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Front page figure 1 Photograph of the Nazca desert where the mummified human remains are scattered across the desert. (Photo by Marloes Attema)

Review and comparison of bioarchaeological research techniques for mummified human remains (100 BC-650 AD) in Nazca, Peru

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1. Introduction

“For dust thou art, and unto dust shalt thou return.” (King James Bible Online, 2023). Since time immemorial it was known that after death the body would decompose. Through decay and putrefaction human remains break down completely until nothing remains. Environmental causes or cultural practices can sometimes cause one or both of these post-mortem processes to be impeded. In those cases the human remains stay preserved to this day, creating mummified human remains (Piombino-Mascali et al., 2017, pp. 101-119).

A region that is strongly characterized by the discovery of these mummified human remains is the Central Andean. Archaeologists have found mummified human remains from the tops of the Andean Mountains, such as the Inca ice girl Juanita, to the Chinchorro mummified human remains discovered in the Atacama Desert (Lombardi & Arriaza, 1998, p. 154; B. Arriaza et al., 1998, pp. 190-234). Mummification has been in use for at least 9,000 years in the central Andean region. The ubiquity of mummified human remains in this region is due to a combination of factors: not only does the dry climate create near-ideal conditions for natural mummification, but there are also several precolonial societies like the Chachapoya, Chinchorro and Chiribaya that performed mummification as part of their burial rites (Guillén, 2004, pp. 141–157). These mummification processes led to the existence and subsequent discovery of mummified human remains in this region.

One region in the Central Andean where a lot of these mummified human remains have been found is the Nazca region. The environment of Nazca is dry and hot with temperatures varying between 19°C and 31°C and an annual rainfall of merely 5 mm (Ministerio del Ambiente, 2020). The hot climate and the lack of precipitation make this area suitable for natural mummification. Mummified human remains are quite often discovered within the Nazca region as a result of these ideal factors.

Discovered mummified human remains are often researched because of their scientific value in medical, cultural and taphonomic fields. Medical research provides information such as the individual’s age, gender, cause of death and other medical conditions. It’s sometimes also possible to link internal parasites, bacteria or their diet to the mummified human remains (Araújo et al., 2015, pp. 349-387; Mytum, 2021, pp. 96-109). Mummified human remains also reveal a lot of information about the culture where the individual lived and died. Clothing can indicate social status and occupation, the human body can have culturally characteristic tattoos or other ornamental decorations, and even the way the body is found can be indicative of a culture’s mortuary behavior and postmortem treatment (Mytum, 2021, pp. 96-109). Taphonomy seeks to determine the reason the mummified human remains have been preserved over time. By determining why the remains do not suffer from the usual post-mortem processes of decay and putrefaction, it is possible to learn about the environmental impact and cultural practices of the mummification (Piombino-Mascali et al., 2017, pp. 101-119) All these three fields combined give a rich narrative on the life and death of both the individual the mummified human remains once were, as well as the culture the individual belonged to (Mytum, 2021, pp. 96-109).

Research has been performed on the mummified human remains of Nazca. Rosendahl et al. (2014), for example, made the mummified human remains of an individual belonging to the Nazca culture around AD 450-600 undergo a CT-scan at the University Clinic of Mainz. With the captured information the researchers determined the sex and age of the mummified human remains (Rosendahl et al., 2014, p. 101). Sawicki et al. (1976), made human remains undergo an autopsy where a biopsy of fecal material was taken. The samples were tested for various antigens as a first attempt to perform paleo-serology, the study of ancient body fluids (Sawicki et al., 1976, pp. 805-810). Because of research like these, new knowledge about the people who used to live in the Nazca region is obtained.

One point where the Nazca research of human mummified remains can be improved is in how the archaeological data is archived. According to Shimada and Vega-Centeno (2011) North-American archaeological projects tend to be problem-oriented and individualistic in nature. A research organization consisting of a single professor and students who after graduating seek off their own site to establish their own projects. Because a lot of the Peruvian archaeology is insular, it gives researchers in Peru a significant challenge when it comes to the spreading of information between archaeological sites.

The limited spread of archaeological information makes it easier to tamper with the mummified human remains. One example where that happened were the so-called “Nazca aliens”. These are a recent hoax of a supposed extraterrestrial mummified remains that in reality are an amalgamation of several looted human remains haphazardly put together (Lombardi & Rodríguez Martín, 2021, pp. 7-13). The creation of an archive or database in which Peruvian researchers could submit their reports would greatly help prevent possible tampering (Shimada & Vega-Centeno, 2011, pp. 569-612; Tomasto-Cagigao, 2020, pp. 141-149).

Another point of improvement with the research of Nazca mummified human remains is that most of the research techniques utilized in Peru are dated. Peruvian archaeology places the focus on rescue archaeology and less on research archaeology. This puts a limit on the amount of funding that goes to research archaeology, especially when compared to other regions in the world that do place the focus on research archaeology. With limited funding there is less incentive to update on technologies for archaeological research. (Shimada & Vega-Centeno, 2011, pp. 569-612; Lane, 2012, p. 223).

Technological advancements in the field of archaeology continue to this very day. Even the meaning of once clearcut concepts like “site” or “preservation” change through the onset of new technology (McCoy, 2020, pp. S18-S26; Zhong et al., 2021, pp. 535-551). Better technology would help improve the depth and the width of the research that can be performed on the mummified human remains in the Nazca region. It is for this reason that it is important that good and updated technology is being used in archaeological research (Shimada & Vega-Centeno, 2011, pp. 569-612).

The combination of poor archiving of the mummified human remains and dated research limits how well research on mummified human remains in the Nazca region can be performed. If one or more of the aforementioned issues can be resolved then the ability to perform research towards the people who used to live in the Nazca region improves greatly. Better documentation and archiving would allow archaeological research to make better use of the knowledge obtained from previous research and make cross-cultural comparisons, while updated research techniques would give us better knowledge of the individual and culture the mummified human remains belonged to (Shimada & Vega-Centeno, 2011, pp. 569-612; Mytum, 2021, pp. 96-109). Improvements to the research of mummified human remains would thus be a valuable addition.

To improve the research on mummified human remains in the Nazca area it is important to look at other mummified human remains research performed in similar locations. This allows us to understand what methods of research would prove most effective of obtaining archaeological knowledge while preserving the mummified remains for the future. However, there have been no comparisons made of the research techniques between Nazca and similar locations to date. It is for this reason that my research seeks to perform this task to improve future research of mummified remains in the Nazca region.

The main goal of this research is to set up a comparison of the research techniques used on mummified human remains found in the Nazca region compared to the research techniques used on similar types of mummified human remains found in other regions. This comparison can then be used to guide future research on how to improve research on mummified human remains in the Nazca region. For that reason, this research has the following primary research question:

"How do the methods of research towards mummified human remains for the Nazca region in Peru compare to mummified human remains research in other arid regions in the world?"

To answer this main question, I have four secondary research questions that first need to be answered before I have the necessary knowledge to properly answer the primary research question:

- Which research techniques are used on the mummified human remains found on Nazca sites?
- Which other arid regions in the world perform research on mummified human remains most similar to those found in the Nazca region?
- Which research techniques are used in these aforementioned regions?
- What is the potential use of the aforementioned research techniques for mummified human remains research in the Nazca region?

In the first part of this research, I answer the four secondary research questions through systematic literature review. This starts with cataloguing the mummified human remains found in the Nazca region and determining what type of mummified human remain it is as well as the research techniques used on them. The categorization will minimally include natural or artificial mummification, as well as the specific characteristics of the mummification progress. This is followed by an interregional study between Nazca, China and the Nile region to compare theory and practice of the archaeological investigation of mummified human remains, seeking out similarities and differences to Nazca region, and cataloguing which research is performed on the mummified human remains in those regions.

The results of this interregional comparison will form the basis of a database that is structured so as to categorize each mummified human remains by type and form of mummification, location, and used archaeological techniques. Combining the knowledge obtained will allow us to give an answer in the primary research question in the conclusion.

2. Methodology

The goal of this research is to determine how the archaeological study of mummified human remains in the Nazca region differs from other arid regions in the world. To do this, a database will be created containing a list of discovered mummified human remains as well as the corresponding research techniques performed on them. The database will contain both mummified human remains found in the Nazca region as well as mummified human remains discovered in other arid regions around the world similar to those of the Nazca region.

The following steps have been taken to create the database:

1. Systematic literature review of the mummified human remains discovered in the Nazca region and their corresponding research techniques.
2. Comparison of other arid regions with mummified human remains similar to the Nazca region.
3. Systematic literature review of the mummified human remains discovered in the regions discovered in step 2.
4. Implementing the results from step 1 and 3 into a database.

After the database is constructed, I will then answer the main question of this research. This is done by using the database to compare which technology differences there are between the Nazca region and the compared regions. After obtaining the answer to this question I then perform one last step to answer the fourth sub-question in the Introduction:

5. Systematic literature review of which research techniques, only used in the regions determined in step 2, have potential use in the Nazca region.

All the literature acquired has been placed in a personal database in the Zotero application. By doing this, the literature is sorted and easily accessible. The database and all of the tables will be created using Microsoft Excel.

2.1. Mummified human remains and corresponding techniques in the Nazca region

The first step in this research is to perform a systematic literature review of the mummified human remains and its research techniques. This is done to get an overview of the currently performed research on the Nazca mummified human remains.

To determine which literature is suitable and can be used for this research, the literature need to meet a few requirements. The literature needs to be objective and needs to come from a reliable source. The literature has been found trough the use of the search engines Google Scholar and Academia.edu as well as through the online library of Leiden University. Generic search terms have been used in the search engines to find literature. These search terms include: “mummified human remains research”, “Nazca mummified remains”, and “Chauchilla Cemetery” among others. To find more specific literature on certain topics, detailed search terms have been used such as “Isotope analysis of the Xinjiang mummified human remains”. Apart from finding literature through search engines, some literature has been used from academic books belonging to my personal collection. Other literature has been found through the bibliography of other literature to get more insight on certain subjects.

The discovered literature has been sorted inside of table 3, located in Appendix A, sorted on the following points: Mummified human remains identifier, amount of researched mummified human remains, artificial or natural mummification, institute/university, country of research, research technique, reason of research, date of research/publication and literature documentation.

The research techniques have been categorized in 10 different research methods: Paleopathology, Osteology, Dating, Radiology, Isotope Analysis, Endoscopy, Paleohistology, Hematology, DNA analysis and Toxicological analysis. In tables 4 and 5, which can be found in appendix A, the literature publications are numbered and sorted in the different research methods.

2.2. Comparison of other arid regions

During this step I seek to compare the other arid regions in the world where mummified human remains are found with the Nazca region. I do this to determine which areas have the most comparable mummified human remains and whose corresponding research techniques could best be compared with those of the Nazca region.

This step starts with listing all the arid regions in the world, and performing a systematic literature review to determine if it has a history of mummified human remains being discovered in that area. This list can be found in table 6 in appendix B. The countries have been sorted on the following points: Region, hot desert climate, cold desert climate, containing mummified human remains, containing arid mummified remains and the general name of the mummified material. A summarized overview of this list can be found in table 7, in appendix B.

A comparison between the region and the Nazca region has been made to select two regions who will be used in chapter 3.3. All of the regions containing arid mummified remains have been placed in table 8, which can be found in appendix B, and have been sorted on the following points: Region, climate, precipitation, mean temperature, culture age, find place, natural/artificial mummification, mummification method, latest research date, if research has been carried out in country of origin and amount of research techniques.

The two regions with the most comparable factors are selected for the comparison in the following parts of the research.

2.3. Mummified human remains and corresponding techniques in other regions

During the third step of my results, I will use a systematic literature review of the research techniques utilized on the mummified human remains from the two chosen regions. The two regions have been added into tables 9 till 12, which can be found in appendix C.

The tables are divided into two parts: in the first part the articles are documented with an associated article number. The second part holds all the region's research techniques. For each different research technique, the literature numbers in which these techniques appear are listed.

2.4. Implementation of Database

The fourth step in my research is to implement the gathered data of the research techniques from the Nazca region and the selected two regions into a database. I do this to make a clear list of data which can be easily accessed, adjusted, or edited. The database can be found in appendix D and contains the tables 13-18. The database will consist of 6 different Excel sheets: Peru, Peru literature, Region (A), Region (A) literature, Region (B) and Region (B) literature.

For each different region, the region sheets will have the same structure as well as that region's literature sheets will have the same structure. The region sheets consist of the different research techniques per different publication. The publications are numbered by their own identifier. Each sheet is sorted on the following aspects for every publication: Amount of researched mummified human remains, mummified human remains identifier, artificial/natural mummification, institute/university country of research, used research techniques, reason of research and date of publication/research.

The sheets of the region's literature consist of the publications and their given literature identifier. The identifier is based on the place where the publication is focused on. For example, the literature of the research in the Nazca region receives the identifiers N1, N2, N3, etc.

2.5. Potential use research techniques Nazca region

In the last part of the results step, I will compare the research techniques of the selected areas to see if the research techniques have a potential use in the research of the mummified human remains of the Nazca region.

I will start with comparing the different types of research techniques from the two selected areas with the research techniques of the Nazca region. I will see if there are research techniques which are only used by a specific region or if there are differences in the research techniques used by two or all the regions.

From the techniques which have not yet been utilized in the Nazca region, I will look at the potential for using these techniques in the Nazca region. I will look at how expensive the research techniques are, if specific equipment is needed for the research techniques, if the mummified human remains can stay on site or if the mummified human remains have to be transported and if the techniques are able to be transported and utilized in the desert of the Nazca region.

3. Results

3.1 Nazca mummified human remains and its techniques

In this study, I have found 15 publications in which research is performed on natural mummified human remains from the Nazca regions. There were no publications indicating that any Nazca mummified human remains were artificially created. The mummified human remains of the Nazca culture have been found all over Ica province, and at the surrounding borders of the Ayacucho and Huancavelica province. Natural mummified human remains occur when there is preservation of the nonbony human tissues of a deceased body induced by natural influences without the help of human intervention. The mummified human remains of the Nazca culture have been mummified through the process of desiccation. The Nazca Valley has a mixed hot desert climate and cold desert climate. The extreme dryness of these types of climates provide favorable conditions for natural mummification (Lynnerup, 2007, pp. 162-164).

Systematic literature research shows that there is no standard way of examining Nazca mummified human remains. Various researchers and agencies have examined some of the Nazca mummified human remains for their own areas of interest. The researchers use samples from the mummified human remains for various reasons. Often they are used for paleopathological research or population studies. The research techniques used on the Nazca mummified human remains and there occurrence can be found in Table 1. A full description of which technique was used in which literature can be found in Table 4 in appendix A.

	Paleopathology	Osteology	Dating (Age)	Radiology	Isotope Analysis	Endoscopy	Paleohistology	Haematology	DNA analysis	Toxicological analysis
Amount of occuracnes in used literatue	8 Pieces of literature	3 Pieces of literature	3 Pieces of literature	5 Pieces of literature	2 Pieces of literature	1 Pieces of literature	2 Pieces of literature	4 Pieces of literature	1 Pieces of literature	1 Pieces of literature

Table 1 The occurrence of the different research techniques in used literature who are utilized on the mummified human remains in the Nazca region. (Made by Marloes Attema)

3.1.1 Paleopathology

Paleopathology is the scientific study of diseases in the past to get a better understanding of past living conditions. The research of Sawicki et al. (1976) used the study of paleopathology to investigate antigens of different diseases in multiple Nazca mummified human feces. Sokiranski et al. (2011) used paleopathology for the investigation of cervical rotation trauma in Nazca mummified human remains. Nerlich et al. (1993) investigated interstitial collagen in the mummified human remains of a Nazca infant. In the publication of Olivera (2005), the author used XRF-spectroscopy for the investigation of past diseases. Gerszten et al. (1976) used paleopathology for the research of thyroid disease. Allison et al. (1974) utilized paleopathology to get a look inside of childhood illnesses in pre-Colombian inhabitants, among which those of the Nazca culture. In the research of Gerszten et al. (2012), the researchers used various research techniques to get more information on the ancient diseases of South American mummified human remains. Paleopathology is also used in the research of Lombardi and García Cáceres (2000) to understand multisystemic tuberculosis in the mummified human remains from the Nazca culture (Gerszten et al., 1976, pp. 52-53; Gerszten et al., 2012, pp. 247–256; Lombardi & Arriaza, 1998, pp. 55-60; Nerlich et al., 1993, pp. 279-285; Olivera, 2005, pp. 8-10 ; Sawicki et al., 1976, pp. 805-813; Sokiranski et al., 2011, pp. 609-615).

3.1.2 Radiology

Radiology is a technique that allows researchers to look inside the body in a non-destructive way by means of radiation or waves (Alt & Ruhli, 2015, p. 20). In the publications that used radiology, they used computed tomography and x-ray scanning. Radiology in the form of computed tomography (CT) is being used in the publication of Sokiranski et al. (2011) to visualize the skull and vertebrae. In the publication of Lombordi and García Cáceres (2000) they use CT-scans as well, this time for visualizing the neural duct of the spine. X-rays are used in the publications of Allison et al. (1974), Gerszten et al. (1976), and Gerszten et al. (2012), for the visualization of the skeleton (Allison et al., 1974, pp. 409-415; Gerszten et al., 1976, pp. 52-53; Gerszten et al. 2012, pp. 247-256; Lombardi & Arriaza, 1998, pp. 55-60; Sokiranski et al., 2011, pp. 609-615).

3.1.3 Osteology

The practice of osteology is the study of bones. This field of study tries to get insights into the skeleton of an individual by performing techniques like morphological analysis, pathological analysis etc. (White et al., 2011, p.2). Osteological research has also been performed in the publications of Sawyer et al. (1976-1978) and Sokiranski et al. (2011). The research of Sawyer et al. (1976-1978) used osteological research methods to investigate the mandible and the dentition of mummified human remains. Sokiranski et al. (2011) used morphology to look at the skeleton remains of an individual of the Nazca culture (Sawyer et al., 1976, pp. 54-63 ; Sawyer et al., 1978, pp. 9-15; Sokiranski et al., 2011, pp. 609-616).

3.1.4 Carbon dating

Carbon dating, also known as C14-dating, is used for determining the age of an object containing the carbon element. In the publications of Sokiranski et al. (2011), Allison et al. (1978) and Gerszten et al. (1976) this method is used to determine the age of multiple Nazca mummified human remains (Allison et al., 1978, p. 139 ; Gerszten et al., 1976, p. 52; Sokiranski et al., 2011, pp. 609-615).

3.1.5 Hematology

The scientific technique that involves testing the blood group of a blood sample is hematology. This technique is used in the multiple publications of Allison et al. (1976-1978) for their population studies research of pre-colonial mummified human remains in South-America. The publication of Gerszten et al. (1976) used hematology to determine the blood group of a Nazca mummified human body in their research of thyroid disease (Allison et al., 1976, pp.55-61; Allison et al., 1978, pp. 139-142; Gerszten et al., 1976, pp.52-53; Hossaini & Allison, 1976, pp. 67-73).

3.1.6 Isotope analysis

Isotope analysis is utilized to gain information related to mobility, diet, and other living conditions in the past by investigating the different ratios of isotopes of a periodic element. In the publications that used isotope analysis, they used the following common elements for isotope analysis: Strontium, Sulphur, Oxygen, Carbon, Hydrogen and Nitrogen (Madgwick et al., 2021, pp. 361-385; Makarewicz & Sealy, 2015, pp. 146-158). Isotope analysis has also been utilized in the publications of Sokiranski et al. (2011) and of Knudson et al. (2009). Sokiranski et al. (2011) has used this method to research the nutrition and mobility of the researched mummified human remains from the Nazca culture, while Knudson et al. (2009) tried to investigate the origin of the Nazca trophy heads (Knudson et al., 2009, pp. 244-257; Sokiranski et al., 2011, p.609).

3.1.7 Paleohistology

Paleohistology is the research method of studying the microscopic anatomy of ancient tissues and their microstructures. In the research of Gerszten et al. (1976), this technique has been used on a biopsy of a Nazca mummified human body to research thyroid diseases. Other researchers like Sokiranski et al. (2010), have used the same technique for the identification of ligaments, brain residues and internal bleeding (Gerszten et al., 1976, p. 53; Sokiranski et al., 2011, p. 609) .

3.1.8 DNA analysis

In the publication of Gerszten, Allison and Maguire (2012), DNA analysis has been used in the examination of the mummified body of a child from the Nazca culture. The technique of DNA analysis has been used to check for infectious diseases. A sample of rehydrated mummified material is needed to perform DNA analysis (Gerszten et al., 2012, pp. 52-53).

3.1.9 Endoscopy

The common use of endoscopy is to visualize the internal organs and structures of a body. This procedure is considered standard medical practice, but it also has been utilized in mummified human remains studies. In the study of Sokiranski et al. (2011), they use endocranial endoscopy to visualize the internal structures of the upper cervical spinal canal. For this procedure they need to insert a small camera attached to a long, thin, flexible tube inside of the cranial cavities of the mummified human remains (Sokiranski et al., 2011, pp. 609-612)

3.1.10 Toxicological analysis

In the publication of Socha, Sykutera and Orefici (2022), the authors used toxicological analysis consisting of a combination of liquid chromatography and mass spectrometry on 22 individual trophy heads to get a better understanding of the religiosity, medicine use and the trade network during the Nazca culture. This toxicological analysis had as main goal to detect if there is a presence of metabolites, like cocaine and benzoylecgonine, as well as a presence of alkaloids, like mescaline, tryptamine, harmaline and harmine, originally belonging to coca leaves.

3.2 Similarities in arid regions

The Nazca region's climate is an arid desert. Worldwide, there are 47 arid regions that can be used for a climatic comparison to the Nazca region. Of those regions, 20 have had mummified human remains discovered in them, and of those, 9 regions have a mummification method similar to that of the mummified human remains found in the Nazca region. A description of all the regions falling in the latter category can be found below. A full table with all the arid regions listed can be found in appendix B.

3.2.1 Botswana

The Tuli Mummified human remains has been found at the 'Cut Line Rock, Loensa Propert´ site, in the north-eastern part of Botswana. Currently, this is the only mummified body found in Botswana. The individual has been placed in a flexed position within a shallow grave, with their left side facing upwards. The deceased was wrapped in a brown cow skin turned inside out, tied with a rope to secure the body. Due to the climate conditions and soil conditions the body is naturally mummified (Mosothwane, 2011, pp. 157-160).

The north-eastern side of Botswana has a hot desert climate. Temperatures in the summer can reach 37°C during the day. The site is dry and hot and has little precipitation every year. No exact precipitation numbers of this site are known (Mosothwane, 2011, p. 158; The World Bank Group, 2021a).

3.2.2 Canary islands

The Canary Islands consist of a group of seven islands, located in the Atlantic Ocean. El Hiero, La Gomera, La Palma and Tenerife are the western Canary islands, and Lanzarote, Fuerteventura and Gran Canaria are the eastern Canary islands. The western Canary islands have a mixed climate. The Northern side of the western islands have a humid climate while the southern part of the islands, divided by the mountains have an arid climate. The mean precipitation of the islands is around 300 mm every year (Cockburn et al., 1998, pp. 283-285; The World Bank Group, 2021i). Archaeologist have found mummified human remains from the Guanche culture on the different Canary Islands. The Guanches were the inhabitants of the Canary islands before the colonization by Spain. For the Guanche inhabitants, the mummification of the deceased was a common practice even though they only practiced this on four of the seven islands: El Hiero, Gran Canaria, Tenerife and La Gomera. A debate is going on if the human remains were natural or artificial mummified. At least three practices of artificial mummification have been recorded on mummified human remains from Tenerife: evisceration, preservatives, and sand-stuffing. The island's climate provided a suitable environment for the mummification and preservation of the bodies (Cockburn et al., 1998, pp. 283-285).

3.2.3 Chile

The Chinchorro culture existed from about 7020 to 1110 BC in the Atacama desert on the northern site of present-day Chili. Archaeologists have found over 200 mummified human remains along the Atacama coast of which an estimated 21% are naturally mummified and 79% are artificially mummified. The mummification of the Chinchorro culture can be divided into three categories: natural, complex, and mud-coated. The natural mummification occurs by burying the body in the dry sand. The climate and dryness of the desert create the perfect conditions for natural mummification. In complex mummification, three variations of the mummification are observable: Black mummification, where the bodies were supported in a skeletal framework of sticks; Red mummification, a variation where the mummified human remains were internally stuffed with all sorts of fibers instead of supporting the body with a skeletal framework; The last variation is bandage mummification, which is a combination between the other two variations. In the category of mud-

coated mummification the process can be subdivided into two variations: The easier variation where the organs stay inside of the body, and the extensive eviscerated variation (B. T. Arriaza, 1995, pp. 35-46).
The northern part of Chili hosts a dry desert climate with temperatures ranging from 17°C during the day to 1°C at night. The climate of the Atacama desert is characterized by extremely arid conditions, with a precipitation of 100 mm a year (The World Bank Group, 2021b).

3.2.4 China

The Xinjiang mummified human remains have been found in the Taklamakan desert, located in the northwest region of China. The mummified human remains are considered the oldest naturally formed mummified human remains found in China, with the oldest individuals dating to 2000-1500 BC in the Early Bronze Age. The natural mummification of the deceased bodies took place as the next of kin buried the bodies in the Xiaohe cemetery, located on a massive sand dune. The arid climate and the burial of the bodies in desert sand have ensured that the bodies have been highly preserved (Kang et al., 2020, pp. 2-6).
The Taklamakan desert has a cold desert climate. The desert has cold winters with temperatures dropping below freezing point, while the temperatures in the summer are on average 20 °C. The desert has an annual precipitation of 100 mm (The World Bank Group, 2021c).

3.2.5 Nile region (Egypt and Sudan)

The Nile region has a broad history of mummification culture and discovering mummified human remains. The origin of Egyptian mummification can be traced back to the predynastic period. In this period, natural mummification occurred when the deceased were buried in the sand. Mummification occurred through dehydration. However, it was during the Old Kingdom period that artificial mummification was officially established. This consisted of a thorough 70-day mummification process. After a person passes away, the mummification process begins with the removal and preservation of the internal organs separately. After this, the body was disinfected and desiccated for 40 days. This was followed by a 30-day period where the final steps in the mummification process were made. Among other things, the body was embalmed in these days. After the 30 days, the body was wrapped in linen before being buried. (Ikram, 2010, pp. 2-3).
The Nile region has a subtropical climate, consisting of hot and arid summers with mild winters. Temperatures vary between 7°C during the night to a maximum of 43°C during the day. Most of the country is covered with a desert landscape, making the Nile region arid with receiving little precipitation (The World Bank Group, 2021d).

3.2.6 Jordan

Over the years multiple mummified bodies have been found at the southern side of the dead sea in Jordan. The first rescue excavation of mummified human remains was in 1994, when archaeologist excavated the mummified remains of an adult male at the Khirbit Qazone site located in a cave near the southern side of the dead sea. In the following years, multiple other mummified human remains were revealed because of the looting in that area. The mummified human remains date back to 1200 – 1500 AD. All the mummified human remains found in Jordan have been preserved by natural mummification. The climate at the southern side of the dead sea in Jordan is optimal for spontaneous mummification. This region is characterized with an arid hot desert climate. The soil has a high salinity, causing the body to dehydrate quickly and decelerate the decay of the body. Temperatures are elevated throughout the year with a mean temperature of 30°C. The region is characterized with a low precipitation of around 100 mm every year (Al-Shorman, 2005, pp. 51-54; The World Bank Group, 2021e).

3.2.7 Libya

The Tashwinat mummified human remains is a well-preserved body of an infant found at the Uan Muhuggiag site, in the central Sahara of south-western Libya. The mummified human remains of the infant were found in a squatting position wrapped in animal skin. Micro- and macroscopic research on the human remains support that the mummification process were the beginnings of artificial mummification in that area. The mummification of the infant's body was obtained by the dehydration of the body after removing the thoracic and abdominal viscera (Cockburn et al., 1998, pp. 281-283; Di Vincenzo et al., 2015, pp. 575-580) . The climate of Libya is extremely arid and hot, making it a hot desert climate. Summers in Libya are very hot with a mean maximum temperatures of 31°C, while winters can be mild with temperatures around 15°C. The Sahara desert has very low annual rainfall with a precipitation below 10 mm annually (The World Bank Group, 2021f).

3.2.8 Mexico

In Guanajuato City, a collection of natural preserved human remains has been found in an offsite administration building. In the 1800s people had to pay to have family members buried at the public cemetery called Panteón Santa Paula. A tax was created for the relatives to pay if they wanted that the deceased body would stay buried at the cemetery. Without paying this tax, the body was transferred to an offsite administration building. 111 males, females and children were exhumed and stored in the administration building. Due to its combination of a hot desert climate and a hot-semi arid climate, the 111 bodies are naturally preserved and mummified. The province of Guanajuato has a mean temperature of 20°C and a precipitation of 600 mm annually. Due to that the bodies were stored in a house, protected from external climate influences, but with an arid climate inside the house, there emerged a suitable environment for natural mummification (Balistreri, 2014, pp. 3-7; The World Bank Group, 2021g) .

3.2.9 Peru

Other than the Nazca mummified human remains on the south-western side of country, Peru also hosts multiple kinds of other mummified human remains. The Paracas culture, which predates the Nazca culture, is known for natural mummification of their deceased individuals in arid regions, similar to the Nazca culture. At the Great Necropolis of Wari Kayan, below the Cerro Colorado terrace, the mummified human remains of at least 429 individuals have been found wrapped up in mummified human remains bundles. The bodies were placed in a seated position bound together in bundles by fine woven linen. It seems that no artificial mummification has taken place on the mummified human remains of the Paracas culture. The site is located on the Paracas peninsula and hosts a hot desert climate. The mean maximum temperature is around 19°C with a precipitation of around 76 mm annually (Cappigao et al., p.78 , 2013; Dagget, 1994, pp. 53-56; The World Bank Group, 2021h).

3.3 Comparison and selection of the regions

There are nine regions in the world besides the Nazca region that contain arid mummification. A list of the specifics of these regions can be found in table 8, located in appendix B. At the moment of writing, no research has been utilized to compare the different research techniques in correlation with the variety of characteristics of the mummified human remains. Because there is no previously done comparison of research techniques this study seeks to make sure that the chosen arid regions most closely match the Nazca region.

There are multiple possible exclusion factors to use when choosing which arid regions are most similar to the Nazca region. These exclusion factors are described in table 2. As this research seeks to implement research techniques in Peru, previously used on mummified human remains that have gone through similar degradation progresses, three exclusion factors are chosen: Age of the mummified remains is chosen to ensure similar degradation progresses, amount of research techniques is to ensure that there are enough possible techniques to implement in Peru, and origin of research techniques is to ensure that the new research techniques can be implemented in Nazca itself. For this reason the exclusion factors of age of mummified human remains, amount of research techniques and origin of research techniques are chosen.

Exclusion factors	Used?
Condition mummified human remains	No
Age mummified human remains	Yes
Landscape	No
Climate	No
Amount of research techniques	Yes
Origin of research technies	Yes
Variety of research techniques	No

Table 2 A visual representation of the excluding factors. (Made by Marloes Attema)

Of the nine regions, two regions were excluded for the difference in culture age. The mummified individuals found in Jordan and Mexico originate from 1450 and 1800 AD respectively. In comparison the Nazca mummified human remains stem from between 200 BC and 650 AD. No research has yet been carried out into whether the age of the mummified human remains matters for the research. To make sure that the degradation processes that may have occurred over the years are comparable, the youngest mummified individuals are excluded.

The regions of the Canary Islands, Chili and Peru are excluded from the comparison because the research performed on the mummified human remains is executed in countries other than the country of origin. The mummified human remains from these countries are disturbed by moving them to other countries for research. Little information is known about the research techniques used on the mummified human remains when they were still located at the place of origin. To get a broad overview all the variations of research on site and in research facilities, the regions of the Canary Islands, Chili and Peru are excluded.

Of the remaining four regions I also exclude Botswana and Libya for a lack of research towards the discovered mummified human remains. Little information is known about what research techniques were used on the mummified human remains of these areas. This makes it very difficult to compare the research techniques with the techniques from the Nazca area. This excludes Botswana and Libya from this research.

This leaves us with two regions, China and the Nile region. These regions have a similar arid landscape, the same type of mummification method, are from a similar cultural age and have plenty of research performed on their human mummified remains. These two regions will be analyzed in Chapter 3.4.

3.4 Research techniques in the arid areas

The Nile region, consisting of Egypt and Sudan, and China have been selected for the comparison with the Nazca region. Various research techniques have been used for the examination and research on the mummified human remains in these regions. The used research techniques of these regions have been placed inside of the created database alongside the research techniques utilized in the Nazca region.

3.4.1 China

After the excavation of the Xinjiang mummified human remains in the Tarim basin of the Taklamakan desert, the mummified human remains have had a detailed documentation accompanied with extensive research.

The documentation of the Xinjiang mummified human remains is detailed and sorted. Every individual found on the site underwent a visual examination. The researchers documented the visual aspects like the height and the hair-type as well as the preservation status of the mummified human remains. They also documented the clothes and objects alongside the mummified human remains. These objects underwent a different type of research compared to the mummified human remains (Kang et al., 2020, pp. 11-15; Pankova, 2013, pp. 75-86).

The researchers estimated the age at death of all mummified human remains through morphological estimation of the skeletal remains. All the mummified human remains were carbon dated and in combination with the discovered artefacts a final time period have been given to the individual remains. A biopsy has been taken for examination of the blood-type and for DNA analysis. The DNA analysis was performed to get a better understanding of the migration of the Xiaho culture (Kang et al., 2020, pp. 13-14; Mallapaty, 2021, pp. 19-20; Tan et al., 2013, pp. 299-306; Zhang et al., 2021, pp. 256-261).

An individual buried at tomb 75TAM601 in the Astana cemetery underwent a paleodietary study. The digestive contents of the mummified human remains were examined using a combination of Fourier-transform infrared spectroscopy (FTIR spectroscopy) with archaeobotanical research techniques (Chen et al., 2020, pp. 847-862). Other researchers have performed paleodietary research on mummified human remains using different approaches such as stable isotope analysis, dental calculus examination and proteomics analysis (Chen et al., 2020, p. 2; Tao et al., 2015, pp. 485-491; Yang et al., 2014, pp. 178-186; Yi et al., 2018, pp. 636-644) .

Multiple individuals have been examined in the publication of Wang (1996). He performed radiological research by making various X-ray photos of the mummified human remains to identify the skeletal remains. He also used paleohistological research and Trans Electron Microscopy (TEM) to investigate the internal properties of the mummified human remains (Wang, 1996, pp. 62-64)

The research techniques used on the Xinjiang mummified human remains are sorted in Table 9 in appendix C.

3.4.2 Nile region

Bonaparte's unsuccessful incursion into Egypt in the eighteenth-century sparked interest in Egypt and its mummified human remains. This fascination grew to become the breeding ground of the research on this topic (Buikstra & Nystrom, 2021, p. 3). Every year more research techniques are improved and utilized on the mummified human remains. A lot of research has been done while more research techniques are being published. All the research techniques used on the Xinjiang mummified human remains of the Taklamakan desert in China and the research techniques on the Nazca mummified human remains in Peru have been utilized on Egyptian mummified remains. The publications where these research techniques are utilized are sorted in table 12 in appendix C. Beyond these techniques other research techniques not seen in either China or Nazca have been utilized in publications which are described below.

Just as with the examination of the mummified human remains in China, it is important to look at the objects found accompanied with the remains. Objects buried alongside the individuals can give us information about the living conditions and time-period in the past. In the publication of Tarek et al. (2021), corn mummies and funerary objects were examined using non-destructive methods. The authors used radiography to visualize the internal object and the preservation status of the object.

For the documentation, digital imaging was used to visualize all surface features. To enhance the details of the exterior that may not be readily visible to the naked eye, the captured photographs were processed using D-stretch software. (Tarek et al., 2021, pp. 10-14).

Infrared reflectography (IR) and ultraviolet fluorescence (UV) are frequently used in research of the skin of mummified human remains to visualize changes to the skin which are not visible to the naked eye. These changes can be unintentional, like scars and pathological changes, or intentional like tattoos (Lynnerup, 2009, p. 363). This non-destructive and non-invasive method has been utilized in the publications of Alvurus et al. (2001) and Lee & Stenn (1978). Alvurus et al. (2001) used this method to visualize tattoos on mummified tissue while Lee & Stenn (1978) used the method as a control in their biochemical analysis (Alvrus et al., 2001, pp. 396-400; Lee & Stenn, 1978, p. 138).

Raman spectroscopy is a method used in the research on mummified human remains to determine the molecular composition of the mummified tissue (Lynnerup, 2009, p. 364). This method can tell you about the degradation and preservation status of the mummified tissues, as seen as in the publication of Petersen et al. (2003). It can also be utilized in the research to the mummification process. The technique of embalmment is determined in the research of Edwards (2004). Raman spectroscopy is a non-destructive and a non-invasive method, and therefore can be used on the mummified material without taking an autopsy (Edwards, 2004, pp. 159-170; Petersen et al., 2003, pp. 375-379).

Nuclear Magnetic Resonance Imaging (NMRI) is similar to a CT-scan but gives a 3D end result. This technique is also capable of performing spectroscopic analysis. NMRI has been utilized on a Egyptian human finger for the visualization of the spatial distribution of ^{1}H and ^{23}N isotopes. This is a non-destructive and non-invasive research technique (Lynnerup, 2009, p. 370; Watanabe, 2009, p. 364).

Biochemical analysis is performed in various researches on mummified tissue. This research method analyses the substances from chemical processes in and on mummified tissue. Various chemical substances can be examined using this technique. Each individual substance can give specific information about the past. An example of biochemical analysis is protein and lipid analysis, preservation status, alcohol consumption, hormone levels, and drug analysis (Barraco et al., 1977, pp. 533-546; Lee & Stenn, 1978, pp. 136-138; Lynnerup, 2009, pp. 357-384; Parsche & Nerlich, 1995, pp. 380-384).

3.5 Application of research techniques on the Nazca mummified human remains

In chapter 3.1 “Nazca mummified human remains and its techniques” I found that there were ten research techniques used on the mummified human remains of the Nazca region. Of these techniques nine were also used in China and all of them were used in the Nile region. When comparing the way these research techniques were utilized between these regions there were research techniques with noticeable differences. The biggest difference between the research techniques is the date of utilization. Besides that there are differences in individual focus & method of documentation & amount of research techniques used.

3.5.1 Differences in research techniques

In regards to the date of usage for the research techniques, most of the research techniques on the Nazca mummified human remains have been utilized in the 1970s, in comparison to the techniques used in China and the Nile region whose research has been ongoing till today. There is an age gap of at least 30 years between the use of the same techniques in Peru and in the other two regions.

When it comes to the individual focus, little attention was given to the individual. In the publications of Allison et al. (1976), the goal of the research technique was for population studies. The authors focused on reviewing the results of the research on mummified human as a group, rather than also looking at it with an individual focus. This is different compared to the publications of Zaki et al. (2020) who researched Egyptians mummified human remains. Here, the individual was looked at, to see what the blood group can say about the mummified human remains as an individual.

Regarding the method of documentation, there is a difference between the research techniques in the different regions in how detailed and the way how the mummified human remains are documented. Taking the Xinjiang mummified human remains for example, before the explanation of the research methods used in publications, the individual mummified human remains are properly introduced by giving an archaeological background (Chen et al., 2020, pp. 3-5). In the publications of the mummified remains of the Nazca region. Archaeological backgrounds are often forgotten. Apart from that, most of the times it is not clear which individuals are used for the techniques, there is no universal identifier for every mummified individual from the Nazca culture.

As far as the amount of research techniques used, there are eleven research techniques used outside of the Nazca region that have not yet been used inside of the region. Of these techniques five are used in China, six are used in Egypt and are five used in both. Of the techniques which are not yet used on the mummified remains of the Nazca culture, seven are suitable to use on the Nazca mummified human remains.

3.5.2 Possibility of application of research techniques

There are eleven research techniques who have not yet been used on the Nazca mummified human remains, but who are in use in the Nile region or in China. Of these eleven research techniques, seven techniques are suitable to be applied on the mummified human remains of the Nazca region. These are: a detailed documentation, visual research, digital imaging, infrared reflectography,

ultraviolet reflectography, Raman spectroscopy and object analysis. Four techniques are less suitable for the application on the Nazca mummified human remains: Nuclear Magnetic Resonance Imaging (NMRI), paleodietary studies, biochemical analysis and archaeobotanical analysis.

A detailed documentation of the mummified individuals is possible. The researchers do not need to move the mummified remains, and can document them easily on site. This research method is cheap and allows you to get an overview of the amount of individuals, location, status of preservation and degradation etc. Visual research can be added after the documentation process. The individuals can be described in detail and added to the archaeological documentation.

Digital imaging is a research technique which can be done on site as well. For most sorts of digital imaging, only a standard DSLR-camera is necessary.
The usage of infrared and ultraviolet reflectography can be done on site as well. The equipment has advanced over the years and portable infrared and ultraviolet cameras have been made and can be brought to site. Infrared reflectography can complement the visual research by highlighting aspects which are not visible to the naked eye. Ultraviolet reflectography can be used to determine the preservation status of the mummified human remains.

Raman spectroscopy is a research technique that the molecular composition of mummified tissues can determine. The equipment needed for this technique is portable and can be performed on site. Like the aforementioned research techniques, this method is non-destructive and non-invasive. The disadvantage of this research technique is that the equipment can be expensive to purchase. Lending this from a nearby research facility, university or hospital might be a suitable solution.

Associating surrounding objects with the mummified human remains can make information clearer during investigations. It is therefore important not only to look at the mummified human material, but also at the objects.

Nuclear Magnetic Resonance Imaging (NMRI) is less suitable to be used on the mummified human remains of the Nazca culture. The machine used for the research is too big, it is impossible to carry and use it on site. The mummified human remains need to be transported to a hospital where they can make use of this apparatus. Apart from the difficulty of moving the mummified human remains to the machine, the usage of this machine alongside with the transport of the mummified remains is expensive.

Paleodietary studies are used for the examination of the diet of the mummified individuals. An autopsy needs to be taken from the intestines of the mummified human remains. This is impossible to perform on site without the possibility of contaminating the sample. The procedure of taking an autopsy is expensive as well as the research of the sample taken. Biochemical analysis has the same problem. To perform a biochemical analysis an autopsy is needed, this sample can be contaminated easily so proper care has to be taken.

Archaeobotanical study is less suitable to use on the Nazca mummified remains but is possible. If the sample for the examination is taken out of the intestines, an autopsy is required. This autopsy faces the same problems as the aforementioned research techniques. If the sample is collected from the surrounding landscape, it can be examined. The collected sample, for example seeds, still has been transported to a research facility where they can examine the fossils under a microscope.

4. Discussion

This study indicates that there is still the possibility for improvement when it comes to the state of archaeological research on the Nazca mummified human remains. One possibility of improvement is to archive reports on mummified human remains into a digital database. Another possibility to improve the Nazca archaeological research is the implementation of research techniques from other arid regions of the world, such as Egypt and China. Of these techniques, the simpler research techniques that cost little money and are easily transportable to site are suitable to be used in future studies of the Nazca mummified remains. These include digital imaging, Raman spectroscopy and detailed documentation among others.

For the first sub question of "Which research techniques are used on the mummified human remains found on Nazca sites?" our original hypothesis that the Nazca research on mummified human remains is more dated proved somewhat incorrect. In terms of techniques used, the Nazca research used modern techniques quite similar to those used by other countries' research. The part that is dated is the onsite research and documentation of the mummified human remains. The research done on the Nazca mummified human remains mostly took place in foreign countries like Germany or the United States. Furthermore, the mummified human remains of the Nazca culture were not given further identification beyond being from the Nazca region. Our hypothesis of the less dated research proved to be only applicable to the onsite archaeological analysis and documentation and not the actual techniques used.

When looking for other arid regions in the world containing mummified human remains it was quite surprising to find so many locations that fit these set requirements. A further subdivision of these regions based on culture age, location of research and mount of research was needed to determine the best regions for the comparison with the Nazca region. Thanks to these further subdivisions, I could more precisely select two other arid regions for answering the second sub question "Up to which two other arid regions in the world perform research on mummified human remains most similar to those found in the Nazca region?".

As the Nile region is the cradle of research towards mummified human remains, I expected that the research technologies of this region would prove to be the most technologically advanced. This hypothesis proved to be correct, but the difference in the amount of research performed and utilized in the Nile region compared to both Nazca and China was even larger than expected. We found no techniques in the latter two regions that were not used in the Nile region. Despite this lack of unique techniques China has the advantage of having great documentation. An archaeological background was given as a proper introduction before the description of the research in most of the publications of the Xinjiang mummified human remains from the Taklamakan desert. This gives the reader a good overview of the previously done research and an introduction to the individual mummified human remains. In the end, both the research from the Nile region and China helped provide a good comparison with the Nazca region.

When looking for which research techniques could be implemented in the Nazca region, I expected that the two main determinants would be the price and the transport possibilities of the research technique. While these factors did prove to be important, another important factor not originally within my expectations was how old the techniques of the Nazca are. Most research techniques performed on the Nazca mummified human remains date back to the 1970s. In the 50 years between the use of the techniques on the mummified human remains and nowadays, the techniques have improved. It is important to look at how the research techniques are currently utilized for the

comparison rather than looking at how the techniques were used 50 years ago and take that into consideration when determining which research technique to use.

In conducting this research, I also encountered several limitations. One of the limitations which I came across is that most of the publications on Nazca mummified remains dates to the 1970s. Since then, new technologies and research techniques haven been created or been improved upon. The quality of the techniques between the regions are difficult to compare due to the age gap in utilizing these techniques. However, this does not affect my research since I aimed to look at which current research techniques can be utilized for future archaeological research on the Nazca mummified human remains. Another limitation is the lack of description of the mummified human individuals of the Nazca region. Apart from describing the research in the publications, there is no information about which individuals are used for the research. The last limitation I came across is that there was no possibility to physically test the research techniques from China and the Nile region.

While there is no possibility for me to physically test out the research techniques on mummified human remains in the Nazca region, a future study would be able to build upon my research. I recommend looking into the possibilities of interdisciplinary research and if useful incorporating it into the possible research techniques for the Nazca mummified human remains. Similar research can also be done on the options for research techniques that can be applied to the objects and garments of the Nazca culture.

In addition, I recommend creating a universal database in the future where a new detailed documentation of all individual mummified human remains can be entered and supplemented after any further investigation of the Nazca mummified human remains. If all individual mummified human remains of the Nazca culture get their own identifier, it will be easier to know per publication what has been done to each mummified individual of the Nazca culture.

5. Conclusion

This research aimed to identify the current state of the research techniques used on the mummified human remains of the Nazca region. The central question for this research was as follows:

"How do the methods of research towards mummified human remains for the Nazca region in Peru compare to mummified human remains research in other arid regions in the world?"

A database was created that lists the techniques used on the mummified human remains in Nazca as well as in the two areas determined most similar to Nazca: China and the Nile region. By comparing the techniques used in the three regions this research discovered that there were eleven research techniques not used in the Nazca region that already see use in the research of mummified human remains in other regions. There was also no indication that there is a research technique that has only been used in Nazca but not in the other regions, confirming our hypothesis that the research of mummified human remains is less extensive compared to other regions like China and the Nile region.

This study clearly illustrates that there is potential for new research techniques on human mummified remains to be introduced in the Nazca region. With this study only being a literature review limits the ability to directly recommend which research techniques should be used in Nazca, but it does provide good insight for the technology used by future researchers of the Nazca mummified human remains. Future research on the Nazca mummified human remains can use this study and the created database as a guideline to determine the most optimal research techniques needed for this own research.

Abstract

This study investigates the current state of archaeological research performed on the mummified human remains of the Nazca culture in Peru. At the time of writing, there is a lack in the archiving of archaeological research of the Nazca mummified remains as well as the datedness of the used research techniques. To improve the research on mummified human remains in the Nazca region, a bioarcheological comparison of research techniques is carried out between the Nazca region and the arid regions most similar to Nazca, in this case the regions of China and the Nile.

A database was created with the research techniques utilized in the Nazca, China and Nile region. After comparing the different research techniques utilized in the different regions, the study concludes that eleven research techniques are not used in the Nazca region. Of these research techniques seven are suitable for future research on site.

The findings of this study demonstrate that there is potential for the creation of a database for archiving reports of the mummified human remains and corresponding research techniques, as well as the utilization of newer and more modern research techniques. Both are expected to have a positive impact on the research of mummified human remains in Nazca. This research can be used as a guideline for future archaeological research on the Nazca human mummified remains.

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Appendix

Appendix A:

	Amount of researched mummified remains?	Mummified human remains codes?	Artificial/ Natural	Insitute/ University	Country of research	Research technique	General term	Reason research?	Date research	Literature research
1	1 Individual	No.24	Unknown	Virginia University	USA	Detection of bacterial antigens	Paleopathology	Immunofluorescence techniques + Paleoserology	1976	Sawicki, V. A., Allison, M. J., & Dalton, H. P. (1976). Presence of Salmonella antigens in feces from a Peruvian mummy. *Bulletin of the New York Academy of Medicine* , *52* (7), 805–813.
2	20 Individuals	Unknown	Unknown	Virginia University	USA	Expression of the mylohyoid bridge (Mandible)	Osteology	Marker for population studies	1978	Sawyer, D. R., Allison, M. J., Elzay, R. P., & Pezzia, A. (1978). The mylohyoid bridge of Pre-Columbian Peruvians. *American Journal of Physical Anthropology* , *48* (1), 9–15. https://doi.org/10.1002/ajpa.1330480103
3	1 Individual	Unknown	Unknown	University of Ulm + University of Munich	Germany	Biochemical analysis, Morphometry, Radiocarbon dating, Immunohistochemistry, Stable isotope analysis, High-resolution multi-slice computer tomography, Endoscopy, Paleohistology, Surface microscopy	Dating | Computed Tomography | Paleopathology | Isotope Analysis | Osteology | Endoscopy | Paleohistology	Research rotational spine trauma	2011	Sokiranski, R., Pirsig, W., Richter, H.-P., & Nerlich, A. G. (2011). Unique paleopathology in a pre-Columbian mummy remnant from Southern Peru—Severe cervical rotation trauma with subluxation of the axis as cause of death. *Acta Neurochirurgica* , *153* (3), 609–616. https://doi.org/10.1007/s00701-010-0842-z
4	Unknown amount of Nazca (232 Chile/Peru)	Unknown	Unknown	Virginia University	USA	ABO Blood groups research / carbon dating	Dating | Haematology	Population studies	1978	Allison, M. J., Hossaini, A. A., Munizaga, J., & Fung, R. (1978). ABO blood groups in Chilean and Peruvian mummies. II. Results of agglutination-inhibition technique. *American Journal of Physical Anthropology* , *49* (1), 139–142. https://doi.org/10.1002/ajpa.1330490121
5	Unknown amount of Nazca (11 Pre-colombian)	Unknown	Unknown	Virginia University	USA	ABO Blood Group Research & HL-A typing	Haematology	Detect presence of antibodies	1976	Hossaini, A. A., & Allison, M. J. (1976). Paleoserologic Studies: ABO and Histocompatibility Antigens in Mummified American Indians. *MEDICAL COLLEGE OF VIRGINIA QUARTERLY* , *12* (2), 67–73.
6	5 Nazca individuals (140 in total)	Unknown	Unknown	Virginia University	USA	ABO blood group research: Induction of antibody production, Agglutination-inhibition & Mixed cell agglutination	Haematology	Population studies	1976	Allison, M. J., Hossaini, A. A., Castro, N., Munizaga, J., & Pezzia, A. (1976). ABO blood groups in Peruvian mummies. I. An evaluation of techniques. *American Journal of Physical Anthropology* , *44* (1), 55–61. https://doi.org/10.1002/ajpa.1330440108
7	1 individual	Unknown	Unknown	University of Munich	Germany	Immunohistochemical analysis	Paleopathology	Identifying interstitial collagens present in remaining cartilage and bone tissue	1993	Nerlich, A. G., Parsche, F., Kirsch, T., Wiest, I., & Von Der Mark, K. (1993). Immunohistochemical detection of interstitial collagens in bone and cartilage tissue remnants in an infant Peruvian mummy. *American Journal of Physical Anthropology* , *91* (3), 279–285. https://doi.org/10.1002/ajpa.1330910303
8	1 individual	Unknown	Unknown	International Atomic Energy Agency Laboratories, Seibersdorf	Austria	XRF spectroscopy	Paleopathology	Mycobacterium tuberculosis detection	2005	Olivera, P. (2005). *X-ray fluorescence in IAEA Member States: Peru[X-ray fluorescence in the IAEA and its Member States]* (Technical Report INIS-XA-954; pp. 8–10). International Atomic Energy Agency Laboratories. https://www.osti.gov/etdeweb/biblio/20901537
9	1 Individual	Unknown	Unknown	Virginia University	USA	Carbon dating, X-ray, autopsy, microscopic examination	Dating| Computed Tomography | Paleopathology | Paleohistology	Research Thryoid problem	1976	Gerszten, E., Allison, M. J., Pezzia, A., & Klurfeld, D. (1976). Thyroid Disease in a Peruvian Mummy. *MCV Quarerly* , *12* (2), 52–53.
10	3 Nazca individuals (108 in total)	Unknown	Unknown	Virginia University	USA	Radiograms	Computed Tomography |Paleopathology	Paleopathology	1974	Allison, M. J., Mendoza, D., & Pezzia, A. (1974). A radiographic approach to Childhood illness in precolumbian inhabitants of Southern Peru. *American Journal of Physical Anthropology* , *40* (3), 409–415. https://doi.org/10.1002/ajpa.1330400313
11	1 Individual	Unknown	Unknown	Virginia University	USA	X-ray, DNA analysis	Computed Tomography | DNA Analysis | Paleopathology	Paleopathology (Tubercolosis)	2012	Gerszten, E., Allison, M. J., & Maguire, B. (2012). Paleopathology in South American Mummies: A Review and New Findings. *Pathobiology* , *79* (5), 247–256. https://doi.org/10.1159/000334087
12	22 Individuals	Unknown	Natural	National Centre of Science Poland	Poland	LC–MS/MS	Toxiological analysis	Toxiological analysis	2022	Socha, D. M., Sykutera, M., & Orefici, G. (2022). Use of psychoactive and stimulant plants on the south coast of Peru from the Early Intermediate to Late Intermediate Period. *Journal of Archaeological Science* , *148* , 105688. https://doi.org/10.1016/j.jas.2022.105688
13	3 Nazca individuals (195 in total)	Unknown	Unknown	Virginia University	USA	Morphological study of dentition	Osteology	evaluate the medical and dental health status	1976	Sawyer, D. R., Allison, M. J., Elzay, R. P., & Pezzia, A. (1976). Morphological Characteristics of the Pre_Columbian Dentition I. Shovel-Shaped Incisors, Carabelli's Cusp, and Protostylid. *MCV Quarterly* , *12* (2), 54–63.
14	Unknown	Unknown	Unknown	Arizona state University	USA	Isotope analysis	Isotope Analysis	Usage of Trophy heads	2009	Knudson, K. J., Williams, S. R., Osborn, R., Forgey, K., & Williams, P. R. (2009). The geographic origins of Nasca trophy heads using strontium, oxygen, and carbon isotope data. *Journal of Anthropological Archaeology* , *28* (2), 244–257. https://doi.org/10.1016/j.jaa.2008.10.006
15	1 individual	67466	Natural	National Museum Lima	Peru	Paleoepidemiology, DNA Analysis, CT-Scan, Autopsy	Paleopathology | DNA Analysis | Computed Tomography	Paleopathology (Tubercolosis)	2000	Lombardi, G. P., & García Cáceres, U. (2000). MULTISYSTEMIC TUBERCULOSIS IN A PRE-COLUMBIAN PERUVIAN MUMMY: FOUR DIAGNOSTIC LEVELS, AND A PALEOEPIDEMIOLOGICAL HYPOTHESIS. *Chungará (Arica)* , *32* (1), 55–60. https://doi.org/10.4067/S0717-73562000000100010

Table 3 The research techniques used on the Nazca mummified human remains in the Nazca region. (Made by Marloes Attema)

	Paleopathology	Osteology	Dating (Age)	Radiology	Isotope Analysis	Endoscopy	Paleohistology	Haematology	DNA analysis	Toxicological analysis
Literature number:	N1	N2	N3	N3	N3	N3	N3	N4	N11	N12
	N3	N3	N4	N9	N14		N9	N5		
	N7	N13	N9	N10				N6		
	N8			N11				N9		
	N9			N15						
	N10									
	N11									
	N15									
total:	8 Pieces of literature	3 Pieces of literature	3 Pieces of literature	5 Pieces of literature	2 Pieces of literature	1 Pieces of literature	2 Pieces of literature	4 Pieces of literature	1 Pieces of literature	1 Pieces of literature

Table 4 Sorted research techniques used in the Nazca region. (Made by Marloes Attema)

Literature number	Literature citation
N1	Sawicki, V. A., Allison, M. J., & Dalton, H. P. (1976). Presence of Salmonella antigens in feces from a Peruvian mummy. *Bulletin of the New York Academy of Medicine* , *52* (7), 805–813.
N2	Sawyer, D. R., Allison, M. J., Elzay, R. P., & Pezzia, A. (1978). The mylohyoid bridge of Pre-Columbian Peruvians. *American Journal of Physical Anthropology* , *48* (1), 9–15. https://doi.org/10.1002/ajpa.1330480103
N3	Sokiranski, R., Pirsig, W., Richter, H.-P., & Nerlich, A. G. (2011). Unique paleopathology in a pre-Columbian mummy remnant from Southern Peru—Severe cervical rotation trauma with subluxation of the axis as cause of death. *Acta Neurochirurgica* , *153* (3), 609–616. https://doi.org/10.1007/s00701-010-0842-z
N4	Allison, M. J., Hossaini, A. A., Munizaga, J., & Fung, R. (1978). ABO blood groups in Chilean and Peruvian mummies. II. Results of agglutination-inhibition technique. *American Journal of Physical Anthropology* , *49* (1), 139–142. https://doi.org/10.1002/ajpa.1330490121
N5	Hossaini, A. A., & Allison, M. J. (1976). Paleoserologic Studies: ABO and Histocompatibility Antigens in Mummified American Indians. *MEDICAL COLLEGE OF VIRGINIA QUARTERLY* , *12* (2), 67–73.
N6	Allison, M. J., Hossaini, A. A., Castro, N., Munizaga, J., & Pezzia, A. (1976). ABO blood groups in Peruvian mummies. I. An evaluation of techniques. *American Journal of Physical Anthropology* , *44* (1), 55–61. https://doi.org/10.1002/ajpa.1330440108
N7	Nerlich, A. G., Parsche, F., Kirsch, T., Wiest, I., & Von Der Mark, K. (1993). Immunohistochemical detection of interstitial collagens in bone and cartilage tissue remnants in an infant Peruvian mummy. *American Journal of Physical Anthropology* , *91* (3), 279–285. https://doi.org/10.1002/ajpa.1330910303
N8	Olivera, P. (2005). *X-ray fluorescence in IAEA Member States: Peru[X-ray fluorescence in the IAEA and its Member States]* (Technical Report INIS-XA-954; pp. 8–10). International Atomic Energy Agency Laboratories. https://www.osti.gov/etdeweb/biblio/20901537
N9	Gerszten, E., Allison, M. J., Pezzia, A., & Klurfeld, D. (1976). Thyroid Disease in a Peruvian Mummy. *MCV Quarerly* , *12* (2), 52–53.
N10	Allison, M. J., Mendoza, D., & Pezzia, A. (1974). A radiographic approach to Childhood illness in precolumbian inhabitants of Southern Peru. *American Journal of Physical Anthropology* , *40* (3), 409–415. https://doi.org/10.1002/ajpa.1330400313
N11	Gerszten, E., Allison, M. J., & Maguire, B. (2012). Paleopathology in South American Mummies: A Review and New Findings. *Pathobiology* , *79* (5), 247–256. https://doi.org/10.1159/000334087
N12	Socha, D. M., Sykutera, M., & Orefici, G. (2022). Use of psychoactive and stimulant plants on the south coast of Peru from the Early Intermediate to Late Intermediate Period. *Journal of Archaeological Science* , *148* , 105688. https://doi.org/10.1016/j.jas.2022.105688
N13	Sawyer, D. R., Allison, M. J., Elzay, R. P., & Pezzia, A. (1976). Morphological Characteristics of the Pre_Columbian Dentition I. Shovel-Shaped Incisors, Carabelli's Cusp, and Protostylid. *MCV Quarterly* , *12* (2), 54–63.
N14	Knudson, K. J., Williams, S. R., Osborn, R., Forgey, K., & Williams, P. R. (2009). The geographic origins of Nasca trophy heads using strontium, oxygen, and carbon isotope data. *Journal of Anthropological Archaeology* , *28* (2), 244–257. https://doi.org/10.1016/j.jaa.2008.10.006
N15	Lombardi, G. P., & García Cáceres, U. (2000). MULTISYSTEMIC TUBERCULOSIS IN A PRE-COLUMBIAN PERUVIAN MUMMY: FOUR DIAGNOSTIC LEVELS, AND A PALEOEPIDEMIOLOGICAL HYPOTHESIS. *Chungará (Arica)* , *32* (1), 55–60. https://doi.org/10.4067/S0717-73562000000100010

Table 5 The used literature with the corresponding given literature number. (Made by Marloes Attema)

Appendix B:

Country:	Climate BWh?	Climate BWk?	Human mummified remains?	Arid mummified remains?	Which ones?
Afghanistan		x	x	x	x
Algeria		x	x	x	x
Angola			x	x	x
Argentina			yes	x	x
Australia		x	yes	x	x
Bahrein		x	x	x	x
Botswana		x	yes	Yes	Tuli mummified human remains
Brazil		x	yes	x	x
Canary islands			yes	yes	Guanche mummified human remains
Chad		x	x	x	x
Chili	x		yes	yes	Chinchorro mummified human remains
China	x		Yes	Yes	Xinjiang mummified human remains
Egypt		x	yes	yes	Too many to note
Ethiopia		x	x	x	x
India		x	yes	x	x
Iran			Yes	x	x
Iraq		x	x	x	x
Israel		x	x	x	x
Jemen		x	yes	x	x
Jordan			yes	yes	Dead sea mummified human remains
Kazachstan	x		x	x	x
Kenia		x	x	x	x
Kuwait		x	x	x	x
Libiya		x	yes	yes	Tashwinat mummified human remains
Mali		x	x	x	x
Mauritania		x	x	x	x
Mexico			Yes		Mummified human remains of Guanajuato
Mongolia			yes	x	x
Morocco		x	x	x	x
Nambia			x	x	x
Niger		x	x	x	x
Oezbekistan	x		x	x	x
Oman		x	x	x	x
Pakistan			yes	x	x
Peru			Yes	Yes	Nazca / Paracas mummified human remains
Qatar		x	x	x	x
Saudi-Arabia			x	x	x
Somalia		x	x	x	x
South Africa			yes	x	x
Sudan		x	Yes	yes	Predynastic Egyptian mummified human remains
Syria			x	x	x
Tunesia		x	x	x	x
Turkmenistan	x		x	x	x
united Arab Emirates		x	x	x	x
USA			Yes	x	x
Western Sahara		x	x	x	x
Zimbabwe		x	x	x	x

Table 6 A list of countries with an arid desert climate sorted on climate and mummified human remains. (Made by Marloes Attema)

Region:	Climate BWh?	Climate BWk?	Arid mummies?	Which ones?
Botswana		x	Yes	Tuli mummified human remains
Canary islands	x		yes	Guanche mummified human remains
Chili	x		yes	Chinchorro mummified human remains
China	x		Yes	Xinjiang mummified human remains
Egypt + Sudan		x	yes	Too many to note
Jordan			yes	Dead sea mummified human remains
Libiya		x	yes	Tashwinat mummified human remains
Mexico			yes	Mummified human remains of Guanajuato
Peru			Yes	Nazca / Paracas mummified human remains
Sudan		x	yes	Predynastic Egyptian mummified human remains

Table 7 Small overview of the arid countries with arid mummified human remains. (Made by Marloes Attema)

Region:	Climate	Precipitation	Mean temperature	Culture Age	Findplace	Natural vs Artificial	Mummification method	Latest research date	Research on site/country of origin?	Research techniques
Nazca	**BWh & BWk**	**4 mm**	**20°C**	**200 BC - 650 AD**	**Desert**	**Natural**	**Dehydration**	**2022**	**Little**	**Little**
Botswana	BWk	No data	21°C	Late iron age (1200 BC and 1000 BC)	Desert	Natural	Dehydration	2016	Yes	little: Radiological and genetic analysis
Canary islands	BWk	300 mm	15°C	1200 AD	Cave	Artificial	Evisceration, preservatives and sand-stuffing	2021	Little to none	Paleopathology + Computed Tomogaphy
Chile	BWk	100 mm	10°C	7000-3000 BC	Desert	Artificial (Both)	Dehydration + Black, red & bandage mummification	2016	Little (Mostly in USA)	Description + Chemical analysis
China	BWk	100 mm	10°C	1800 BC- 500 BC	Desert	Natural	Dehydration	2020	Yes	Well documented, all together, precise
Egypt +Sudan	BWh	20 mm	28°C	3000BC - 400BC	Desert + tombs	Artificial (Both)	Dehydration + embalming (etc.)	2023	Yes	Alot
Jordan	BWh & BWk	100 mm	20°C	1450 AD	Cave	Natural	Dehydration	2005	Little to none	Little: Visual + radiological
Libiya	BWh	10 mm	23°C	6250 BC	Desert	Artificial	Evisceration	2015	Little to none	Micro- and macrocopic research
Mexico	BWh & BWk + BSh & BWk	inapplicable	20°C	1800 AD	Administration office	Natural	Dehydration	2014	Little (Mostly Brazil and spain)	Little
Peru	BWh & BWk	60 mm	20°C	800 BC – 100 BC	Necropolis (desert)	Natural	Dehydration	2022	Little (Mostly in USA)	Little

Table 8 A list containing the climate, archaeological background and research of the countries with arid mummified human remains. (Made by Marloes Attema)

Appendix C:

China	Article number:
Excavation process	C1
Documentation process	C1 |C8
Visual research	C1 | C8 | C10
Object examination	C1
Osteology	C1
Carbon dating	C1 | C3 | C4 | C6 | C7
Blood type research	C1 |C8
DNA analysis	C1 | C2 | C3 | C4| C9
Paleodietary studies	C2| C4 | C5 |C6 | C7
Archaeolobotanical	C4 | C5
Isotope analysis	C7
Radiology	C8
Transmission electron microscopy (TEM)	C8
Paleohistology research	C8

Table 9 Research techniques performed on the Xinjiang mummified human remains. (Made by Marloes Attema)

Egypt	Article number:
Excavation process	E6
Documentation process	E6
Visual research	E5
Object examination	E6
Osteology	E2 | E5
Carbon dating	E2 | E4 |
Blood type research	E5
DNA analysis	E1 | E2 | E4
Paleodietary studies	E4
Archaeolobotanical	E4
Isotope analysis	E2 | E4 |
Radiology	E2 | E5 | E6
Paleohistology research	E2
Endoscopy	E2
Toxicological examination	E3
Digital imaging	E6
Infrared refloctography	E6| E7 | E10
Raman spectroscopy	E8 | E9
Nuclear Magnetic Resonance Imaging (NMRI)	E11
Biochemical analyses	E10 | E12 | E13
Ultraviolet fluorescence	E10

Table 10 Research techniques performed on the mummified human remains from the Nile region. (Made by Marloes Attema)

China Article numbers:	Articles:
C1	Kang, I. U., Han, J., Hong, J. H., Kim, J., Shin, D. H., & Mair, V. H. (2020). Archaeological Findings of the Tarim Basin Graves and Mummies. In D. H. Shin & R. Bianucci (Eds.), *The Handbook of Mummy Studies* (pp. 1–16). Springer Singapore. https://doi.org/10.1007/978-981-15-1614-6_28-1
C2	Mallapaty, S. (2021, April 11). DNA REVEALS SURPRISE ANCESTRY OF XINJIANG MUMMIES. *Nature* , 19–20.
C3	Zhang, F., Ning, C., Scott, A., Fu, Q., Bjørn, R., Li, W., Wei, D., Wang, W., Fan, L., Abuduresule, I., Hu, X., Ruan, Q., Niyazi, A., Dong, G., Cao, P., Liu, F., Dai, Q., Feng, X., Yang, R., … Cui, Y. (2021). The genomic origins of the Bronze Age Tarim Basin mummies. *Nature* , *599* (7884), Article 7884. https://doi.org/10.1038/s41586-021-04052-7
C4	Chen, T., Wang, B., Mai, H., & Jiang, H. (2020). Last meals inferred from the possible gut contents of a mummy: A case study from Astana Cemetery, Xinjiang, China*. *Archaeometry* , *62* (4), 847–862. https://doi.org/10.1111/arcm.12555
C5	Tao, D., Zhang, J., Zheng, W., Cao, Y., Sun, K., & Jin, S. (2015). Starch grain analysis of human dental calculus to investigate Neolithic consumption of plants in the middle Yellow River Valley, China: A case study on Gouwan site. *Journal of Archaeological Science: Reports* , *2* , 485–491. https://doi.org/10.1016/j.jasrep.2015.05.003
C6	Yang, Y., Shevchenko, A., Knaust, A., Abuduresule, I., Li, W., Hu, X., Wang, C., & Shevchenko, A. (2014). Proteomics evidence for kefir dairy in Early Bronze Age China. *Journal of Archaeological Science* , *45* , 178–186. https://doi.org/10.1016/j.jas.2014.02.005
C7	Yi, B., Liu, X., Yuan, H., Zhou, Z., Chen, J., Wang, T., Wang, Y., Hu, Y., & Fuller, B. T. (2018). Dentin isotopic reconstruction of individual life histories reveals millet consumption during weaning and childhood at the Late Neolithic (4500 bp) Gaoshan site in southwestern China. *International Journal of Osteoarchaeology* , *28* (6), 636–644. https://doi.org/10.1002/oa.2676
C8	Wang, B.-H. (1996). Excavation and preliminary studies of the ancient mummies of Xinjiang in China. In K. Spindler, H. Wilfing, E. Rastbichler-Zissernig, D. Zur Nedden, & H. Nothdurfter (Eds.), *Human Mummies* (pp. 59–69). Springer Vienna. https://doi.org/10.1007/978-3-7091-6565-2_7
C9	Tan, J., Li, L., Zhang, J., Fu, W., Guan, H., Ao, X., Wang, L., Wu, X., Han, K., Jin, L., & Li, H. (2013). Craniometrical evidence for population admixture between Eastern and Western Eurasians in Bronze Age southwest Xinjiang. *Chinese Science Bulletin* , *58* (3), 299–306. https://doi.org/10.1007/s11434-012-5459-6
C10	Pankova, S. V. (2013). One More Culture with Ancient Tattoo Tradition in Southern Siberia: Tattoos on a Mummy from the Oglakhty Burial Ground, 3rd-4th century AD. In P. Della Casa & C. Witt (Eds.), *Tattoos and Body Modifications in Antiquity* (Vol. 9, pp. 75–86).

Table 11 The used literature for the research techniques of the Xinjiang mummified human remains with the corresponding given literature number. (Made by Marloes Attema)

Egypt Article numbers:	Articles:
E1	Gad, Y. Z., Hassan, N. A.-M., Mousa, D. M., Fouad, F. A., El-Sayed, S. G., Abdelazeem, M. A., Mahdy, S. M., Othman, H. Y., Ibrahim, D. W., Khairat, R., & Ismail, S. (2021). Insights from ancient DNA analysis of Egyptian human mummies: Clues to disease and kinship. *Human Molecular Genetics* , *30* (R1), R24–R28. https://doi.org/10.1093/hmg/ddaa223
E2	Wurst, C., Paladin, A., Wann, L. S., Frohlich, B., Fritsch, K. O., Rowan, C. J., Sutherland, M. L., Sutherland, J. D., Michalik, D. E., Allam, A. H., Zesch, S., Rosendahl, W., Thompson, R. C., Thomas, G. S., Seyfried, F., & Zink, A. R. (2020). Minimally invasive bone biopsies of fully wrapped mummies guided by computed tomography and fibre-optic endoscopy: Methods and suggested guidelines. Journal of Archaeological Science: Reports, 31, 102363. https://doi.org/10.1016/j.jasrep.2020.102363
E3	Silva-Bessa, A., Forbes, S. L., Ferreira, M. T., & Dinis-Oliveira, R. J. (2023). Toxicological Analysis of Drugs in Human Mummified Bodies andProposed Guidelines. Current Drug Research Reviews, 15(1), 62–72. https://doi.org/10.2174/2589977514666220914084543
E4	Schrader, S. (2019). Examining Diet and Foodways via Human Remains. In S. Schrader, Activity, Diet and Social Practice (pp. 127–164). Springer International Publishing. https://doi.org/10.1007/978-3-030-02544-1_4
E5	Zaki, A., & Elkashef, D. (2020). The Re-Investigation of Tutankhamun's Mummy: The Expedition of Harrison In 1968. International Journal of Tourism and Hospitality Management, 3(2), 153–191. https://doi.org/10.21608/ijthm.2020.134235
E6	Tarek, A., Ali, I., & Abdelrahman, M. (2021). Visualization, Documentation and Non-Destructive Investigation of an Ancient Egyptian Corn Mummy in a Falcon-shaped Wooden Coffin. Advanced Research in Conservation Science, 2(1), 10–20. https://doi.org/10.21608/arcs.2021.49811.1011
E7	Alvrus, A., Wright, D., & Merbs, C. (2001). Examination of Tattoos on Mummified Tissue using Infrared Reflectography. Journal of Archaeological Science - J ARCHAEOL SCI, 28, 395–400. https://doi.org/10.1006/jasc.2000.0596
E8	Edwards, H. G. M. (2004). Forensic applications of Raman spectroscopy to the non-destructive analysis of biomaterials and their degradation. Geological Society, London, Special Publications, 232(1), 159–170. https://doi.org/10.1144/GSL.SP.2004.232.01.15
E9	Petersen, S., Nielsen, O. F., Christensen, D. H., Edwards, H. G. M., Farwell, D. W., David, R., Lambert, P., Gniadecka, M., & Wulf, H. C. (2003). Near-infrared Fourier transform Raman spectroscopy of skin samples from the 'Tomb of the Two Brothers,' Khnum-Nakht and Nekht-Ankh, XIIth dynasty Egyptian mummies (ca 2000 BC). Journal of Raman Spectroscopy, 34(5), 375–379. https://doi.org/10.1002/jrs.1006
E10	Lee, S. L., & Stenn, F. F. (1978). Characterization of mummy bone ochronotic pigment. JAMA, 240(2), 136–138.
E11	Watanabe, T. (2009). Nuclear magnetic resonance imaging. In G. A. Webb (Ed.), Nuclear Magnetic Resonance (Vol. 38, pp. 450–490). Royal Society of Chemistry. https://doi.org/10.1039/b704486k
E12	Barraco, R. A., Reyman, T. A., & Cockburn, T. A. (1977). Paleobiochemical analysis of an egyptian mummy. Journal of Human Evolution, 6(6), 533–546. https://doi.org/10.1016/S0047-2484(77)80011-0
E13	Parsche, F., & Nerlich, A. (1995). Presence of drugs in different tissues of an egyptian mummy. Fresenius' Journal of Analytical Chemistry, 352(3–4), 380–384. https://doi.org/10.1007/BF00322236

Table 12 The used literature for the research techniques of the mummified human remains of the Nile region with the corresponding given literature number. (Made by Marloes Attema)

Appendix D: Database

Excel sheet I: Peru

	Amount of researched mummified remains?	Mummy codes?	Artificial/ Natural	Insitute/ University	Country of research	Research technique	Reason research?	Date research
N1	1 Individual	No.24	Unknown	Virginia University	USA	Detection of bacterial antigens	Immunofluorescence techniques + Paleoserology	1976
N2	20 Individuals	Unknown	Unknown	Virginia University	USA	expression of the mylohyoid bridge (Mandible)	Marker for population studies	1978
N3	1 Individual	Unknown	Unknown	University of Ulm + University of Munich	Germany	Biochemical analysis, Morphometry, Radiocarbon dating, Immunohistochemistry, Stable isotope analysis, High-resolution multi-slice computer tomography, Endoscopy, Paleohistology, Surface microscopy	Research rotational spine trauma	2011
N4	Unknown amount of Nazca (232 Chile/Peru)	Unknown	Unknown	Virginia University	USA	ABO Blood groups research / carbon dating	Population studies	1978
N5	Unknown amount of Nazca (11 Pre-colombian)	Unknown	Unknown	Virginia University	USA	ABO Blood Group Research & HL-A typing	Detect presence of antibodies	1976
N6	5 Nazca individuals (140 in total)	Unknown	Unknown	Virginia University	USA	ABO blood group research: Induction of antibody production, Agglutination-inhibition & Mixed cell agglutination	Population studies	1976
N7	1 individual	Unknown	Unknown	University of Munich	Germany	immunohistochemical analysis	Identifying interstitial collagens present in remaining cartilage and bone tissue	1993
N8	1 individual	Unknown	Unknown	International Atomic Energy Agency Laboratories, Seibersdorf	Austria	XRF spectroscopy	mycobacterium tuberculosis detection	2005
N9	1 Individual	Unknown	Unknown	Virginia University	USA	Carbon dating, X-ray, autopsy, microscopic examination	Research Thryoid problem	1976
N10	3 Nazca individuals (108 in total)	Unknown	Unknown	Virginia University	USA	Radiograms	Paleopathology	1974
N11	1 Individual	Unknown	Unknown	Virginia University	USA	X-ray, DNA analysis	Paleopathology (Tubercolosis)	2012
N12	22 Individuals	Unknown	Natural	National Centre of Science Poland	Poland	LC–MS/MS	Toxiological analysis	2022
N13	3 Nazca individuals (195 in total)	Unknown	Unknown	Virginia University	USA	Morphological study of dentition	evaluate the medical and dental health status	1976
N14	Unknown	Unknown	Unknown	Arizona state University	USA	Isotope analysis	Usage of Trophy heads	2009
N15	1 individual	67466	Natural	National Museum Lima	Peru	Paleoepidemiology, DNA Analysis, CT-Scan, Autopsy	Paleopathology (Tubercolosis)	2000

Table 13 The used literature of the Nazca region with the corresponding given literature number sorted in the created database. (Made by Marloes Attema)

Excel sheet II: Peru Literature

Literature number	Literature citation
N1	Sawicki, V. A., Allison, M. J., & Dalton, H. P. (1976). Presence of Salmonella antigens in feces from a Peruvian mummy. *Bulletin of the New York Academy of Medicine* , *52* (7), 805–813.
N2	Sawyer, D. R., Allison, M. J., Elzay, R. P., & Pezzia, A. (1978). The mylohyoid bridge of Pre-Columbian Peruvians. *American Journal of Physical Anthropology* , *48* (1), 9–15. https://doi.org/10.1002/ajpa.1330480103
N3	Sokiranski, R., Pirsig, W., Richter, H.-P., & Nerlich, A. G. (2011). Unique paleopathology in a pre-Columbian mummy remnant from Southern Peru—Severe cervical rotation trauma with subluxation of the axis as cause of death. *Acta Neurochirurgica* , *153* (3), 609–616. https://doi.org/10.1007/s00701-010-0842-z
N4	Allison, M. J., Hossaini, A. A., Munizaga, J., & Fung, R. (1978). ABO blood groups in Chilean and Peruvian mummies. II. Results of agglutination-inhibition technique. *American Journal of Physical Anthropology* , *49* (1), 139–142. https://doi.org/10.1002/ajpa.1330490121
N5	Hossaini, A. A., & Allison, M. J. (1976). Paleoserologic Studies: ABO and Histocompatibility Antigens in Mummified American Indians. *MEDICAL COLLEGE OF VIRGINIA QUARTERLY* , *12* (2), 67–73.
N6	Allison, M. J., Hossaini, A. A., Castro, N., Munizaga, J., & Pezzia, A. (1976). ABO blood groups in Peruvian mummies. I. An evaluation of techniques. *American Journal of Physical Anthropology* , *44* (1), 55–61. https://doi.org/10.1002/ajpa.1330440108
N7	Nerlich, A. G., Parsche, F., Kirsch, T., Wiest, I., & Von Der Mark, K. (1993). Immunohistochemical detection of interstitial collagens in bone and cartilage tissue remnants in an infant Peruvian mummy. *American Journal of Physical Anthropology* , *91* (3), 279–285. https://doi.org/10.1002/ajpa.1330910303
N8	Olivera, P. (2005). *X-ray fluorescence in IAEA Member States: Peru[X-ray fluorescence in the IAEA and its Member States]* (Technical Report INIS-XA-954; pp. 8–10). International Atomic Energy Agency Laboratories. https://www.osti.gov/etdeweb/biblio/20901537
N9	Gerszten, E., Allison, M. J., Pezzia, A., & Klurfeld, D. (1976). Thyroid Disease in a Peruvian Mummy. *MCV Quarerly* , *12* (2), 52–53.
N10	Allison, M. J., Mendoza, D., & Pezzia, A. (1974). A radiographic approach to Childhood illness in precolumbian inhabitants of Southern Peru. *American Journal of Physical Anthropology* , *40* (3), 409–415. https://doi.org/10.1002/ajpa.1330400313
N11	Gerszten, E., Allison, M. J., & Maguire, B. (2012). Paleopathology in South American Mummies: A Review and New Findings. *Pathobiology* , *79* (5), 247–256. https://doi.org/10.1159/000334087
N12	Socha, D. M., Sykutera, M., & Orefici, G. (2022). Use of psychoactive and stimulant plants on the south coast of Peru from the Early Intermediate to Late Intermediate Period. *Journal of Archaeological Science* , *148* , 105688. https://doi.org/10.1016/j.jas.2022.105688
N13	Sawyer, D. R., Allison, M. J., Elzay, R. P., & Pezzia, A. (1976). Morphological Characteristics of the Pre_Columbian Dentition I. Shovel-Shaped Incisors, Carabelli's Cusp, and Protostylid. *MCV Quarterly* , *12* (2), 54–63.
N14	Knudson, K. J., Williams, S. R., Osborn, R., Forgey, K., & Williams, P. R. (2009). The geographic origins of Nasca trophy heads using strontium, oxygen, and carbon isotope data. *Journal of Anthropological Archaeology* , *28* (2), 244–257. https://doi.org/10.1016/j.jaa.2008.10.006
N15	Lombardi, G. P., & García Cáceres, U. (2000). MULTISYSTEMIC TUBERCULOSIS IN A PRE-COLUMBIAN PERUVIAN MUMMY: FOUR DIAGNOSTIC LEVELS, AND A PALEOEPIDEMIOLOGICAL HYPOTHESIS. *Chungará (Arica)* , *32* (1), 55–60. https://doi.org/10.4067/S0717-73562000000100010

Table 14 The literature number with the corresponding literature in the created database of the Nazca region. (Made by Marloes Attema)

Excel Sheet III: Nile Region

	Amount of researched mummified remains?	Mummy codes?	Artificial/ Natural	Insitute/ University	Country of research	Research technique	Reason research?	Date research
E1	Unknown	Unknown	Unknwon	Colleboration of Museums in Egypt	Egypt	DNA Analysis	Research into paleopathology	2021
E2	Unknown	Unknown	Artificial	Collaboration of Universities	Italy, Germany & USA	Osteology | Carbon Dating | DNA Analysis | Isotope Analysis | Radiology | Paleohistology | Endoscopy	Obtain information of Egyptian Mummies	2020
E3	Unknown	Unknown	Unknown	Unknown	Unknown	Toxicological examination	Guideline for toxicological report	2023
E4	Unknown	Unknown	Unknwon	Leiden University	The Netherlands	Carbon dating | DNA Analysis | Paleodietary studies | Archaeobotany | Isotope Analysis	Paleodietary study	2019
E5	1	KV62	Artificial	University of Sadat City	Egypt	Visual research | Osteology | Radiology	Reinvestigation of the mummified remains	2020
E6	x	x	x	Cairo University	Egypt	Documentation process | Object examination | Radiology | Digital imaging | Infrared reflectography	Documentation and visual research	2021
E7	Unknown	unknown	Natural	Arizona state University	USA	Infrared reflectography	Research into the visual tattoos	2001
E8	1	Unkown	artificial	University of Bradford	United Kingdom	Raman spectroscopy	More insight into mummification	2004
E9	1	Unknown	Artificial	University of Copenhagen	Denmark	Raman spectroscopy	Investigation of mummified skin and preservation status	2003
E10	1	Unknown	Artificial	University of Chicago	USA	Infrared reflectography | Biochemical analysis | Ultraviolet fluorescence	Visualize changes in ochronosis.	1978
E11	1	Unknown	Artificial	Unknown	Japan	Nuclear Magnetic Resonance Imaging (NMRI)	Visualizing dry mummified tissues	2009
E12	1	Unkown	Natural	Wayne state University	USA	Biochemical analyses	Examination of proteins and lipids on mumified remains	1977
E13	1	Unknown	Artificial	University of München	Germany	Biochemical analyses	Testing of the prescence of drugs	1995

Table 15 The used literature of the Nile region with the corresponding given literature number sorted in the created database. (Made by Marloes Attema)

Excel sheet IV: Nile Region Literature

Nile Region Article numbers:	Articles:
E1	Gad, Y. Z., Hassan, N. A.-M., Mousa, D. M., Fouad, F. A., El-Sayed, S. G., Abdelazeem, M. A., Mahdy, S. M., Othman, H. Y., Ibrahim, D. W., Khairat, R., & Ismail, S. (2021). Insights from ancient DNA analysis of Egyptian human mummies: Clues to disease and kinship. *Human Molecular Genetics* , *30* (R1), R24–R28. https://doi.org/10.1093/hmg/ddaa223
E2	Wurst, C., Paladin, A., Wann, L. S., Frohlich, B., Fritsch, K. O., Rowan, C. J., Sutherland, M. L., Sutherland, J. D., Michalik, D. E., Allam, A. H., Zesch, S., Rosendahl, W., Thompson, R. C., Thomas, G. S., Seyfried, F., & Zink, A. R. (2020). Minimally invasive bone biopsies of fully wrapped mummies guided by computed tomography and fibre-optic endoscopy: Methods and suggested guidelines. Journal of Archaeological Science: Reports, 31, 102363. https://doi.org/10.1016/j.jasrep.2020.102363
E3	Silva-Bessa, A., Forbes, S. L., Ferreira, M. T., & Dinis-Oliveira, R. J. (2023). Toxicological Analysis of Drugs in Human Mummified Bodies andProposed Guidelines. Current Drug Research Reviews, 15(1), 62–72. https://doi.org/10.2174/2589977514666220914084543
E4	Schrader, S. (2019). Examining Diet and Foodways via Human Remains. In S. Schrader, Activity, Diet and Social Practice (pp. 127–164). Springer International Publishing. https://doi.org/10.1007/978-3-030-02544-1_4
E5	Zaki, A., & Elkashef, D. (2020). The Re-Investigation of Tutankhamun's Mummy: The Expedition of Harrison In 1968. International Journal of Tourism and Hospitality Management, 3(2), 153–191. https://doi.org/10.21608/ijthm.2020.134235
E6	Tarek, A., Ali, I., & Abdelrahman, M. (2021). Visualization, Documentation and Non-Destructive Investigation of an Ancient Egyptian Corn Mummy in a Falcon-shaped Wooden Coffin. Advanced Research in Conservation Science, 2(1), 10–20. https://doi.org/10.21608/arcs.2021.49811.1011
E7	Alvrus, A., Wright, D., & Merbs, C. (2001). Examination of Tattoos on Mummified Tissue using Infrared Reflectography. Journal of Archaeological Science - J ARCHAEOL SCI, 28, 395–400. https://doi.org/10.1006/jasc.2000.0596
E8	Edwards, H. G. M. (2004). Forensic applications of Raman spectroscopy to the non-destructive analysis of biomaterials and their degradation. Geological Society, London, Special Publications, 232(1), 159–170. https://doi.org/10.1144/GSL.SP.2004.232.01.15
E9	Petersen, S., Nielsen, O. F., Christensen, D. H., Edwards, H. G. M., Farwell, D. W., David, R., Lambert, P., Gniadecka, M., & Wulf, H. C. (2003). Near-infrared Fourier transform Raman spectroscopy of skin samples from the 'Tomb of the Two Brothers,' Khnum-Nakht and Nekht-Ankh, XIIth dynasty Egyptian mummies (ca 2000 BC). Journal of Raman Spectroscopy, 34(5), 375–379. https://doi.org/10.1002/jrs.1006
E10	Lee, S. L., & Stenn, F. F. (1978). Characterization of mummy bone ochronotic pigment. JAMA, 240(2), 136–138.
E11	Watanabe, T. (2009). Nuclear magnetic resonance imaging. In G. A. Webb (Ed.), Nuclear Magnetic Resonance (Vol. 38, pp. 450–490). Royal Society of Chemistry. https://doi.org/10.1039/b704486k
E12	Barraco, R. A., Reyman, T. A., & Cockburn, T. A. (1977). Paleobiochemical analysis of an egyptian mummy. Journal of Human Evolution, 6(6), 533–546. https://doi.org/10.1016/S0047-2484(77)80011-0
E13	Parsche, F., & Nerlich, A. (1995). Presence of drugs in different tissues of an egyptian mummy. Fresenius' Journal of Analytical Chemistry, 352(3–4), 380–384. https://doi.org/10.1007/BF00322236

Table 16 The literature number with the corresponding literature in the created database of the Nile region. (Made by Marloes Attema)

Excel Sheet V: China

	Amount of researched mummified remains?	Mummy codes?	Artificial/ Natural	Insitute/ University	Country of research	Research technique	Reason research?	Date research
C1	Unknown	Unknown	Natural	Kyung Hee University & Seoul National University	South Korea	Documentation process | Visual research | Object examination | Carbon dating | Hematology | DNA analysis	Overview research on Xinjiang mummified remains	2020
C2	Unknown	Unknown	Natural	x	x	DNA Analysis | paleodietary studies	Migration studies	2021
C3	18	Unknown	Natural	Collaboration of Universities	China, Germany, USA, South Korea	Carbon dating | DNA analysis	Migration studies	2021
C4	1	75TAM601	Natural	University of Oxford	United Kingdom	Carbon dating | DNA analysis | Paleodietary studies | Archaeobotany	Paleodietary studies	2020
C5	Unknown	Unknown	Natural	Zhengzhou University	China	Paleodietary studies | Archaeobotany	Paleodietary studies	2015
C6	Unknown	Unknown	Natural	University of Chinese Academy of Sciences	China	Carbon dating | Paleodietary studies	Paleodietary studies	2014
C7	12	Unknown	Natural	University of Chinese Academy of Sciences	China	Carbon dating | Paleodietary studies | Isotope analysis	Paleodietary studies	2018
C8	Unknown	Unknown	Natural	Institute of Relics and Archaeology	China	Documentation process | Visual research |Hematology | Radiology Transmission electron Microscopy	Overview research on Xinjiang mummified remains	1996
C9	21	Unknown	Natural	Fudan University	China	Osteology	Population studies	2013
C10	Unknown	Unknown	Natural	Department of Archaeology of Eastern Europe and Siberia	Russia	Infrared reflectoscopy	Study of tattoos	2013

Table 17 The used literature of the Taklamakan desert with the corresponding given literature number sorted in the created database. (Made by Marloes Attema)

Excel Sheet VI: China Literature

China Article numbers:	Articles:
C1	Kang, I. U., Han, J., Hong, J. H., Kim, J., Shin, D. H., & Mair, V. H. (2020). Archaeological Findings of the Tarim Basin Graves and Mummies. In D. H. Shin & R. Bianucci (Eds.), *The Handbook of Mummy Studies* (pp. 1–16). Springer Singapore. https://doi.org/10.1007/978-981-15-1614-6_28-1
C2	Mallapaty, S. (2021, April 11). DNA REVEALS SURPRISE ANCESTRY OF XINJIANG MUMMIES. *Nature* , 19–20.
C3	Zhang, F., Ning, C., Scott, A., Fu, Q., Bjørn, R., Li, W., Wei, D., Wang, W., Fan, L., Abuduresule, I., Hu, X., Ruan, Q., Niyazi, A., Dong, G., Cao, P., Liu, F., Dai, Q., Feng, X., Yang, R., … Cui, Y. (2021). The genomic origins of the Bronze Age Tarim Basin mummies. *Nature* , *599* (7884), Article 7884. https://doi.org/10.1038/s41586-021-04052-7
C4	Chen, T., Wang, B., Mai, H., & Jiang, H. (2020). Last meals inferred from the possible gut contents of a mummy: A case study from Astana Cemetery, Xinjiang, China*. *Archaeometry* , *62* (4), 847–862. https://doi.org/10.1111/arcm.12555
C5	Tao, D., Zhang, J., Zheng, W., Cao, Y., Sun, K., & Jin, S. (2015). Starch grain analysis of human dental calculus to investigate Neolithic consumption of plants in the middle Yellow River Valley, China: A case study on Gouwan site. *Journal of Archaeological Science: Reports* , *2* , 485–491. https://doi.org/10.1016/j.jasrep.2015.05.003
C6	Yang, Y., Shevchenko, A., Knaust, A., Abuduresule, I., Li, W., Hu, X., Wang, C., & Shevchenko, A. (2014). Proteomics evidence for kefir dairy in Early Bronze Age China. *Journal of Archaeological Science* , *45* , 178–186. https://doi.org/10.1016/j.jas.2014.02.005
C7	Yi, B., Liu, X., Yuan, H., Zhou, Z., Chen, J., Wang, T., Wang, Y., Hu, Y., & Fuller, B. T. (2018). Dentin isotopic reconstruction of individual life histories reveals millet consumption during weaning and childhood at the Late Neolithic (4500 bp) Gaoshan site in southwestern China. *International Journal of Osteoarchaeology* , *28* (6), 636–644. https://doi.org/10.1002/oa.2676
C8	Wang, B.-H. (1996). Excavation and preliminary studies of the ancient mummies of Xinjiang in China. In K. Spindler, H. Wilfing, E. Rastbichler-Zissernig, D. Zur Nedden, & H. Nothdurfter (Eds.), *Human Mummies* (pp. 59–69). Springer Vienna. https://doi.org/10.1007/978-3-7091-6565-2_7
C9	Tan, J., Li, L., Zhang, J., Fu, W., Guan, H., Ao, X., Wang, L., Wu, X., Han, K., Jin, L., & Li, H. (2013). Craniometrical evidence for population admixture between Eastern and Western Eurasians in Bronze Age southwest Xinjiang. *Chinese Science Bulletin* , *58* (3), 299–306. https://doi.org/10.1007/s11434-012-5459-6
C10	Pankova, S. V. (2013). One More Culture with Ancient Tattoo Tradition in Southern Siberia: Tattoos on a Mummy from the Oglakhty Burial Ground, 3rd-4th century AD. In P. Della Casa & C. Witt (Eds.), *Tattoos and Body Modifications in Antiquity* (Vol. 9, pp. 75–86).

Table 18 The literature number with the corresponding literature in the created database of the Taklamakan desert region. (Made by Marloes Attema)