, Cantaluppi M, et al. Diagenesis of juvenile skeletal remains: A multimodal and multiscale approach to examine the post-mortem decay of children's bones. J Archaeol Sci. 2021; 130:105477. https://doi.org/10.1016/j.jas.2021.105477