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Faculty of Biology

Palaeodemography and palaeopathology in early mediaeval Säben-Sabiona, South Tyrol, Italy

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by
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Ich versichere hier mit an Eides statt, dass meine Dissertation selbständig und ohne unerlaubte Hilfsmittel angefertigt worden ist.

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München, den 07.07.2023

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1. Abstract

The early mediaeval period was characterised by continuous variations of frontiers, leadership, and consequently also socio-economic instabilities. Located in the central Alps, along one of the most important passageways between Germany and Italy, the episcopal see of Säben-Sabiona played a central role and was particularly affected by these fluctuations. The site is located on a mount in the Eisack-Isarco valley, which, starting from the 7th century A.D. was occupied by Germanic groups, such as Bavarians and Longobards. Three archaeological excavations uncovered a palaeochristian church, dated to the 5th-8th centuries A.D., featuring between 366 and 370 graves. Due to the quantity of burials and wealth of some of these, Säben-Sabiona is regarded as the largest early mediaeval burial site in South Tyrol and the only one evidencing an admixture of autochthonous, i.e., local Romans, and allochthonous groups, i.e., Bavarians and/or Longobards.

Up to date, only detailed historical and archaeological investigations concerning the palaeochristian church were accomplished, yet the anthropological analysis of these remains was still outstanding. As the first anthropological study ever performed on this site, the present thesis focused on establishing the palaeodemographic composition as well as the living and health conditions of the individuals buried within and surrounding the palaeochristian church. Due to the unavailability of skeletal remains from earlier archaeological investigations and the limited archaeological and historical contextualisation of these, the present anthropological analysis focused on the subpopulation addressed in the publication by Bierbrauer and Nothdurfter (2015). A traditional osteological approach to endeavour this aim was predefined, after consulting with my supervisors. A full anthropological analysis, i.e., consisting of the biological and pathological profile of the human skeletal remains, recovered during the last excavation, i.e., 185 graves, was performed. The biological profile included the estimation of the minimum number of individuals, sex, age at death, stature, body weight and robusticity. These data were used to perform further palaeodemographic analyses, such as estimation of the masculinity index, the probability of dying at a certain age, the average life expectancy at different ages and population size. Additionally, an extensive palaeopathological examination was conducted, concentrating on dental alterations yielding information about diet, dental and skeletal conditions linked to the exposure to chronic stress as well as skeletal lesions used to infer information about activity and lifestyle. Due to the nature of the site and in consideration of the archaeological and historical evidence, identifying Säben-Sabiona as a burial ground of the ruling classes, which appears to have been stratified by rank as suggested by the variations of burial context and location, the sample was subdivided into an elite (n=107), i.e., graves within the church, inside a

crypt and/or featuring wealthy material culture, and a non-elite group (n=78), i.e., burials outside the church with poor or no funerary goods.

The examined graves featured a minimum number of 226 individuals, which consisted of 94 males, 39 females, 54 subadults and 39 adults of not determinable sex. Based on the previously mentioned classification, 133 individuals were assigned to the elite group and 93 individuals to the non-elite group. In both subsamples, males were overrepresented. The lack of female burials for both subgroups further enforced the notion of a selective burial ground, whereby females appeared to have been interred elsewhere. Both subsamples displayed adaptations to the alpine environment, i.e., high levels of bone robusticity, and palaeopathological profiles consistent with a macronutrient rich diet, fairly frequent exposure to chronic stress and extremely physically demanding lifestyles. Even though osteological disorders were found in similar frequencies in both subgroups, thus, suggesting that social stratification was low, for almost all conditions the non-elite sample was more commonly and/or more severely affected.

This thesis provided novel insights into the demographic structure, diet and health of populations associated with early mediaeval Säben-Sabiona. Unique information about the composition of the Säben-Sabiona cemetery, which elucidates socio-cultural values and practices of populations residing in early mediaeval South Tyrol, was generated. The detailed palaeopathological analysis informs about health and living conditions of the people buried at this important site, in consideration of their social stratification. The combination of a thorough palaeodemographic and palaeopathological investigation in conjunction with an evaluation of funerary customs and materials provides a holistic interpretation, not only of the individual life history, but also the population as a whole. Thus, improves the contextualisation of the palaeochristian church at Säben-Sabiona and aids the understanding of early mediaeval social stratification. As for South Tyrol, standardised anthropological research concerning osteological samples is still in its very early stages, the present thesis provides a first step in supplying data, which can be used to establish normal osteological parameters, thus provides a solid foundation for future research.

2. Introduction

The early mediaeval period is characterised by mass migration, political and economic instability that lacks historical documentation, thus, is also referred to as the “Dark Ages”. This gap of knowledge between antiquity and High/Late Middle Ages poses a great obstacle in understanding how current societies and populations developed. Especially for South Tyrol (Südtirol- Provincia di Bolzano), an autonomous province in the north-eastern Italian Alps, information about this period is mainly limited to a few historical sources (e.g., Dudley, 2003; Kustatscher and Romeo, 2010; Landi, 2005; Winckler, 2012) and archaeological inquiries (e.g., Alberti et al., 2004; Bierbrauer and Nothdurfter, 2015; Dal Ri, 2010; Marzoli et al., 2009; Nothdurfter, 1991). From these studies it is known that this region experienced continuous large scale political and socioeconomic changes (Fig. 1), yet the impacts of these instabilities onto the lives of the local population are poorly understood.

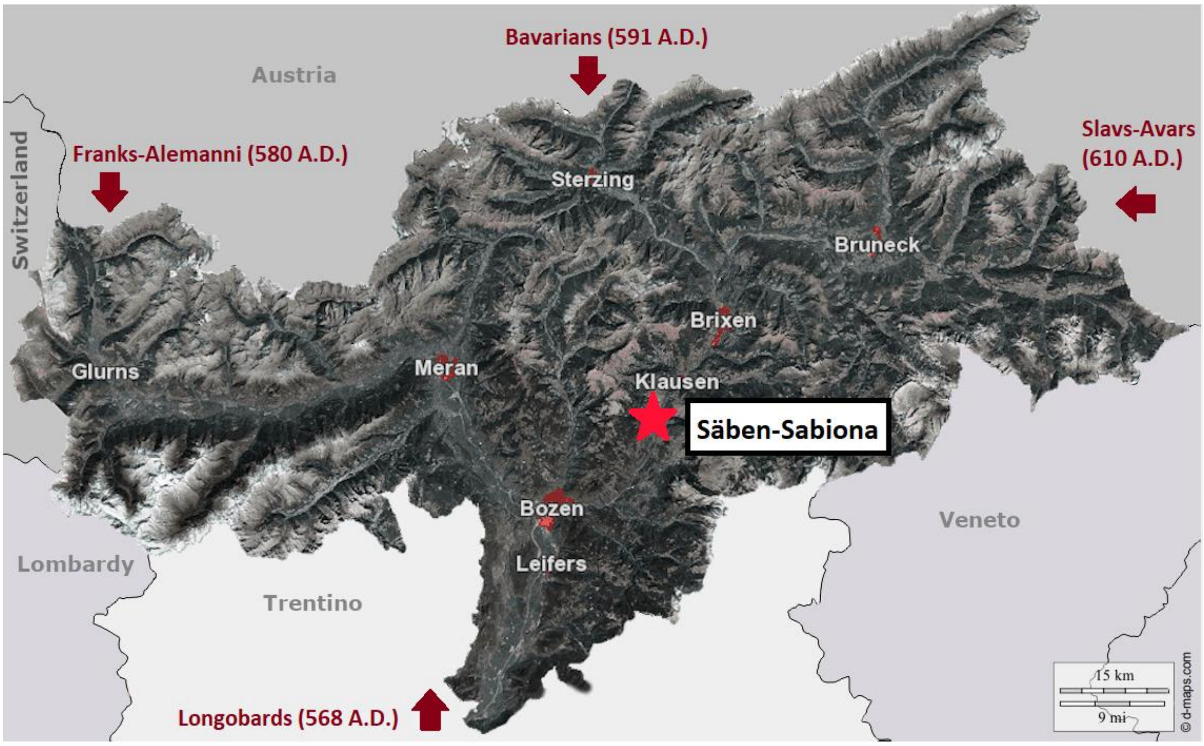

Figure 1. Germanic occupation of South Tyrol between the 6th to 7th century, adapted from Autonome Provinz Bozen-Südtirol, Informationstechnick-Geobrowser and D-maps, and based on Bierbrauer (2005a), Gleirscher (1986) Hauptfeld (1982), Heitmeier (2005) Kustatscher and Romeo (2010) Winckler (2012) and Wolfram (1995a).

Sometimes, living conditions are mentioned in historical sources, e.g., *Paulus Diaconus* (Dudley, 2003), although as they are believed to be highly subjective, i.e., the information retrieved may be biased depending on the authors affiliation and mindset (Etches et al., 2006), thus, more weight is put onto archaeological evidence, which also poses its limitations, i.e., commonly accidental discoveries, incompleteness of the archaeological record, provides general information about social, economic and political aspects of a population etc. Much of the local archaeological research concentrates primarily on the excavation, assessment and interpretation of profane and sacral structures and funerary culture (Bierbrauer and Nothdurfter, 2015; Gleirscher and Nothdurfter, 1987), all of which provide important pieces of information about past societies. However, to gain insights into population composition, living conditions, morbidity and mortality rates, subsistence strategies and conflict, during these periods of political and economic instability, one needs to examine the osteological record. The analysis of human skeletal remains provides exclusive data from which the biological and socio-cultural context of a past population can be reconstructed. Osteological research on early mediaeval South Tyrolean sites are greatly limited to specific case studies (Tumler et al., 2019) and/or topics focusing on a subsample (Mundle, 2018; Paladin et al., 2020, 2018; Tumler et al., 2021), general examinations of smaller sites (Giovannini, 2003, 2002; Renhart, 2008, 2006; Tumler, 2015) or osteological reports of larger sites (Renhart, 1991). These analyses have furnished a substantial amount of crucial information, yet all of these are restricted in some form. The methodology used to collect osteological data often lacks standardisation, thus hinders comparisons between the different sites, access to raw data is limited and rarer diseases are not assessed. In conjunction to this, a small sample size, which is a prevalent issue for archaeological samples, is one of the major limiting factors for anthropological research on early mediaeval sites in South Tyrol. Due to lower population densities in less urbanised areas (e.g., less accessible mountain valleys), larger anthropological datasets are lacking, c.f., St. Prokulus- S. Procolo in Naturns-Naturno (60 individuals dated to the early mediaeval period), Elzenbaum in Freienfeld- Campo di Trens (11 individuals), Castelfeder Montan-Montagna (10 individuals dated to the early mediaeval period, Terlan- Terlano (16 individuals) (Giovannini, 2003; Renhart, 2006, 1991; Tumler, 2015). Hence, to interpret social structures, subsistence strategies, living and health conditions of the early mediaeval population in South Tyrol larger sites need to be approached.

By assessing the human skeletal remains recovered from Säben-Sabiona, which is regarded as the largest early mediaeval cemetery in South Tyrol (366-370 excavated graves), this research attempts to unravel novel information on population composition, lifestyle, and health in the Early Middle Ages. As Säben-Sabiona is regarded as the first and sole episcopal see in South Tyrol, through which the Christianisation of the Alps was coordinated and implemented (Raybould, 1921; Sparber, 1942; Winckler, 2012), it was an important locality (Bierbrauer and Nothdurfter, 2015). The significance of this site is also discernible from the archaeological record and the recovered material culture, suggesting both autochthonous and allochthonous groups used the church and cemetery as burial ground (Bierbrauer and Nothdurfter, 2015). Hence, Säben-Sabiona can be regarded as one of the few sites in South Tyrol that can provide meaningful bioarchaeological data, which can be used to infer living and health conditions from this spatiotemporal context.

2.1. Aims and research questions

This research endeavours to create a comprehensive anthropological narrative for the burials within and around the early mediaeval church in the vineyard at Säben-Sabiona. By reconstructing the biological and palaeopathological profile it is aimed to generate, for the first time, the necessary anthropological data to interpret and contextualise Säben-Sabiona through comparisons with other sites from similar settings. The aims of this thesis can be summed in the following overall areas of inquiry:

1. To establish a full demographic and palaeopathological profile of the individuals buried within the early mediaeval church and cemetery in the vineyard of Säben-Sabiona.
2. To contextualise the demographic composition of the population buried at Säben-Sabiona.
3. To examine sex and age differences in relation to burial location and disease prevalence rates.
4. To reconstruct lifestyle, health and subsistence patterns of the buried individuals based on their palaeopathological profile.
5. To investigate whether there are differences between individuals featuring rich grave goods and buried inside the church and/or in crypts and those without grave goods and interred outside the church.
6. To compare the anthropological data of the studied sample with other populations to identify temporal and spatial similarities and/or differences.
7. To provide an overall understanding of population health and socio-cultural structure of the site to lay the foundation for future investigations.

3. Historical and archaeological background

From archaeological and historical sources it is known that due to its central location, connecting northern Europe and Italy, South Tyrol has experienced substantial political and sociocultural changes throughout history (Loose, 1999; Lunz, 2006, 2004; Winckler, 2012). The earliest evidence for such large-scale shifts has been associated with the Roman colonisation of the Alps, dividing South Tyrol into *Raetia prima* (North-West), *Raetia Secunda, Noricum Mediterraneum* (North-East) and *Venetia et Histria* (South) (Christ, 1955; Kustatscher and Romeo, 2010; Maczynska, 1998; Terrenato, 2019). Economic contact between Romans and the native groups appears to have been established since the 1st century B.C. and was consolidated thereafter through the construction and expansion of road networks (e.g., *Via Claudia Augusta, Via Raetia* etc.) and the foundation of infrastructures along these (Kaufmann, 2012; Kustatscher and Romeo, 2010; Marzoli et al., 2009; Vittore and Binotto, 2003). The administration of these estates and military bases was allocated to both the elite of local Celts and Raeti as well as residing Roman officials, thus leading to a gradual romanisation of the autochthonous groups (Gleirscher, 1986; Kustatscher and Romeo, 2010; Loose, 1999).

3.1. Late antiquity

With the breakthrough of the Danubian *Limes* by Germanic groups and the crossing of the Alps by the Huns (401-410 A.D.) the intrusions and raids by these pagan allochthonous populations on local settlements and other infrastructures became more frequent (Kustatscher and Romeo, 2010; Winckler, 2012), also settlement structures and military organisation changed. Already starting from the 3rd century A.D. and especially for the 5th century A.D., the archaeological records show an increased emergence of hilltop settlements, fortifications (*castra*), e.g., *castrum maiense* near Meran- Merano, and/or border inspection posts (*clausae*), e.g., potentially Klausen-Chiusa near Säben-Sabiona (Dal Ri, 2010; Gleirscher, 1986; Kaufmann, 2012; Marzoli et al., 2009; Sparber, 1942; Winckler, 2012; Zagermann, 2014). Early on, the effects of the Migration Period on the South Tyrolean population, are believed to have been rather low, as economic relations and alliances between the Romans and Germanic peoples were already established previously (4th -6th centuries A.D.) (Kustatscher and Romeo, 2010; Raybould, 1921). An example is the Ostrogoth occupation (493-526 A.D.) during which the Roman laws and customs including Christianity were largely maintained (Kustatscher and Romeo, 2010; Maczynska, 1998; Scheuch, 1994).

Christianity was introduced as early as in the 4th-5th centuries A.D. through missionaries, e.g., St. Vigilius, the 3rd bishop of Trento (Trentino) (Bitschnau and Obermair, 2009; Kustatscher and Romeo, 2010; Raybould, 1921; Sparber, 1942; Winckler, 2012). According to historical sources, especially for the people situated in more inaccessible valleys (e.g., Ultental- Val Ultimo, Schnalstal- Val Senales, Gadertal- Val Gardena, etc.) that were bound to the traditional pagan cults and rites, the adoption of Christianity was a rather difficult proposition, claiming the lives of various missioners from Rome (i.e., "Martyrs") as well as local converted individuals (Bierbrauer and Nothdurfter, 2015; Bitschnau and Obermair, 2009; Kustatscher and Romeo, 2010; Semmler, 1999; Sparber, 1942). When the institutional power from the Roman Empire retreated during the 5th century A.D. the religious authority became more influential (Dal Ri, 2010; Loose, 1999; Semmler, 1999; Sparber, 1942; Winckler, 2012). From the second half of the 5th century A.D. onwards episcopal sees were constructed or relocated onto hills and expanded, featuring double churches and baptismal fonds, e.g., potentially Säben-Sabiona for which written evidence exists for 590 A.D. (Bierbrauer and Nothdurfter, 2015; Dal Ri, 2010; Sparber, 1942; Winckler, 2012). By ca. 600 A.D. the majority of the local population is assumed to have been Christianised (Kustatscher and Romeo, 2010; Winckler, 2012).

3.2. Early mediaeval period

With the increase of invasions and conquests by Ostrogoths, Byzantines, Franks, Longobards, Bavarians and Slavic populations between the 6^{th}- 8^{th} centuries A.D. (Fig. 2) the frontiers varied continuously (Dal Ri, 2010; Dudley, 2003; Heuberger, 1932; Kustatscher and Romeo, 2010; Loose, 1999; Michalowski, 2002; Winckler, 2012).

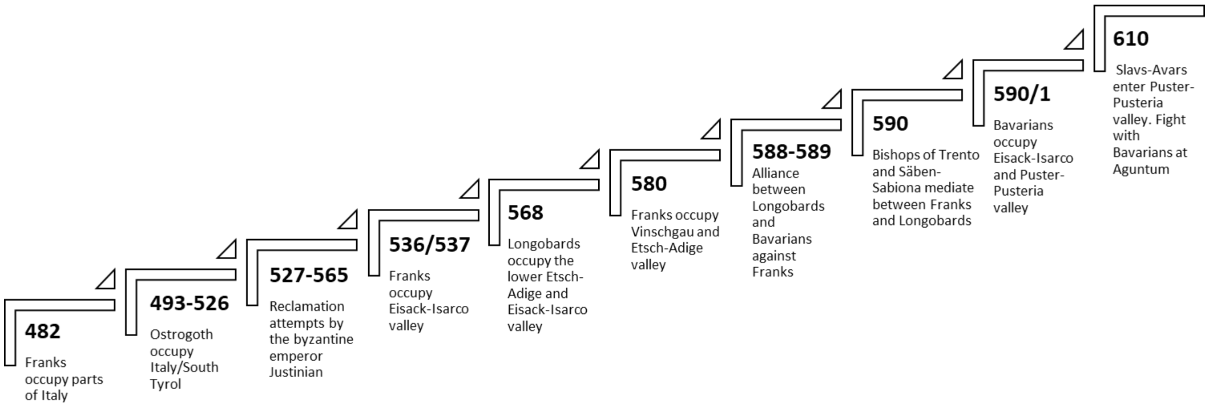

Figure 2. Diagram displaying the political situation in South Tyrol during the 6^{th} -8^{th} century based on research by Dudley (2003), Gleirscher (1986), Heitmeier (2005), Kustatscher and Romeo (2010), Maczynska (1998), Raybould (1921) and Winckler (2012).

This constant advance and retreat of different nationalities, most of which were still pagan, is associated with political and economic instabilities as well as raids on neighbouring groups, all of which may have had substantial impacts on local sociocultural organisation and subsistence patterns (Dudley, 2003; Giostra and Lusuardi Siena, 2004; Haas-Gebhard, 2004; Raybould, 1921; Winckler, 2012). This is particularly evident in the archaeological records, which document the abandonment of Roman settlements in the valley floor as well as the destruction of various hilltop settlements, *castra* and *clausae* (Marzoli et al., 2009). When the Franks invaded South Tyrol (580 A.D.), they crossed the Vinschgau-Venosta valley, the Etsch-Adige valley and raided Trento (Hammer, 2011; Kustatscher and Romeo, 2010; Winckler, 2012). According to historical sources, a more ferocious intrusion by the Franks (i.e., Merovingians) is documented for 590 A.D., when the Longobards occupied the Etsch-Adige valley (up until Meran-Merano) and parts of the Eisack-Isarco valley (Kustatscher and Romeo, 2010). In this context the Franks captivated 600 men and only through interventions of the bishops from Trento (Agnellus) and Säben-Sabiona (Ingenuinus) parts of the population were spared (Dudley, 2003; Kustatscher and Romeo, 2010; Winckler, 2012).

The archaeological records of the South Tyrolean Alps demonstrate an increased prevalence of artefacts most likely associated with the Bavarian culture in the north-eastern regions (Inn valley, Eisack-Isarco valley and the Puster-Pusteria valley), whereas the southern parts, i.e., Trentino, featured a higher abundance of burials potentially linked to the Longobards (Bierbrauer, 2005a; Bierbrauer and Nothdurfter, 2015; Giostra and Lusuardi Siena, 2004; Haas-Gebhard, 2004; Kustatscher and Romeo, 2010; Michalowski, 2002). Especially during the 7th and 8th centuries A.D., where Longobard and Bavarian leadership shifted constantly, the residents near these frontlines may have experienced direct impacts of these changes (Hammer, 2011; Kustatscher and Romeo, 2010). Some studies argue (e.g., Martin, 1996; Winckler, 2012; Wolfram, 1995a, 1995b) that during the Germanic (Langobard and Bavarian) occupation the military control of the autochthonous population was reinforced through the deployment of officials, whereas the civil administration was managed by the native Roman elite (Hammer, 2011; Winckler, 2012). For the Longobard occupation it is reported that separate justice systems were in place differentiating between Longobards and the local population (Albertoni, 2005; Kustatscher and Romeo, 2010; Obermair, 2005). Yet, as these periods were characterised by political turmoil, raids and other violent unrest, ultimately, they were forced to liaise with the natives (Dudley, 2003; Kustatscher and Romeo, 2010). Evidence for a more harmonious coexistence between Germanics and Romans is manifested in the Bavarian legislation that was the same for both, Bavarians and the native population (Winckler, 2012; Wolfram, 1995a, 1995b). Consequently over the 6th to 7th century A.D. this governance caused a gradual fusion of the respective cultures and customs, which eventually led to the emergence of a novel elite group (Albertoni, 2005; Bierbrauer, 2005a; Bierbrauer and Nothdurfter, 2015; Winckler, 2012). The seamless development of these regional traditions into a more homologous culture, is also evident from the archaeological records, as from the 7th century A.D. onwards burials clearly show an exponential increase in prosperity and an advanced prevalence of such wealthy graves (Bierbrauer and Nothdurfter, 2015; Menghin, 1964; Winckler, 2012; Zagermann, 2014).

3.3. Säben-Sabiona

Säben-Sabiona (46°38'28.19" N 11°34'3.59" E) is located on a mount next to the city of Klausen-Chiusa in the Eisack-Isarco valley of South Tyrol, Italy (Fig. 1). A Roman milestone found in the Eisack-Isarco valley, i.e., Freienfeld-Campo di Trens, identified this area as part of the Roman Province *Raetia Secunda* and the road *Via Raetia*, which was used since the 1st century A.D., provide the first written evidence associated with the site (Heitmeier, 2005; Winckler, 2012; Zanier, 2017). As the site is excellently protected by steep precipices sloping into the Eisack-Isarco river (East) and Tinne-Tina river (West), access to Säben-Sabiona is highly limited. This is also shown archaeologically, which displays an infrequent occupation of this "natural *castra*" during the 3rd -4th centuries A.D. (Bierbrauer and Nothdurfter, 2015; Gleirscher, 1986; Kaufmann, 2017). The excavations by Adrian Egger (1929/30), Nothdurfter and Kromer (1976) and Nothdurfter and Bierbrauer (1978-1982) identified settlement structures (350 A.D.), a baptistry and parish church including a burial site (400

A.D.) in the areas of the “Liebfrauenkirche” and the vineyard south of it, which supports the notion that around 400 A.D. the local Roman populations retracted to protective hilltop sites (Bierbrauer and Nothdurfter, 2015; Gleirscher, 1986; Kuhnen, 2020; Sparber, 1942; Winckler, 2012). Bierbrauer and Nothdurfter (2015) describe the excavated settlement (350 A.D.) as modest, consisting of nine rooms featuring archaeological finds linked to artisanal activity, potentially agriculture or metal working. Following two fires (second half of the 4th century A.D. and first half of the 6th century A.D.), the latter possibly caused by the Franks or Longobards (Fig. 3), the settlement was abandoned (Bierbrauer and Nothdurfter, 2015; Sparber, 1942).

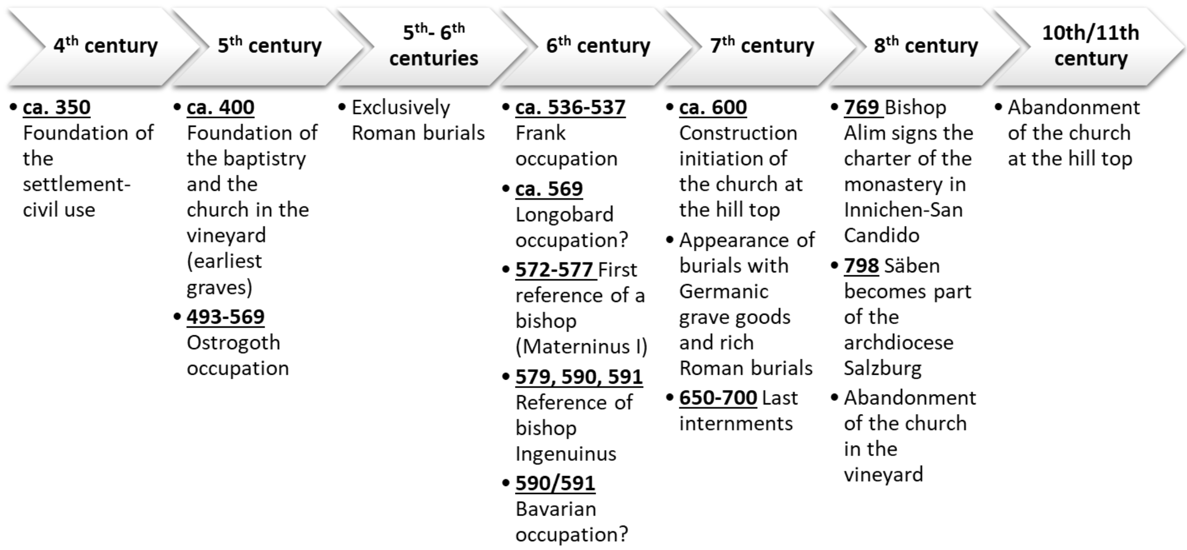

Figure 3. Outline of historical and archaeological milestones from Säben-Sabiona based on Bierbrauer (2005), Bierbrauer and Nothdurfter (2015), Gleirscher (1986) Heitmeier (2005), Sparber (1942) and Winckler (2012).

A fire was also documented for the parish church in the vineyard (“Kirche im Weinberg”) that featured a *loculus* for relics and became an episcopal see (Bierbrauer and Nothdurfter, 2015; Bitschnau and Obermair, 2009; Sparber, 1942). Even though the archaeological data suggests another destructive event, i.e., landslide, around 600 A.D., signs of renovations and a continuity of cemeterial use persisted until 650-700 A.D. (Bierbrauer and Nothdurfter, 2015). During those later periods the use of the parish church was mostly profane and all religious functions were transferred to the newly build double church on top of the hill (underneath “Heilig-Kreuz-Kirche”) (Bierbrauer and Nothdurfter, 2015; Kaufmann, 2017; Winckler, 2012). When the episcopal see was moved to Brixen-Bressanone (960 A.D.) the Säben-Sabiona hill was transformed into a castle and in the 17th century a Benedictine Convent (1687-2021) was established (Hagemayer, 1967; Köpf, 1999; Kustatscher and Romeo, 2010; Moser, 1992).

3.3.1. Episcopal see

When the first Roman missionaries reached the Alps (4^{th} -5^{th} century A.D.), they established Christian congregations and sanctuaries at geographically and economically favourable locations, e.g., near major routes or other central locations (Kustatscher and Romeo, 2010). These religious headquarters are believed to have been named after the martyrs, missionaries and bishops who played a major role in the foundation and spread of Christianity in these areas (Kustatscher and Romeo, 2010; Winckler, 2012). According to a mediaeval legend (first documented in the 12^{th} century A.D.) in the quest of Christianising the north-eastern parts of the South Tyrolean Alps, the Roman missionary Cassian (4^{th} century A.D.) was sent to Säben-Sabiona (Gleirscher, 1986; Sparber, 1942). Yet, the connection between Saint Cassian and Säben-Sabiona is highly speculative, as the foundation of the episcopal see at this site, which has been estimated to have occurred around 400 A.D., is not in agreement with the time period of Saint Cassian, who died in the 4^{th} century A.D. (Bierbrauer and Nothdurfter, 2015; Gleirscher, 1986; Sparber, 1942).
As the credibility of the Saint Cassian legend cannot be validated and Materninus I signed the protocol of the synods in Grado (571/572 A.D. and 576/77 A.D.) as *Materninus Sabionensis*, he is regarded as the first attested bishop of Säben-Sabiona (Bierbrauer, 2006; Gleirscher, 1986; Menghin, 1964). Materninus I (575-577 A.D.) was replaced by Ingenuinus (577-605 A.D) for whom historical sources also report the engagement in profane duties, e.g., salvation of the inhabitants of the *castrum Ferruge* during the Frank invasion in 590 A.D. (Gleirscher, 1986; Hammer, 2011; Kustatscher and Romeo, 2010). Especially in these politically unstable periods, local bishops were an important reference point for both the locals and allochthonous groups (Kustatscher and Romeo, 2010; Winckler, 2012). Also the signature of Ingenuinus on a petition from the bishops of Venice (under the control of the Longobards) to the byzantine emperor Mauritius (591 A.D.), which is the last mentioning of Säben-Sabiona in the historical literature for the interim period, highlights the authority and the field of action of this diocese (Gleirscher, 1986). Particularly in the 6^{th} and 7^{th} centuries A.D. the high-ranking position and relevance of Säben-Sabiona as religious centre is evidenced through both, historical sources, where the bishops from Säben-Sabiona were amongst the first to sign important documents, and archaeological findings, i.e., wealthy equipped graves, a double church (Bierbrauer, 2006; Bierbrauer and Nothdurfter, 2015; Kustatscher and Romeo, 2010; Sparber, 1942; Winckler, 2012). Even though historical sources for the 7^{th} and early 8^{th} century A.D. are scarce the archaeological records suggest an uninterrupted Christian tradition (Bierbrauer, 2005b; Bierbrauer and Nothdurfter, 2015; Gleirscher, 1986; Winckler, 2012). Around 900 A.D. Säben-Sabiona is mentioned again in the historical literature as unprosperous episcopal see, which eventually led to its translocation (Winckler, 2012).

Some authors (c.f., Sparber, 1942; Winckler, 2012; Menghin, 1964) associate the foundation of an episcopal see at Säben-Sabiona with the refuge of an early bishop as a result of the Germanic invasion. Also the fact that Säben-Sabiona differs from the standard episcopal see, i.e., stipulating that the foundation of a diocese is limited to locations that fulfil the prestige requirements of a bishop, and it is not linked with a Roman *civitas* makes this site very unique (Bierbrauer, 2005b; Bierbrauer and Nothdurfter, 2015; Gleirscher, 1986; Winckler, 2012). In fact, religious centres that are located near important trade routes and are not associated with a settlement, are commonly interpreted as sites of political and regiment value (Loose and Lorenz, 1999; Nothdurfter, 1999).

3.3.2. Origin and archaeological identity of the buried

The archaeological excavations from 1929-1982 uncovered 366-370 graves, whereby Bierbrauer and Nothdurfter (2015) estimate between 700-800 graves dispersed across the Säben-Sabiona hill. The size of the cemetery as well as the topographic properties of Säben-Sabiona, making it an ideal location for a hilltop settlement, suggested the existence of a larger settlement (Bierbrauer, 2005b). In the Early Middle Ages, settlements were often developed near important religious places, i.e., funerary churches of martyrs, episcopal sees, etc. Even following abandonment, these sites did not lose their significance (i.e., *ad sanctos* burials) and were continuously used as a burial site (Bierbrauer, 2005b; Winckler, 2012). Archaeological investigations of the whole mount, including the convent garden, i.e., through surface soil probing and superficial test trenches, featured no evidence for a settlement large enough to inhabit the number of individuals buried within and around the parish church in the vineyard (Bierbrauer, 2005b; Bierbrauer and Nothdurfter, 2015). An increased use of ephemeral construction materials, such as wood, has also been proposed as an explanation for the lack of foundation walls. Due to shifts in field fertility, early mediaeval settlements and sometimes also churches had to be mobile and were moved on a regular basis (Gleirscher and Nothdurfter, 1987; Sennhauser, 2003; Winckler, 2012). Both the fact that the church in the vineyard was stone-built and the lack of archaeological evidence for a settlement suggested that most of the deceased originated from one or a few different settlements nearby or even the wider area (Bierbrauer, 2005b). So far, no single early mediaeval site in the Eisack-Isarco Valley could be directly associated with such a large amount of burials as estimated for Säben-Sabiona (Bierbrauer and Nothdurfter, 2015). Based on general similarities, particularly in funerary culture, Natz-Naz and Elvas near Brixen-Bressanone were identified as occupation sites potentially linked to Säben-Sabiona (Bierbrauer and Nothdurfter, 2015; Dal Ri, 2010). Hence, despite being the largest early mediaeval cemetery of South Tyrol, the lack of an associated settlement implies that the cemetery population cannot be regarded as a representation for a single population deriving from the same settlement.

Even though Säben-Sabiona was an important Christian site, whose burials are commonly associated with a lack of funerary goods, some individuals were buried with grave goods. The recovered artefacts were very precious and versatile, including golden threads, golden rings, finely manufactured pearl necklaces, bracelets, multipart belt sets and weaponry (Bierbrauer, 2006; Bierbrauer and Nothdurfter, 2015; Winckler, 2012). This variety in material culture was interpreted as an indicator for an adaptation and coexistence between the autochthonous Roman and allochthonous Germanic (Bavarian or Longobard) groups and a mutual use of the burial grounds, see Figure 4 (Bierbrauer and Nothdurfter, 2015; Kaufmann, 2017; Winckler, 2012).

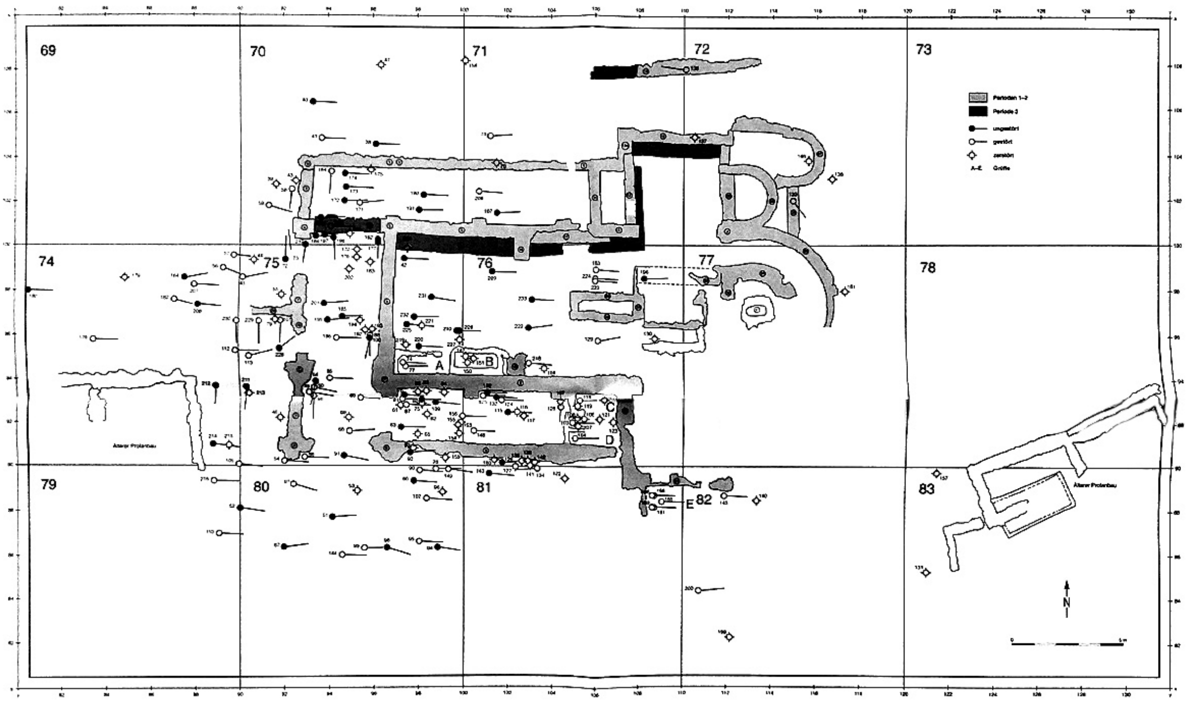

Figure 4. Planimetry of the excavated "Kirche im Weinberg" of Säben-Sabiona, adapted from Bierbrauer and Nothdurfter (2015).

The modest lifestyle of the local population, relying mostly on subsistence economy, i.e., farming and pastoralism, and their conversion to Christianity was also reflected in the grave goods of the general population (Bierbrauer, 2005a; Winckler, 2012). An exception form the elite groups, consisting of local land owners that adapted to Germanic burial traditions featuring rich grave goods (Winckler, 2012). In fact the artefacts from grave 112 and 215 were interpreted as potential evidence for the gradual fusion of the two cultural groups (Bierbrauer and Nothdurfter, 2015).

3.3.2.1. Romans

From 350-700 A.D. the church in the vineyard and the surrounding areas were used as a burial ground by the local population in the form of stonewalled family crypts, wooden coffins/panels, ordinary stone lined or earthen pits (Bierbrauer and Nothdurfter, 2015). These internments followed typical Christian burial traditions, i.e., supine position; West-East oriented (head-feet), with the lower arms flexed above the pelvis, and extended legs (Bierbrauer, 2005a; Bierbrauer and Nothdurfter, 2015; Winckler, 2012). Such a trend was seen in almost all burials, apart from those located near walls or those interred in closer vicinity of the relics (Bierbrauer and Nothdurfter, 2015). Based on the Christian afterlife conception, most burials either lacked grave goods altogether or featured only sparse artefacts, i.e., combs and knives (Tab. 1., Bierbrauer and Nothdurfter, 2015; Kaufmann, 2017; O'Sullivan, 2013; Watts, 2014). Exceptions to this included individuals that were buried wearing their traditional clothes, featuring needles, fibulae and jewellery or those individuals forming the Roman elite (6^{th}-7^{th} century A.D.) who were interred with brocades, headpieces, earrings and rings made out of gold, combs, knives and glassware (Bierbrauer and Nothdurfter, 2015; Winckler, 2012).

Grave N°	Location	Chronology	Grave goods
1	Outside	6th-7th century	Comb and an iron knife, a bangle, and a belt buckle.
52	Outside		Iron knife and a spike of a buckle.
63	Inside- southern aisle	Period 3b or younger	Comb and three iron rivets.
76	Inside- southern aisle	Period 3b or younger	Gold tubes, comb with 5 fragmented iron rivets.
81	Inside- southern aisle		Three gold tubes.
91	Outside		Comb and an iron knife and a ring.
92	Outside		Comb and an iron knife.
95	Outside		Bonze needle, comb, an iron knife, and the remains of an iron buckle.
100	Inside- atrium	Period 1-2b	Golden earrings, two gold textiles, a comb, knife (iron) with wooden traces on handle, bronze rivets on a silver plating.
102	Outside		Broken glassware and an iron knife.
110	Outside		Iron knife.
118	Inside-crypt C	7th-8th century	Iron knife (could belong to anyone of Crypt C).
119	Inside-crypt C	7th-8th century	Iron knife (could belong to anyone of Crypt C).
120	Inside-crypt C	7th-8th century	Iron knife (could belong to anyone of Crypt C).
121a	Inside-crypt C	7th-8th century	Iron knife (could belong to anyone of Crypt C).
121b	Inside-crypt C	7th-8th century	Iron knife (could belong to anyone of Crypt C).
139	Outside	Older than 3b	Fragmented iron knife.
187	Inside- northern aisle	Period 1-2a	Iron knife.
197	Inside- atrium	Period 1-2b	Comb with six fragmented iron rivets.

207	Outside	Period 3b or younger	Iron knife with leather traces.
211	Outside		Iron knife and a comb.
212	Outside	7th-8th century	Comb, an iron knife and buckle.
214	Outside		Iron knife.
216	Outside		Iron knife.
217	Inside- atrium	Period 2a	Fragmented iron knife.
220	Inside- nave	6th-7th century	Iron knife, a fragmented comb and four pearls.
226	Inside- nave		Fragmented iron knife, spindle whorl and two small rings (connected).

Table 1. Burials identified as autochthonous, i.e., Roman, based on their funerary goods, with their grave location and chronology, following the interpretations of Bierbrauer and Nothdurfter (2015).

3.3.2.2. Germanics

From 600 A.D. onwards the funerary culture indicates the presence of allochthonous groups, i.e., Bavarians or Longobards (Tab. 2), which were buried in single graves, mainly located in the narthex, nave and presbytery (Bierbrauer and Nothdurfter, 2015). Some of these graves showed remains of wooden stakes, which are common grave markers in Longobard burial sites (Bierbrauer, 2005a). Others however, featured complete sets of traditional costumes and multi-part belt sets associated with Bavarian culture (Bierbrauer, 2006; Michalowski, 2002). These included two graves with chain pendants (“Kettengehänge“), exclusively found in Bavarian burial grounds, and one grave featuring weaponry that were interpreted as belonging to individuals from the Germanic elite (Bierbrauer and Nothdurfter, 2015; Marti, 2000; Reinecke, 1941; Winckler, 2012).

Grave N°	Location	Chronology	Grave goods
64	Inside- atrium	7th-8th century	Earrings, pearl necklace, belt chain and pendant, two bangles, one ring and two knives.
68	Inside- atrium	7th-8th century	Belt set consisting of four parts, coated silver and brass, bronze buckle (Aldeno type) and an iron knife.
112	Outside	7th-8th century	Folding knife, ordinary knife, and iron buckle.
156	Inside- southern aisle	6th-7th century	A spatha, a buckle and multiple differently shaped belt trimming out of iron, scramasax, a bag with two knives and a scissor.
163	Inside- nave	7th century	Full belt set (four parts) with a buckle in silver and brass (Tierstil II), parts of a scramasax belt, five strap-ends, multiple belt parts spiral ornaments.
177	Inside- atrium	8th century	Pearl necklace, belt chain that is connected to a pendant, iron knife and a bangle.
215	Outside	7th-8th century	Ordinary knife and folding knife made of iron.
231	Inside- nave	7th century	Belt set with multiple parts and strap ends.

Table 2. Burials exhibiting allochthonous funerary goods with their grave location and chronology, based on Bierbrauer and Nothdurfter (2015).

Even though the relationship between funerary culture and ethnicity is controversial (Funari, 1998; Knapp, 2001), the amount and variety of rich grave goods implies that the individuals featuring these were of elevated social status. Hence, highlighting the admixture of pagan and Christian traditions and the importance of Säben-Sabiona as burial ground for both, the lower and upper class (Bierbrauer and Nothdurfter, 2015; Dal Ri, 2010). However, to gain information on social structure, demography, lifestyle and health of these individuals, systematic and comprehensive anthropological studies are necessary.

4. Bioarchaeological research in South Tyrol

Prior to 1930, local antiquarians dealt with all archaeological findings recovered in Tyrol (Dal Ri, 2010; Terzer, 2005). These prioritised commercial aspects, thus, took the opportunity of a standardised archaeological excavation, causing the loss of important artefacts (Dal Ri, 2010; Terzer, 2005). The situation was even worse for human remains, as being without monetary value, they were often destroyed, reburied or discarded (Lunz, 2006, 2004). The value of bioarchaeology was also overlooked once archaeological research was established in South Tyrol. Archaeologists documented the presence of skeletal remains, yet, as the predominance of these are still lost without trace, no information is available for these assemblages (Lunz, 2006, 2004). As a result, most knowledge on early mediaeval life in South Tyrol is based on archaeological and historical sources.

One of the first documented anthropological research attempts was initiated in the 19th century by the physicians Franz Tappeiner (1816-1902) and Moritz Holl (1852-1920), which applied cranial osteometry on both living individuals as well as on skulls from ossuaries to discriminate between individuals deriving from Germanic or Roman groups (Hartung von Hartungen, 2005; Holl, 1884; Jantsch, 1972; Tappeiner, 1883). Even though the results of their research were highly inconclusive, the presumption that cranial shape can be used to differentiate between ethnic groups persisted well into the 20th century and became a paramount conception of national socialists (Hartung von Hartungen, 2005; Lilienthal, 1984; Sauser, 1938). Following the misuse and interpretation of anthropological data through right wing extremism, research on skeletal remains in South Tyrol declined substantially until the end of the 20th century, when the importance of this discipline in relation to the reconstruction of past lifestyle and health was rediscovered (Giovannini, 2003; Renhart, 1991). Even though the conception of utilising craniometric data to categorise individuals persisted in many of these studies (c.f., Capitanio, 1993; Renhart, 2008, 2006), their focus shifted primarily towards the reconstruction of lifestyle and health from past populations (c.f., Giovannini, 2003; Renhart, 2006, 1991,).

Most of these analyses solely provided osteological reports featuring processed data without integrating their results in a more extensive context (e.g., Conzato et al., 2009; Giovannini, 2003, 2002; Paladin and Zink, 2015; Renhart, 2008, 2006, 1991, see Appendix 1). Only within the last few years, local osteological research started to focus more on comprehensive bioarchaeological approaches to understand population composition and living conditions in early mediaeval South Tyrol (Tumler, 2015), specific bioarchaeological topics (e.g., Paladin et al., 2018; Tumler et al., 2021, 2019), or subsistence strategies and mobility patterns through stable isotope analyses (Mundle, 2018; Paladin et al., 2020). Up to date bioarchaeological research about early mediaeval South Tyrol suggests that the individuals inhabiting these areas experienced continuous hardship through strenuous lifestyles (Paladin and Zink, 2015; Tumler, 2015), with high injury risks (Tumler et al., 2021), occasional exposure to interpersonal conflict (Tumler et al., 2021, 2019) and periodic resource depletion (Paladin et al., 2020), which all may have contributed to elevated mobility patterns and altitude-related variations in dietary habits (Mundle, 2018; Paladin et al., 2020). Osteoarchaeology uses theories, methods and data from archaeology, biological anthropology, history, cultural anthropology, medical science and other related disciplines to contextualise human skeletal remains (Buzon, 2012; Quinn and Beck, 2016). As based on an interdisciplinary approach, bioarchaeological research can provide more information about the biological, e.g., fertility, mortality and morbidity, economic and political, ideological and cultural framework, e.g., social organisation, religious practices, subsistence strategies, of past populations, thus, yields a more integrative and holistic interpretation (Quinn and Beck, 2016). In bioarchaeology the focus lies primarily in understanding past lives on an individual and societal level that is accomplished by reconstructing the biological and palaeopathological profile (also referred to as osteobiography) of each individual through the examination of their skeletal features (Agarwal, 2016; Saul and Saul, 1989). The potential of bioarchaeological research and the current state of knowledge in relation to the osteobiographical profiles of the populations occupying South Tyrol and its surrounding areas in the early mediaeval period is addressed more in detail in subsequent sections.

4.1. Biological profile

The biological profile consists of information concerning sex, age at death, non-metric traits, stature, body dimensions and form, all of which are essential aspects in demographic analyses of past populations.

By examining the sex and age ratio of a site, important information on cultural practices of populations and the occurrence of different socio-political and environmental events can be gained (Bardsley, 2014; Fernández-Crespo and De-la-Rúa, 2015; Gautam et al., 2015; Hesketh and Xing, 2006). Whereas in modern societies culturally driven sex-specific infanticides (mostly females) are the most prevalent factor for an imbalanced sex ratio (Gautam et al., 2015; Oomman and Ganatra, 2002), in archaeological cemetery settings skewed sex ratios have also been associated with selective burial practices, thus, offering insights into social structures and cultural perceptions (Bardsley, 2014; Fernández-Crespo and De-la-Rúa, 2015). Some sex disproportions were already noted in different South Tyrolean, e.g., St. Lorenzen-S. Lorenzo in the Puster-Pusteria Valley, 14 males versus 17 females (Renhart, 2008); Elzenbaum in the Wipp-Alta Isarco Valley, 10 males and no females (Renhart, 2006); Langhütten-Gand, three males versus one female (Paladin and Zink, 2015) and Castelfeder, two males versus five females (Giovannini, 2003) in the Etsch-Adige Valley, and other northern Italian sites, e.g., Biverone in Veneto 31.4% males versus 16.3% females (Gadioli et al., 2018), Trento in Trentino, seven males versus eight females (Capitanio, 1993). However, even though all of these studies supply basic demographic data of each of the examined sites, the interpretation of sample composition was only attempted in one study (Renhart, 2008), linking the site to a nunnery. Mortality rates, chances of survival, growth rates, etc., could not be calculated due to low sample sizes for each site. More contextualised approaches assessing palaeodemography were employed for larger sites such as St. Prokulus-S. Procolo in the Vinschgau-Venosta Valley (Renhart, 1991), featuring information about life expectancy, mortality rates and patterns, or when combining different sites (Tumler, 2015). Yet, systemic investigations, e.g., comparing the data to other sites, linking the observed pattern to funerary or burial contexts, or examining the reasons for unequal sex ratios are still lacking, and therefore limit our knowledge on demographic and social organisation in early mediaeval South Tyrol.

Cemetery composition can also provide clues on political, economic or military events, such as wars, which are commonly linked to higher death rates of adult males (Binder and Quade, 2018; Hesketh and Xing, 2006; Nicklisch et al., 2017) or natural disasters, e.g. floods, droughts, etc., with long term impacts on subsistence and economy that are often followed by an increase in infant mortality (Kumar et al., 2016; Norling, 2018; Reher, 1995). Even though the local historical record lacks evidence for larger societal or environmental events (Dudley, 2003; Winckler, 2012), the fluctuating political situation, as proven by both historical and archaeological sources (Bierbrauer and Nothdurfter, 2015; Marzoli et al., 2009; Winckler, 2012), would have impacted the population in different ways. The effects of these occurrences, e.g., famines can be reconstructed based on cemetery composition. Indications for limited access to food materials and/or social variations in food intake, potentially linked to the socioenvironmental context of early mediaeval South Tyrol were noted by Paladin et al. (2020, 2018). Demographic data are also highly valuable for the interpretation of less conventional burial sites, such as those where a large proportion of a population was wiped out in a single event, such as through pandemics, violence, i.e., massacres, or natural catastrophes, e.g., landslides (Alfsdotter et al., 2018; Alfsdotter and Kjellström, 2019; Schroeder et al., 2019). Especially, for regions with limited historical and/or archaeological documentations, the osteological record features unique insights into early mediaeval life. An example is the cemetery of St. Prokulus-S. Procolo near Naturns-Naturno in the Vinschgau-Venosta Valley, which featured two cemeterial populations, one dating to the early mediaeval period and another one linked to a pandemic (possibly plague) dated to the 17th century A.D. (Renhart, 1991). The demographic differences between the two groups, seem to support the historical record, which mentions the occurrence of a pestilence in the 17th century A.D.

Especially when studying cemeteries featuring crypts and mausolea, which may have been used by whole families, not only sex and age at death estimation are essential pieces of information but also the identification of kinship becomes an important attribute. Even though kinship and ancestry have to be confirmed through molecular analysis, the osteological assessment can provide indications to which individuals might be related to each other. Non-metric traits, also referred to as anatomical variants, discontinuous or epigenetic traits, have a long history in osteoarchaeological and forensic research as markers for relatedness and ancestry (Alt, 1997; Cvrček et al., 2018; Ferreri, 2011; Irish et al., 2020; Mann and Hunt, 2019; Palamenghi et al., 2021; Wheat, 2009), but also habitual activity (Finnegan, 1978; Hauser and De Stefano, 1989; Lavallo, 2013). Studies focusing on the South Tyrolean and Trentino area used non-metric traits predominantly for habitual activity reconstruction, whereby linking these skeletal abnormalities to horseback riding is most prevalent, e.g., S. Martino di Lundo (Larentis, 2017), Elzenbaum (Renhart, 2006), Langhütten-Gand (Paladin and Zink, 2015).

Another osteological technique that was and is still used to reconstruct activity from skeletal remains and to assess similarities among different individuals is osteometry (Becker, 2020; Godde and Taylor, 2013; Katherine Spradley and Jantz, 2016; Milella et al., 2015; Ousley and Jantz, 2014, 1996). As mentioned already, most of the earlier bioarchaeological studies collected osteometric data with the aim to assess ethnic affinity (Capitanio, 1993, 1981; Corrain, 1985; Corrain et al., 1983; Giovannini, 2002; Paladin and Zink, 2015; Renhart, 2008). Yet, as the reliability of osteometry as an ethnicity marker has been highly discussed in both the bioarchaeological as well as forensic literature, nowadays, such research questions are investigated through stable isotope and molecular analyses (Göhring et al., 2020; Torroni et al., 2001). Due to the controversial nature of assessing ethnicity through osteological analysis (DiGangi and Hefner, 2013; Sauer, 1992; Skalic, 2018; Wagner et al., 2017), especially for archaeological material with no reference data, bioarchaeologists use osteometric data now more commonly to estimate activity (i.e., robusticity indices), body form (i.e., osseous frame index), height and composition, i.e., body mass index (Albanese et al., 2016; Campanacho and Santos, 2013; Coussens et al., 2002; Jasch et al., 2018; Myszka and Piontek, 2013). Such data provides important key information through which a better understanding of how the human body adapts to different environments and what physiological changes different extrinsic and intrinsic factors cause. An example is the calculation of body height that yields clues on growth patterns, environmental adaptation (e.g., Inuit versus Maasai), lifestyle and general health of past populations (Acosta et al., 2017; Baldoni et al., 2016; Binford, 2019; Johnson, 2014; Lewis et al., 2016; Ruff et al., 2013; Sjöstrand, 2015). For archaeological populations, this is particularly relevant as it allows comparisons with modern anthropometric research (Mumm et al., 2021; Navazo et al., 2020; Scheffler, 2011; Scheffler and Hermanussen, 2021). Most of the anthropological studies focusing on South Tyrolean skeletal material solely utilised the collected osteometric data to provide stature estimates (Renhart, 2008, 2006, 1991; Tumler, 2015). Hence, a substantial amount of osteoarchaeological information about activity patterns, body form and composition of the individuals inhabiting early mediaeval South Tyrol is currently unavailable.

4.2. Palaeopathological profile

Palaeopathology is a discipline comprising medical, anthropological, ecological and historical research that focuses on skeletal abnormalities caused through intrinsic, e.g. congenital conditions, and/or extrinsic factors, e.g., trauma (Ortner, 2003; Roberts and Manchester, 2010). A palaeopathological profile is created through a differential diagnosis by considering various pathological conditions affecting the skeletal and dental apparatus, including congenital conditions, degenerative joint diseases, infections, metabolic disorders, neoplastic conditions and trauma (Aufderheide and Rodríguez-Martín, 1998; Brickley and Ives, 2008; Hillson, 1996; Judd and Redfern, 2012; Lovell, 1997; Ortner, 2003; Pinhasi and Mays, 2008). For South Tyrol, the majority of bioarchaeological studies are merely more extensive osteological reports, thus mainly provide information about the presence of different conditions (Giovannini, 2003, 2002; Renhart, 2008). Details about disease frequency or a detailed analysis of the origins of the observed lesions is limited to a few studies and only available for specific alterations and not for all identified conditions (Paladin et al., 2018; Paladin and Zink, 2015; Renhart, 1991; Tumler, 2015). Through a comprehensive palaeopathological analysis, disease frequencies and patterns can be generated to infer past living conditions, health status, lifestyle and human behaviour from an entire population more holistically. The potential and importance of such research have also been demonstrated by the publications of the "Global History of Health Project", which identified similarities and distinctions in disease prevalence patterns based on geographical, social, economic and temporal settings in American and European societies from prehistory to the 19th century A.D. (Steckel et al., 2018; Steckel and Rose, 2002). Through the foundation of an international project that was based on a thorough and standardised assessment approach of different dental and skeletal abnormalities, novel information on how health, subsistence and lifestyle of a population vary and develop across different temporospatial contexts was gained.

4.2.1. Dental features

The assessment of dental diseases, such as caries, calculus, antemortem tooth loss (AMTL), periodontitis, periapical lesions and enamel hypoplasia is commonly employed in a bioarchaeological analysis (Freeth, 2000; Garcin et al., 2010; Hillson, 1996). By examining the frequency and severity of dental abnormalities within a population, dietary patterns and general health of these past populations can be reconstructed (Bonfiglioli et al., 2003; Esclassan et al., 2009; Garcin et al., 2010).

4.2.1.1. Dental wear

Dental wear, both occlusal and interproximal can be produced through attrition (tooth-to-tooth contact) or abrasion, i.e., interaction with food or other foreign materials (d'Incau and Saulue, 2012; Hillson, 1996). The degree to which mastication and activity related wear affects dentition has been shown to vary greatly among individuals and is predominantly determined based on genealogical factors, the types of foods being consumed/how these are processed or the length of an activity being carried out (Arcini, 2005; Berbesque et al., 2012; Molnar, 1970; Ubelaker, 1996). An ethnographic study by Berbesque et al. (2012) found sex-related differences in dental wear, which were attributable to sex-specific dietary habits and the use of teeth as tools. Thus, through assessing the degree of dental wear on an individual as well as population level, knowledge on food preparation practices, the types of food consumed and/or whether teeth were used as tools can be gained. For South Tyrolean sites, knowledge on these aspects is limited to a few studies, e.g., the late antique and early medieval sites of Kapuziner Kloster- Convento dei Cappuccini in Bozen-Bolzano, Laag-Laghetti in Neumarkt- Egna, Pfatten-Vadena, Castelfeder and Elzenbaum in Freienfeld-Campo di Trens (Giovannini, 2003, 2002; Renhart, 2006), only mentioning the presence of dental wear, yet lacking further interpretations and contextualisation of the data.

4.2.1.2. Caries and calculus

Dental caries and calculus are the most common dental alterations in both modern and ancient societies (Caselitz, 1998; Hillson, 1996). As opposed to caries, which is characterised by perforative lesions at the enamel surface that progressively destroy the whole tooth, dental calculus is mineralised plaque that adheres to the tooth surface. Caries and dental calculus are caused through an imbalance of the oral microbiome, due to genetic predisposition, infections, specific dietary habits, and/or inadequate oral hygiene (Caselitz, 1998; Demirci et al., 2010; Freeth, 2000; Hillson, 1996; Lingström et al., 2000). An increased intake of fermentable carbohydrates, e.g., sugar and starch has been found to be positively linked with caries development, whereas calculus deposition is associated with more alkaline diets, i.e., a high protein and/or carbohydrate consumption (Hillson, 1996; Roberts and Manchester, 2010).

Thus, prevalence rates of caries and dental calculus are commonly used as indicators for past dietary patterns (Betsinger, 2007; Bonfiglioli et al., 2003; Salo, 2005; Steckel and Rose, 2002). Knowledge about dietary patterns is also crucial when assessing social differences as a study by Miliauskienė and Jankauskas (2015) illustrates, i.e., poor quality carbohydrate diets in layman individuals versus higher quality and more nutritious diets in local elite individuals. Again, for most studies on South Tyrolean sites, true and crude prevalence rates or the raw data to calculate these is available (Giovannini, 2003; Paladin and Zink, 2015; Renhart, 1991), yet these were not contextualised or lack comparisons with other parameters (cf. Paladin and Zink, 2015; Renhart, 2006).

4.2.1.3. Antemortem tooth loss, periapical and periodontal disorders

In past populations the main causes for antemortem tooth loss (AMTL) are considered to be trauma, and periapical and periodontal diseases (Alt et al., 1998; Lukacs, 2007).

Attrition, caries, injury or any other process that exposes the pulp cavity can cause a pulpitis that leads to a periapical lesion (Akinyamoju et al., 2014; Alt et al., 1998; Hillson, 1996; Molnar, 1972). Periodontal disease commences with gingivitis and is defined as alveolar inflammation that is triggered by microorganisms and other agents in non-mineralised dental plaque (Hillson, 1996;

Lukacs, 1989). The inflammation causes alveolar bone resorption and progressively disrupts the periodontal ligament, which binds tooth roots to the alveolus, thus leads to AMTL (Hillson, 1996; Lukacs, 2007). By examining the prevalence rates of AMTL, periapical lesions and periodontitis information on dental treatment, food consumption/preparation and medical care in general can be obtained. Despite the importance of considering these dental diseases, especially in relation to dental wear, caries and calculus prevalence rates, information about disorder frequencies in individuals from early medieval South Tyrol is scarce. The presence of these dental disorders is either not addressed at all, only mentions the presence of a condition (Giovannini, 2002; Renhart, 2006), and in rare cases true (Giovannini, 2003) and crude (Paladin and Zink, 2015) prevalence rates are available. If frequency data were present, these often lacked further differential analyses, e.g., possible infection/abscess etc., and more detailed information, such as which tooth was affected. Only the study by Renhart (2008) incorporated the prevalence of AMTL when assessing the caries frequency and compared the rates and severity of periodontal disease with demographic parameters in the St. Lorenzen- S. Sebato-Sonnenburg sample. Crude frequencies of antemortem tooth loss and periodontitis in relation to sex and age were also examined by Tumler (2015), yet as this study analysed the data of different sites as a single population the representativeness of these data is greatly limited.

4.2.1.4. Enamel Hypoplasia

Enamel hypoplasias only occur in still developing teeth in the form of lines (Linear enamel hypoplasia), pits or planes of decreased enamel thickness that are caused through a defect in enamel matrix formation, i.e., temporary disruption of ameloblast activity (Hillson and Bond, 1997; Skinner et al., 2016; Towle and Irish, 2019). These alterations have been reported to be more prevalent in individuals that were exposed to episodes of systemic stress, e.g., disease and/or malnutrition (Goodman et al., 1991; Larsen and Hutchinson, 1992; Reitsema and McIlvaine, 2014; Yaussy et al., 2016). A study by Yaussy et al. 2016 on mediaeval famine victims of London, found a positive association between the presence of enamel hypoplasia and increased frailty during famine. In such contexts, enamel defects are of particular importance as the position of the enamel defect allows establishing a chronological framework of when and how often events of systemic stress occurred (Berbesque and Hoover, 2018; Gamble et al., 2017; Goodman and Armelagos, 1985; Goodman and Rose, 1990). Similar as for previously mentioned dental conditions, most studies focusing on South Tyrolean sites either do not address linear enamel hypoplasia at all or only mention that lesions were found in the sample (Giovannini, 2002; Paladin and Zink, 2015). Only three studies provide information about the crude prevalence rates, number of defects and the age ranges when these lesions most likely occurred (c.f., Giovannini, 2003; Paladin et al., 2018; Tumler, 2015).

4.2.2. Skeletal features

As one of the key elements of bioarchaeology, different skeletal abnormalities are assessed to reconstruct life style and physical activity of past populations (Leiberman et al., 2001; Niinimäki and Baiges Sotos, 2013; Peck, 2013; Perréard Lopreno et al., 2013; Schrader, 2019; Williams et al., 2019; Zhang et al., 2017). Some of these can provide information about physical hardship of a population, e.g., joint diseases and enthesopathies (Andelinović et al., 2015; Jensen, 2008; Kacki et al., 2011; Molnar et al., 2011; Niinimäki and Baiges Sotos, 2013; Palmer et al., 2014; Perréard Lopreno et al., 2013; Sandmark et al., 2000; Villotte et al., 2010a), episodes of nutritional and physiological stress, e.g., cribra (Betsinger, 2007; Facchini et al., 2004; Šlaus et al., 2004; Steckel, 2005; Yaussy et al., 2016) and sometimes even yield insights into potential causes of death, e.g., trauma (Forsom et al., 2017; Nicklisch et al., 2017; Tumler et al., 2019).

4.2.2.1. Joint diseases

Joint diseases, such as osteoarthrosis (OA), spondyloarthrosis, Schmorl's nodes are generally relatively prevalent in archaeological populations (Eng, 2016; Roberts and Manchester, 2010; Rogers and Waldron, 1995; Williams et al., 2019). Hence, a lot of research has focused on joint diseases, especially in relation to lifestyle and activity reconstruction.

4.2.2.1.1. Osteoarthrosis

The joint disease osteoarthrosis is also referred to as osteoarthritis and degenerative joint disease, with osteoarthritis being the most frequently used expression (Salter, 2002; Tanchev, 2017; Weiss and Jurmain, 2007). As the suffix "*-itis*" implies an inflammation, which is not a primary feature of joint degeneration (Tanchev, 2017) the term "osteoarthrosis" is preferred. Osteoarthrosis affects synovial joints and is characterised by a focal loss of joint cartilage and subsequent subchondral bone damage that leads to porosity, eburnation, the formation of marginal osteophytes and subchondral cysts (Ortner, 2003; Rogers and Waldron, 1995). Subchondral bone damage occurs in response to a variety of biological, genetic and environmental agents, such as age, body weight, hormones, workload or injury, which have all been associated with the development of OA (Harding et al., 2016; Molnar et al., 2011; Pearson and Buikstra, 2006; Rogers and Waldron, 1995; Sandmark et al., 2000; Waldron, 2009). Even though the importance of these factors in the development of OA is highly discussed, there is a general consensus that joint use, i.e., movement contributes substantially to joint deformation (Block and Shakoor, 2010; Moskowitz et al., 2004). Like other

conditions, OA is age-progressive and aggravates through joint loading, hence its suitability to assess physical activity in the past (Ortner, 2003; Schrader, 2019).
A publication by Wells (1964), found a link between high levels of OA and farming activities and linked the presence of OA in foot bones of soldiers to frequent marching. Also, more recent investigations, associate OA with mechanical loading, e.g., Eng (2016) who was able to distinguish a sexual division of labour between hunter-gatherer and nomadic pastoralist societies based on the respective OA patterning.
Even though the use of OA as an activity marker is justified, for South Tyrol such investigations are highly limited. Only a few publications address the presence of OA, some of these only mention that signs of OA were observed (Giovannini, 2003, 2002) and outline the most severely affected joints (Renhart, 1991), others describe single cases in more detail (Paladin and Zink, 2015). Yet, trying to link the prevalence and severity of OA to activity and evaluating sexual division of labour was only attempted by one study (c.f., Tumler, 2015). Due to the nature of this study, assessing multiple different sites as one population, the interpretations of these data may provide an inaccurate depiction of early mediaeval lifestyle in this region. Despite the lack of large samples, which would be essential for such analyses, none of the above-mentioned studies, apart from Tumler (2015), provide detailed accounts of the severity and distribution of OA. Also, the absence of raw data addressing these points further limits our knowledge of OA prevalence in early mediaeval South Tyrol, which in turn hinders any attempts to investigate activity patterns.

4.2.2.1.2. Spondyloarthrosis, Schmorl's nodes and less common joint disorders

Degenerative processes of the spine, also referred to a spondyloarthrosis follow similar destructive mechanisms as osteoarthrosis, although they affect both the synovial joints of the articular facets and the cartilaginous joints of the vertebral bodies (Pearson and Buikstra, 2006; Waldron, 2009; Wendling and Claudepierre, 2013). As in OA, the aetiology of this condition is diverse, yet, especially joint overloading, holding incorrect postures for prolonged time, trauma and individual variation, e.g., spinal curvature has been identified to increase both the prevalence and severity of spondyloarthrosis (Kahl and Ostendorf Smith, 2000; Knüsel et al., 1997). Thus, by assessing spondyloarthrosis information about lifestyle and long-term exposure to physiological strain of an individual and a whole population can be obtained.

Schmorl's nodes are circular depressions on vertebral bodies that result from a herniation of the intervertebral disc (*nucleus pulposus*) into the vertebral body through an area of weakness in the endplate (Hamanishi et al., 1994; Resnick and Niwayama, 1978). Due to their high frequency in the lower thoracic and lumbar spine, they have often been linked to spinal injuries involving excessive workload, but also infections, genetics and several metabolic conditions (Pfirrmann and Resnick, 2001; Saluja et al., 1986; Williams et al., 2007). In the bioarchaeological literature, Schmorl's nodes are most frequently used as indicators for physical activity, e.g., carrying heavy objects, thus, form an important element in activity reconstruction of past populations (McNaught, 2006; Schrader, 2019; Stirland and Waldron, 1997; Üstündag, 2009).

The recording and assessment of less common joint disorders, such as osteochondrosis dissecans, gout and diffuse idiopathic skeletal hyperostosis (DISH) is crucial to establish activity and lifestyle patterns as well as when trying to differentiate between social classes with a sample (Fornaciari and Giuffra, 2013; Smith et al., 2013; Van der Merwe et al., 2012).
Like for most skeletal alterations already mentioned, information on the prevalence and severity of degenerative spinal conditions in the South Tyrolean osteoarchaeological record is highly limited. The available literature mentions mainly crude prevalence rates of spondyloarthrosis and/or Schmorl's nodes of the whole sample or based on sex (c.f., Renhart, 1991, 2006, 2008; Tumler 2015). Although Paladin and Zink (2015) refer to individual vertebrae, the presence of spondyloarthrosis in these locations was solely mentioned in evidence for potential engagement in horseback riding. None of the South Tyrolean publications mentions the presence of less common joint disorders, thus, limiting our knowledge on the prevalence of rarer conditions as well as on lifestyle patterns, which can potentially shed light on societal differences.

4.2.2.2. Entheseal changes

Entheses are the osseous interfaces where muscle, tendons, and ligaments attach to bone (Benjamin et al., 2006, 2002; Schlecht, 2012). Hence, as increased physical activity is believed to stimulate osteogenic processes at these structures, thus, leading to bone hypertrophy, which can be observed macroscopically (Churchill and Morrs, 1998; Hoyte and Enlow, 1966), these are commonly used as markers for activity (Havelkova et al., 2011; Nikita et al., 2019; Villotte et al., 2010a, 2010b). A number of studies used entheseal changes to reconstruct occupations, such as the study by Havelkova *et al.* (2011) who found differences in hardship of labour between the mediaeval castle inhabitants and farmers of Mikulčice in the Czech Republic. Other recent studies testing the correlation between EC and activity on skeletal reference collections or in combination with other traits known to affect bone remodelling established variable results (Alves Cardoso and Henderson, 2013; Milella et al., 2012; Palmer and Waters-Rist, 2019; Schrader, 2019). As entheseal changes are frequently observed in human skeletal remains and a link between entheseal morphology and activity is encountered more frequently in the bioarchaeological literature (Havelkova et al., 2011; Karakostis et al., 2019; Sick, 2021; Villotte et al., 2010a), entheseal changes can be regarded as suitable indicators for activity patterns. Only through a detailed assessment and by considering the various factors affecting entheseal development, e.g., age, sex, body size, an accurate contextualisation can be yielded (Acosta et al., 2017; Claudepierre and Voisin, 2005; Milella et al., 2012; Schlecht, 2012; Sick, 2021). Thus, even though still highly debated (Alves Cardoso and Henderson, 2013; Milella et al., 2015; Palmer and Waters-Rist, 2019; Schrader, 2019), in conjunction with other skeletal markers, e.g., OA and robusticity indices, entheseal changes offer the unique opportunity to gain knowledge about habitual activities, thus, lifestyle of past populations (Becker, 2020; Foster et al., 2014; Myszka and Piontek, 2013; Palmer et al., 2014).

As more detailed analyses of entheseal changes, especially in respect to activity reconstruction, are a rather new phenomenon, most of the older bioarchaeological studies concerning South Tyrolean sites focused mainly on bone robusticity and merely mention alterations at entheses (Giovannini, 2003; Renhart, 2008, 2006). Both Giovannini (2003) and Renhart (2008) mention osteometric differences in the robusticity values and entheses between males and females and interpret these in conjunction with stature data as indicator for farming. Only recently, Paladin and Zink (2015) were some of the first to utilise entheseal, OA and non-metric data as an indicator for horseback riding in an individual from Langhütten-Gand in Eppan-Appiano. A more detailed and extensive study focusing on the severity of EC in relation to sex and location was performed by Tumler (2015), yet due to a lack of differentiation among the various sites and scarce contextualisation of the data, knowledge about the frequency and severity of EC on a population level of a confined site is still highly limited.

4.2.2.3. Metabolic conditions

Metabolic disorders can be genetically and/or environmentally induced, whereby only chronic conditions are discernible on bone (Brickley and Ives, 2008; Roberts and Manchester, 2010). Hence, especially for environmentally caused metabolic conditions, e.g., famine, malnutrition, etc., skeletal alterations mark the length of exposure and severity of an episode. The most frequently observed metabolic conditions in archaeological samples include anaemia and nutritional deficiencies, such as iron, vitamin D (rickets and osteomalacia) and C (scurvy) deficiency (Brickley and Ives, 2008; Steckel and Rose, 2002; Veselka et al., 2018). Typical skeletal indicators for these disorders are porotic lesions on the external cranial vault (*cribra cranii*), orbital roof (*cribra orbitalia*), sphenoid, hard palate (*cribra palatinii*), maxilla, mandible, ribs (sternal end), scapulae, pelvis and on the neck of the humerus and femur (*cribra humeralis* and *femoralis*) (Brickley and Ives, 2008; Ortner, 2003; Roberts and Manchester, 2010).

Cribrotic lesions were also noted in individuals from different South Tyrolean sites, e.g., Laag-Laghetti, Pfatten-Vadena, Castelfeder, Elzenbaum and Schloss Tirol-Castel Tirolo (Giovannini, 2003, 2002; Paladin et al., 2018; Renhart, 2006; Tumler, 2015). Most of these provide quite a lot of information about the observed lesions, including frequency and severity of the alterations in relation to sex and age (Giovannini, 2003, 2002; Renhart, 2008, 2006, 1991; Tumler, 2015). The data and interpretation of three studies even suggests the presence of metabolic conditions such as scurvy, rickets and osteomalacia (Paladin et al., 2018; Renhart, 2006; Tumler, 2015).

4.2.2.4. Infections

Both bacterial, which are believed to be more common and less acute, and viral infections that tend to progress more rapidly and are often fatal, have shown to spread from affected soft tissue to the skeleton causing an inflammation (Ortner, 2003; Roberts and Manchester, 2010; Wilks et al., 2003). These bone lesions are categorised into specific infections, i.e., a specific causative organism, which include leprosy, tuberculosis, brucellosis or treponemal diseases, or non-specific infections that are caused through an unspecified microbe, most commonly staphylococci, streptococci or pneumococci (Ortner, 2003; Pinhasi and Mays, 2008; Roberts and Manchester, 2010; Waldron, 2009). In archaeological samples an inflammation of the periosteum (periostitis), the cortex (osteitis) and the medullary cavity (osteomyelitis) are most frequent (Marques et al., 2019; Obertová, 2008; Roberts and Manchester, 2010).

Out of these three, periostitis (periosteitis/periostosis) is most often found in skeletal assemblages and manifests itself as mild pitting/striations to large more severe plaque formations or complete deformation of the outer bone surface (Ortner, 2003). Anything that irritates the periosteum leading to a stimulation of osteoblast activity, such as general infections, ulcers, varicose veins, nutritional deficiencies and trauma can cause periostitis (Robbins et al., 2009; Roberts and Manchester, 2010; Waldron, 2009).

The prevalence rate of infectious diseases, particularly their healing stages reflect how susceptible an individual/the whole population is to such pathogens. Thus, inevitably also provide information on the immunological health of an individual/population, their chances to recover from more lethal conditions and whether they had access to some sort of treatment. Information about the prevalence of specific and non-specific infections in early mediaeval South Tyrol is very scarce and limited to the studies of Renhart (1991) and Tumler (2015).

4.2.2.5. Trauma

Along with dental, joint and metabolic disease, trauma is the most common pathological condition in archaeological remains (Knüsel and Smith, 2014; Obertová, 2008; Ortner, 2003). Bioarchaeological trauma analysis involves the examination of any damage, irritation or inflammation on human skeletal remains that has been caused by an external, i.e., environmental forces, or internal mechanisms, i.e., weakening due to pathology (Black and Ferguson, 2011; Byers, 2017; DiMaio and DiMaio, 2001; Kimmerle and Baraybar, 2008).

A chronological framework, antemortem (AM, survival of the individual), perimortem (PeM, injuries linked to the time of death) and postmortem (PM, damage obtained after death) trauma, can be established by examining the appearance and colouration of a lesion (Byers, 2017; DiMaio and DiMaio, 2001; Roberts and Manchester, 2010; Šlaus et al., 2012). Bone trauma can be provoked through diseases, the application of stress or forces that causes bone to fail. The resulting injuries are generally subdivided into fractures (FX), blunt force (BFT), projectile (PT), sharp force (SFT) and miscellaneous trauma (Black and Ferguson, 2011; Kimmerle and Baraybar, 2008; Mole et al., 2015; Spatola, 2015; Ubelaker, 2019). By considering all of these aspects, a thorough trauma assessment can thus provide information about an individual's lifestyle, e.g., injuries associated with habitual activities, potential involvement in conflict and frequency of exposure to violence, as well as the overall health of an individual, e.g., ability to recover from trauma (Martin and Anderson, 2014; Redfern, 2016; Smith, 2017).

For early mediaeval South Tyrol, most of the earlier studies (Giovannini, 2003; Renhart, 2008, 2006), but also some of the more recent ones (Paladin and Zink, 2015; Tumler, 2015) mentioned the presence of trauma in their sample but do not provide a thorough trauma analysis, which would be required to be able to understand more complex sociocultural practices. Some of these publications also yield data about the type and/or timing of the observed lesions (Renhart, 1991; Tumler, 2015), yet, again this information lacks a differential diagnosis and contextualisation. Up to now, only two studies on South Tyrolean skeletal remains that assess trauma prevalence and pattern thoroughly are available (c.f., Tumler et al., 2021, 2019). In both publications, Tumler (2019, 2021) clearly outlines the amount of information that can be gained, i.e., about lifestyle and the sociocultural impacts of the constantly changing political and economic situation throughout the early mediaeval period. While these publications provide a systematic investigation at the population and aetiological level of the observed trauma, there remains a paucity of contextualisation in relation to the social status and burial pattern of the injured at Säben-Sabiona.

4.2.2.6. Congenital and neoplastic conditions

The earliest manifestation of some skeletal abnormalities occur already during gestation, hence, they are referred to as congenital conditions (Barnes, 1994; Roberts and Manchester, 2010). As more severe defects are usually not compatible with life, these are rarely encountered in archaeological contexts (Aufderheide and Rodríguez-Martín, 1998; Barnes, 1994). Yet, those alterations that have less serious consequences are frequently seen in archaeological samples and mostly include spinal deformations, e.g., spina bifida occulta and lumbosacral transitional disorders (Barnes, 1994; Copp et al., 2015; Ferembach, 1963; Roberts and Manchester, 2010). Congenital abnormalities can provide important information about a society, such as maternal health, marriage patterns and societal integrity (Barnes, 1994; Holst, 2010; Sture, 2001). Furthermore, as congenital conditions have a genetic origin, assessing these skeletal alterations is also highly valuable in combination with non-metric traits, to gain preliminary data aiding the selection of samples for molecular kinship analyses.

Bone neoplasms are the result of mutations that cause uncontrolled cytogenesis of bone, cartilage, fibrous tissue or blood vessels and are subdivided into benign and malignant tumours (Brothwell, 2008; Czerniak, 2016; Ortner, 2003; Roberts and Manchester, 2010). Benign neoplasms are localised, often chronic and clinically insignificant, and include cysts, osteoblastic, chondroblastic and fibroblastic tumours (Brothwell, 2008; Ortner, 2003). Malignant bone tumours, such as osteosarcomas, chondrosarcomas and Ewing's sarcomas, spread from a primary growth centre to other organs through the blood and/or lymphatic system (metastases formation) and tend to be more acute and fatal (Brothwell, 2008; Ortner, 2003). Analysing ancient human bone cancers is not only a valuable aspect of a thorough palaeopathological analysis, but may also contribute to modern oncological research, e.g., the natural prevalence of neoplasms in certain geographical areas, potential triggers and links to specific lifestyles, etc. (Binder et al., 2014a; Dennis, 2018).

Only the publications by Renhart (1991) and Tumler (2015) mention the presence of congenital and neoplastic conditions in South Tyrolean skeletal assemblages, yet, more detailed descriptions, i.e., number of lesions, specific location, etc., and differential diagnoses of the observed alterations are not available.

5. Materials and Methods

5.1. The parish church and cemetery in the vineyard at Säben-Sabiona

A total of three archaeological excavations was carried out at the Säben-Sabiona hill from 1929-1982 uncovering between 366 and 370 graves. The first excavation focused on the parish church and its associated cemetery located in the area South of the crenellation and "Liebfrauenkirche", which is now a vineyard. This was carried out by the cleric Adrian Egger in 1929/30 and established the outline of the church and recovered individual grave goods (H. Nothdurfter, personal communication on the 27th July 2020) as well as between 110 and 114 graves (Bierbrauer and Nothdurfter, 2015; Gleirscher, 1986). Further 59 graves were discovered at the southern end of the hill in 1976 by Kromer and Nothdurfter. During a third archaeological survey from 1978 to 1982 by Bierbrauer and Nothdurfter (2015) the remnants of the parish church, several profane buildings and 234 burials, including five crypts were exposed.

As the skeletal remains from the first two excavations were not available for analysis and 37 graves from the third excavation, i.e., 1978 to 1982, are currently in the process of being contextualised archaeologically (personal communication Prof. Hans-Peter Kuhnen, Archaeologist from the University of Mainz), the present study focuses on those graves published by Bierbrauer and Nothdurfter (2015), i.e., 197 graves. The grave catalogue from Bierbrauer and Nothdurfter (2015) lists 199 grave numbers, yet two of these, i.e., 111 and 188 were not assigned to a grave, hence, only 197 graves were actually excavated. Furthermore, one grave (i.e., 232) only exhibited faunal remains, three graves were older than the church (i.e., 129, 136 and 157) and eight graves could not be located (i.e., 131, 145, 154, 158, 183, 196, 203, 234), thus were excluded from the anthropological analysis. In total, 185 out of the published 197 graves from the crypts, within and around the church were analysed. Crypt A (n=2), B (n=3), C (n=5) and D (n=6) are located inside, and crypt E (n=5) was found outside of the church further South. Generally, more burials were excavated within (n=100) than around (n=85) the church (Fig. 4). Most graves within the church were situated in the southern aisle (n=27) or the atrium (n=25), 16 inhumations were found in the crypts of the nave (crypt A and B), or the southern side aisle (crypt C and D) and 14 burials were recovered from the northern aisle. The external burials were mainly scattered in the areas south (n=36) or west (n=33) of the church, fewer graves were excavated in the northern (n=9) and eastern zones (n=2). Nineteen of these graves were deposited in closer proximity of the external church walls and five inhumations were identified in crypt E.

Based on the grave catalogue supplied in the publication by Bierbrauer and Nothdurfter (2015), most interments were single graves (n=141) and primary depositions (n=109) were more prevalent than secondary burials (n=36). Stone lined graves (n=39) were most common, followed by inhumations in crypts (n=21) and earthen pit graves (n=6). All available archaeological and funerary information of the studied graves is listed in Appendix 2. The influence of Christian afterlife conception is clearly displayed in grave orientation and body posture, which was predominantly West-East (n=71) with the arms flexed above the pelvis or chest and feet extended (n=31), as well as the excavated grave goods that were mainly modest (n=40) or lacking altogether (129). Sixteen burials featured exceptionally diverse and wealthy funerary goods, including gold objects, jewellery, multipart belt sets and weaponry. Through these and the relative chronology of the church, the site was dated to the 5^{th} -8^{th} centuries A.D.

5.1.1. Elite versus non-elite groups

Following archaeological research by Bierbrauer and Nothdurfter (2015) 27 graves were identified as local Romans (Tab. 1) and at least six inhumations, possibly eight, featured typical Germanic artefacts (Tab. 2). For the presumed local Roman burials, not only the gold artefacts in burials 76, 81 and 100 suggested an elevated social status, but also their location inside the church. Similarly, although recovered solely with a knife, also the graves 118, 119, 120, 121a and 121b that were excavated from crypt C in the southern side aisle of the church can be regarded as belonging to an elite group. The remaining individuals with little or no artefacts potentially belong to this group of Christianised Romans, yet there is no scientific evidence to assign any of these to a specific ethnic group. Indications for elevated social status were also recorded in the presumed “Germanic” inhumations, all of which were located inside the church and featured a rich funerary culture, mostly multipart belt sets and weaponry.

Based on the available historical information about Säben-Sabiona, which suggest a site of great importance (Bierbrauer, 2005a; Kaufmann, 2017; Kuhnen, 2020; Sparber, 1942; Winckler, 2012), and the presence of prestigious grave goods, e.g., gold jewellery, multipart belt sets and weaponry, in some of the interments (Bierbrauer, 2006; Bierbrauer and Nothdurfter, 2015), it can be assumed that the present cemeterial population may not represent a natural population. As Säben-Sabiona is such an important locality, it can be assumed that burial within and around the church may have been limited to selected groups and/or single individuals from the whole population. According to Nothdurfter (1999), graves, evidence burial rights of a church and from an archaeological perspective, socially high-ranking individuals are only identifiable through rich funerary goods and/or separate burial places. The burial patterns at Säben-Sabiona, i.e., location within crypts and inside of the church, especially the nave, southern aisle and atrium, which has been found to be a strong indicator for elevated social status (Brather and Friedrich, 2013; Brownlee, 2020; Ferreri, 2011; Marti, 2000; Passalacqua, 2012; Pinhasi and Bourbou, 2008), supports this view. A personal communication with Prof. Hans-Peter Kuhnen, who continues the archaeological investigations of the Säben-Sabiona mount from Bierbrauer and Nothdurfter, also confirmed this notion. Due to the importance of the site, all interred individuals may have held elevated social status, yet variations in funerary culture and burial location suggest further social stratifications within this selected group of individuals, thus, it appears reasonable to divide the sample in an elite and non-elite subsample. To be able to contextualise Säben-Sabiona more accurately, all individuals featuring grave goods that could be classified into average wealth, wealthy or exceptionally wealthy, following the proposed categorisation outlined by Sayer (2013a), and those that were buried inside crypts or within the church, i.e., nave, atrium and southern/northern aisle were grouped into the subsample elite/rich burials. This differentiation led to a subsample of 107 elite/rich and 78 non-elite/poor graves (see Appendix 2).

5.2. Methods

Up until the start of the data collection in March 2017 at the facilities of the Institute for Mummy Studies (Eurac Research in Bozen-Bolzano), the skeletal material was stored in the warehouse of the Amt für Bodendenkmäler-Ufficio Beni archaeologici in Bozen-Bolzano, Italy.

All skeletal remains recovered from Säben-Sabiona were already cleaned prior to the start of this project, thus no major washing and drying had to be performed. Once the remains were unboxed, most bones were solely dry brushed to remove soil particles from important features that were assessed during the anthropological analysis or to enhance the photographic documentation. Data were collected by utilising a digital database on Microsoft Excel as well as more visual cartographic recording sheets (see Osteobiographic catalogue). Most of the data, especially more detailed information, i.e., scores for certain pathologies or osteometric data were registered in the digital database. The main purpose of the cartographic recording sheets was to give a general overview of each individual. A full osteobiographic profile including the recording sheet as well as photographic documentation of each individual is supplied in the osteobiographic catalogue. Fragmented bones were reconstructed by utilising a water-soluble glue (Vinavil®). The reconstruction of fragmented bones was limited to bones that presented minor fracturing, had to be intact for metric data collection or for photographic documentation (see Appendix 3). Damaged crania and other highly fragmented skeletal elements for which bone integrity was not essential to be able to perform an anthropological analysis were not reconstructed. Taphonomic alterations and associated of faunal remains were also recorded (see Appendix 4). Following a supervisor consultation and in consideration of the scope of a thorough osteoarchaeological research, which up until now has not been performed on this skeletal collection, it was agreed to focus on anthroposcopic and osteometric approaches to assess the present skeletal collection.

5.2.1. Preservation, number of individuals and representativeness of the population

In order to determine the state of qualitative and quantitative preservation, the skeletal remains were scored from low to good, indicating the quality of the bone surface and from <25%-100% to estimate the quantity of skeletal elements present. Qualitative bone preservation rating followed the long bone inventory recording system developed during the Global History of Health Project (Steckel et al., 2006), although the scoring was applied on the whole skeleton rather than on individual bones. As taphonomic factors, i.e., funerary practices, grave type, soil pH and type, etc., are known to affect bone preservation (Lieverse et al., 2006; Manifold, 2012), the effect of burial location, i.e., inside versus outside burials, and whether the presence of grave goods had an effect on bone preservation was assessed.

In order to calculate true prevalence rates of palaeopathological conditions and trauma, quantitative bone preservation recording also included a minimum number of elements (MNE) estimation, for each individual, i.e., registering all identifiable bones (Egaña et al., 2008; Lambacher et al., 2016). The MNE data was recorded in both the digital and cartographic recording sheets, whereby the digital version only provides information on presence/absence of an element and the cartographic documentation also indicates which section of a bone was preserved (see Appendix 5). Furthermore, also the total number of identified specimens (NISP), by counting all bone fragments (including human and fauna remains), and the minimum number of individuals (MNI) was estimated (Lambacher et al., 2016; White, 1953). The MNI was calculated by dividing the skeletal elements into right and left and using the most abundant number for the final estimate, whereby robusticity, morphology, and the developmental status of the respective bone were also considered (Buikstra and Ubelaker, 1994; White, 1953). In order to ensure completeness of the analysis also any scattered remains were recorded (see Appendix 6).

5.2.2. Biological profile

5.2.2.1. Sex estimation

Sex estimation of human skeletal remains focuses on secondary sex characteristics that develop during puberty and include changes in body size and shape (Bogin, 1999; Moore, 2013). The macroscopic and metric methods used to sex an individual rely on the degree of sexual dimorphism of these secondary sex traits, which are influenced by intrinsic (e.g., genetics, hormones, etc.) and extrinsic factors, such as the environment, diseases, nutrition, etc. (Binford, 2019; Bittles, 2012; Moore, 2013; Stinson et al., 2012). Environmental effects on body size and shape, i.e., the levels of robusticity, have shown to be substantial among populations from different environments (Binford, 2019; Leonard and Katzmarzyk, 2010; Ruff, 2002). Hence, especially for unknown individuals, ancestry should be estimated prior to assessing sex (Byers, 2017; Tawha et al., 2020). However, currently available evidence suggests that the individuals buried in the Säben-Sabiona cemetery originated either from the local area or nearby regions, i.e., from modern day Austria, southern Germany or northern Italy (Bierbrauer and Nothdurfter, 2015), thus, probably consisted of Caucasian individuals. Osteological ancestry estimation relies on skeletal differences that develop as a result of specific environmental conditions, thus significant physiological differences among populations are required to yield an accurate ancestry assessment (Algee-Hewitt et al., 2020; Byers, 2017). As for the regions within and surrounding the central Alps, environmental influences are highly similar, and population admixture and low population variations, especially for ancestral subgroups, proved to be a significant limiting factor for successful ancestry estimation, for the present sample, no ancestry estimation was performed.

Despite these population specific differences, sex is generally estimated through visual/macroscopic assessment and metric estimations focusing on the pelvis, skull and long bones, whereby the highest accuracy is yielded when looking at the entire skeleton. Following this reasoning the cranial and postcranial features summarised in Table 3 were examined to estimate sex.

Method type	Bone	Feature examined
Morphoscopic	Cranium	Nuchal crest
		Mastoid process
		Forehead
		Parietal/frontal eminence
		Glabella
		Supraorbital ridge
		Supraorbital margin
		Orbital shape
		Zygomatic arch
	Mandible	Ramus flaring
		Ramus angle
		Mental protuberance
		Mandibular shape
	Os coxae	Ilium size
		Sciatic notch
		Ventral arc
		Medial ischiopubic ramus
		Subpubic concavity
		Arc composé
		Inlet shape
		Pubic body width
		Obturator foramen shape
		Subpubic angle
	Sacrum	Sacrum orientation
		Size of sacral body
	Humerus	Vertical diameter of the head (M10)
	Femur	Vertical diameter of the head (M18)

Osteometric	Os coxae	Acetabulo-symphyseal pubic length (PUM, M14)
		Cotylo-pubic width (SPU)
		Innominate or coxal length (DCOX, M1)
		Greater sciatic notch height (IIMT, M15.1)
		Ischium post-acetabular length (ISMM)
		Iliac or coxal breadth (SCOX, M12)
		Spino-sciatic length (SS)
		Spino-auricular length (SA)
		Cotylo-sciatic breadth (SIS, M14.1)
		Vertical acetabular diameter (VEAC, M22)
		Horizontal acetabular diameter (HOAC, M22)

Table 3. Skeletal features assessed to estimate sex.

Visual assessment was performed by following the methods proposed by Acsádi and Nemeskéri (1970), Buikstra and Ubelaker (1994), Ferembach et al. (1979), Phenice (1967), and Walker (2008).As macroscopic approaches have been described as quick visual assessments and are known to exhibit high inter- and intraobserver error rates (Moore, 2013; Walker, 2008), metric methods were used to validate the results of these. Metric sex estimation was established through the approaches by Murail et al. (2005) for pelvic measurements and Pearson and Bell (1917) and Stewart (1979) for long bone metrics (Bass, 1995). The osteological measurements were guided by the publications of Buikstra and Ubelaker (1994), Martin and Saller (1959) and Murail et al. (2005). Anthropological research found that due to childbirth related changes in the pelvic bones, i.e., *os coxae* and sacrum, they display the most divergence between the sexes, thus, they pose the highest degree of accuracy when assessed alone (Krogman and Iscan, 1986; Moore, 2013; Stewart, 1979). Spradley and Jantz (2011) proposed that in the absence of pelvic bones for sex estimation, postcranial elements should be preferred, as extrinsic factors, e.g., robusticity (Moore, 2013), appear to have a greater effect on skull morphology than on postcranial bones. Hence, leading to a decreased accuracy in sex estimation when using the skull. In consideration of these points and in situations when the skeleton was incomplete and fragmented more weight was given to the data resulting from the pelvic bones, followed by long bones and then the skull. A detailed tabulation of the sex estimation data can be found in Appendix 7. Based on this sex assessment approach, all individuals were initially grouped into female (F), possible female (F?), male (M), possible male (M?) and not determinable (ND). Those individuals who displayed subtle female or male characteristics were grouped into the possible female/male category. To facilitate data analysis and display, once sexual variation within the sample was clearer, where possible those individuals identified as possible female/male were assigned to the respective sex category or as ND, where sex estimation remained inconclusive. Hence, only the following three classifications were used in all demographic and palaeopathological calculations: F, M and ND.

For individuals below the age of 13, sex was not assessed due to a lack of reliable osteological methods and general disagreement in regard to the accuracy of the developed approaches (Komar and Buikstra, 2009; Moore, 2013; Scheuer and Black, 2004). Thus, sex assessment was limited to individuals over 13 years of age, by following the same sex estimation approaches as used for adults. The measurements of the internal auditory canal, which has been found to be a reliable sex estimation approach for subadults (Goncalves et al., 2011; Graw et al., 2005; Norén et al., 2005), was not utilised for the present sample as the petrous bones of juveniles were either not preserved, lacked preservation for the method to be carried out accurately or were unavailable, i.e., were sampled for molecular analyses prior to the anthropological analysis was carried out. Even though molecular sex estimation of subadults would have been possible, this would have exceeded the scope and timeframe of the present study. As males and females age at slightly different rates it is generally advised to estimate sex prior to age at death (Buikstra and Ubelaker, 1994; Byers, 2017; Moore, 2013), which was also incorporated in this research.

5.2.2.2. Age at death

In the life course of an individual, the body completes different maturation stages that manifest themselves as age related changes on the skeleton, thus, form the basis for age at death estimation. These skeletal traits, however, provide information on biological age, i.e., physiological state of an individual, and do not represent chronological age that can only be established when birth and death dates are known (Couoh, 2017; Garvin et al., 2012). Similar as for sexual dimorphism, biological age is highly influenced by intrinsic (e.g., sex and hormones, genetic predisposition for joint degeneration or cell maturation) and extrinsic mechanisms, such as the environment (e.g., terrain, temperature, altitude etc.), activity, health and nutrition, all of which can alter bone turnover rates, thus consequently also the appearance of the skeletal traits used in aging (Garvin et al., 2012; Melzer et al., 2007; Passarino et al., 2016; Roberts and Manchester, 2010; Rosen et al., 1999). Age at death estimation relies mostly on visual assessment of changes associated with skeletal and dental development, i.e., long bone fusion or dental eruption, as well as age-related degeneration, particularly at joints, has also been proposed to be a good age indicator (Buikstra and Ubelaker, 1994; Freemont and Hoyland, 2007; Lovejoy et al., 1985; Todd, 1920; Ubelaker, 1989).
As aging is performed by assessing modifications linked to skeletal and dental development, subadults and young adults that are still in course of skeletal growth are more accurately aged than older adults, whose growth has already been terminated (Byers, 2017; Garvin et al., 2012; Harth et al., 2009; Schmitt et al., 2006; White et al., 2012). Subadult age is most commonly estimated by examining dental eruption patterns, measuring long bone length and epiphyseal fusion, whereby dental aging has been shown to determine juvenile chronological age most accurately (Garvin et al., 2012; Scheuer and Black, 2000; Ubelaker, 1989). In the present study subadult aging was performed

by focusing on dental eruption following the methods by AlQahtani et al. (2010) and Ubelaker (1989); epiphyseal fusion as proposed by Scheuer et al. (2000) and the length of long bones (Fazekas and Kosa, 1978; Maresh, 1955).

For those individuals whose skeletal development has already been ceased, methods relying on degenerative or even pathological osseous modifications become more relevant as age indicators. As adult age estimation approaches focus on skeletal changes associated with the aging process, they are unable to yield a biological age as such but instead provide information on the aging rate of an individual, hence, the large age categories. To do this, the cartilaginous changes observed at the pubic symphysis and auricular surface on the *os coxae* or the sutures on the cranium are most frequently used (Brooks and Suchey, 1990; Buckberry and Chamberlain, 2002; Mann et al., 1991; Meindl and Lovejoy, 1985). However, also approaches analysing dentition, i.e., tooth root translucency (Lamendin et al., 1992), dental cementum annulations (Wittwer-Backofen et al., 2004) or dental wear (Brothwell, 1989; Lovejoy, 1985; Molnar, 1971), bone histology (Kerley, 1965; Kerley and Ubelaker, 1978) or by considering osteoarthrosis (Stewart, 1958) as a marker for advanced age are commonly used. Due to the vast amount of mechanisms affecting biological age, age at death estimations in adults, especially older adults are often inaccurate, hence, various authors encourage the use and combination of multiple aging methods, i.e., multifactorial approach (Byers, 2017; Garvin et al., 2012; Meindl et al., 1995; White et al., 2012). This research estimated adult age at death by assessing the degree of ectocranial suture closure (Meindl and Lovejoy, 1985), variation of the pubic symphysis (Brooks and Suchey, 1990; Todd, 1920), auricular surface and acetabulum (Buckberry and Chamberlain, 2002; Lovejoy et al., 1985; Rouge-Maillart et al., 2009) as well as dental wear (Brothwell, 1989). As the accuracy of suture obliteration as an age indicator has been challenged by several publications (Carazo, 2017; Dayal, 2009; Hershkovitz et al., 1997; Masset, 1989; Todd and Lyon, 1924) and dental wear has been shown to be significantly influenced by other factors, e.g., diet and food processing (Brothwell, 1981; Molnar, 1971; Roberts and Manchester, 2010), more weight was given to age estimations from the pubic symphysis, auricular surface and acetabulum. In contexts where no other age indicator was available, the data for suture closure and/or dental wear was utilised. Tooth root translucency, dental cementum annulations and bone histology were not used to estimate age in the present study, mainly due to a lack of access to facilities allowing the performance of such analyses as well time constraints of the project. The presence of osteoarthrosis was considered when performing an age estimate utilising the above-mentioned approaches, yet it was not employed as a primary age estimator.

As accurate age estimation is one of the most encountered issues in both forensic and archaeological anthropology, the present final age estimation approach followed the publication by Byers (2017), which proposed the use of a “Range Charts”. For or each of the used methods, age ranges were plotted against each other on a Gantt chart and those ranges overlapping the most were utilised as final age estimate, i.e., lowest range yielded the oldest age, and the highest range supplied the lowest age. As illustrated in Fig. 5, for most aging methods, i.e., pubic symphysis (highest weight), auricular surface and cranial sutures, the highest overlap was found between age 30 and 40 years. Hence, the estimated age range of SK76 was 30-40 years. Mean age and standard deviation were only calculated for each method, but not for the final age estimate of each individual (see Appendix 8).

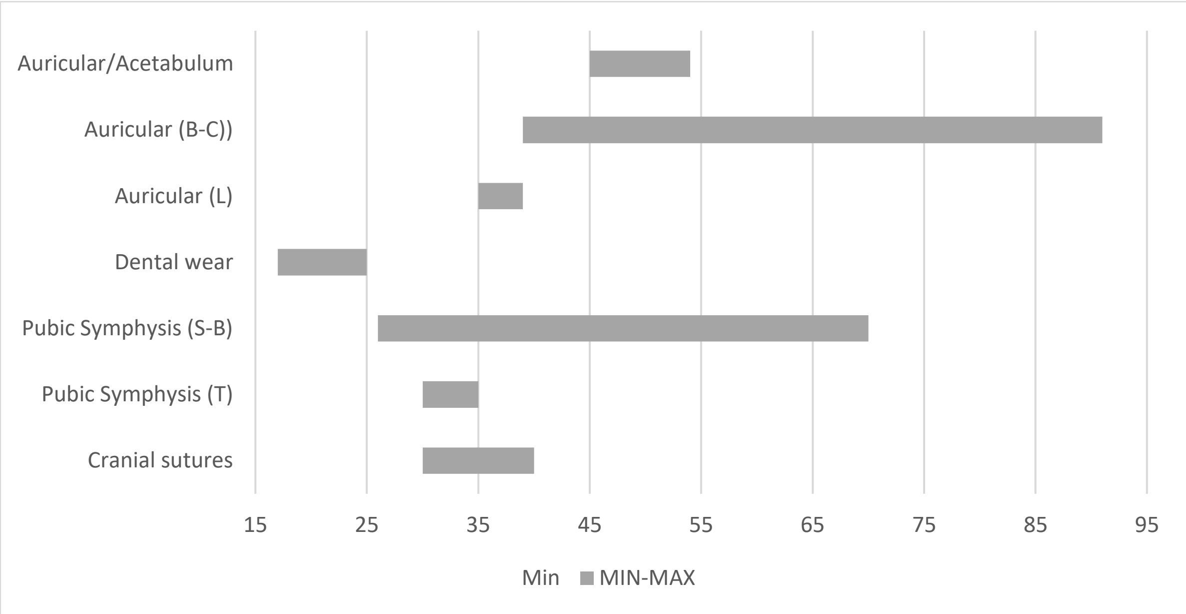

Figure 5. Multifactorial age estimation of SK76, with an estimated age range of 30-40 years.

To facilitate statistical analysis and data display all individuals were grouped into the following age categories: Perinatal (before birth- up until birth), infans I (0-6 years), infans II (7-12 years), juvenile (13-19 years), adult (20-40 years), mature (41-60 years), senile (60+ years) and non-determinable adult (>20, adult-ND) (Herrmann et al., 1990).

5.2.2.3. Palaeodemographic methods

Palaeodemographic information, such as population composition, death probability, life expectancy at a certain age, average population size and infant underrepresentation can be obtained through the calculations of indices (e.g., masculinity index) and mortality/life tables (Acsádi and Nemeskéri, 1970). The masculinity index (MI) was calculated by using the following formula:

$$MI = \frac{males\ (N)}{females\ (N)} 100$$

To construct mortality tables, age ranges instead of individual years were employed to decrease the age estimation error margin, especially for adults (Grupe et al., 2005). All individuals that could be aged were grouped into age groups (x) of five-year intervals, i.e., 0-4, 5-9, 10-14, 15-19, and seven-year intervals, i.e., 20-26, 27-34, 35-41, 42-49, 50-57 and 58∞ (a). Adult age groups comprised 20 years, and with the assumption of equal distribution within these groups, 7-year intervals were chosen. Mortality tables were calculated based on the values and formulas outlined in Table 4.

Character	Explanation and formula
D_x	The number of individuals in x.
d_x	Relative number of individuals in x. $$\frac{Dx}{\sum Dx}100$$
l_x	Relative number of survivors in x. $$lx = (lx - 1) - (dx - 1)$$
q_x	Probability of dying in x. $$qx = \frac{dx}{lx}$$
L_x	Average years per person lived within a given age interval. $$Lx = \frac{a(lx + lx_{+1})}{2}$$
T_x	Sum of average years lived within the current and remaining age intervals. $$Tx = Tx_{-1} - Lx_{-1}$$ Whereby $Tx_{=0} = \sum Lx$
e_x	Average years of life remaining (average life expectancy). $$ex = \frac{Tx}{lx}$$

Table 4. Definition of characters and formulas used to calculate mortality tables based on Acsádi and Nemeskéri (1970).

If the estimated age range overlapped more than one category (e.g., 20-40 years or >20) the individuals were expressed as percentages that were evenly distributed to the adjacent age groups. Following the recommendation by Grupe et al. (2015), mortality tables were calculated for the whole population as well as for both sexes separately. In the presumption that the studied population is stationary, the reliability of the estimated data was assessed through the mortality rate (Q_x) model by Weiss and Wobst (1973) using the formula outlined below.

$$Q_x = \frac{l_{x+1}}{l_x}$$

According to Weiss and Wobst (1973), skeletal populations can only be used as a representation of a living population if they meet the following equation criteria: $Q_{10}<Q_{15}$ and $Q_0>Q_{15}$. Because, in a natural population, the lowest mortality rates are commonly observed in juveniles and higher rates are generally associated with infants (Hug et al., 2018; Weiss and Wobst, 1973).

In relation to the representation of the analysed population, some important key aspects need to be considered, i.e., sample size and composition. As mentioned in previous sections, this study incorporates only 185 burials excavated within and around the church in the vineyard and the analysed cemeterial population may consist of individuals from different cohorts, thus, it represents merely a sample of the living population. Based on this knowledge, the size of the living population (P) of this sample over a given period of time, i.e., occupation of the site (t) was assessed by applying the equation proposed by Acsádi and Nemeskéri (1970), with 1.1 being a correction factor, assuming that approximately 10% of the living population were interred elsewhere:

$$P = 1.1 \frac{D\, e_0^0}{t}$$

5.2.2.4. Non-metric traits and anthropometry

In skeletal remains, human variation, the degree of sexual dimorphism, stature, body composition and sometimes even activity can be assessed and reconstructed by focusing on non-metric traits and osteometry (Coppa et al., 2008; Cox and Mays, 2000; Hauser and De Stefano, 1989; Jasch et al., 2018; Ruff, 2002).

Non-metric traits or anatomical variants (especially those on the cranium and dentition) are often used for ancestry estimation in human identification (i.e., forensic anthropology), kinship analysis and as markers for occupational activities (Algee-Hewitt et al., 2020; Capasso et al., 1999; Finnegan, 1978; Hauser and De Stefano, 1989; Mann et al., 2016; Rhine, 1990). As part of the osteological assessment, the presence and quantity of a selection of cranial and postcranial non-metric traits as outlined in Table 5 and Table 6 were recorded. The non-metric traits listed in Table 5 were used to assess osteological kinship, which can be used in the selection of samples for molecular kinship analysis, and those in Table 6 are frequently associated with activity (Bradshaw et al., 2020; Finnegan, 1978; Hauser and De Stefano, 1989; Lozanoff et al., 1985).

Bone	Non-metric trait
Cranium	Metopic suture
	Bregmatic ossicle
	Coronal ossicle
	Sagittal ossicle
	Squama parietal ossicle
	Parietal notch bone
	Parietal foramen
	Lambdoid ossicles
	Inca bone
	Apical bone
	Maxillary torus

Table 5 List of selected cranial non-metric traits that are commonly used to assess kinship.

Bone	Non-metric trait
Mandible	Double condyloid facets
Scapula	Bipartite acromion
Humerus	Septal aperture
Os coxae	Pre-auricular sulcus
Femur	Riding facet
	Third trochanter
Tibia	Lateral squatting facets
	Medial squatting facets

Table 6 List of selected postcranial non-metric traits that are commonly used as activity markers.

As opposed to non-metric traits, which provide more information on skeletal anomalies that are then used to infer relatedness between individuals, metric analyses enable the detection of changes in body size and shape not only among different individuals, but also a whole population. Based on the osteometric landmarks outlined by Martin (1928) and Buikstra and Ubelaker (1994), the cranial and postcranial measurements shown in Table 7 were taken following the approaches by Martin and Saller (1957) and Murail et al. (2005). Only those marked with an asterisk, were used in further analyses, i.e., to calculate indices and stature (see also Appendix 9).

Bone	Measurement
Cranium	M1- Maximum cranial length (g-op)
	M5- Cranial base length (n-ba)
	M8- Maximum cranial breadth (eu-eu)
	M9- Minimum forehead breadth (ft-ft)
	M10- Maximum forehead breadth (co-co)
	M12- Biasteric diameter (ast-ast)
	M17- Basion-Bregma height (ba-br)
	M20- Auricular height (po-br)
	M23- Horizontal circumference (g-op)
	M24- Transverse arc (po-b-po)
	M25- Mediosagittal arc (n-op-o)
	M45- Bizygomatic diameter (zyg-zyg)
	M47- Facial height (n-gn)
	M51- Orbital breadth (mf-ect)
	M52- Orbital height
	M54- Nasal breadth (al-al)
	M55- Nasal height (n-ns)
Mandible	M65- Bicondylar breadth (cdl-cdl)
	M66- Bigonial breadth (go-go)
Humerus	Hu1- Maximum length*
	Hu4- Epicondylar breadth*
	Hu5- Maximum diameter at midshaft
	Hu6- Minimum diameter at midshaft
	Hu7- Minimum circumference*
	Hu9- Transversal diameter of the head
	Hu10- Sagittal/vertical diameter of the head
Radius	Ra1- Maximum length
	Ra2- Physiologcial length
Ulna	Ul1- Maximum length
	Ul3- Minimum circumference
Os coxae	PUM- Acetabulo-symphyseal pubic length*
	SPU- Cotylo-Pubic width*
	DCOX- Coxal height *

Os coxae	IIMT- Sciatic height*
	ISMM- Post-acetabular ischium length*
	SCOX- Coaxal breadth *
	SS- Spino-Sciatic length*
	SA- Spino-Auricular length*
	SIS- Cotylo-Sciatic diameter*
	VEAC- Vertical acetabular diameter*
	HOAC- Horizontal acetabular diameter*
Femur	Fe1- Maximum length*
	Fe2- Bicondylar length
	Fe6- Sagittal diameter*
	Fe7- Transverse diameter*
	Fe8- Midshaft circumference
	Fe9- Superior transverse diameter
	Fe10- Superior sagittal diameter
	Fe18- Vertical diameter of the head*
	Fe21- Epicondylar breadth
	Transverse diameter fovea capitis
	Sagittal diameter fovea capitis
Tibia	Ti1b- Maximum length*
	Ti2- Bicondylar length
	Ti3- Maximum proximal epiphyseal breadth
	Ti8a- Sagittal diameter at the nutrient foramen*
	Ti9a- Transverse diameter at the nutrient foramen*
	Ti10b- Minimum circumference*

Table 7 List of selected cranial and postcranial measurements.

Even though a variety of cranial measurements were taken, cranial indices were not calculated for the present study as the whole sample derived from European descent and was associated with the same spatiotemporal context.

Some of the collected postcranial osteometric data were used to estimate stature. To accurately estimate body height several methods have been developed by different authors (Bach, 1965; Breitinger, 1937; Dwight, 1894; Jacobs, 1992; Olivier et al., 1978; Trotter and Gleser, 1958, 1952). Despite the differences in elements utilised, formulas applied, and the way measurements were taken, the lower limbs, particularly the femur followed by the tibia, appear to produce the most reliable stature estimate (Trotter and Gleser, 1958), as they contribute to body height in contrast to the upper limbs. For the present study, osteometric data from the humerus, ulna, radius, femur, and tibia were collected, yet as more reliable results are generated from femur, femoral osteometric data was used to estimate body height for most individuals (55/226). Twelve individuals (SK62, SK63, SK65I, SK100, SK133A, SK151A, SK173, SK174, SK184, SK211A, SK222, SK233) lacked a femoral data; thus, the tibial measurements were utilised. For ten individuals (SK51, SK94, SK99, SK103A, SK118, SK164, SK179, SK187, SK213A, SK230) both the femur and tibia were unavailable, thus the humerus was used to estimate stature. For those individuals that lacked femoral, tibial, and humeral osteometric data, measurements of the radius (SK48, SK79, SK121A, SK208) or ulna (SK39, SK61, SK65II) were used. Only sexed adults were used for stature estimation, which was calculated by following the recommendations by Siegmund (2010), who proposed that for European samples, a more accurate stature estimation could be obtained by taking the mean stature estimate from the methods of Pearson (1899) and Trotter and Gleser "American White" and "American Negro" (1952, 1977). This could only be performed on those individuals featuring osteometric data of the femur, tibia, or humerus (Table 8, for a full list of the formulas used to estimate stature from all available long bones see Appendix 9).

Reference	Bone	Formula (measurements in mm)
(Pearson, 1899)	Humerus	$Males = Hu1 * 2.894 + 706.41$ Females= $Hu1 * 2.754 + 714.75$
	Femur	$Males = Fe1 * 1.880 + 813.06$ Females= Fe$1 * 1.945 + 728.44$
	Tibia	$Males = Ti1b * 2.376 + 786.64$ Females= $Ti1b * 2.352 + 747.74$
(Trotter and Gleser, 1952)- "American Negro"	Humerus	$Males = Hu1 * 3.26 + 621.0$ Females= $Hu1 * 3.08 + 646.7$
	Femur	$Males = Fe1 * 2.11 + 703.5$ Females= $Fe1 * 2.28 + 597.6$
	Tibia	$Males = Ti1b * 2.19 + 860.2$ Females= $Ti1b * 2.45 + 726.5$
(Trotter and Gleser, 1977, 1952)- "American White"	Humerus	$Males = Hu1 * 3.08 + 704.5$ Females= $Hu1 * 3.36 + 579.7$
	Femur	$Males = Fe1 * 2.38 + 614.1$ Females= $Fe1 * 2.47 + 541.0$
	Tibia	$Males = Ti1b * 2.52 + 786.2$ Females= $Ti1b * 2.90 + 615.3$

Table 8 The main formulas used to estimate body height following Siegmund (2010).

Aside from stature, osteometric data can also provide additional information about body weight and form. Even though the methodology to calculate BMI and body weight have been established within the last two centuries and most anthropological analyses incorporate the osteometric data used to calculate these, both are rarely estimated from archaeological skeletal remains (Jasch et al., 2018; Pomeroy et al., 2018; Siegmund and Papageorgopoulou, 2011; Yorke-Edwards, 2019). The same applies for the osseous frame index (OFI), established more recently, and is based on the frame index (FI), which is commonly used in modern populations to gain information about skeletal robustness (Jasch et al., 2018; Mumm et al., 2021; Navazo et al., 2020). Thus, a substantial amount of analogous data from modern populations is available for further analyses and comparisons (Mumm et al., 2021; Navazo et al., 2020; Scheffler, 2011). The OFI, bodyweight and body mass index (BMI) were estimated using the equations outlined in Table 9. As only the vertical diameter of the femoral head was ascertained and the values for both transverse and vertical femoral head diameters should be fairly similar in healthy individuals, this slight change in methodology is valid (Buikstra and Ubelaker, 1994).

Type of calculation	Equation	Reference
Osseous frame index (OFI)	$\frac{Hu4\ in\ mm}{bodyheight\ (Pearson\ 1899)}\ 100$	(Jasch et al., 2018)
Body weight	$Females = [(2.426 * Fe18\ (in\ mm)) - 35.1] * 0.9$ $Males = [(2.741 * Fe18\ (in\ mm)) - 54.9] * 0.9$	(Ruff et al., 1991
Body mass index (BMI)	$\frac{(body\ weight\ in\ kg)^2}{(bodyheight\ in\ m)}$	(Quetelet, 1871)

Table 9 Formulas used to estimate body weight and osseous frame and body mass indices.

In addition to the OFI and to gain more information about body form and skeletal robusticity of the sample the collected postcranial osteometric data were also used to calculate a variety of indices. For the humerus the length-breadth index was estimated, for the femur the robusticity and platymeric index was calculated and for the tibia the length-breadth and platycnemic index was estimated (Table 10).

Bone	Name of index	Equation
Humerus	Length-breadth (robusticity)	$\frac{Hu7}{Hu1}100$
Femur	Robusticity	$\frac{Fe6 + Fe7}{Fe1}100$
	Platymeric	$\frac{Fe10}{Fe9}100$
Tibia	Length-breadth (robusticity)	$\frac{Ti10b}{Ti1b}100$
	Platycnemic	$\frac{Ti9a}{Ti8a}100$

Table 10 List of selected long bone indices calculations (Martin and Saller, 1957).

5.2.3. Palaeopathological profile

To gain better insights into the quality of life in early mediaeval Säben-Sabiona, the presence, location, quantity and severity of several pathological conditions and traumata was investigated using standard collection procedures and specialised studies offering differential diagnoses of osseous lesions. Any macroscopically observable skeletal alteration was recorded and described in detail, whereby for most lesions a differential diagnosis allowed a categorisation into the major disease groups. These included dental pathologies/diseases associated with the masticatory apparatus such as abscesses, antemortem tooth loss, calculus, caries, linear enamel hypoplasia and periodontitis as well as disorders affecting single skeletal elements or the whole organism. Data collection of dental pathologies mainly focused on establishing the presence/absence of a condition and general information on the location and severity of a disease.

5.2.3.1. Dental features

Dental status was recorded by using a simple scoring system, providing information about the condition of the alveolus, i.e., presence/absence of a tooth or not recordable, if the skeletal element was not available for analysis, whether the tooth was lost antemortem or postmortem, and the condition of the tooth, i.e., tooth in situ, isolated tooth/root, broken root within alveolus, tooth enclosed within alveolus, or tooth agenesis (see Appendix 10). As a highly detailed study on dental abnormalities would have exceeded the capacity of the present work, the applied methodology was aimed to provide an overall picture of dental health. Table 11 outlines the methods used to record dental health, although for dental calculus, wear, periodontitis, and periapical lesions the severity grading approaches were changed slightly by scoring teeth in groups, i.e., incisors and canine together, and premolars and molars together, rather than individually. This approach was chosen following a supervisor consultation.

Evaluation	Method/Scoring approach
Dental calculus	Brothwell (1981)
Dental caries	The prevalence, severity (1- superficial caries, 2-lesion reaches dentin, 3-perforating lesion, 4-complete destruction), number of lesions and caries location (Crown, cemento enamel junction (CEJ) or root and occlusal, buccal/labial, lingual or interproximal) were registered.
Dental wear	Molnar (1971)
Periodontitis	The registration of periodontitis followed the same principles as outlined by Kerr (1991), although it was highly simplified to three levels: 0- no resorption, 1-low resorption (3-4mm) or 2- high resorption (>4mm).
Periapical lesions	Presence or absence of periapical lesions was recorded on an alveolar level. Lesion severity was scored following a 3-scale system: 0- no modification, 1- apical true cyst, 2- apical pocket cyst.
Linear enamel hypoplasia	Reid and Dean (2000)
Antemortem tooth loss	Antemortem tooth loss was recorded as present or absent.

Table 11 Outline and explanation of the employed dental disease recording methods.

5.2.3.2. Skeletal features

Skeletal alterations comprised congenital conditions, bone infections, joint degeneration on the appendicular and spinal skeleton, metabolic and/or developmental disorders, neoplastic alterations, and trauma. An attempt was made to identify and diagnose all macroscopically discernible skeletal alterations following the recommendations of current palaeopathological literature (e.g., Aufderheide and Rodríguez-Martín, 1998; Barnes, 2012, 1994; Brickley and Ives, 2008; Mann and Hunt, 2012; Ortner, 2003; Pinhasi and Mays, 2008; Rogers and Waldron, 1995; Waldron, 2009).

5.2.3.2.1. Joint and entheseal alterations

To obtain more information on osteological characteristics of early mediaeval lifestyles in alpine environments and potentially also physical activity, both the presence and severity of osteoarthrosis (OA), spondyloarthrosis, Schmorl's nodes and entheseal changes (EC) were recorded and analysed for all individuals over 13 years of age. Furthermore, also the presence of any other observable joint alteration was registered.

As recommended by Rogers and Waldron (1995) and Waldron (2009), eburnation or a combination of new bone formation or pitting on the joint, marginal osteophytes or contour changes of the joint were regarded as pathognomonic features of the OA. The presence and severity of osteoarthrosis was recorded mainly following the procedures outlined in the Global History of Health Project (GHHP) (Steckel *et al.* 2006), by scoring joint surfaces as absent (0), slight (1), moderate (2), severe (3) or joint fusion (4, Table 12). From the appendicular skeleton only synovial joints (i.e., shoulder, elbow, wrist, hip, knee, and ankle) and from the spine, both synovial (articular facets) and cartilaginous joints (vertebral body) were considered. Vertebrae were scored as a group based on their location within the spine, i.e., cervical, thoracic, lumbar and sacrum (S1). This scoring approach was utilised as most European samples have been assessed using the data collection codebook of the Global History of Health Project (GHHP) as shown in the "The Backbone of Europe" publication (Steckel et al., 2006, 2018). Thus, this makes the present data standardised and improves its' comparability to other European sites of similar spatiotemporal contexts.

Scoring	**Associated joint surface/margin alteration**
None (0)	Without OA/osteophytes.
Slight (1)	Slight marginal lipping (<3mm) and pitting of 10%.
Moderate (2)	Moderate marginal lipping (>3mm) and pitting of 10-15% of the joint.
Severe (3)	Considerable marginal lipping and pitting of more than 80% of the joint and/or eburnation.
Ankylosis (4)	Bony bridge between two adjacent joints.

Table 12 The scoring criteria for cartilaginous and synovial joints, adapted from Steckel et al. (2006)

Schmorl's nodes were identified following the guidelines by Rogers and Waldron (1995). They were recorded both qualitatively (present/absent) and quantitatively. The scores were given on a vertebral group level, i.e., cervical, thoracic, lumbar, and sacrum, rather than on individual vertebrae or elements affected.

Osteochondritis dissecans was recorded as present/absence with a detailed description of lesion location and quantity of bone involvement. The identification of osteochondritis dissecans was based on the descriptions and illustrations by Baxarias and Herrerin, (2008) and Ortner (2003).

Rare degenerative joint disorders were described in detail, including location and quantity of elements involved following Barnes (2012), Ortner (2003), Roberts and Manchester (2010) and Rogers and Waldron (1995).

Entheseal changes are defined as any abnormal alteration on a muscular insertion site, which includes marginal irregularities, calcification/ossification of soft tissue, surface vascularisation and cavitation (Schrader, 2019; Villotte, 2006; Villotte and Knüsel, 2013). The appearance of the entheses presented in Table 13 were described based on the approach by Villotte (2006) and Villotte *et al.*, (2010).

Analysed Enthesis	**Type of enthesis**	**Location**	**Group**
Lig. costoclavicularis	Fibrocartilaginous	Clavicle	Shoulder
M. deltoideus	Fibrocartilaginous	Clavicle	
M. subscapularis	Fibrocartilaginous	Humerus	
Mm. supra/infraspinatus	Fibrocartilaginous	Humerus	
M. pectoralis major	Fibrous	Humerus	
M. deltoideus	Fibrous	Humerus	
Mm. epicondylus medialis (M. pronator teres, M. palmaris longus, M. flexor carpi ulnaris)	Fibrocartilaginous	Humerus	Wrist
Mm. epicondylus lateralis (M. supinator, M. extensor carpi radialis brevis, M. extensor carpi radialis longus)	Fibrocartilaginous	Humerus	
M. pronator teres	Fibrous	Radius	Elbow
M. biceps brachii	Fibrocartilaginous	Radius	
M. triceps brachii	Fibrocartilaginous	Ulna	
M. gluteus minimus	Fibrocartilaginous	Femur	Hip
M. gluteus medius	Fibrocartilaginous	Femur	
M. gluteus maximus	Fibrous	Femur	
M. Vastus medialis, adductor magnus, and longus (linea aspera)	Fibrous	Femur	
M. iliopsoas	Fibrocartilaginous	Femur	
Mm. semimembranosus, semitendinosus, biceps femoris	Fibrocartilaginous	Os coxae	Knee
Mm. quadriceps femoris	Fibrocartilaginous	Patella	
M. soleus	Fibrous	Tibia	Ankle
M. triceps surae	Fibrocartilaginous	Calcaneus	

Table 13 Listing the entheses examined, including their localisation and type.

Even though the *Lig. costoclavicularis* is not addressed in the publications by Villotte (2006) and Villotte et al. (2010) the scoring followed their descriptions for fibrocartilaginous joints. For fibrocartilaginous entheses both the outer (contour) and inner part a three-point scale was applied, ranging from no or slight alteration (0), through moderate (1) to severe involvement (2). By adding these scores up an overall score for the whole enthesis was generated (A=0, B=1-2, C=3-4). The same three-point scale was used for fibrous entheses, although the whole enthesis was scored rather than the inner and outer part of it. To facilitate the utilisation of the overall enthesis score in statistical analysis and display the levels A, B and C were converted to A=1, B=2, C=3. Entheses were analysed individually and based on the location of the insertion site, they were grouped into the same categories for the appendicular skeleton as were used for OA (Table 12).

5.2.3.2.2. Metabolic and infectious disease

Cribra orbitalia, cranii and palatinii were scored following the data collection codebook by Steckel et al. (2006). Even though the severity of *cribra orbitalia, cranii* and *palatinii* were recorded, more detailed analysis on the severity levels of these were not performed as this would have exceeded the scope of the present study. *Cribra humeralis* and *femoralis* were solely scored as present and absent.

The presence of scurvy was solely documented if a combination of bilateral porotic lesions on the skull, axial and appendicular skeleton were observable (Brickley and Ives, 2008; Buikstra, 2019; Ortner, 2003; Snoddy et al., 2018). Diagnostic lesions on the skull included: ectocranial surface of the parietal and/or squamous temporal bones, orbital roofs (*cribra orbitalia*), greater wings and/or pterygoid fossae of the sphenoid bone, anterior surface (region near infraorbital foramen and/or alveolar margins) and/or inferior surface (hard palate) of the maxilla, anterior and posterior surface of zygomatic bones, medial coronoid process, and ramus of the mandible (Brickley and Ives, 2008; Buikstra, 2019; Ortner, 2003; Snoddy et al., 2018). For the axial and appendicular skeleton, general porotic lesions or subperiosteal new bone formation in combination with the above-mentioned alterations on the skull were regarded as diagnostic (Brickley and Ives, 2008; Buikstra, 2019; Ortner, 2003; Snoddy et al., 2018). Porosities in the supra and/or infraspinatus fossae of the scapulae were regarded as diagnostic for scurvy and on new bone formation the diaphyses of long bones were only diagnostic in association with cranial and/or mandibular lesions (Brickley and Ives, 2008; Buikstra, 2019; Ortner, 2003; Snoddy et al., 2018). A positive identification of rickets/osteomalacia was yielded when porotic lesions on cranial, mandibular, and long bone elements were present in conjunction with the typical curvature of long bones. The assessment of both scurvy and rickets/osteomalacia followed the differential diagnosis guidelines of Ortner (2003) Brickley and Ives (2008), Snoddy et al. (2018) and based on these, they were scored as present, possibly present or absent.

Periostitis was recorded quantitatively and qualitatively by following the method outlined in Table 14, which was adapted from Steckel et al. (2006). Osteomyelitis was registered through a detailed description of lesion location and quantity of elements involved following Ortner (2003) and Roberts and Manchester (2010)

Scoring	**Associated periosteal alteration**
None (0)	No osteoperiostitis present.
Slight (1)	Markedly accentuated longitudinal striations and/or foramina.
Moderate (2)	Slight, discrete patch(es) of reactive bone involving less than one quarter of the long bone surface.
Severe (3)	Moderate involvement of the periosteum, but less than one-half of the long bone surface (larger plaque of new bone).
Deformation (4)	Extensive periosteal reaction involving over half of the diaphysis, with cortical expansion, pronounced deformation.

Table 14 The scoring criteria for periostitis, adapted from Steckel et al. (2006).

5.2.3.2.3. Trauma

To increase the accuracy of trauma prevalence estimations (Lovell, 2008; Šlaus *et al.*, 2012; Boucherie, Jørkov and Smith, 2017), all identifiable osteological elements that were available for analysis, whether complete or fragmented, were assessed for injuries (n=8044). Trauma analysis consisted of the identification of the lesion, whether an alteration was observable, and a detailed description of the exact trauma location, timing and type of the defect (Byers, 2017; Murphy et al., 2010; Passalacqua and Rainwater, 2015; Sauer, 1998; Wheatley, 2008). Trauma timing was established through differentiating among lesions that showed signs of healing (antemortem), those that did not show signs of healing but displayed typical fresh bone responses (perimortem) and injuries with no signs of healing and dry bone characteristics (postmortem) (Byers, 2017; Kimmerle and Baraybar, 2008). Only antemortem and perimortem injuries were recorded. Trauma type was also assessed, by subdividing lesion into fractures (FX), sharp force trauma (SFT) and cranial blunt force trauma (BFT, Kimmerle and Baraybar, 2008; Passalacqua and Rainwater, 2015; Byers, 2017). A more focused description of the methods used in trauma timing and type assessment at Säben-Sabiona was already addressed by Tumler et al. (2021) and thus, the present study will not discuss the same content in greater detail. For all trauma investigations, both true, lesions per bone, and crude, trauma per individual, prevalence data were collected to gain more detailed information on overall frequency patterns and actual lesion distribution within the injured.

5.2.3.2.4. Congenital and neoplastic conditions

Congenital alterations, e.g., spina bifida, sacralisation, surplus skeletal elements, etc., were recorded as present or absent, with a detailed description of lesion location and quantity of elements involved by considering the recommendations of Barnes (1994).

Neoplasms were documented as present/absent and their quantity, where appropriate. A differentiation between benign and malignant tumours was carried out for each of the observed neoplastic alterations. Benign and malignant tumours were differentiated based on distribution (solitary versus multifocal), location, quantity, size and character of margins (Ortner, 2003; Pinhasi and Mays, 2008; Ragsdale et al., 2018; Roberts and Manchester, 2010). As benign tumours are known to be solitary/localised, slow growing and commonly of modest size, thus, typically feature well-defined and sharp rounded margins, these criteria were utilised to identify benign neoplasms. For malignant tumours, lesions that feature more diffused patterns, i.e., are multifocal and occur in greater numbers, and are erosive and destructive, were classed as malignant. Where possible a more detailed differential diagnosis was made to establish the type of benign/malignant neoplasm following Ortner (2003) and Aufderheide and Rodríguez-Martín (1998).

5.2.4. Statistical methods

Digital data collection was performed on Microsoft Excel sheets, through which also basic statistical variables (e.g., mean, standard deviation, minimum, maximum) were calculated. Prevalence rates were either calculated on an individual (crude prevalence) or elemental (true prevalence) basis by dividing the number of affected individuals/bones (n) by the total number of examined individuals/bones (N) and multiplying it by 100.

More elaborate statistical testing was performed by using JASP 0.11.1.0 software package. To test whether the frequency of males and females equals a balanced sex ratio a binomial test was performed. A chi square test (X^2) was applied to test differences in distribution between two variables, e.g., whether there was a difference between bone preservation and sex, age group and/or burial location (i.e., inside, and outside), the prevalence of disease and/or the coexistence of two pathological lesions, etc. T-tests (*t*) were performed to investigate whether the means of two datasets were equal, e.g., life expectancy between elite and non-elite individuals, etc. To assess the relationship between the prevalence of disorders, e.g., osteoarthrosis, that have been shown to be dependent on other factors, e.g., age, sex, etc., logistic regression analyses and Spearman's rank correlation tests were performed. For adults, only individuals with a sex and age at death estimate were used for such analyses and for subadults, an age at death estimate was a requirement to qualify for statistical testing. When assessing OA and EC, the overall severity of the alteration on an individual basis was calculated from the mean score of all observable joints or entheses. To test the relationship between OA and EC, the sample was reduced to individuals displaying both joint and entheseal alterations. As the employed scoring systems produced categorical data on an ordinal scale, the relationship between the variables was examined through nonparametric Spearman's rank correlation tests based on the mean. The null hypothesis (H_0) was rejected at the level of $p<0.05$.

6. Results

The anthropological analysis was performed on 185 out of 197 excavated graves featuring an MNI of 226. Most graves contained a single individual and two or more individuals per grave were common in areas featuring multiple graves that sometimes disturbed each other, and inside the crypts where commingling was frequently seen.

6.1. Taphonomic profile and burial practices

Bone preservation was found to vary across the whole sample (Figure 6). In terms of bone quality, most individuals displayed good preservation (44.2%), followed by very good (29.2%) and low preservation (26.5%, Appendix 11). Burial location, i.e., inside, or outside burials (X^2=2.838, df=2, p=0.243), or the presence of grave goods (X^2=2.345, df=2, p=0.31) did not appear to affect qualitative bone preservation (see Appendix 12).

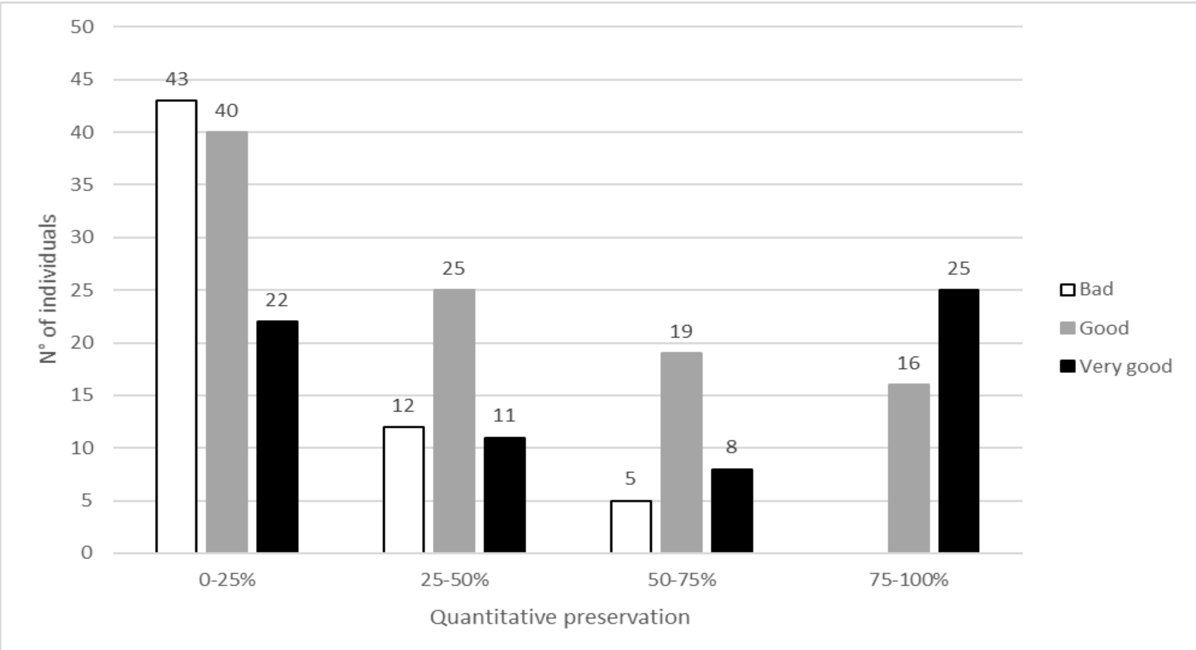

Figure 6 Qualitative and quantitative bone preservation at Säben-Sabiona.

Seventeen bones exhibited signs of animal activity, most of which was identified as rodent gnawing. Alterations associated with metal objects were observed on 52 bones (see Appendix 4).

Almost half of assessed individuals were represented by ≤25% of their skeleton (46.5%). For the remaining individuals, quantitative bone preservation gradually decreased with declining qualitative preservation (Figure 6). Similar as for qualitative bone preservation, being buried inside or outside of the church (X^2=1.182, df=3, p=0.757) and the presence of grave goods (X^2=3.901, df=3, p=0.272) did not seem to increase bone degradation (see Appendix 12).

More detailed information on taphonomic alterations and the preservation of each individual can be found in Appendix 4.

To investigate funerary practices of the buried the analysis relied heavily on the data published in the grave catalogue by Bierbrauer and Nothdurfter (2015). A summary of the available funerary information can be found in Appendix 2. Based on this information, an assessment for burial location and practices, such as body position, orientation, arm positioning, burial type and the presence of grave goods was attempted for all 226 individuals, i.e., 185 burials. Yet, as some remains were disturbed body and arm positioning, orientation and burial type could not be established for all remains. More than half of the buried were located inside the church (n=126), whereby outside interments seem to have been only slightly less common (n=100). All assessable individuals were buried in supine position (n=98) with their legs extended and their arms either extended (n=7) or flexed (n=52) above the pelvis or chest. Most individuals were buried in west-east orientation, i.e., head to the west and feet to the east (n=78), with the remainder displaying varying burial orientations (see Appendix 2 for more detailed information). Burials in earthen or stone lined pits were most common (n=51), yet quite a few individuals featured more elaborate burial chambers or crypts (n=36). Utilising this information, the Säben-Sabiona burials were analysed further and subdivided following the categorisation of grave goods by Sayer (2013a) into poor, average wealth, wealthy and exceptionally wealthy. Based on this approach, most internments at Säben-Sabiona could be classified as poor graves (n=210 individuals), yet the burials of 16 individuals can be regarded as wealthy (n=1 individual), average wealth (n=2 individual) and exceptionally wealthy graves (n=13 individuals). Eleven of the individuals with exceptionally wealthy graves were buried inside the church and those that were buried outside were located in crypt E.
As already mentioned in the materials chapter, all individuals buried within the church, in crypts outside the church and those featuring rich grave goods were classed as rich/elite individuals (n=133) and the remaining inhumations as poor/non-elite (n=93). The following sections will provide general data on the whole population and for more detailed analyses and comparisons, elite and non-elite individuals were assessed separately.

6.2. Biological profile

6.2.1. Palaeodemography

6.2.1.1. Sex and age estimation

Sex estimation was performed on 133 of the 160 adult and 18 juvenile individuals of which 94 exhibit male and 39 had female characteristics (Figure 7). For 39 adult and six juvenile skeletons sex assessment was not possible (Appendix 7 and 11).

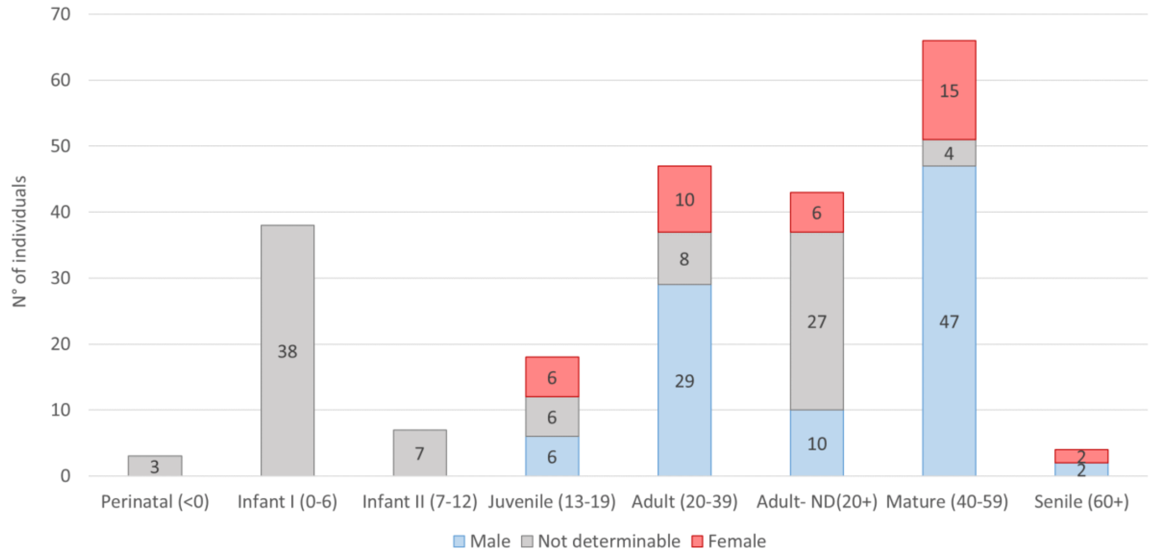

Figure 7 Sex and age at death estimation of the whole cemeterial population.

Already the masculinity index (MI=241.0) showed a male surplus in the Säben-Sabiona cemetery and also the binomial test showed a statistically significant sex imbalance between male (70.7%, $p<0.001$) and female (29.3%, $p<0.001$) proportions. This adds to the assumption that the present cemeterial population does not represent a natural living population.

Differences in burial location between the sexes were relatively low ($X^2=0.061$, df=1, p=0.805). Both females and males were interred to almost identical proportions, inside (48.7% vs 51.1%) and outside of the church (51.3% vs 48.9%, Appendix 13). Females that were buried within the church were mostly situated in the southern (47.4%) or northern aisle (26.3%). Most male graves inside the church were located in the nave (35.4%), followed by the southern aisle (33.3%) and atrium (22.9%, Figure 8). The observed burial pattern within the church in relation to sex was not found to be statistically significant ($X^2=7.3$, df=3, p=0.063).

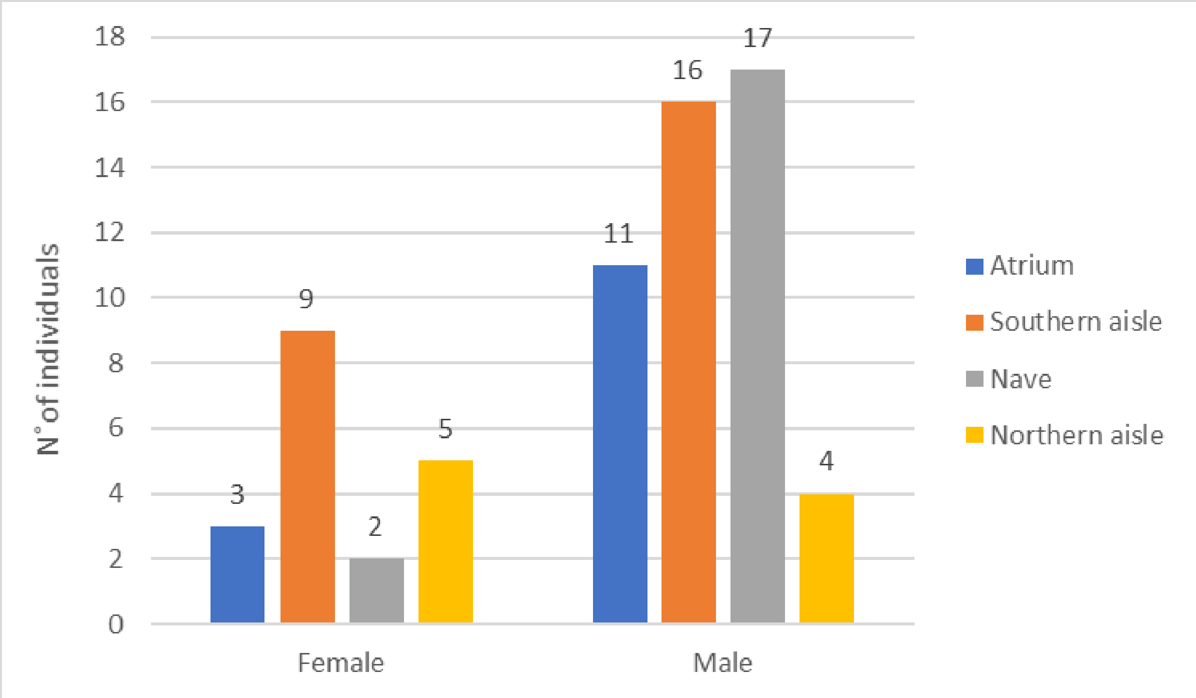

Figure 8 Burial location of females and males inside the church.

A similar variation in burial location was observed for outside graves (X^2=4.487, df=3, p=0.213), where 75% (n=15) of the outside-female-interments were located in the southern part as opposed to males, whose graves were more equally distributed between the southern (n=22, 47.8%) and western (n=18, 39.1%) parts of the church. Major sex differences in relation to the presence of grave goods were not found (X^2=0.092, df=1, p=0.762, Appendix 13).

In terms of age distribution, substantially more adults (70.8%) were buried at Säben-Sabiona than subadults (29.2%). Mortality was the highest in the 40-59 age group for adults of both sexes (41.3%) and between 0-6 years (57.6%) for subadults (Figure 7). Out of the studied females (n=39) and males (n=94), more females than males died as juveniles (15.4% females versus 6.4% males) or above 60 years of age (5.1% females versus 2.1% males), whereas higher male deaths were found in the adult (28.2% females versus 30.9% males) and mature age category (38.5% females versus 50% males).

From the data it appears that the chances of being buried within the church increased with advancing age, i.e., 33.3% (1 out of 3) perinatal, 71.1% (27 out of 38) infans I, 42.9% (3 out of 7) infans II, 44.4% (8 out of 18) juveniles, 48.9% (23 out of 47) adults, 54.5% (36 out of 66) mature and 75% (3 out of 4) senile individuals, whereas the opposite was true for outside burials, i.e., 66.7% (2 out of 3), 28.9% (11 out of 38) infans I, 57.1% (4 out of 7) infans II, 55.6% (10 out of 18) juveniles, 51.1% (24 out of 47) adults, 45.5% (30 out of 66) mature and 25% (1 out of 4) senile individuals. An exception to this, are infants aged 0-6 years, which were mostly buried inside (n=27, 71.1%) rather than outside (n=11, 28.9%) the church. Both adults (61.4%, 62 out of 101) and subadults (38.6%, 39 out of 101) were more commonly interred inside the church, yet the prevalence rates of subadult burials within (59.1%, 39 out of 66) versus outside the church (40.9%, 27 out of 66) are almost 20% higher than those of adults (53%, inside; 47%, outside). The age distribution in crypts was fairly similar to the overall pattern, consisting mostly of adult burials, i.e., 57.1% (20 out of 35), and slightly less subadult burials, i.e., 42.9% (15 out of 35). Even though there seems to be an age-related pattern in relation to burial location, the observed differences were not statistically significant (X^2=6.888, df=6, p=0.331). This further enforces the presumption of selective burial practices.

The examination of age distribution versus grave location within the church showed that the southern aisle was commonly used for all age groups (n=46, Appendix 13). Perinatal individuals (n=1, 100%) and infants between 7-12 years (n=3, 100%) buried within the church were solely situated in the southern aisle, which also featured most Infans I (n=15, 55.6%), adult (n=10, 43.5%) and mature (n=13, 36.1%) graves. Juveniles (n=4, 50%) were mostly buried in the atrium and individuals over 60 (n=2, 66.7%) were mainly identified in the nave.
A similar pattern was observable for outside burials, whereby individuals from all age classes were mostly buried in the southern (n=36, 43.9%) or western parts (n=28, 34.1%) of the church.

As individuals from most age groups (all except perinatal and Infans II) featured grave goods, age did not appear to have a significant influence on the presence of grave goods (X^2=12.697, df=7, p=0.08).

6.2.1.1.1. Elite and non-elite individuals

Based on the selection criteria outlined in previous sections, 133 individuals were classified as elite/rich and 93 as non-elite/poor (Table 15, Appendix 2).

The elite subsample was composed of 35 subadults and 98 adults and juveniles, out of which 51 were males, 22 were females and 60 could not be sexed.

Age classes in years (x)	**Number of individuals (Dx)**							
	Elite				**Non-elite**			
	Total	M	F	ND	**Total**	M	F	ND
Perinatal	1	-	-	1	2	-	-	2
Infant I (0-6)	27	-	-	27	11	-	-	11
Infant II (7-12)	3	-	-	3	4	-	-	4
Juvenile (13-19)	9	3	2	4	9	3	4	2
Adult (20-39)	25	15	7	3	22	14	3	5
Mature (40-59)	39	29	8	2	27	18	7	2
Senile (>60)	3	1	2	0	1	1	0	0
Adult-ND (>20)	26	3	3	20	17	7	3	7
Sum (D)	133	51	22	60	93	43	17	33
e^0_x	31.5	-	-	-	31.7	-	-	-

Table 15 Sex, age at death and life expectancy at birth (e^0_0) of the elite and non-elite subsample.

The masculinity index (M1=231.8) and sex ratio (70% vs 30%) of the elite subsample does not differ substantially from the values yielded when assessing the whole population. Most of the elite females died between 40-59 years of age (36.4%) or as adults (31.8%), whereby only 9.1% died between 13-19 or over 60 years, respectively. Elite males displayed a similar pattern, with most deaths between 40-59 years (56.9%) or 20-39 years (29.4%) and only a few died as juveniles (5.9%) or above 60 (2%). No statistically significant relationship was found for the observed elite age and sex distribution (X^2=4.561, df=4, p=0.35). For the subadult sample, the Infans I category exhibited considerably higher death rates (67.5%) than the perinatal (2.5%) or Infans II (7.5%) age groups.

The non-elite subsample was represented by 19 subadults, and 74 adults and juveniles (Table 15), whereby most of these were males (n=43) and only a few individuals were classified as females (n=17), not- determinable adults (n=17) or subadults (n=19).

Similar as for the elite sub-sample, also the non-elite group displayed a significant disproportion between the sexes, i.e., MI= 252.9 and sex ratio 72% to 28%. Non-elite females died mostly between 40-59 years (41.2%) or as juveniles (23.5%), whereby the adult age category featured the lowest number of individuals (17.6%). Non-elite males on the other hand displayed similar patterns as elite males, with most deaths associated with the mature age category (41.9%), followed by the adult (32.6%), juvenile (7%) and senile age category (2.3%). The recorded sex and age distribution for non-elite individuals was not found to be statistically significant (X^2=4.228, df=4, p=0.38). The composition of the non-elite subadult sample was quite similar to that of the elite group with 42.3% of individuals from 0-6 years, 15.4% of individuals from 7-12 years and 7.7% of individuals that died around the time of birth.

6.2.1.2. Palaeodemographic parameters

In consideration of the incompleteness of the skeletal sample, i.e., only 185 graves were studied anthropologically and most of the Säben-Sabiona hill is yet to be excavated, the population size based on the present anthropological data was calculated using the formula outlined in the materials and methods chapter. As a thorough archaeological investigation, which includes a full excavation of the whole Säben-Sabiona hill is still outstanding and archaeological sources only provide an estimate of the number of graves supposedly buried, the calculation of population size is justified. The present anthropological data represents most of the available osteological sample; thus, it provides preliminary insights into population density of the groups associated with this site of importance. Over a cemetery occupation timespan of 400 years (5^{th}-8^{th} centuries A.D.) producing an MNI of 226, the analysed individuals represent a sample of around 20 contemporaneously living inhabitants.

Mortality tables were initially calculated for the whole population (see Appendix 14) to establish whether the analysed skeletal collection is representative in relation to their age distribution. Based on the mortality rate equation by Weiss (1973), the present sample can be regarded as representative with Q_{10}=0.02<Q_{15}=0.07 and Q_0=0.14>Q_{15}=0.07. To assess whether elite and non-elite individuals had contrasting lifestyles, thus, were exposed to different risks, e.g., higher mortality rates at a certain age, mortality tables for the respective subsample were calculated.

For elite individuals, life expectancy at birth (e^0_0) was estimated to be 31.5 years with mean age at death of 31.7 years (Table 16). The mean age at death of non-elite individuals was 32.7 years and with e^0_0 being 31.7 years, non-elite individuals also displayed a slightly higher life expectancy at birth (Table 17). Aside from life expectancy at birth, also the life expectancy for different age groups needs to be considered as this can indicate changes in population dynamic processes, e.g., conflict, mobility, infanticide, age-specific diseases, etc. (Foreman et al., 2018; Grupe et al., 2005).

x	a	Dx	dx	lx	qx	Lx	Tx	e°_x
0-4	5	20.50	15.4	100.00	0.15	461.47	3144.99	31.45
5-9	5	10.00	7.5	84.59	0.09	404.14	2683.52	31.73
10-14	5	1.50	1.1	77.07	0.01	382.52	2279.39	29.58
15-19	5	5.33	4.0	75.94	0.05	369.67	1896.87	24.98
20-26	7	10.17	7.6	71.93	0.11	476.75	1527.19	21.23
27-34	7	15.42	11.6	64.29	0.18	409.43	1050.44	16.34
35-41	7	23.17	17.4	52.69	0.33	307.89	641.01	12.16
42-49	7	19.17	14.4	35.28	0.41	196.49	333.11	9.44
50-57	7	15.67	11.8	20.86	0.56	104.82	136.62	6.55
58+	7	12.08	9.1	9.09	1.00	31.80	31.80	3.50
Total		133.00				3144.99		

Table 16 Mortality table for elite individuals buried at Säben-Sabiona.

x	a	Dx	dx	lx	qx	Lx	Tx	e°_x
0-4	5	11.00	11.8	100.00	0.12	470.43	3167.74	31.68
5-9	5	4.00	4.3	88.17	0.05	430.11	2697.31	30.59
10-14	5	3.00	3.2	83.87	0.04	411.29	2267.20	27.03
15-19	5	7.00	7.5	80.65	0.09	384.41	1855.91	23.01
20-26	7	7.00	7.5	73.12	0.10	485.48	1471.51	20.13
27-34	7	11.58	12.5	65.59	0.19	415.55	986.02	15.03
35-41	7	19.42	20.9	53.14	0.39	298.88	570.47	10.74
42-49	7	15.42	16.6	32.26	0.51	167.79	271.59	8.42
50-57	7	8.08	8.7	15.68	0.55	79.35	103.81	6.62
58+	7	6.50	7.0	6.99	1.00	24.46	24.46	3.50
Total		93.00				3167.74		

Table 17 Mortality table for non-elite individuals buried at Säben-Sabiona.

Whereas for non-elite individuals, e_x decreased gradually with advancing age, the life expectancy for elite individuals was higher for those aged 5-9 years, with e_x being 31.7 years, rather than at 0-4 years of age with e_x being 31.5 years (Figure 9). From e_{10-14} onwards both groups display a gradual linear decrease in years left to live, which is analogous to what was found for other archaeological populations, i.e., one could die at any time, but differs from modern patterns, where life expectancy is very high for all ages until a certain advanced age, e.g., 80 years, and then drops dramatically. Elite individuals consistently displayed significantly higher life expectancies across all age classes (*t*=3.585, df=9, p=0.006), e.g., for e_{10-14} 29.6 years versus 27.03 years, for e_{15-19} 25 years versus 23 years, etc. At e_{20-26} the difference in life expectancy for elite and non-elite was lowest with 21.2 years versus 20.1 years, thus between 20-26 years, elite individuals only outlived non-elite individuals by about one year. By e_{50-57} both groups displayed similar life expectancies with 6.55 years for elites and 6.62 years for non-elites, at e_{58+} both groups were only expected to live for another 3.5 years.

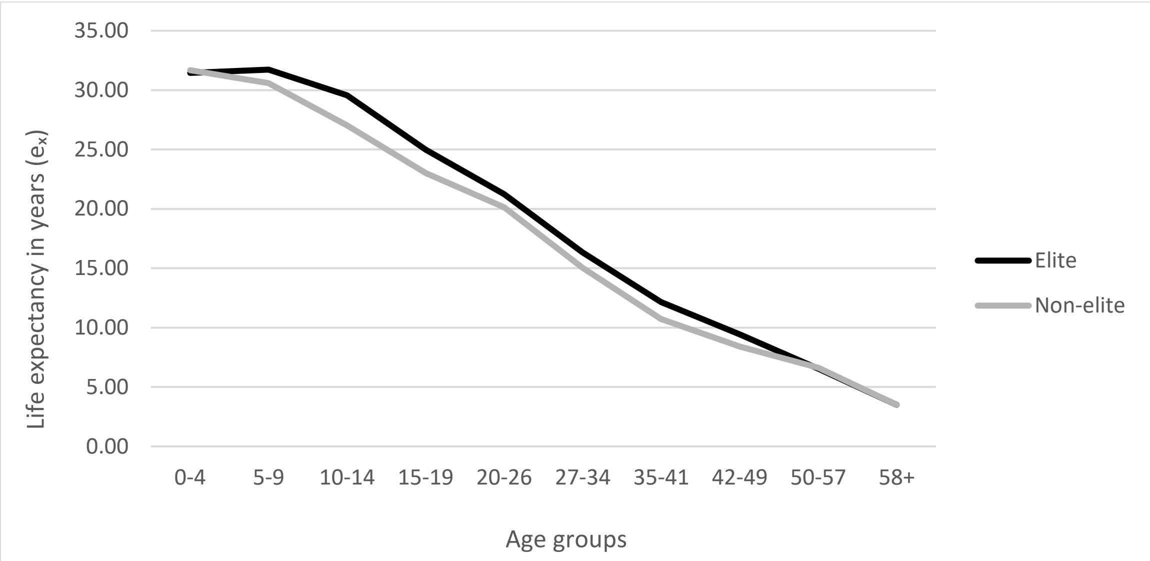

Figure 9 Life expectancy (e_x) of elite and non-elite individuals at Säben-Sabiona.

As life expectancy at birth was almost identical between the two subgroups, yet variations in life expectancy at different ages were observed different interpretations can be proposed. As the assessed individuals coinhabited the same environment, the observed differences may indicate socioeconomic divergences resulting in imbalanced living conditions for the two subgroups. An alternative reason for these differences could have been bone preservation, yet this was not found to be the case, i.e., burial location did not influence bone preservation and 18.8% of elite and 15.1% of non-elite individuals were non-determinable adults. This implies that socioeconomic difference, that may have manifested themselves since early childhood appear to be the most plausible explanation for the observed divergence.

As subadults under 15 years of age were not sexed, life expectancy at birth could not be calculated for either sex, yet, for both sexes' life expectancy values for the 15-19 age group are available (Figure 10). For the total sample it was found that for the 15-19 (25.1 years, males; 23.4 years, females) and 20-26 age categories (21.4 years, males; 20.7 years, females) males had a higher life expectancy than females, whereas the opposite was true for the 27-34 (15.6 years, males; 16 years, females), 35-41 (11.1 years, males; 11.9 years, females), 42-49 (8.4 years, males; 10.1 years, females) and 50-57 age categories (6.1 years, males; 7.4 years, females). For the 58+ year age category both sexes featured identical life expectancies (3.5 years each).

At $e_{15\text{-}19}$ the females of the elite group had a slightly higher life expectancy than males (26 years versus 25.6 years), whereas for the non-elite group the opposite was true, i.e., 19.9 years for females and 24.5 years for males. As differences below one year generally do not have a tremendous impact, such low variations may imply that regardless of social status, socioeconomic impacts were reduced for individuals aged 15 to 19 years of age. A similar pattern was also found for the mean age at death with 41.1 years for elite females versus 40.8 years for elite males and 34.5 for non-elite females versus 39.9 for non-elite males. This aligns well with the above-mentioned notion about better living conditions of elites, which generally also increases life expectancy of females, more so than that of males. Out of both groups, elite females appear to have had the highest life expectancy at all ages, followed by elite males and non-elite males, whereby non-elite females had the lowest life expectancies up to 42-49 years of age. On average, elite females lived 3.2 years longer than their non-elite counterparts, the differences between the male samples were substantially lower with average of only 0.3 years. In fact, for $e_{42\text{-}49}$ and $e_{50\text{-}57}$ elite males displayed lower life expectancies than non-elite males, i.e., 8.35 years versus 8.4 years (non-elites lived 0.05 years longer) and 5.8 years versus 6.6 years (non-elites lived 0.87 years longer). As these differ in less than one year, the observed variation may be linked to the sample, i.e., differences of one or two individuals in a given age category can have an impact.

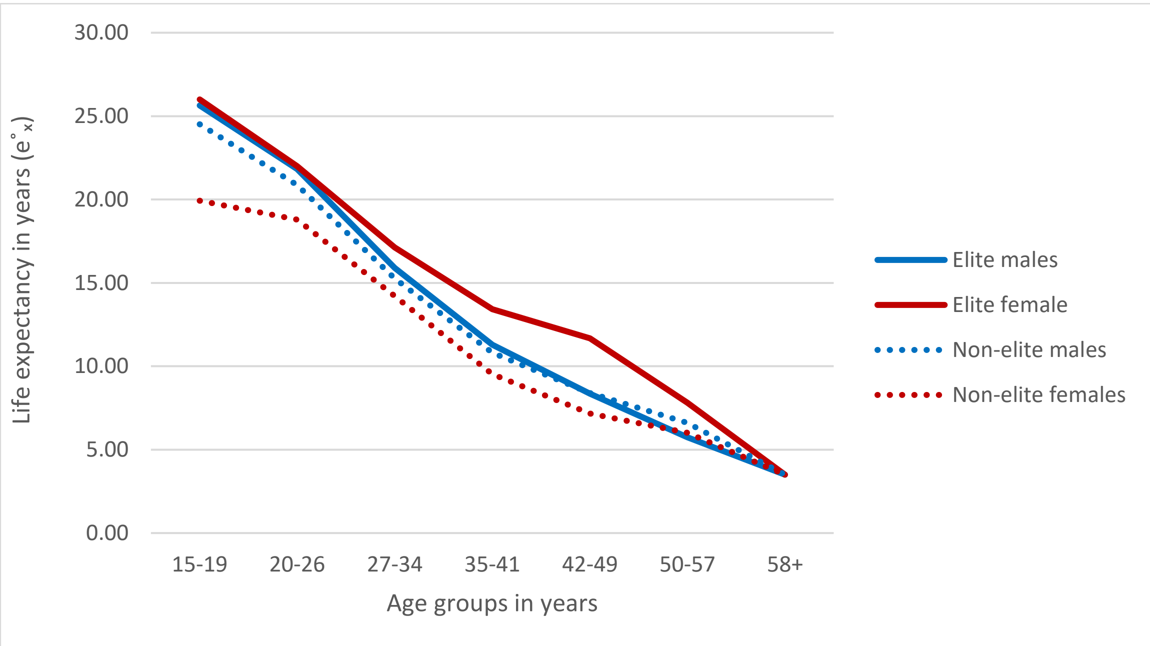

Figure 10 Life expectancy of elite and non-elite males and females from the early mediaeval cemetery of Säben-Sabiona.

As well as life expectancy at birth and successive ages, mortality tables also offer information about the probability of dying at a certain age. For the present data set, the probability of dying was between 10% and 20% for individuals aged 0-4 years, decreased then to almost 0% at 10-14 years of age and then gradually increased to 100% by the age 58 or over. Looking at subadults, the highest likelihood to die was recorded for individuals aged 0-4 years of age, whereby elite individuals (q_x=0.15) were slightly more likely to die at this age than non-elite individuals (q_x=0.12). Also, at 5-9 years of age, elite individuals displayed higher q_x values, i.e., q_x=0.09 versus q_x=0.05. For both groups, individuals aged 10-14 displayed the lowest probability of dying with q_x=0.01 for elites and q_x=0.04 for non-elites (Figure 11). The present pattern follows a normal mortality rate in human populations.

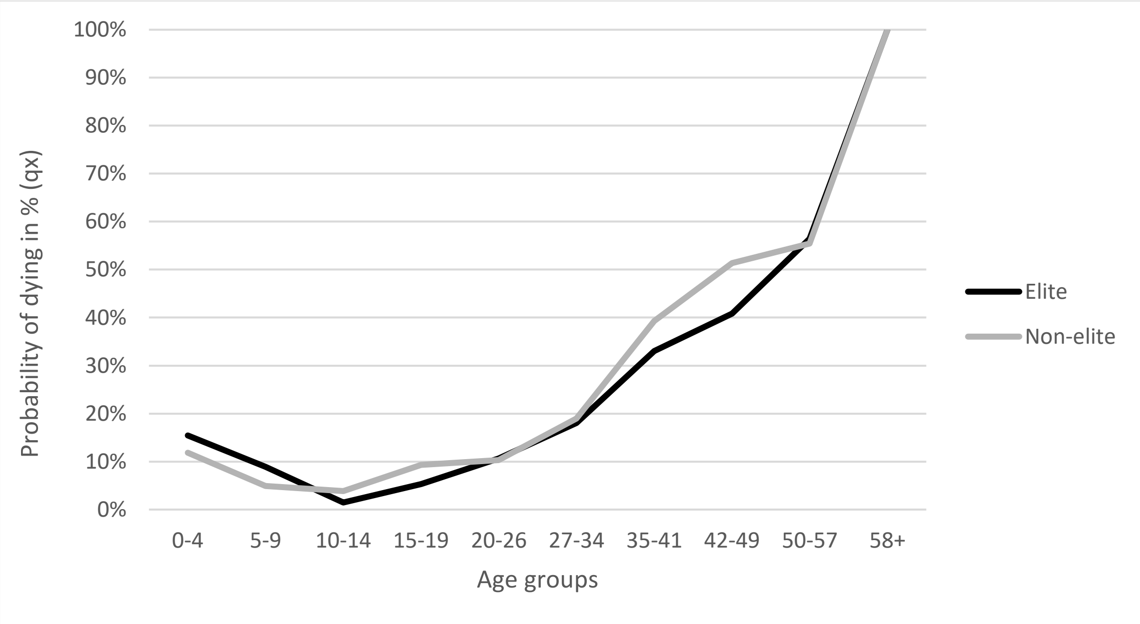

Figure 11 Probability of dying (q_x) of elite and non-elite individuals.

At all ages in the adult sample, non-elite individuals exhibited either a higher probability of dying or the same as elite individuals. The most pronounced divergence between the two groups was found at 42-49 years with q_x= 0.41 for elites and q_x=0.51 for non-elites, suggesting that non-elite individuals were 10% more likely to die between 42 and 49 years.

Like life expectancy, also the probability of dying at different ages from 15-19 years onwards was calculated for both sexes (Figure 12). Females generally displayed a higher probability of dying for the 15-19 (12% for females versus 5% for males), 20-26 (12% for females versus 6% for males), 27-34 (19% for females versus 17% for males) and 35- 41 age categories (38% for females versus 36% for males), whereas males had higher chances of dying in the 42-49 (49% for males versus 40% for females) and 50-57 age categories (63% for males versus 44% for females). At 15-19 years, non-elite females exhibited the highest probability of dying (21%), followed by non-elite males (6%) and both elite sexes (5% respectively). The higher probabilities of dying for non-elite females prevailed for the 20-26 age category (14%) as well as the 35-41 and 42-49 age categories (43% and 62%). Only at 27-34 years of age, elite females displayed a slightly higher chance of dying than non-elite females (19%

versus 18%). Yet, especially between 35-57 years, elite females exhibited the lowest probabilities of dying (i.e., 35%, 28%, 38%). With 68%, elite males featured the highest probability of dying at 50-57 years.

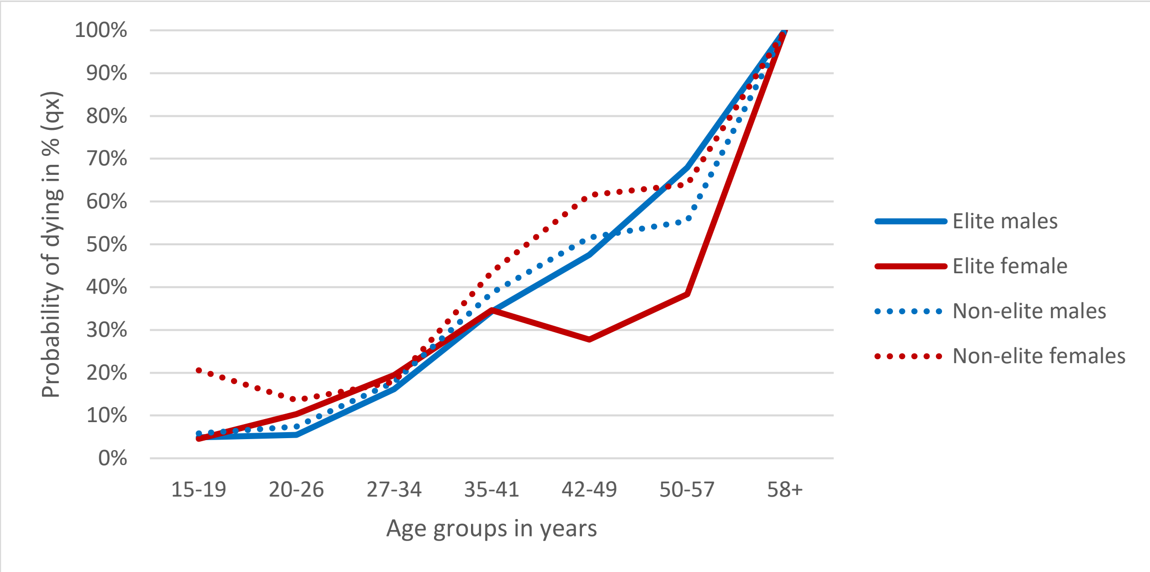

Figure 12 Probability of dying for elite and non-elite males and females.

6.2.2. Non-metric traits

Non-metric traits were found in 108 out of 226 (47.8%) individuals, whereby the highest frequencies were recorded in the cranial bones (n=55), tibia (n=47) and femur (n=42, Appendix 10 and 15). As shown in Table 18 for the cranium, both elite and non-elite individuals featured parietal foramina most frequently, i.e., 12.8% and 14%. Due to the relatively low prevalence of inherited cranial traits, a detailed kinship analysis was not performed.

Non-metric trait	**Elite † n (%)**	**Non-elite † n (%)**
Metopic suture	6 (4.5)	6 (6.5)
Coronal ossicles	2 (1.5)	2 (2.2)
Squama-parietal ossicles	1 (0.8)	0 (0)
Parietal notch bone	3 (2.3)	2(2.2)
Parietal foramen	17 (12.8)	13 (14)
Lambdoid ossicles	9 (6.8)	9 (9.7)
Inca bone	0 (0)	3 (3.2)
Apical bone	4 (3)	2 (2.2)
Maxillary torus	12 (9)	5 (5.4)
Dental non-metric traits	8 (6)	4 (4.3)

Table 18 Crude frequency of inherited cranial non-metric traits at Säben-Sabiona. † n= number of individuals featuring non-metric traits, %= percentage of N, N= total number of elite/non-elite individuals.

Acquired or activity-related non-metric traits were mostly recorded in the femur, i.e., Poirier's facet (16.5%), and tibia, i.e., lateral squatting facets (16.5%), for elite individuals (Table 19, Figure 13). Even though the prevalence of Poirier's facets was slightly higher in the non-elite sample (21.5%), this difference was not statistically significant (X^2= 0.891, df= 1, p= 0.345).

Non-metric trait	**Elite † n (%)**	**Non-elite † n (%)**
Scapula- Bipartite acromion	3 (2.3)	1 (1.1)
Humerus- Septal aperture	4 (3)	3 (3.2)
Os coxae- Preauricular sulcus	11 (8.3)	8 (8.6)
Femur- Poirier's facet	22 (16.5)	20 (21.5)
Tibia- lateral squatting facets	22 (16.5)	13 (14)
Tibia- medial squatting facets	19 (14.3)	9 (9.7)
Other non-metric traits	11 (8.3)	10 (10.8)

Table 19 Crude frequency of acquired postcranial non-metric traits at Säben-Sabiona. † n= number of individuals featuring non-metric traits, %= percentage of N, N= total number of elite/non-elite individuals.

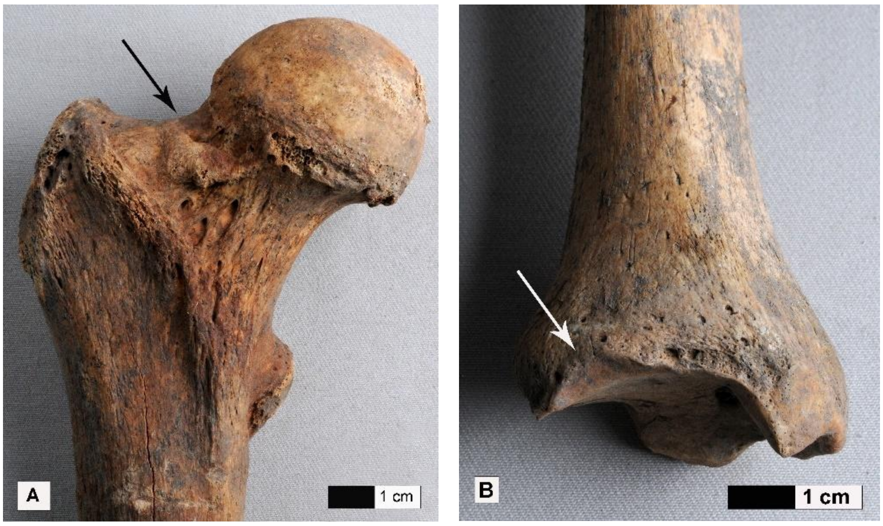

Figure 13 A) Poirier's facet on the right femur from SK230; B) Lateral squatting facet on the right tibia from SK52.

6.2.3. Osteometry

6.2.3.1. Stature

Eighty-eight individuals (38.9%) featured long bones suitable for stature calculation (Appendix 9), 62 of these were males, 22 were females (Table 20) and four were not determinable. Males (167.8cm± 3.5cm) were on average taller than females (156.8cm± 3.6cm), which is consistent with the global data, i.e., males are typically up to 10cm taller than females (Carson, 2022; Deheeger et al., 2002; Hermanussen, 2013).

Sex	Pearson 1899	Trotter and Gleser		Mean stature
		1952	1977	
Females	155±3.1	156.4±3.7	159.2±3.9	156.8±3.6
Males	166.6±3.1	166.7±4.0	170.3±3.4	167.8±3.5
Mean stature	160.8±3.1	161.6±3.9	164.6±3.6	162.3±3.6

Table 20 Stature estimates of the whole sample; all measurements are in centimetres.

When splitting the population into an elite and non-elite group, the former was represented by 52 individuals and the latter by 36 individuals. Overall body height was greater in the elite sample than the non-elite group, i.e., 162.6cm± 3.4cm versus 160.9cm± 3.4cm, at a non-statistical level (Table 21 and Table 22; t= 1.212, df= 85, p= 0.229). The sex related differences in body height as registered when analysing the whole population were also observed in the subsamples. Here it was noted that elite females and males were on average about 2cm taller than their non-elite counterparts.

Sex	Pearson 1899	Trotter and Gleser		Mean stature
		1952	1977	
Females	154.7±3.1	155.7±3.4	158.1±3.7	156.2±3.4
Males	168.1±3.0	167.8±3.9	171.3±3.3	169.1±3.4
Mean stature	161.4±3.1	161.8±4.1	164.7±3.5	162.6±3.4

Table 21 Stature estimates of elite individuals; all measurements are in centimetres.

Sex	Pearson 1899	Trotter and Gleser		Mean stature
		1952	1977	
Females	153.6±3.1	154.4±3.4	156.6±3.7	154.8±3.4
Males	166.2±3.0	165.7±3.9	168.9±3.3	166.9±3.4
Mean stature	159.9±3.1	160.0±3.7	162.8±3.5	160.9±3.4

Table 22 Stature estimates of non-elite individuals; all measurements are in centimetres.

6.2.3.2. Body weight, body mass index (BMI) and osseous frame index (OFI)

Body weight and the BMI could be estimated from 40 males and 13 females of the total sample. Based on these, average adult body weight could be estimated to be 64.5kg and with a BMI of 24.8. Elite individuals featured a slightly larger body weight and BMI than non-elite individuals, i.e., 65.6kg versus 65kg and 25.1 versus 24.9 (Table 23). Looking at the total sample, mean female bodyweight was 59.1kg yielding BMI of 24.8, and a mean male bodyweight was 69.9kg, which resulted in a BMI of 24.9. The observed sex-related differences are congruent with the commonly accepted notion, that on average, males tend to be larger and heavier than females. Elite females exhibited a higher body weight (60.5kg) and BMI (25.2) than their non-elite counterparts (59kg and 24.5). With a body weight of 70.9kg versus 71kg and a BMI of 25.1 versus 25.3, the opposite was true for elite and non-elite males. Yet, due to the low differences between the two subsamples this distinction does not appear to be meaningful.

Sex	Body weight in kg		BMI		OFI	
	Elite	Non-elite	Elite	Non-elite	Elite	Non-elite
Females	60.5	59.0	25.2	24.5	36.7	36.8
Males	70.9	71.0	25.1	25.3	37.8	38.0
Mean	65.6	65.0	25.1	24.9	37.2	37.4

Table 23 Body weight, body mass and osseous frame index of elite and non-elite individuals.

The OFI could be calculated from 27 individuals yielding an OFI of 37.2. When separating these into elite and non-elite individuals, the OFI of the former is identical to the average of the whole population, most likely due to the higher number of elite individuals (n=20 versus n=7), whereas the OFI of non-elites was slightly higher (37.4).
The mean OFI for the total number of males (n=23) and females (n=4) was lower for females (36.7) than for males (37.8). As the distribution of muscle versus fat mass is known to differ among the sexes and larger body frame indices are commonly associated with males, the present data are consistent with the anthropological consensus. Both non-elite females (36.8) and males (38) exhibited slightly larger OFI values than elite females (36.7) and males (37.8).

In order to gain more information about body size, handedness and mobility, the following indices were estimated for individuals featuring data for both the left and right side of the total sample as well as elite and non-elite subsamples: robusticity indices of the humerus (N=15, n=11, n=4), femur (N=28, n=20, n=8) and tibia (N=20, n=17, n=3), and the platymeric index of the femur (N=49, n=30, n=19) and platycnemic index of the tibia (N=42, n=27, n=15). As the name suggests, robusticity indices provide information on the skeletal exposure to stress, i.e., activity, that causes bone to adapt in a certain way. Hence, the higher a robusticity score, the more stress was applied. This is an important aspect to consider, especially in relation to handedness. All individuals featured a higher robusticity score for their right side (21.3) as opposed to the left (20.9), whereby this pattern was also consistent over both subsamples (21.3 versus 20.8 and 21.3 versus 21.2) (Table 24). Statistically significant differences between elite and non-elite individuals were not found (right humerus- t= 0.009, df= 23, p= 0.993; left humerus- t= 0.25, df= 19, p=0.805).

Hum-Robusticity	Elite † (11)		Non-elite † (4)		Total sample † (15)	
	R	**L**	**R**	**L**	**R**	**L**
Males	21.4	20.8	21.3	21.2	21.35	21
Females	21.1	20.8	-	-	21.1	20.8
ND	-	-	-	-	-	-
Mean	21.3	20.8	21.3	21.2	21.3	20.9

Table 24 Humerus robusticity scores in relation to sex of the total sample and both subsamples, whereby the mean scores were calculated based on the data of the whole elite, non-elite, and total sample † (n)= number of individuals available for humerus robusticity index estimations.

Data for both sexes were only available for the elite subsample. The right humerus was more robust in elite males and non-elite males than elite females.

Femoral robusticity was also assessed, displaying equal levels of robusticity in the total sample (12.6 and 12.6), yet in the non-elite individuals the left side (12.7) appeared to be slightly more robust than the right side (12.6, Table 25). However, these variations of left (*t*= 0.337, df= 36, p= 0.738) and right (*t*=0.228, df=37, p= 0.821) femoral robusticity between elite and non-elite individuals was not statistically significant.

Femur-Robusticity	Elite † (20)		Non-elite † (8)		Total sample † (28)	
	R	L	R	L	R	L
Males	12.6	12.6	12.8	12.6	12.7	12.6
Females	12.2	12.1	12.4	12.7	12.3	12.4
ND	-	-	-	-	-	-
Mean	12.5	12.5	12.6	12.7	12.6	12.6

Table 25 Femur robusticity scores in relation to sex of the total sample and both subsamples, whereby the mean scores were calculated based on the data of the whole elite, non-elite, and total sample † (n)= number of individuals available for femur robusticity index estimations.

Regardless of subsample, males always exhibited higher femoral robusticity scores than females. Non-elite individuals appeared to be more robust than elite individuals. In elite males, no difference between left and right was observed. Non-elite males on the other hand featured a higher score in their right femora. Differences in laterality were also observed in females of both subsamples, whereby the right femur was more robust in elite females (12.2 versus 12.1) and the left femur had a higher robusticity score in non-elite females (12.7 versus 12.4).

Tibial robusticity (Table 26) was found to be more elevated in the right side (20.8) than the left (20.3). In both elite and non-elite individuals, the right tibia (20.8 and 20.6) was more robust than the left (20.6 and 20.1). However, the tibiae of elite individuals appeared to be slightly more robust than those of non-elite individuals. The differences in tibial robusticity between the two subsamples were not found to be statistically significant (right tibia- *t*= -1.083, df=28, p=0.288; left tibia- *t*=-0.718, df=33, p=0.478).

Tibia-Robusticity	Elite † (17)		Non-elite † (3)		Total sample † (20)	
	R	L	R	L	R	L
Males	21.3	20.7	20.6	20.1	20.95	20.6
Females	20	19.6	-	-	20	19.6
ND	-	-	-	-	-	-
Mean	20.8	20.3	20.6	20.1	20.8	20.3

Table 26 Tibia robusticity scores in relation to sex of the total sample and both subsamples, whereby the mean scores were calculated based on the data of the whole elite, non-elite, and total sample † (n)= number of individuals available for tibia robusticity index estimations.

Similar as for the humerus robusticity index, also for the tibia only in the elite subsample both sexes were represented. Elite males had the highest robusticity scores followed by non-elite males and elite females had the lowest scores. Regardless of sex, the right tibiae were always more robust than the left.

To gain information about mobility, both the platymeric index of the femur (Table 27) and platycnemic index of the tibia were estimated (Table 28). Looking at the total sample, for the right femur a larger platymeric index could be calculated (89.5 versus 88.5). Such a laterality difference was only observed for the non-elite subsample (82.2 versus 81.4) but not for elite individuals (89.6 for both sides). Even though elite individuals generally displayed higher platymeric scores than non-elite individuals, these data were not statistically significant (right femur- *t*= -0.125, df=61, p=0.901; left femur- *t*=0.622, df=56, p=0.536).

Femur-Platymeric	**Elite † (30)**		**Non-elite † (19)**		**Total sample † (49)**	
	R	**L**	**R**	**L**	**R**	**L**
Males	89.3	89.3	91.4	88.5	90.1	88.9
Females	90.5	90.6	86.5	82.2	89.3	88.1
ND	-	-	68.8	73.5	68.8	73.5
Mean	89.6	89.6	82.2	81.4	89.5	88.5

Table 27 Femur platymeric scores in relation to sex of the total sample and both subsamples, whereby the mean scores were calculated based on the data of the whole elite, non-elite, and total sample † (n)= number of individuals available for femur platymeric index estimations.

When assessing the total sample, males tended to have higher, but statistically insignificant, platymeric scores than females (right femur- *t*= 0.553, df=60, p=0.582; left femur- *t*= -0.966, df=55, p=0.338). Yet in the elite subsample, the platymeric indices were higher for females than males. For non-elite individuals, the platymeric index was higher in males.

In the total sample a greater platycnemic index of the tibia was recorded for right tibiae (74.8 versus 74.5, Table 28). An analogous pattern was found for elite individuals, however, in the non-elite subsample (74.5 versus 73.7) a higher platycnemic score was registered for the left tibiae (80.6 versus 79.6). Overall, non-elite individuals had higher platycnemic scores than elite individuals, yet these variations were not statistically significant (right tibia- *t*= 0.697, df=55, p=0.489; left tibia- *t*=-1.074, df=55, p=0.288).

Tibia-Platycnemic	Elite † (27)		Non-elite † (15)		Total sample † (42)	
	R	L	R	L	R	L
Males	74.2	74.4	73.1	73.9	73.65	74.15
Females	75.1	72.1	79.6	79	76.3	74
ND	-	-	86.2	89	86.2	89
Mean	74.5	73.7	79.6	80.6	74.8	74.5

Table 28 Tibia platycnemic scores in relation to sex of the total sample and both subsamples, whereby the mean scores were calculated based on the data of the whole elite, non-elite, and total sample † (n)= number of individuals available for tibia platycnemic index estimations.

The data of the total sample suggested higher, but statistically insignificant, platycnemic scores for females than males (right tibia- t= 0.585, df=53, p=0.561; left tibia- t= -0.107, df=54, p=0.915), this was also found in the non-elite sample (79.3 versus 73.5). In the elite sample, the right platycnemic index was greater in females (75.1 versus 74.2), yet the left platycnemic index was larger in males (74.4 versus 72.1).

6.3. Palaeopathological profile

Signs of abnormal skeletal and dental alterations were found on 80.5% (n=182) of the studied individuals. The observed disorders affected mainly the skeleton (n=163) but also masticatory apparatus and dentition (n=117). Forty-three percent of the studied sample exhibited both skeletal and dental disorders (n=98). Both elite (71% and 53%) and non-elite (74% and 51%) individuals featured similarly high prevalence rates of skeletal and dental disorders.

6.3.1. Dental abnormalities

To establish the frequency of dental and alveolar conditions, a total number of 1785 teeth and 2652 alveoli of 134 individuals were assessed for the present study (Appendix 10). The crude prevalence of alterations affecting the masticatory apparatus was 87.3% (n=117, Figure 14, Appendix 10 and 16).

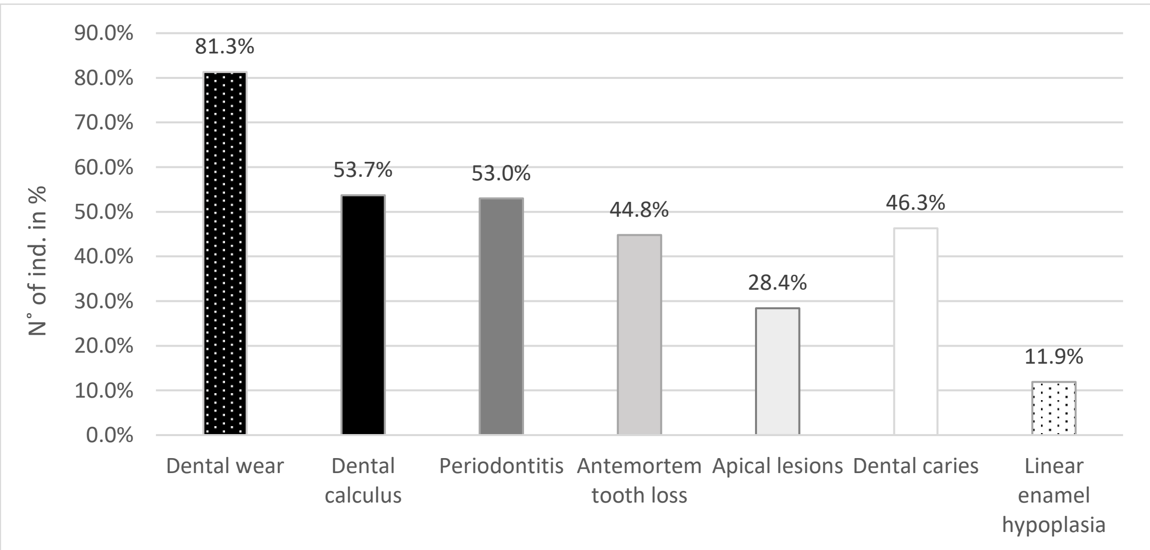

Figure 14 Crude frequency of alterations affecting the masticatory apparatus.

Dental wear (n=109), dental calculus (n=72), periodontitis (n=71), dental caries (n=62) and antemortem tooth loss (n=60) were most prevalent, whereby apical lesions (n=38) and linear enamel hypoplasia (n=16) were less common (Figure 15).

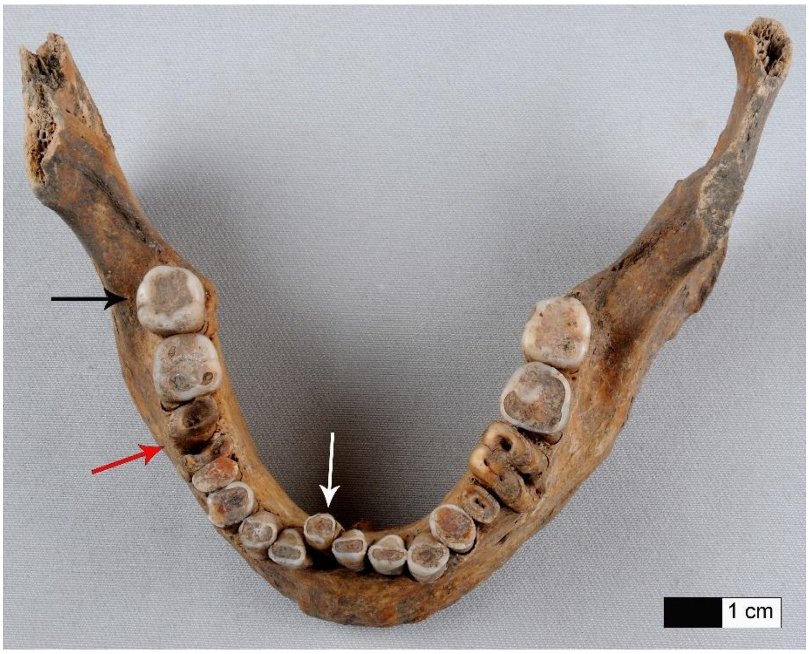

Figure 15 Superior view of the mandible from SK48, featuring pronounced dental wear (white arrow), destructive caries (red arrow) and occlusal dental calculus (black arrow), which indicates a prolonged absence of the maxillary antagonist.

When splitting the sample into an elite and non-elite group, 85.5% of the elite (71 out of 83) and 90.4% of the non-elite (47 out of 52) featured dental alterations. The observed frequencies were not statistically significant (X^2=1.457, df=2, p=0.483). In terms of lesion prevalence order, both subsamples follow the already outlined pattern, i.e., mostly dental wear, dental calculus, etc., however, on a whole, non-elite individuals exhibited these alterations much more frequently than those classed as elite individuals (Table 29). A statistically significant relationship between social status, i.e., elite/ non-elite, was only found for dental caries (X^2=10.864, df=2, p=0.012).

Type of disease	**Elite †n (%)**	**Non-elite †n (%)**	**Statistical significance**
Dental wear	65 (81.9)	44 (84.6)	X^2= 1.698, df=2, p=0.428
Dental calculus	41 (49.4)	31 (59.6)	X^2=1.617, df=2, p=0.446
Periodontitis	40 (48.2)	31 (59.6)	X^2=1.075, df=2, p=0.584
Antemortem tooth loss	33 (39.8)	27 (51.9)	X^2=0.642, df=2, p=0.725
Apical lesions	20 (24.1)	20 (38.5)	X^2=3.661, df=3, p=0.300
Dental caries	29 (34.9)	33 (63.5)	X^2=8.919, df=2, p=0.012
Linear enamel hypoplasia	8 (9.6)	8 (15.4)	-

Table 29 Crude frequency of alterations affecting the masticatory apparatus of elite (N=83) and non-elite individuals (N=52). For LEH no X^2 test was performed due to the low sample size.

The dental alteration frequency of the two ethnic groups as differentiated in the publication by Bierbrauer and Nothdurfter (2015) showed that autochthonous, i.e., Romans (48.5%), and allochthonous, i.e., Longobards or Bavarians (55.5%), featured similarly high rates. Following the already mentioned rationale of splitting the population into an elite and non-elite subsample, all more detailed palaeopathological analyses concerning dental disorders will focus on the respective subsample and not on the ethnic differentiation solely based on grave goods.

6.3.1.1. Dental wear

For the total sample, dental wear was found to be more prevalent (crude) in males (97.1%) than females (80%). In the elite group, dental wear (Figure 15) was observed in 65 individuals of which ten lacked a sex and/or age estimate (Appendix 16). The crude prevalence of dental wear was higher in males (97.5%) than in females (83.3%) and subadults (43.5%, Table 30).

Adult age	**Subadults**			**Females**			**Males**			**ND**		
	n	N	%	n	N	%	n	N	%	n	N	%
Adult-ND				1	1	100.0	1	2	50.0	3	4	75.0
Adult				6	6	100.0	14	14	100.0	2	3	66.7
Mature				2	3	66.7	24	24	100.0	0	1	0.0
Senile				1	2	50.0	0	0	0.0	0	0	0.0
Total	10	23	43.5	10	12	83.3	39	40	97.5	5	8	62.5

Table 30 Crude prevalence rates of dental wear in relation to sex and age of elite individuals. † n= number of individuals featuring dental wear, %=percentage of N, N= total number of elite individuals available for analysis.

Individuals that died between 20-40 years of age exhibited the highest rates of dental wear (95.7%), followed by the mature (92.9%) and senile (50%) age categories. For dental wear severity, most individuals featured medium or low levels of dental wear, whereby premolars and molars displayed more commonly medium or high wear as opposed to incisors and canines. This pattern is congruent with the eruption times of the respective teeth, i.e., those that erupt earlier feature a longer exposure to extrinsic factors, thus are expected to display more alterations than those erupting later (Hillson, 1996; Kaifu et al., 2003).

Forty-four individuals of the non-elite sample featured signs of dental wear, whereby a sex estimate was possible for 35 individuals. Similar as for the elite group, males (93%) featured dental wear more commonly than females (78%) or subadults (69%, Table 31).

Adult age	Subadults			Females			Males			ND		
	n	N	%	n	N	%	n	N	%	n	N	%
Adult-ND				0	0	0.0	0	0	0.0	0	0	0.0
Adult				3	3	100.0	10	11	90.9	3	3	100.0
Mature				4	6	67.7	14	15	93.3	0	0	0.0
Senile				0	0	0.0	1	1	100.0	0	0	0.0
Total	9	13	69.2	7	9	77.8	25	27	92.6	3	3	100.0

Table 31 Crude prevalence rates of dental wear in relation to sex and age of non-elite individuals. † n= number of individuals featuring dental wear, %=percentage of N, N= total number of non-elite individuals available for analysis.

In terms of dental wear in relation to age at death, the data for non-elite individuals is slightly differently distributed than that of the elite group, with senile individuals featuring the highest prevalence (100%), followed by adults (94%) and mature individuals (86%). As with most alterations, the frequency of dental wear is expected to increase with advancing age, yet for the present sample, individuals who died earlier, i.e., adults had higher rates of dental wear than mature individuals. The severity of dental wear was mainly found to be medium or low, with premolars and molars displaying medium or high alterations more frequently.

6.3.1.2. Dental calculus

In the total sample, males featured a higher crude prevalence of dental calculus than females (79.4%, males; 55%, females). Forty-one elite individuals displayed signs of calcified plaque deposits on their dentition (Figure 16, Appendix 16).

Figure 16 Anterior view of the mandible from SK48, displaying dental calculus (black arrow) on incisors and canines as well as periodontitis (white arrow).

Out of these, three individuals lacked a sex or age estimate. For the remaining subsample, dental calculus was most frequently observed in males (77.5%), whereby females (58.3%) and subadults (13%) appeared to be less often affected (Table 32).

Adult age	Subadults			Females			Males			ND		
	n	N	%	n	N	%	n	N	%	n	N	%
Adult-ND				1	1	100.0	0	2	0.0	0	4	0.0
Adult				4	6	66.7	11	14	78.6	0	3	0.0
Mature				1	3	33.3	20	24	83.3	0	1	0.0
Senile				1	2	50.0	0	0	0.0	0	0	0.0
Total	3	23	13	7	12	58.3	31	40	77.5	0	8	0.0

Table 32 Crude prevalence of dental calculus in relation to sex and age of elite individuals. † n= number of individuals with dental calculus, %=percentage of N, N= total number of elite individuals available for analysis.

Mature males presented the highest dental calculus frequency (83.3%), followed by adult males (78.6%) and, adult females (66.7%). For the elite sample, the overall frequency of dental calculus appeared to vary among the age groups, yet, mature (75%) and adult (65.2%) individuals were more often affected than senile individuals (50%). Most individuals featured low or medium levels of dental calculus covering less than half of the tooth. Medium dental calculus levels were mainly registered in premolars and molars. High levels of dental calculus were mostly recorded for mandibular incisors and canines, i.e., in close proximity to salivary glands (Dawes, 2006).

Thirty-one non-elite individuals had dental calculus, only 26 of these featured a sex estimate. Males (77.8%) were almost twice as often affected than females (44.4%) or subadults (38.5%, Table 33).

Adult age	Subadults			Females			Males			ND		
	n	N	%	n	N	%	n	N	%	n	N	%
Adult-ND				0	0	0.0%	0	0	0.0%	0	0	0.0%
Adult				2	3	66.7%	8	11	72.7%	1	3	33.3%
Mature				2	6	33.3%	13	15	86.7%	0	0	0.0%
Senile				0	0	0.0%	0	1	0.0%	0	0	0.0%
Total	5	13	38.5%	4	9	44.4%	21	27	77.8%	1	3	33.3%

Table 33 Crude prevalence of dental calculus in relation to sex and age of non-elite individuals. † n= number of individuals with dental calculus, %=percentage of N, N= total number of non-elite individuals available for analysis.

In the non-elite sample, mature individuals exhibited the highest prevalence of dental calculus (71.4%), especially males (86.7%), followed by adults (64.7%). However, in the female sample adults (66.7%) featured dental calculus more frequently than mature females (33.3%). No data was available for senile individuals. Dental calculus was mainly found at lower or medium frequencies in the non-elite sample. Premolars and molars displayed mostly medium levels of dental calculus. High levels of dental calculus were most prevalent in mandibular incisors and canines.

6.3.1.3. Periodontal disease

Periodontal disease was found at a prevalence of 53% in the total sample (Appendix 16), whereby males (75%) displayed such alterations more commonly than females (65%). Forty individuals of the elite subsample exhibited periodontitis (Figure 17), which was substantially higher in males (75%) than females (66.7%) and subadults (9%, Table 34).

Adult age	**Subadults**			**Females**			**Males**			**ND**		
	n	N	%	n	N	%	n	N	%	n	N	%
Adult-ND				1	1	100.0	0	2	0.0	0	4	0.0
Adult				4	6	66.7	12	14	85.7	0	3	0.0
Mature				2	3	66.7	18	24	75.0	0	1	0.0
Senile				1	2	50.0	0	0	0.0	0	0	0.0
Total	2	23	9	8	12	66.7	30	40	75.0	0	8	0.0

Table 34 Crude prevalence of periodontitis in relation to sex and age of the elite sample. † n= number of individuals with periodontal disease, %=percentage of N, N= total number of elite individuals available for analysis.

Even though one individual could not be aged, more than half of the assessed mature (71.4%) and adult individuals (69.6%) featured periodontal disease. With 85.7%, adult males had highest periodontitis frequency, which was followed by mature males with 75% (Figure 17). In females, the periostitis prevalence pattern was somewhat similar, with more than half of the assessed adult (66.7%), mature (66.7%) and senile females (50%) exhibiting alveolar alterations. The elite sample displayed alveolar resorption exceeding 4mm more often than lower levels of periodontitis. Premolars and molars were most often and most severely affected.

Figure 17 Anterior view of the mandible from SK210, displaying dental calculus (black arrow) deposits and periodontal disease (white arrow).

Even though statistically insignificant, with a prevalence of 60%, non-elite individuals featured a substantially higher rate of periodontitis. In terms of sex distribution, similar as for elites, males (74.1%) were more commonly affected than females (66.7%) or subadults (38%). Yet, the prevalence rates for each sex and subadults were much higher than that of the elite sample (Table 35).

Adult	**Subadults**			**Females**			**Males**			**ND**		
age	n	N	%	n	N	%	n	N	%	n	N	%
Adult-ND				0	0	0.0	0	0	0.0	0	0	0.0
Adult				2	3	66.7	9	11	81.8	0	3	0.0
Mature				4	6	66.7	11	15	73.3	0	0	0.0
Senile				0	0	0.0		1	0.0	0	0	0.0
Total	5	13	38	6	9	66.7	20	27	74.1	0	3	0.0

Table 35 Crude prevalence of periodontitis in relation to sex and age of the non-elite sample. † n= number of individuals with periodontal disease, %=percentage of N, N= total number of non-elite individuals available for analysis.

The periodontal distribution in relation to overall age showed that the highest frequencies of periodontitis were observed in mature individuals (71.4%) followed by adults (64.7%). No data was available for senile individuals. When looking at the periodontal distribution in relation to sex and age, adult males clearly feature the highest prevalence rate of periodontitis (81.8%), followed by mature males (73.3%) and adult and mature females (66.7%), respectively. In terms of periodontitis severity, an analogous pattern to elite individuals was observed, i.e., mostly featuring severe levels of alveolar absorption and mainly affecting premolars and molars.

6.3.1.4. Antemortem tooth loss

With 44.8% of individuals featuring antemortem tooth loss (AMTL) this alveolar condition was less common than dental wear, calculus, and periodontal disease (Appendix 10). However, out of the assessed alveoli (N=2652), 12.4% (n=328) exhibited AMTL (Figure 18). For the total sample, females displayed higher crude (75%) and true (26.7%) prevalence rates of AMTL than males (58.8%, crude; 13.9%, true).

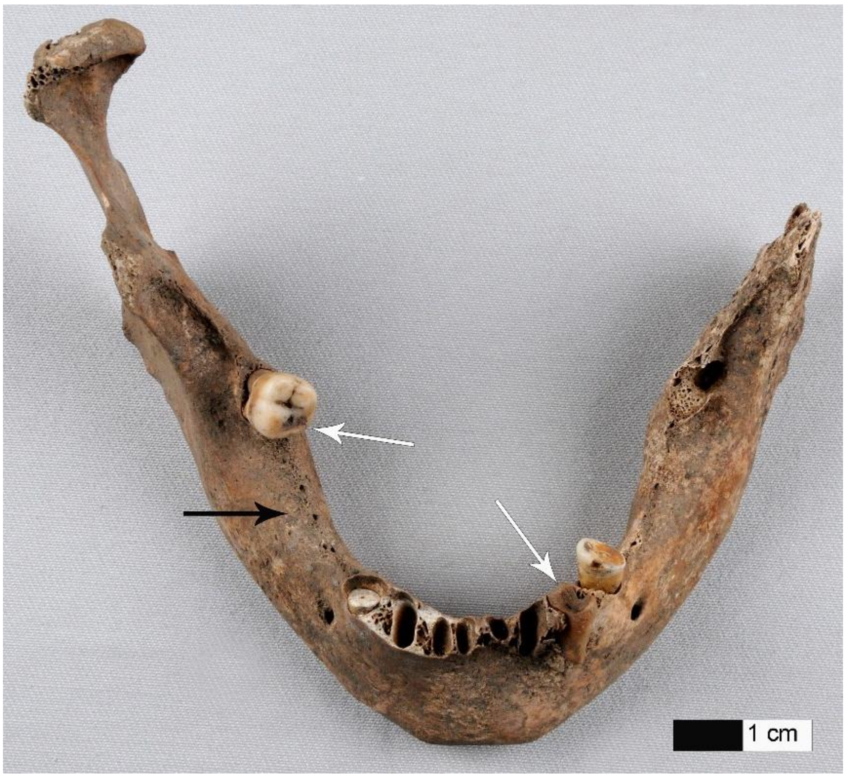

Figure 18 Superior view of the mandible from SK73, featuring antemortem tooth loss (black arrow), and two carious lesions (white arrows).

In the elite subsample, 39.8% individuals exhibited AMTL on 11.2% of their dentition, which is lower than what was recorded for the non-elite sample, with a crude prevalence of 51.9% and a true prevalence of 20.1%. The difference in the prevalence of AMTL between elite and non-elite individuals was not found to be statistically significant.

For the elite group, the highest prevalence of AMTL was registered in females, both their crude (66.7%) and true prevalence rates (22.2%) were significantly higher than those of males (57.5% and 12.1%, X^2= 71.714, df=2, p< 0.001, Table 36).

Age	Subadults & ND		Females		Males	
	TPR n/N (%)	CPR n/N (%)	TPR n/N (%)	CPR n/N (%)	TPR n/N (%)	CPR n/N (%)
Subadults	1/329 (0.3)	1/23 (4.3)	-	-	-	-
Adult-ND	0/14 (0)	0/4 (0)	5/16 (31.3)	1/1 (100)	1/12 (8.3)	1/2 (50)
Adult	0/42 (0)	0/3 (0)	6/137 (4.4)	3/6 (50)	29/374 (7.8)	8/14 (57.1)
Mature	1/3 (33.3)	1/1 (100)	15/80 (18.8)	2/3 (66.7)	79/512 (15.4)	14/24 (58.3)
Senile	-	-	40/64 (62.5)	2/2 (100)	-	-
Total	2/388 (1)	2/31 (6)	66/297 (22.2)	8/12 (66.7)	109/898 (12.1)	23/40 (57.5)

Table 36 Prevalence rates of AMTL in the elite subsample. † TPR= true prevalence rate, CPR= crude prevalence rate n= number of teeth/elite individuals featuring AMTL, %=percentage of N, N= total number of teeth/ elite individuals assessable.

The frequency of AMTL increased gradually with advancing age in the elite sample, whereby senile individuals exhibited both the highest true (62.5%) and crude prevalence rate (100%), and subadults featured the lowest, i.e., 0.3% and 4.3%. In the female sample, the highest true prevalence rates were registered for senile (62.5%, Figure 19) and mature females (18.8%). No data were available for male individuals over 60 years of age; thus, mature males (15.4%) exhibited the highest incidence on a true prevalence level.

Figure 19 Inferior view of the edentulous maxilla from SK118.

Also in the non-elite subsample, AMTL appeared more commonly in females (87.5%) than males (60.7%) or subadults (15%, Table 37). With a true prevalence rate of 38.7%, females were affected significantly more than males (16.6%, X^2= 33.431, df=2, p< 0.001).

	Not determined		**Females**		**Males**	
	TPR	**CPR**	**TPR**	**CPR**	**TPR**	**CPR**
Age	n/N (%)	n/N (%)	n/N (%)	n/N (%)	n/N (%)	n/N (%)
Subadults	10/339 (3)	2/13 (15)	-	-	-	-
Adult-ND	-	-	-	-	-	-
Adult	1/53 (1.9)	1/3 (33.3)	1/20 (5)	1/2 (50)	5/233 (2.1)	4/12 (33.3)
Mature	-	-	42/91 (46.2)	6/6 (100)	94/344 (27.3)	12/15 (80)
Senile	-	-	-	-	2/30 (6.7)	1/1 (100)
Total	11/392 (2.8)	3/16 (18.8)	43/111 (38.7)	7/8 (87.5)	101/607 (16.6)	17/28 (60.7)

Table 37 Prevalence rates of antemortem tooth loss in the non-elite subsample. † TPR= true

prevalence rate, CPR= crude prevalence rate n= number of teeth/ non-elite individuals featuring AMTL, %=percentage of N, N= total number of teeth/non-elite individuals assessable.

Like in the elite sample, also for non-elite individuals the frequency of AMTL increased with advancing age, although mature individuals (31.3%) featured a higher true prevalence rate than adults (2.3%) or senile individuals (6.7%). As females lack data for individuals over 60 years of age, the highest observable crude (100%) and true prevalence (46.2%) was recorded for mature females. In the male sample, senile individuals featured the highest crude prevalence rate (100%), yet, on a dental level, mature males (27.3%) lost more teeth prior to death than senile (6.7%) or adult males (2.1%).

6.3.1.5. Periapical lesions

Periapical lesions were fairly common in the present sample with a crude prevalence of 28.4% (n=38) and a true prevalence of 4.3% (n=114, Appendix 10). Both in elite (24.1%, crude; 3.9%, true) and non-elite individuals (38.5%, crude; 4.8%, true; Figure 20).

Figure 20 Left lateral view of the mandible from SK208, exhibiting three periapical lesions (black arrows).

Periapical lesions in the elite sample were mostly identified in males (40%), with females (25%) and subadults (4.3%) less often affected (Table 38). Significantly more lesions were identified in male (6.1%) than in female (1.7%) maxillae/mandibles (X^2= 28.892, df=2, p< 0.001).

Age	Not determined		Females		Males	
	TPR	CPR	TPR	CPR	TPR	CPR
	n/N (%)	n/N (%)	n/N (%)	n/N (%)	n/N (%)	n/N (%)
Subadults	1/329 (0.3)	1/23 (4.3)	-	-	-	-
Adult-ND	0/14 (0)	0/4 (0)	1/16 (6.3)	1/1 (100)	0/12 (0)	0/2 (0)
Adult	0/42 (0)	0/3 (0)	2/137 (1.5)	1/6 (16.7)	19/374 (5.1)	5/14 (35.7)
Mature	0/3 (0)	0/1 (0)	0/80 (0)	0/3 (0)	36/512 (7)	11/24 (45.8)
Senile	-	-	2/64 (3.1)	1/2 (50)	-	-
Total	1/388 (0.3)	1/31 (3.2)	5/297 (1.7)	3/12 (25)	55/898 (6.1)	16/40 (40)

Table 38 Prevalence rates of periapical lesions in the elite subsample. † TPR= true prevalence rate, CPR= crude prevalence rate n= number of teeth/elite individuals featuring periapical lesions, %=percentage of N, N= total number of teeth/ elite individuals assessable.

Periapical lesions were found to be age progressive, with more cases identified in senile individuals (50%), than mature (39.3%) or adult individuals (26.1%). True prevalence rates, however, indicate that mature individuals (6.1%) exhibited higher rates than adult (3.8%) or senile individuals (3.1%). Senile females (50%) and mature (45.8%) and adult (35.7%) males featured the highest crude prevalence rates. Most lesions were registered for mature males (7%), followed by adult males (5.1%) and senile females (3.1%).

In the non-elite sample, females (62.5%) outnumbered males (50%) and subadults (7.7%) in terms of crude prevalence of periapical lesions (Table 39). Even though with 8.1% and 7.1% fairly similar, females also had significantly more lesions than males (X^2= 17.162, df=2, p< 0.001).

Age	Not determined		Females		Males	
	TPR	CPR	TPR	CPR	TPR	CPR
	n/N (%)	n/N (%)	n/N (%)	n/N (%)	n/N (%)	n/N (%)
Subadults	1/339 (0.3)	1/13 (7.7)	-	-	-	-
Adult-ND	-	-	-	-	-	-
Adult	0/53 (0)	0/3 (0)	1/20 (5)	1/2 (50)	6/233 (2.6)	4/12 (33.3)
Mature	-	-	8/91 (8.8)	4/6 (66.7)	37/344 (10.8)	10/15 (66.7)
Senile	-	-	-	-	0/30 (0)	0/1 (0)
Total	1/392 (0.3)	1/16 (6.3)	9/111 (8.1)	5/8 (62.5)	43/607 (7.1)	14/28 (50)

Table 39 Prevalence rates of periapical lesions in the non-elite subsample. † TPR= true prevalence rate, CPR= crude prevalence rate n= number of teeth/non-elite individuals featuring periapical lesions, %=percentage of N, N= total number of teeth/ non-elite individuals assessable.

In relation to age, both crude and true prevalence rates increased with advancing age. As no data were available for senile individuals, most alterations were encountered for the mature category regardless of sex. Mature males displayed periapical lesions more often than females at a true prevalence rate (10.8% versus 8.8%).

6.3.1.6. Dental caries

Even though 46.3% of the studied individuals featured carious lesions on their dentition, true caries prevalence rates were much lower with 145 out of 1785 (8.1%) teeth featuring such lesions (Appendix 10). In the total sample, males featured both higher crude (64.7%) and true (11.9%) caries prevalence rates than females (55%, crude; 8%, true). Only 34.9% of the elite individuals featured signs of caries, whereby the true prevalence rate was 6.4%. A much higher crude (63.5%) and true (10.6%) caries prevalence was recorded for non-elite individuals (Figure 21).

Figure 21 Left lateral view of the mandible from SK101, displaying three carious lesions on the buccal surfaces of the 1st, 2nd and 3rd left molar (black arrows) as well as periodontitis (white arrow).

In the elite sample, males appear to have been more prone to developing caries (52.5% crude prevalence and 9% true prevalence rates), than females (41.7% and 4%) or subadults (9% and 2%, Table 40). Based on the Chi-square test the observed true caries prevalence in relation to sex was not statistically significant (X^2=5.399, df=2, p=0.067).

Age	Not determined		Females		Males	
	TPR	CPR	TPR	CPR	TPR	CPR
	n/N (%)	n/N (%)	n/N (%)	n/N (%)	n/N (%)	n/N (%)
Subadults	4/245 (2)	2/23 (9)	-	-	-	-
Adult-ND	0/14 (0)	0/4 (0)	2/7 (28.6)	1/1 (100)	0/10 (0)	0/2 (0)
Adult	3/42 (7.1)	1/3 (33.3)	4/108 (3.7)	3/6 (50)	25/264 (9.5)	8/14 (57.1)
Mature	-	0/1 (0)	0/38 (0)	0/3 (0)	31/348 (8.9)	13/24 (54.2)
Senile	-	-	1/24 (4.2)	1/2 (50)	-	-
Total	7/301 (2.3)	3/31 (9.7)	7/177 (4)	5/12 (41.7)	56/622 (9)	21/40 (52.5)

Table 40 Prevalence rates of dental caries in elite individuals. † TPR= true prevalence rate, CPR= crude prevalence rate n= number of teeth/elite individuals featuring caries, %=percentage of N, N= total number of teeth/ elite individuals assessable.

A similar pattern was observable for the crude prevalence rates of non-elite individuals (Table 41), with males (82.1%) displaying carious lesions more often than females (62.5%), yet, when examining the number of teeth affected, females (22.4%) outnumber males (16.4%, X^2=4.174, df=2, p=0.124).

Age	Not determined		Females		Males	
	TPR	CPR	TPR	CPR	TPR	CPR
	n/N (%)	n/N (%)	n/N (%)	n/N (%)	n/N (%)	n/N (%)
Subadults	4/266 (2)	4/13 (31)	-	-	-	-
Adult-ND	-	-	-	-	-	-
Adult	3/48 (6.3)	1/3 (33.3)	3/13 (23.1)	2/2 (100)	25/172 (14.5)	8/12 (66.7)
Mature	-	-	8/36 (22.2)	3/6 (50)	31/156 (19.9)	14/15 (93.3)
Senile	-	-	-	-	1/19 (5.3)	1/1 (100)
Total	7/314 (2.2)	5/16 (31.3)	11/49 (22.4)	5/8 (62.5)	57/347 (16.4)	23/28 (82.1)

Table 41 Prevalence rates of dental caries in non-elite individuals. † TPR= true prevalence rate, CPR= crude prevalence rate n= number of teeth/non-elite individuals featuring caries, %=percentage of N, N= total number of teeth/ non-elite individuals assessable.

In relation to age at death, elite individuals had higher frequencies as adults (52.2%) or senile individuals (50%), with mature individuals displaying the lowest rate (46.4%). Non-elite individuals displayed a gradual increase in caries prevalence with advancing age, whereby individuals aged 60 or more had the highest rates, i.e., 100% of senile individuals, mature individuals also had relatively high rates (81%) and adults exhibited the lowest rates (64.7%). True caries prevalence was slightly different. The elite subsample featured a true caries prevalence rate of 8% in adult and 7.7% in mature teeth as opposed to 4.2% in the senile dentition. Non-elite individuals exhibited the highest true caries prevalence rates in the mature age category (20.3%), with adults (13.3%) and senile individuals (5.3%) featuring lower rates.

Already when assessing the whole sample, it was evident that molars (n=92), particularly the first molar (n=40), was most commonly affected by caries. This was expected as it is the first permanent tooth to erupt, thus is exposed to the environment for longer and has more time to develop caries (Hillson, 1996). The same pattern was recorded for both elite and non-elite individuals with a true caries prevalence of 68% (48 out of 70) and 59% (44 out of 75) in molars. In terms of caries severity, most teeth either displayed superficial caries (40 out of 145) or a complete destruction of the tooth through caries (41 out of 145), superficial lesions reaching the dentin and more severe lesions forming a tooth canal were less common (32 out of 145 for both). Subadult individuals had either superficial caries or a perforating carious lesion, i.e., tooth canal. Lesion quantity was the highest in third molars, on average 1.47, followed by first (1.18) and second molars (1.15). In the elite subsample carious lesions were most often encountered in first molars (22 out of 70). With 25 out of 70 teeth featuring complete destruction due to caries and the other types of lesions spread out across the sample, elite individuals appeared to have been exposed to severe caries load. They featured most lesions in the second premolar (1.15) or second molar (1.12). Similar to elite individuals, in the non-elite subsample, molars, particularly the first and second molar were most commonly affected by caries. Yet, for non-elite individuals' superficial caries (24 out of 75) were most often recorded followed by lesions reaching the dentin (19 out of 75) and more severe lesions forming a tooth canal and complete destruction of the tooth due to caries (16 out of 75, respectively, Figure 22). Most lesions were registered in the first (1.4) or second molar (1.2).

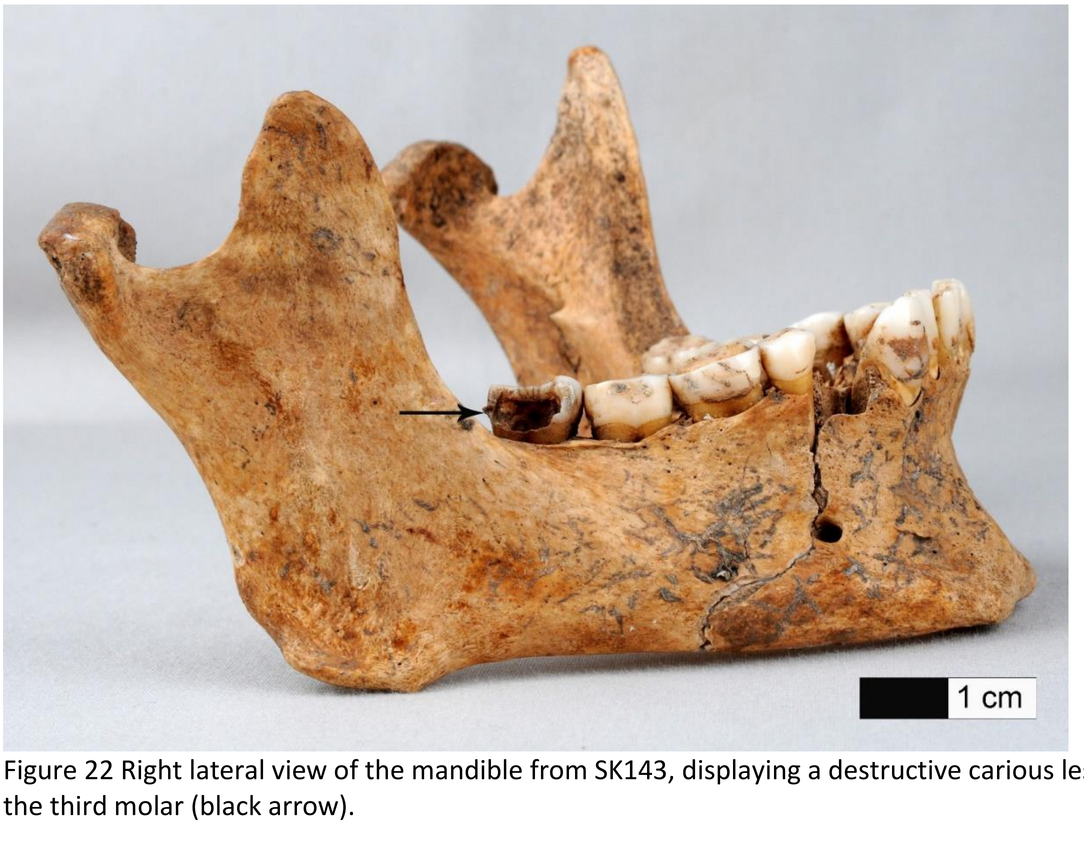

Figure 22 Right lateral view of the mandible from SK143, displaying a destructive carious lesion on the third molar (black arrow).

6.3.1.7. Linear enamel hypoplasia

Linear enamel hypoplasia (LEH) was only observed in 11.9% (16 out of 134) of the assessable individuals and in 2.7% (48 out of 1785) of the analysed dentition (Appendix 10). Both the crude

(9.6% for elites and 15.4% for non-elites) and true prevalence rate of LEH (i.e., 2.2% for elites and 3.4% for non-elites) was slightly higher in non-elite individuals.

In the elite subsample, females were found to display substantially higher crude (33.3%) and true prevalence rates (5.6%, Figure 23) than males (5% and 1.1%) and subadults (4.3% and 1.2%). The recorded differences in true LEH prevalence rates between the sexes were found to be statistically significant (X^2= 21.777, df=4, p< 0.001). The highest number of LEH lesions was found in adult females (9.3%), whereby mature (1.4%) and adult males (0.8%) and subadults (1.2%) exhibited substantially lower frequencies. In terms of time of LEH development, most lesions were estimated to have occurred between two and 2.8 years (12 lesions), nine LEH developed between three and 3.8 years and 7 lesions could be assigned to ages ranging from 1.5 years to 1.8 years and 4.2 years to 4.9 years, respectively.

Figure 23 Left antero-lateral view of the mandible from SK174, exhibiting several linear enamel hypoplasias on the left mandibular canine (black arrow).

Non-elite individuals displayed a fairly similar LEH frequency pattern, with the largest number of LEH defects recorded in females (25%). Although also males (14.3%) and subadults (8%) featured relatively similar frequencies. In terms of true prevalence rate, females (6.1%) outnumbered males (2%) significantly (X^2= 7.133, df=2, p=0.028), whereby also subadults (4%) featured higher rates of LEH in their dentition than males. In relation to age, adult dentition exhibited LEH most often (4.3%), especially adult males (8.3%), followed by mature individuals (2.1%), for which females demonstrated the highest true prevalence rates (8.3%). Most of the defects developed between three to five years of age (34 LEH), ten hypoplasias could be estimated to have occurred between two and 2.8 years. The earliest hypoplasia developed at 1.7 years and the latest at 5.6 years, one lesion each.

6.3.2. Skeletal abnormalities

Seventy-two percent of the assessed individuals (n=163) featured osseous abnormalities linked to a large variety of different pathological conditions (Figure 24). The highest crude prevalence rates were found for joint disease (n=124, Appendix 17), metabolic disorders (n=86, Appendix 18) and infectious disease (n=71, Appendix 19). Trauma (n=37, Appendix 20) was more common than congenital (n=17) or neoplastic conditions (n=13, Appendix 21). Seventy-five individuals featured skeletal abnormalities that could not be classified in the above-mentioned categories (see Appendix 22).

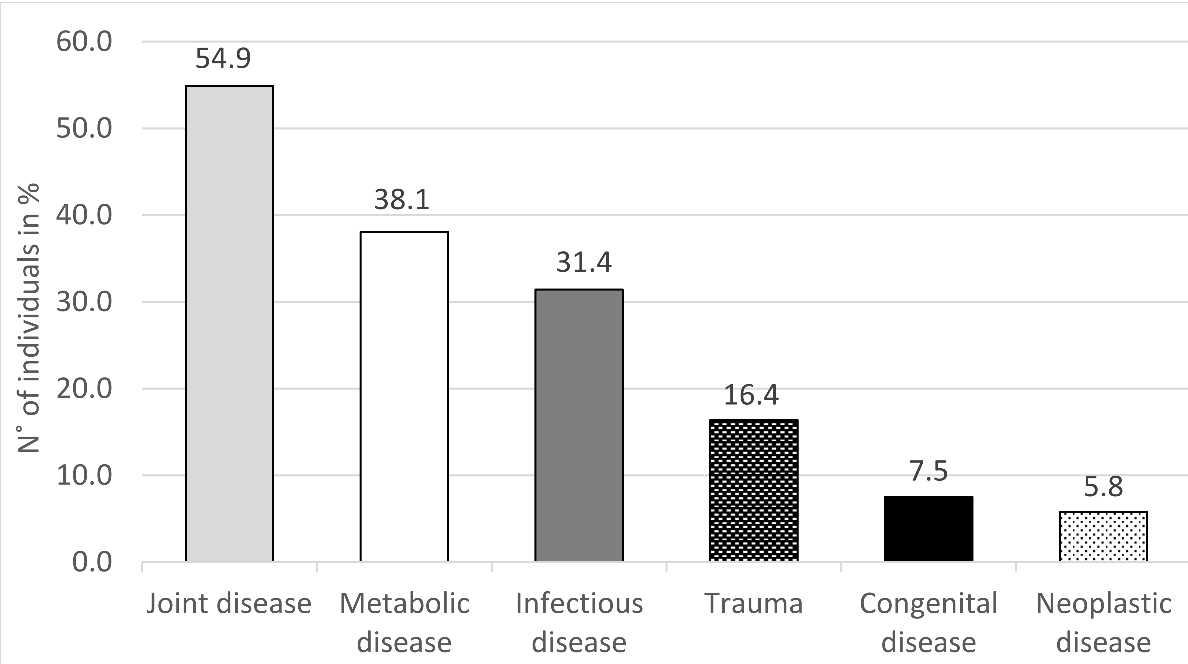

Figure 24 Crude frequency of pathological conditions at Säben-Sabiona.

The prevalence of the identified conditions was slightly lower in elite (71%) than non-elite individuals (74%), although not at a significant level (X^2=0.239, df=2, p=0.887). The distribution of the individual disorders varied between the two subsamples. Non-elite individuals featured higher rates of joint (58% versus 55%), metabolic (43% versus 37%) and infectious diseases (34% versus 29%), whereas elite individuals displayed signs of trauma (20% vs 11%), congenital (8% versus 6%) and neoplastic conditions (8% versus 3%) more commonly.

6.3.2.1. *Joint alterations*

Diseases affecting the joints included mainly osteoarthrosis (n=124), whereby the appendicular skeleton (n=119) was more commonly affected than the spine (n=86). Schmorl's nodes were registered in 55 individuals and 25 cases featured a defined erosive lesion on their joint surface that was identified as osteochondrosis dissecans. From an ethnic/archaeological perspective the individuals identified as Roman featured higher rates of osteoarthrosis (54.5% versus 44.4%), spondyloarthrosis (45.5% versus 22.2%) and Schmorl's nodes (27.3% versus 22.2%) than those with allochthonous grave goods. All more detailed skeletal palaeopathological analyses will focus on previously mentioned separation of the sample in elite and non-elite, rather than based on the ethnic differentiation using the recovered grave goods. Non-elite individuals displayed osteoarthrosis in appendicular skeleton (54.8% versus 49.6%), spondyloarthrosis (39.8% versus 36.1%) and Schmorl's nodes (26.9% versus 22.6%) more frequently than their elite counterparts. Osteochondrosis dissecans was found to be more common in elite individuals (9.7% versus 12.0%). Furthermore, there was one case of diffuse idiopathic skeletal hyperostosis (SK230) in the non-elite group, and one case of possible gout (SK151A) in the elite subsample.

6.3.2.1.1. Osteoarthrosis

A total number of 178 out of 226 (78.8%) individuals, all above 13 years of age, were available to be assessed for OA. Macroscopic signs for joint degeneration were found in 69.7% (n=124) of the assessed individuals. OA was most prevalent in the hip (70.2%) followed by the knee (62.9%), ankle (61.3%), wrist (57.3%) and elbow (50%), whereby the shoulder had the lowest rate (45.2%). Out of the available elite sample (N=102), 64.7% (n=66) had osteoarthrosis and out of the available non-elite sample (N=76), 67.1% (n=51) featured osteoarthritic alterations on their appendicular joints. A performed Chi-square test showed that the difference in prevalence of osteoarthrosis and between the two subsamples was not statistically significant (X^2=1.047, df=2, p=0.592).

In the elite group, more males (43 out of 51, 84.3%) than females (17 out of 22, 77.3%) and not determinable individuals (6 out of 29, 20.7%) featured signs of OA. Overall, osteoarthrosis increased in frequency with advancing age, i.e., 22.2% in juveniles (2 out of 9), 80% in adults (20 out of 25), 84.6% in mature (33 out of 39) and 100% in senile individuals (3 out of 3). This was also true when looking at the incidence rates of females (50% juvenile, 71.4% adult, 87.5% mature, 100% senile) yet for males, OA was found in 33.3% of juveniles, followed by 86.2% in mature, 93.3% in adult and 100% senile individuals. In order to assess potential patterns of activity for either sex, the prevalence of OA was also assessed at an anatomical level (Table 42).

Sex† (N)	Anatomical location † n (%)					
	Shoulder	Elbow	Wrist	Hip	Knee	Ankle
ND (29)	-	3 (10.3)	3 (10.3)	2 (6.9)	1 (3.4)	2 (6.9)
Female (22)	7 (31.8)	8 (36.4)	11 (50.0)	17 (77.3)	14 (63.6)	14 (64.6)
Male (51)	27 (52.9)	30 (58.8)	30 (58.8)	33 (64.7)	33 (64.7)	32 (62.7)
Total (102)	34 (33.3)	41 (40.2)	44 (43.1)	52 (51.0)	48 (47.1)	48 (47.1)

Table 42 Crude frequency of osteoarthrosis in relation to sex and anatomical location in the elite sample of Säben-Sabiona. † n= number of individuals with OA, %=percentage of N, N= total number of elite individuals.

On a joint level, the highest frequency of OA was observed in the hip (51%, Figure 25), whereby lower limb prevalence rates were generally larger than those of the upper limb, and the lowest frequency of OA was recorded for the shoulder (33.3%). As lower limb joints experience more strain, due to body weight loading, they display OA more commonly than upper limb joints. For most joints, i.e., shoulder, elbow, wrist and knee, males (52.9%, 58.8%, 58.8% and 64.7%) were more often affected than females (31.8%, 36.4%, 50% and 63.6%), however for the hip and the ankle joints, females had higher frequencies (77.3% versus 64.7% and 64.6% versus 62.7%).

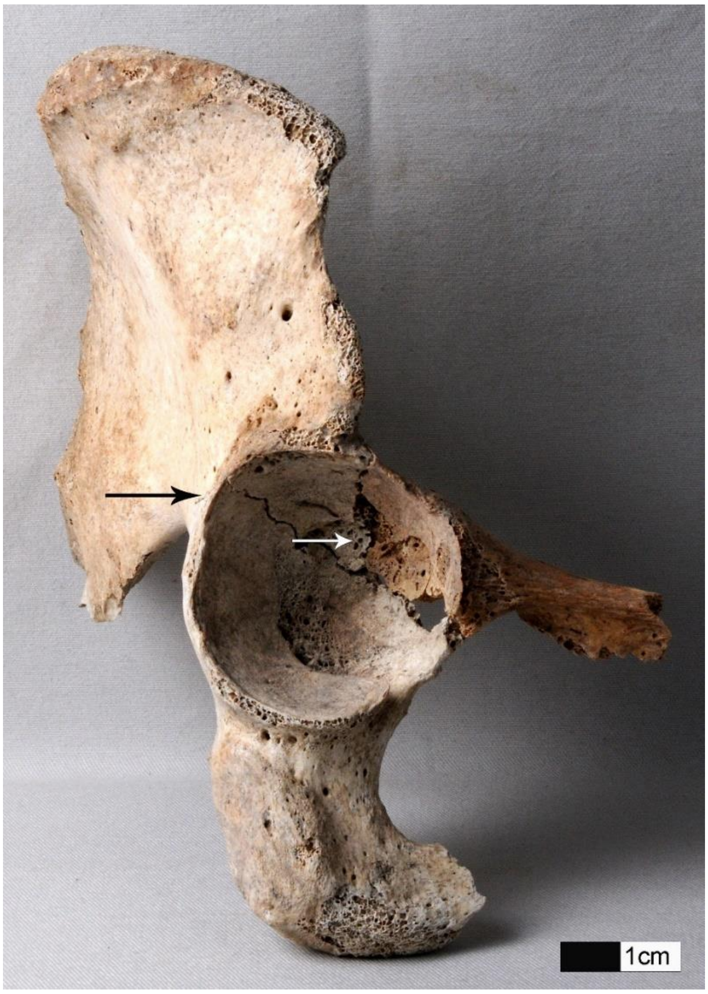

Figure 25 Right os coxae from SK118, displaying thinning of the acetabular rim (black arrow) as well as localised porosities on the semilunar surface as a marker of cartilage degeneration (white arrow).

Non-elite individuals displayed a similar pattern. With 83.7% (36 out of 43), males had OA more frequently than females (70.6%, 12 out of 17) or not determinable adults (18.8%, 3 out of 16). These prevalence rates were very similar to those of the elite sample, yet elite females had higher OA frequencies. Looking at overall OA distribution in relation to age, a gradual increase in OA frequency was observable for adults (63.6%, 14 out of 22), mature (81.5%, 22 out of 27) and senile individuals (100%, 1 out of 1), except that the prevalence of OA in juveniles (55.6%, 5 out of 9) exceeded that of adults. Females displayed the highest OA rates as juveniles (75%) followed by mature (71.4%) and adult (66.7%) individuals (no data were available for senile individuals). In the male sample, OA frequency increased more gradually from juvenile (66.7%) to adult (78.6%), mature (88.9%) and senile (100%) Also, for non-elite individuals the prevalence of OA was assessed in relation to sex and anatomical location (Table 43).

Sex† (N)	**Anatomical location † n (%)**					
	Shoulder	**Elbow**	**Wrist**	**Hip**	**Knee**	**Ankle**
ND (16)	1 (6.3)	1 (6.3)	1 (6.3)	1 (6.3)	1 (6.3)	1 (6.3)
Female (17)	3 (17.6)	4 (23.5)	4 (23.5)	6 (35.3)	3 (17.6)	5 (39.4)
Male (43)	18 (41.9)	16 (37.2)	22 (51.2)	28 (65.1)	25 (58.1)	29 (67.4)
Total (76)	22 (28.9)	21 (27.6)	27 (35.5)	35 (46.1)	29 (38.2)	35 (46.1)

Table 43 Crude frequency of osteoarthrosis in relation to sex and anatomical location in the non-elite sample of Säben-Sabiona. † n= number of individuals with OA, %=percentage of N, N= total number of non-elite individuals.

Non-elite individuals displayed the highest frequency of OA in the hip (46.1%, Figure 26) and ankle joints (46.1%). These are followed by the knees (38.2%), wrists (35.5%) and shoulder (28.9%), whereby the elbow (27.6%) had the lowest prevalence of OA in this subsample. Non-elite males always featured higher frequencies than non-elite females, regardless of joint location.

Figure 26 A) Right acetabulum from SK134, exhibiting initial osteophyte formation on the acetabular rim (black arrow), B) Right femur from SK134, featuring early degenerative modifications at the femoral head-neck border (red arrow), a strongly pronounced iliofemoral ligament (white arrow) and *M. iliopsoas* insertion site (black arrow) is also visible.

To gain more thorough insights into potential activity patterns, also the severity of OA was assessed in relation to sex, age, and anatomical location. On average, the examined elite individuals featured mild to moderate OA scores (1.5). The male and female (n=56) subsamples were assessed for differences in lesion severity between sex and age. Both sexes had an average OA score of 1.5 (1.5, elites; 1.6, non-elites). The severity of bone deterioration worsened with increasing age. Elite juveniles featured the lowest levels of OA (1.0), whereas mature individuals featured an intermediate score (1.6) and adults and senile individuals (both 1.7) had substantially higher mean scores. In relation to anatomical location, the hips (2.1) were most severely affected, followed by the elbow (1.9), shoulder (1.8) and knee (1.6), whereby the wrist and ankle had the lowest scores (both 1.3). Elite males always had higher scores than elite females (1.9 versus 1.6, shoulder; 1.9 versus 1.8, elbow; 1.3 versus 1.2, wrist; 2.1 for both, hip; 1.7 versus 1.4, knee; 1.3 versus 1.2, ankle). Severity differences in laterality were observed for all joints apart from the wrist, whereby for the shoulder (2.2 versus 1.8), elbow (1.9 versus 1.8, Figure 27) and hip (2.2 versus 2.1), the right side featured more severe alterations. For the knee (1.8 versus 1.6) and ankle (1.6 versus 1.4) the left side was more severely affected.

Figure 27 A) Superior view of the right radius from SK121D, displaying eburnation on the articular facet (black arrow), B) Right lateral view of the right radius from SK121D, exhibiting pronounced osteophyte formation on the radial head (black arrow), also visible *M. biceps brachii* (white arrow) and interosseous membrane insertion site (red arrow).

With an average OA score of 1.6, the joints of non-elite individuals appear to have been affected more severely than those of elite individuals (t=0.153, df=114, p=0.878). In contrast, non-elite females (1.3) tended to have slightly lower OA scores than elite females (1.5), whereas the average OA score of non-elite males (1.6) was higher than that of elite males (1.5). Regardless of sex, OA severity increased with advancing age. Same as elite individuals, also the non-elite sample featured the highest OA scores in the hips (2.0, Figure 26), followed by the elbow (1.9, Figure 28). Yet, wrists (1.6) and shoulders (1.5) were more severely affected than knees (1.3) or ankles (1.1). For all joints apart from the wrists, i.e., 1.7 for females and 1.5 for males, males had higher scores than females.

In terms of severity in relation to laterality, for all joints apart from the knee and ankle, both sides of the body had identical scores. For knee joints, the left side had a slightly higher score (1.9) than the right (1.8) and for ankle joints, higher scores were registered for right ankles (1.5) than left ankles (1.4).

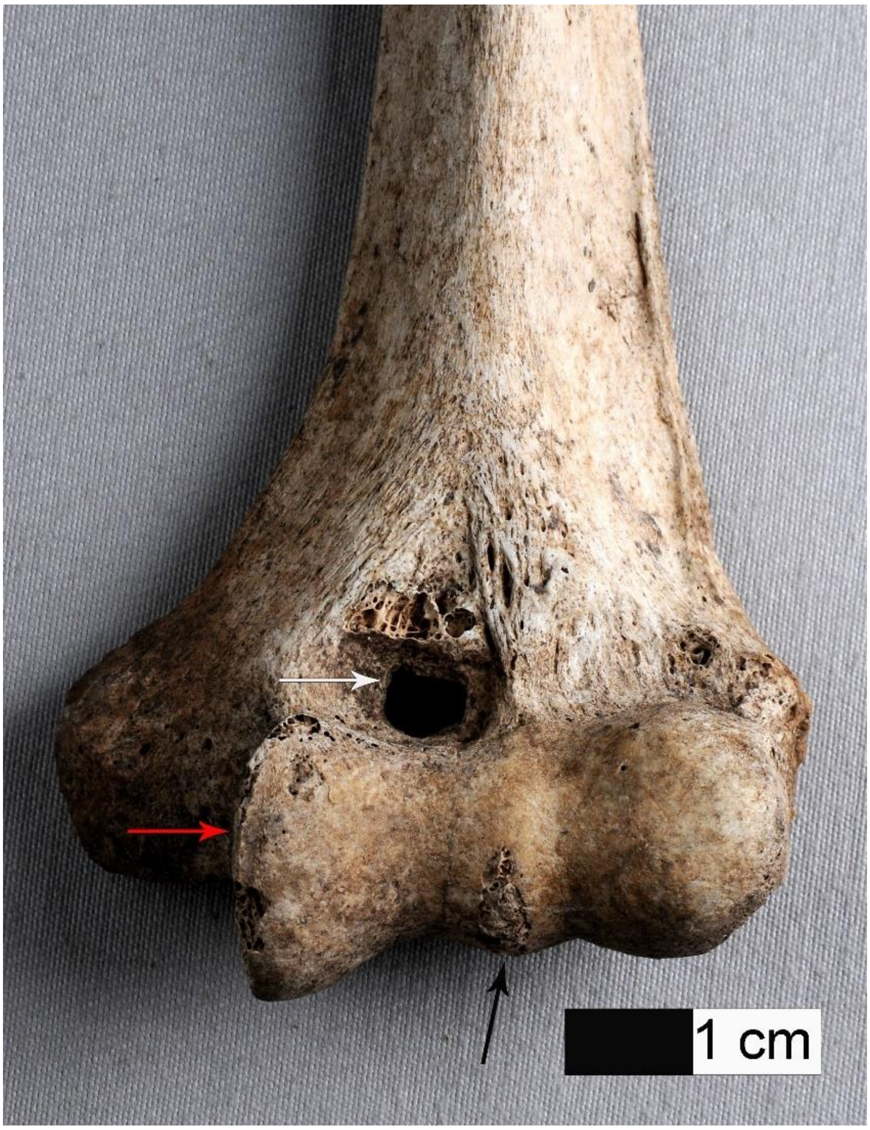

Figure 28 Anterior view of the distal epiphysis of the left humerus from SK149, exhibiting osteophyte formation on the border of the articular surface (red arrow) as well as porosity on the trochlea (black arrow); this individual also features a septal aperture (white arrow), which is a non-metric trait.

6.3.2.1.2. Spondyloarthrosis and Schmorl's nodes

Degenerative lesions on the vertebrae linked to osteoarthrosis were found in 47.7% (n=85) of the assessed adult and juvenile sample (N=178). Forty-seven percent of the assessed elite individuals (48 out of 102) and 49% of the non-elite individuals (37 out of 76) had spondyloarthrosis (X^2=1.273, df=2, p=0.529).

For both, elite (Table 44) and non-elite individuals (Table 45), males were more often affected by spondyloarthrosis than females. Elite and non-elite males (64.7% and 65.1%) had almost the same frequency of spondyloarthrosis, whereas non-elite females (52.9%) showed signs of osteoarthritic changes more frequently than elite females (40.9%).

Age	Females			Males			ND			Total		
	n	N	%	n	N	%	n	N	%	n	N	%
Juvenile	0	2	0.0	1	3	33.3	0	4	0.0	1	9	11.1
Adult-ND	1	3	33.3	1	3	33.3	4	20	20.0	6	26	23.1
Adult	3	7	42.9	9	15	60.0	1	3	33.3	13	25	52.0
Mature	4	8	50.0	21	29	72.4	1	2	50.0	26	39	66.7
Senile	1	2	50.0	1	1	100.0	0	0	0.0	2	3	66.7
Total	9	22	40.9	33	51	64.7	6	29	20.7	48	102	47.1

Table 44 Crude prevalence rates of spondyloarthrosis in relation to sex and age of the elite subsample. † n= number of individuals featuring spondyloarthrosis, %= percentage of N, N= total number of elite individuals.

Age	Females			Males			ND			Total		
	n	N	%	n	N	%	n	N	%	n	N	%
Juvenile	1	4	25.0	0	3	0.0	0	2	0.0	1	9	11.1
Adult-ND	0	3	0.0	2	7	28.6	0	7	0.0	2	17	11.8
Adult	3	3	100.0	8	14	57.1	0	5	0.0	11	22	50.0
Mature	5	7	71.4	17	18	94.4	0	2	0.0	22	27	81.5
Senile	0	0	0.0	1	1	100.0	0	0	0.0	1	1	100.0
Total	9	17	52.9	28	43	65.1	0	16	0.0	37	76	48.7

Table 45 Crude prevalence rates of spondyloarthrosis in relation to sex and age of the non-elite subsample. † n= number of individuals featuring spondyloarthrosis, %= percentage of N, N= total number of non-elite individuals.

The frequency of spondyloarthrosis increased with progressing age for both subsamples, with non-elite mature (81.5%) and senile individuals (100%) featuring the highest rates. This pattern was consistent for both sexes of the elite sample and for non-elite males, yet non-elite females exhibited osteoarthrosis in their spine most frequently as adults (100%).

In terms of prevalence distribution within the spine, for both subsamples the thoracic section featured most incidents of spondyloarthrosis, i.e., 41.2% of elites and 36.8% of non-elites, followed by the lumbar region (37.3% of elite and 32.9% of non-elite individuals, Table 46 and 47). Possibly linked to the slightly higher rates of spondyloarthrosis in the lumbar region, elite individuals (28.4%) featured such alterations more commonly on S1 than non-elite individuals (23.7%). In the cervical vertebrae, spondyloarthrosis was more frequently registered in the non-elite sample (30.3%, Figure 29a) than the elite sample (26.5%, Figure 29b).

† (N)	Anatomical location † n (%)			
	Cervical	Thoracic	Lumbar	Sacrum
Females (22)	6 (27.3)	8 (36.4)	7 (31.8)	6 (27.3)
Males (51)	19 (37.3)	31 (60.8)	28 (54.9)	23 (45.1)
ND (29)	2 (6.9)	3 (10.3)	3 (10.3)	0 (0)
Total (102)	27 (26.5)	42 (41.2)	38 (37.3)	29 (28.4)

Table 46 Crude prevalence rate of spondyloarthrosis in relation to sex and location of elite individuals. † n= number of individuals featuring spondyloarthrosis, %= percentage of N, N= total number of elite individuals.

† (N)	Anatomical location † n (%)			
	Cervical	Thoracic	Lumbar	Sacrum
Females (17)	3 (17.6)	7 (41.2)	7 (41.2)	3 (17.6)
Males (43)	20 (46.5)	21 (48.8)	18 (41.9)	15 (34.9)
ND (16)	0 (0)	0 (0)	0 (0)	0 (0)
Total (76)	23 (30.3)	28 (36.8)	25 (32.9)	18 (23.7)

Table 47 Crude prevalence rate of spondyloarthrosis in relation to sex and location of non-elite individuals. † n= number of individuals featuring spondyloarthrosis, %= percentage of N, N= total number of non-elite individuals.

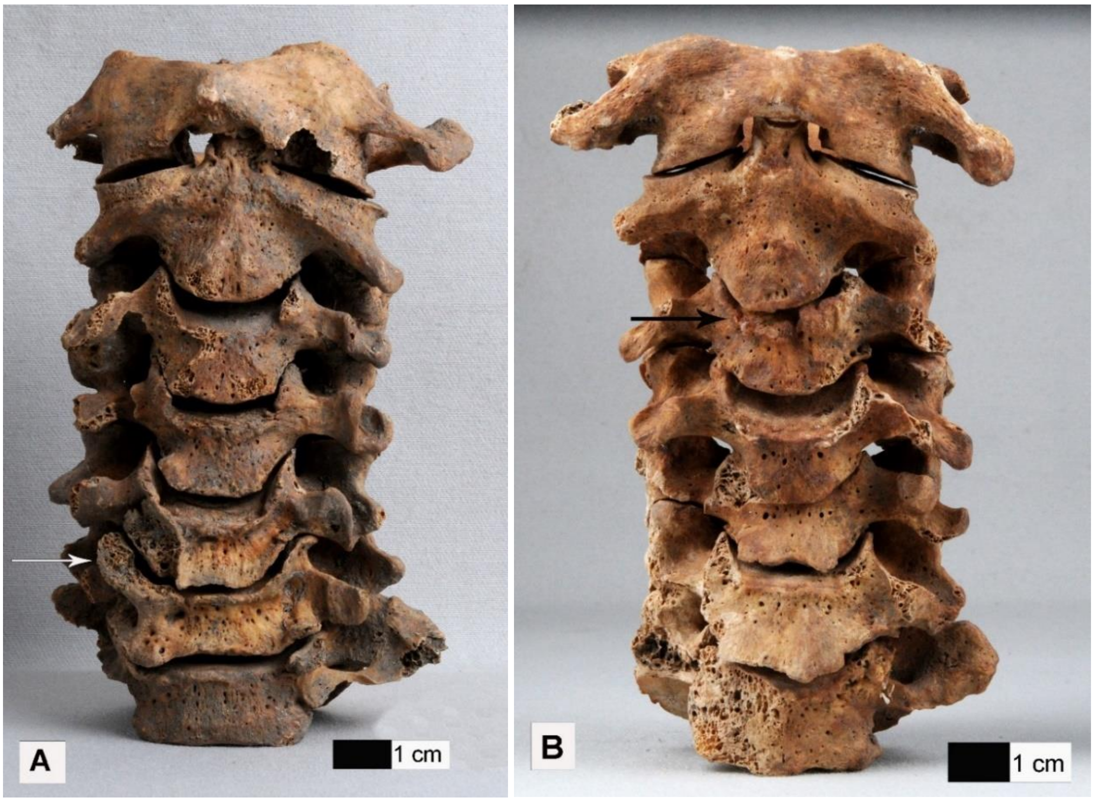

Figure 29 Osteophytic lipping (black and white arrows) A) Anterior view of C1 to C7 from SK86; B) Anterior view of C1 to C7 from SK162.

Regardless of location on the spine, elite and non-elite males had higher rates of spondyloarthrosis than females. In the elite sample, the differences between the sexes were more pronounced in the lumbar (31.8% for females and 54.9% for males) and thoracic region

(36.4% for females and 60.8% for males), whereby non-elite males and females almost displayed identical or fairly similar frequencies at these locations, i.e., 41.9% and 41.2% for lumbar vertebrae and 48.8% and 41.2% for thoracic vertebrae.

Also, the severity of spondyloarthrosis was assessed, whereby the elite group (2.0) displayed slightly more severe alterations on their vertebrae than the non-elite group (1.89). This difference between the subsamples was particularly evident when looking at the severity of spondylarthrosis in relation to the sexes. Elite females had an average spondyloarthrosis score of 1.8 and elite males of 2.35, whereas the mean spondyloarthrosis score of non-elite females was 1.7 and 1.78 for non-elite males. A gradual increase in severity with advancing age was recorded for both subgroups. Only for elite males, mature individuals (2.3) featured a slightly higher score than senile individuals (2).

The thoracic vertebrae exhibited the most severe alterations in both groups, i.e., average score for each was 2.1 (Figure 30), followed by cervical vertebrae (2.35 for elites and 2.1 for non-elites, Figure 29) and lumbar vertebrae (1.95 for elites and 2 for non-elites, Figure 31). With 1.8 for elite individuals and 1.5 for non-elite individuals, the sacrum had the lowest scores. For the most part, males featured more severe lesions, yet, in the elite sample, elite females (2.5) had higher scores than elite males (2.2) for the cervical spine. In the non-elite sample, females (2.1) displayed slightly more severe alterations in their thoracic vertebrae than their male (2) counterparts and for the lumbar spine, both sexes had identical scores (2).

Figure 30 A) Left lateral view of T1 to T6 from SK185, exhibiting fusion of T4 and T5 (arrow); B) Right lateral view of T7 to T11 from SK212, featuring pronounced osteophyte formation with osteophytic bridging between T7 and T8 (arrow).

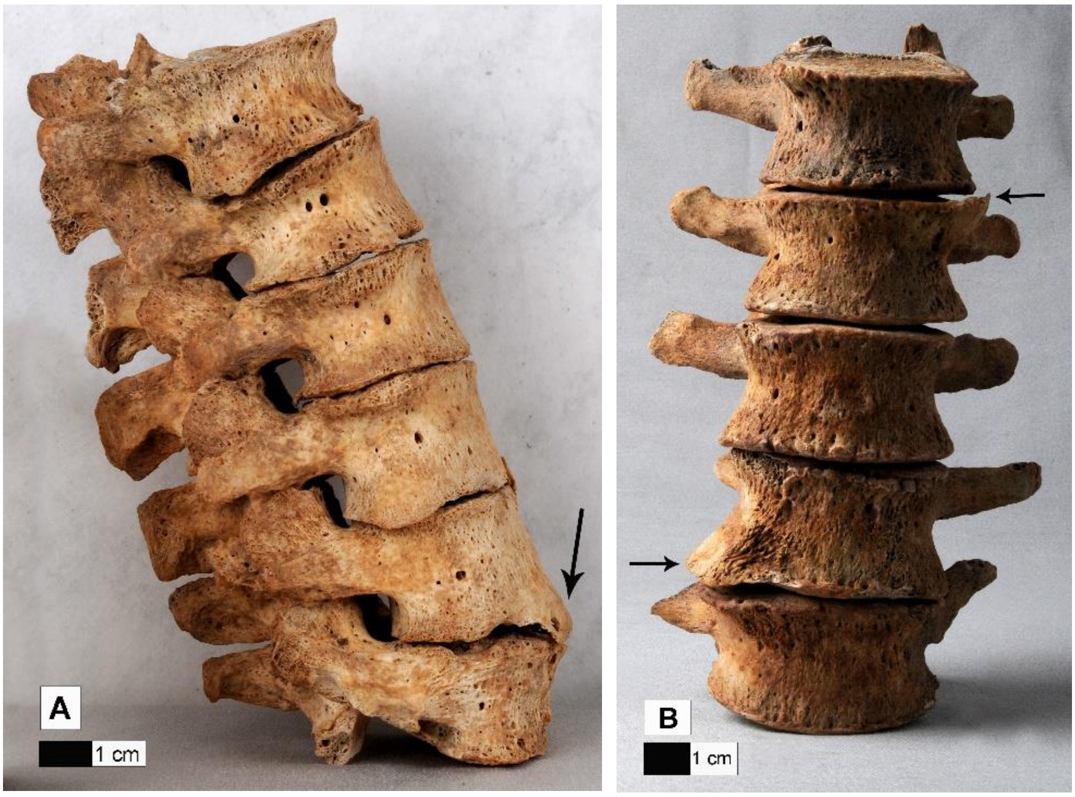

Figure 31 A) Right lateral view of L1 to 6 from SK185 (accessory lumbar vertebrae), exhibiting osteophytic bridging between L5 and L6; B) Anterior view of L1 to L5 from SK170A, featuring osteophyte formation.

The total frequency of Schmorl's nodes in the adult and juvenile sample was 30.9% (n=55). Schmorl's nodes were recorded for 30 elite individuals and 25 non-elite individuals. These were not statistically significant (X^2=1.405, df=2, p=0.495)

Males (43.6%) were generally more often affected than females (25.6%), the same pattern was also found when separating the sample into elite (43.1% of males versus 18.2% of females, Table 48) and non-elite individuals (44.2% of males and 35.3% of females, Table 49). Yet, the differences between the sexes were less substantial in the non-elite sample.

	Females			**Males**			**ND**			**Total**		
Age	n	N	%	n	N	%	n	N	%	n	N	%
Juvenile	1	2	50.0	0	3	0.0	0	4	0.0	1	9	11.1
Adult-ND	1	3	33.3	0	3	0.0	2	20	10.0	3	26	11.5
Adult	0	7	0.0	5	15	33.3	1	3	33.3	6	25	24.0
Mature	1	8	12.5	16	29	55.2	1	2	50.0	18	39	46.2
Senile	1	2	50.0	1	1	100.0	0	0	0.0	2	3	66.7
Total	4	22	18.2	22	51	43.1	4	29	13.8	30	102	29.4

Table 48 Crude prevalence rates of Schmorl's nodes in relation to sex and age in the elite subsample. † n= number of elite individuals featuring Schmorl's nodes, %= percentage of N, N= total number of elite individuals.

	Females			**Males**			**ND**			**Total**		
Age	n	N	%	n	N	%	n	N	%	n	N	%
Juvenile	0	4	0.0	2	3	66.7	0	2	0.0	2	9	22.2
Adult-ND	0	3	0.0	2	7	28.6	0	7	0.0	2	17	11.8
Adult	2	3	66.7	5	14	35.7	0	5	0.0	7	22	31.8
Mature	4	7	57.1	9	18	50.0	0	2	0.0	13	27	48.1
Senile	0	0	0.0	1	1	100.0	0	0	0.0	1	1	100.0
Total	6	17	35.3	19	43	44.2	0	16	0.0	25	76	32.9

Table 49 Crude prevalence rates of Schmorl's nodes in relation to sex and age in the non-elite subsample. † n= number of non-elite individuals featuring Schmorl's nodes, %= percentage of N, N= total number of non-elite individuals.

In both subpopulations Schmorl's nodes became more prevalent with increasing age. In the elite group, females showed the highest frequencies in the senile but also in the juvenile age category (50.0% respectively), whereas for males Schmorl's nodes were registered more commonly in the senile age category (100%). For non-elite individuals, females displayed the highest Schmorl's node prevalence as adults (66.7%) and males as seniles (100%). Yet, the non-elite male juvenile (66.7%) frequency of these lesions was found to be higher than that of adult (35.7%) or mature males (50.0%).

The distribution of Schmorl's nodes across the spinal segments was somewhat similar to that of spondyloarthrosis with thoracic vertebrae (24.7%, Figure 32a) and lumbar vertebrae (14.6%, Figure 32b) being most often involved.

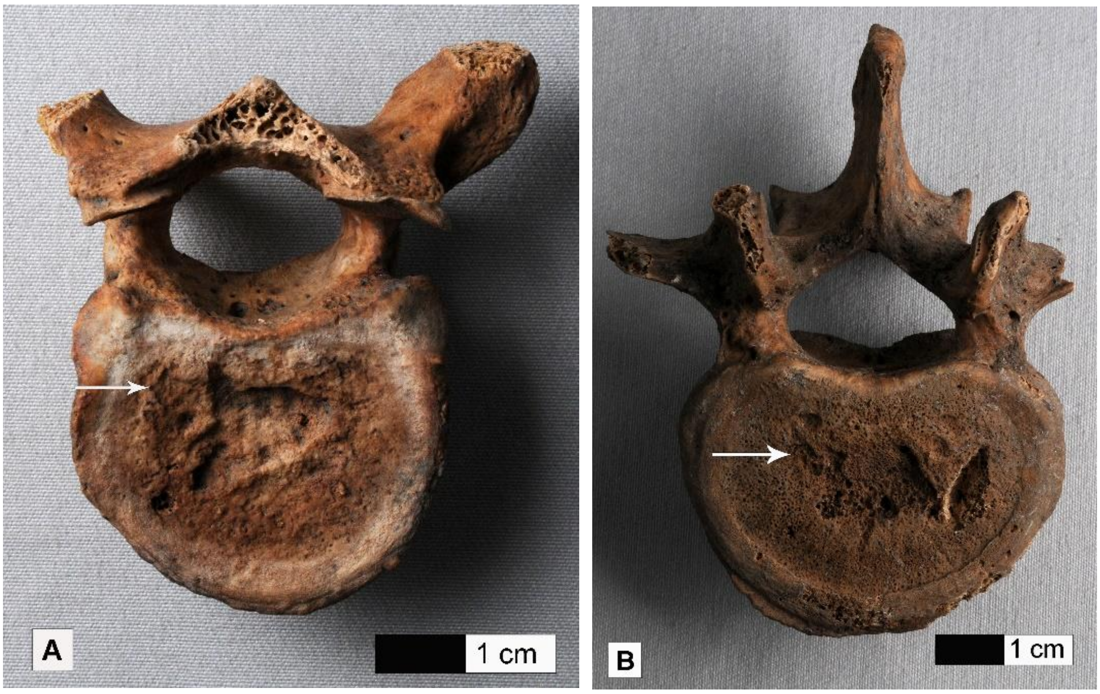

Figure 32 Schmorl's nodes A) Inferior view of T8 from SK162; B) Superior view of L3 from SK116-125B.

The overall differences between elite and non-elite individuals were rather low (Table 50 and 51). Elite individuals were found to display Schmorl's nodes slightly more frequently on the lumbar spine (14.7% versus 14.5%), whereas more non-elite individuals featured such lesions on the cervical vertebrae (2.6% versus 1.0%). Especially for the thoracic and lumbar vertebrae, males were more frequently affected than females, regardless of group. In the elite group, males always outnumbered females and in the non-elite group, females exhibited Schmorl's nodes on their cervical vertebrae (5.9% versus 2.3%) and S1 (5.9% versus 4.7%) more commonly than males.

† (N)	Anatomical location † n (%)			
	Cervical	**Thoracic**	**Lumbar**	**Sacrum**
Females (22)	0 (0)	3 (13.6)	2 (9.1)	0 (0)
Males (51)	1 (2.0)	19 (37.3)	12 (23.5)	3 (5.9)
ND (29)	0 (0)	3 (10.3)	1 (3.4)	0 (0)
Total (102)	1 (1.0)	25 (24.5)	15 (14.7)	3 (2.9)

Table 50 Crude prevalence rates of Schmorl's nodes in relation to sex and location in the elite sample. † n= number of elite individuals featuring Schmorl's nodes, %= percentage of N, N= total number of elite individuals.

† (N)	Anatomical location † n (%)			
	Cervical	Thoracic	Lumbar	Sacrum
Females (17)	1 (5.9)	2 (11.8)	2 (11.8)	1 (5.9)
Males (43)	1 (2.3)	17 (39.5)	9 (20.9)	2 (4.7)
ND (16)	0 (0)	0 (0)	0 (0)	0 (0)
Total (76)	2 (2.6)	19 (25.0)	11 (14.5)	3 (3.9)

Table 51 Crude prevalence rates of Schmorl's nodes in relation to sex and location in the non-elite sample. † n= number of non-elite individuals featuring Schmorl's nodes, %= percentage of N, N= total number of non-elite individuals.

6.3.2.1.3. Osteochondrosis dissecans

Osteochondrosis dissecans was observed in 25 individuals (11.1%), whereby most of these were classified as elite individuals (n=16). In the elite group, males (17.6%) exhibited osteochondrosis dissecans more often than females (13.6%) and in the non-elite subsample this pattern was reversed, i.e., 17.6% females and 14.0% males. For both groups, the prevalence of this condition differed substantially across the age groups. In the elite sample the highest frequencies of osteochondrosis dissecans were recorded for senile females (50.0%), male juveniles (33.3%) and adults (26.7%). On the contrary, for non-elite individuals, this condition was most prominent in female (50.0%) and male (33.3%) juveniles.

When assessing the true prevalence rate, 51 articular surfaces featured lesions associated with osteochondrosis dissecans, most of which were identified on the right side for both groups (23 versus 15 individuals for elites and 7 versus 6 individuals for non-elites). The articular facets of the vertebrae (n=15), phalanges (n=10) and tibiae (n=10) displayed most lesions. Elite individuals featured most lesions on their vertebral facets (n=13), followed by the joint surfaces of the tibiae (n=9, Figure 33). Non-elite individuals had most lesions on their phalangeal joint surfaces (n=6).

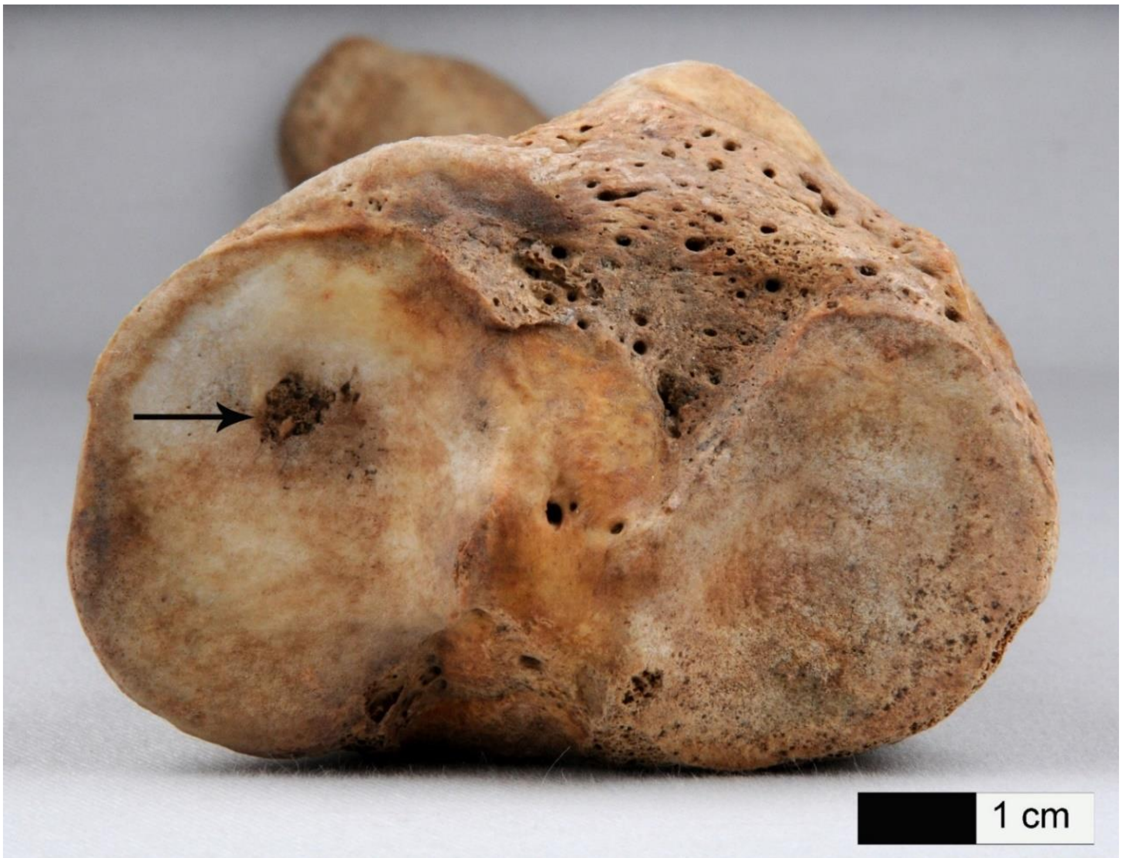

Figure 33 Superior view of the right tibia from SK162, exhibiting osteochondrosis dissecans on the medial condylar articular facet.

6.3.2.2. Entheseal changes

Irregularities on entheses were observed in 113 out of 178 (63.5%) of the adult and juvenile individuals (Appendix 23), which is 63.7% of the elite subgroup (65 out of 102) and 63.2% of the non-elite subgroup (48 out of 76). In the elite sample, females (81.8%) presented higher overall frequencies than males (78.4%) and not determinable individuals (24.1%, Table 52).

Age Group	ND			Females			Males			Total		
	n	N	%	n	N	%	n	N	%	n	N	%
Juvenile (13-19)	1	4	25.0	2	2	100.0	1	3	33.3	4	9	44.4
Adult-ND (>20)	5	20	25.0	2	3	66.7	1	3	33.3	8	26	30.8
Adult (20-40)	0	3	0.0	6	7	85.7	14	15	93.3	20	25	80.0
Mature (40-60)	1	2	50.0	6	8	75.0	24	29	82.8	31	39	79.5
Senile (>60)	0	0	0.0	2	2	100.0	0	1	0.0	2	3	66.7
Total	7	29	24.1	18	22	81.8	40	51	78.4	65	102	63.7

Table 52 Crude prevalence rates of entheseal changes in relation to sex and age in the elite subsample. † n= number of elite individuals featuring entheseal changes, %= percentage of N, N= total number of elite individuals.

The prevalence of EC was found to increase with age. When examining the frequency of EC in relation to sex and age, the data showed that in the elite female sample, the highest rate of EC was registered for individuals over 60 years of age and juveniles (both had 100%), followed by adults (85.7%) and mature females (75.0%). For individuals, who died as juveniles, a much higher frequency would be expected if they had reached adulthood. In the elite male group, the highest incidence rate was reported for adults (93.3%), followed by mature males (82.8%) and juveniles presented the lowest prevalence (33.3%).

With an overall EC frequency of 76.7% in males and 64.7% in females, non-elite individuals exhibited a slightly different pattern (Table 53).

Age Group	ND			Females			Males			Total		
	n	N	%	n	N	%	n	N	%	n	N	%
Juvenile (13-19)	1	2	50.0	2	4	50.0	2	3	66.7	5	9	55.6
Adult-ND (>20)	2	7	28.6	2	3	66.7	6	7	85.7	10	17	58.8
Adult (20-40)	0	5	0.0	3	3	100.0	9	14	64.3	12	22	54.5
Mature (40-60)	1	2	50.0	4	7	57.1	15	18	83.3	20	27	74.1
Senile (>60)	0	0	0.0	0	0	0.0	1	1	100.0	1	1	100.0
Total	4	16	25.0	11	17	64.7	33	43	76.7	48	76	63.2

Table 53 Crude prevalence rates of entheseal changes in relation to sex and age in the non-elite subsample. † n= number of elite individuals featuring entheseal changes, %= percentage of N, N= total number of non-elite individuals.

Senile individuals featured the highest prevalence of EC (100%), followed by mature individuals (74.1%), juveniles (55.6%) and adults (54.5%). A similar distribution was also recorded for non-elite males, i.e., 100% senile, 83.3% mature, 66.7% juvenile and 64.3% adults. Non-elite females on the other hand exhibited a slightly different pattern. Most EC were recorded for adults (100%), followed by mature females (57.1%) and juvenile females had the lowest frequency (50.0%).

In relation to the anatomical location of the observed EC, both subgroups featured the highest frequencies in the hip joints, whereby the non-elite group was more commonly affected, i.e., 51.0% for elite (Table 54) and 52.6% in non-elite individuals (Table 55).

Sex† (N)	Anatomical location † n (%)					
	Shoulder	Elbow	Wrist	Hip	Knee	Ankle
ND (29)	1 (3.4)	3 (10.3)	1 (3.4)	4 (13.8)	1 (3.4)	3 (10.3)
Female (22)	12 (54.5)	9 (40.9)	4 (18.2)	16 (72.7)	9 (40.9)	15 (68.2)
Male (51)	30 (58.8)	30 (58.8)	22 (43.1)	32 (62.7)	25 (49.0)	32 (62.7)
Total (102)	43 (42.2)	42 (41.2)	27 (26.5)	52 (51.0)	35 (34.3)	50 (49.0)

Table 54 Crude frequency of entheseal changes in the elite sample of Säben-Sabiona. † n= number of elite individuals featuring EC, %= percentage of N, N= total number of elite individuals.

After the hip, the elite group showed increased frequencies in the ankle joint (49%), followed by the shoulder (42.2%), elbow (41.2%) and knee (34.3%), with the lowest rate in the wrist. A closer examination of sex related prevalence differences on a joint level, showed that elite females outnumbered elite males in the incidence rate of EC at the hips (72.7% versus 62.7%) and ankles (68.2% versus 62.7%).

For both sexes, the *M. pectoralis major* enthesis was most often affected (49% males, 40.9% females), followed by the *M. deltoideus* (47.1% males, 36.4% females), *M. biceps brachii* (47.1% males, 31.8% females) and *M. subscapularis* (47.1% males, 36.4% females) insertion site.

In non-elite individuals, the highest frequency of EC following the hip joint, was registered in the shoulder (44.7%), followed by the ankle (43.4%), knee (36.8%) and elbow (32.9%). Similar as for elite individuals, the lowest prevalence was found in the wrist. As opposed to elite individuals, in the non-elite group, the frequencies of EC in males always exceeded that of females, regardless of the type of joint.

Sex† (N)	**Anatomical location † n (%)**					
	Shoulder	**Elbow**	**Wrist**	**Hip**	**Knee**	**Ankle**
ND (16)	3 (18.8)	3 (18.8)	-	3 (18.8)	1 (6.3)	2 (12.5)
Female (17)	6 (35.3)	5 (29.4)	4 (23.5)	8 (47.1)	4 (23.5)	5 (29.4)
Male (43)	25 (58.1)	17 (39.5)	13 (30.2)	29 (67.4)	23 (53.5)	26 (60.5)
Total (76)	34 (44.7)	25 (32.9)	17 (22.4)	40 (52.6)	28 (36.8)	33 (43.4)

Table 55 Crude frequency of entheseal changes in the non-elite sample of Säben-Sabiona. † n= number of non-elite individuals featuring EC, %= percentage of N, N= total number of non-elite individuals.

The frequency of individual entheseal involvement for non-elite individuals was different to that of the elite sample, with divergent rates for both sexes. In males, the *Lig. costoclavicularis* (39.5%) and *M. deltoideus* insertion sites (39.5%) on the clavicle were most commonly affected, followed by the *M. deltoideus* enthesis on the humerus (34.9%), the *M. biceps brachii* enthesis on the radius (34.9%) and the *M. pectoralis* insertion site on the humerus (32.6%). On the contrary, females exhibited entheseal changes most frequently on the insertion sites of the *M. pectoralis major* on the humerus (35.3%), *M. deltoideus* on the humerus (35.3%) and *M. pronator teres* on the radius (35.3%).

Looking at the whole population, the average entheseal score was mild to moderate (2.1), whereby both subgroups displayed the same level of severity (t=0, df=94, p=1). Elite and non-elite males and females showed small differences in their severity scores, whereby females had less pronounced EC scores than males. Elite males had the same score as non-elite males, both 2.1, and elite females (1.9) featured a higher score than non-elite females (1.7). In relation to age, severity scores increased with advancing age for both sexes in non-elites, and for males in elite individuals. For elite females the highest EC scores were recorded for mature females (2.1), followed by senile and juvenile females (1.9 each), with female adults displaying the lowest score (1.7).

In terms of severity of entheseal alterations in relation to muscle location, elite individuals had the most severe changes in the hip joints, i.e., 2.2 (Table 56). They also featured substantial changes in their musculature surrounding their shoulder (2.15) and ankle joint (2.15), as well as the knee (2). Lower scores were reported for the elbow (1.55) and wrist (1.65).

Sex	**Anatomical location**					
	Shoulder	**Elbow**	**Wrist**	**Hip**	**Knee**	**Ankle**
Female	2	1.4	1.4	2	1.7	2.1
Male	2.3	1.7	1.9	2.4	2.3	2.2
Average	2.15	1.55	1.65	2.2	2	2.15

Table 56 Average severity scores of entheseal changes in relation to joint location in elite individuals.

In the elite subsample, males always displayed more severe alterations than females regardless of anatomical region. Muscles of the shoulder (2.2 versus 2.1) displayed more severe alterations on the right side, and those associated with the wrist (2.1 versus 2), the hip (2.4 versus 2.2) and knee (2.4 versus 2.3) had higher entheseal scores on the left. Left and right elbows and ankles were equally severe affected. Both sexes featured the highest upper limb EC scores in the *M. pectoralis major* insertion site of the humerus (2.3 for females and 2.6 for males, Figure 34).

Figure 34 Anterior view of the right (inferior) and left (superior) humerus from SK147, exhibiting pronounced *M. pectoralis major* (black arrow) and *M. deltoideus* insertion sites (white arrow).

In elite females this score was followed by that of the *M. biceps brachii* insertion site on the radius (2.1), the *Lig. costoclavicularis* insertion site on the clavicle (1.9) and the *M. subscapularis insertion* site on the humerus (1.9). Elite males had most elevated EC scores for the *Lig. costoclavicularis* (2.4) and *M. deltoideus* (2.1) insertion site on the clavicle, the *M. deltoideus* insertion site on the humerus (2.1) and *M. biceps brachii* insertion site on the radius (2.1). In the lower limbs, the insertion site of the *M. gluteus maximus* on the femur had the highest scores for both sexes (2.5 for females and 2.8 for males). Females also had more prominent EC scores for the *M. soleus* insertion site on the tibia (2.3), which was greater than that of males (2.2), the *M. triceps surae* insertion site on the calcaneus (2.2, Figure 35), as well as for the muscles attaching to the linea aspera on the femur (2.1), i.e., *M. vastus medialis, M. adductor magnus* and *M. adductor longus*.

Figure 35 Posterior view of the right and left calcaneus from SK76, displaying prominent *M. triceps surae* insertion sites.

Males on the other hand, exhibited more pronounced alterations on the entheses of the *M. vastus medialis, M. adductor magnus* and *M. adductor longus* attaching to the femur (2.7), the *M. semimembranosus*, *M. semitendinosus* and *M. biceps femoris* insertion site on the *os coxae* (2.6), as well as the *M. iliopsoas* insertion site on the femur (2.4) and the *M. triceps surae* insertion site on the calcaneus (2.4). A full list of the average severity scores for each muscle is attached in appendix 23. A detailed outline and discussion of the movements carried out by each of these muscles can be found in the discussion section.

In the non-elite subsample, the highest scores were reported for the muscles associated with the hip (2.2) and the shoulder (2.2), followed by the knee (2.15) and ankle (2.15) and with lower scores in the elbow (1.85) and wrist (1.45, Table 57).

Sex	**Anatomical location**					
	Shoulder	**Elbow**	**Wrist**	**Hip**	**Knee**	**Ankle**
Female	2.3	1.9	1.4	2.1	2.1	2
Male	2.1	1.8	1.5	2.3	2.2	2.3
Average	2.2	1.85	1.45	2.2	2.15	2.15

Table 57 Average severity scores of entheseal changes in relation to joint location in non-elite individuals.

For the musculature of the wrist, hip, knee and ankle, non-elite males featured higher scores than females. However, for the shoulder and elbow, non-elite females displayed more severe alterations. Discrepancies were also registered in terms of laterality, whereby right shoulder musculature (2.2 versus 2.1), left wrist (2.3 versus 2.1) and ankle (2.4 versus 2.2) muscles displayed imbalanced entheseal scores. Entheseal scores for elbow, hip and knee muscles were identical. Prominent differences between the two sexes were also observed when examining individual muscles. In the upper limbs, non-elite females had more elevated scores in the *M. pectoralis major* insertion site of the humerus (2.7), this score was also higher than that of males at this site (2.4), M. *biceps brachii* insertion site on the radius (2.2) and the *M. subscapularis* insertion site of the humerus (2). Furthermore, females exhibited higher scores than males in the following entheses: *M. supraspinatus* and *M. infraspinatus* on the humerus (1.8 versus 1.6) and the muscles attaching to the medial epicondyle (1.6 versus 1.3). Females also featured elevated scores for the *M. deltoideus* on the humerus (1.7) and clavicle (1.6), and *M. pronator teres* on the radius (1.5). The most prominent entheses of non-elite males belonged to the *M. pectoralis major* (2.4) and *M. subscapularis* on the humerus (2.3), *M. biceps brachii* on the radius (2.3) *M. deltoideus* on the humerus (2.1, Figure 36) and the *Lig. costoclavicularis* on the clavicle (2).

Figure 36 A) Superior view of the left and right humerus from SK86, exhibiting prominent osteolytic and osteophytic alterations at the *M. subscapularis* insertion site; B) Anterior view of the left (superior) and right (inferior) humerus from SK86, featuring *M. pectoralis* major (white arrow) and *M. deltoideus* entheseal changes (black arrow); C) Anterior view of the left and right radius from SK86, displaying extensive modifications at the *M. biceps brachii* enthesis.

In the lower limbs, both sexes displayed most severe changes in the *M. gluteus maximus* enthesis on the femur (2.6 for females and 2.7 for males, Figure 37). Non-elite females also had more elevated scores for *M. quadriceps femoris* enthesis on the patella (2.3), the *M. soleus* enthesis on the tibia (2.3), the *M. triceps surae* enthesis on the calcaneus (2), the *M. iliopsoas* (2) and the *M. gluteus medius* (2) enthesis on the femur. Whereby the entheses of the *M. gluteus medius* and M. *quadriceps femoris* were more severely affected in females than males, i.e., 2 versus 1.7 and 2.3 versus 1.9. In males, the entheses attaching to the linea aspera of the femur, i.e., *M. vastus medialis*, *M. adductor magnus*, *M. adductor longus* (2.5), the insertion sites of the *M. soleus* on the tibia (2.5), those of the *M. semimembranosus*, *M. semitendinosus* and *M. biceps femoris* on the *os coxae* (2.4), the enthesis of the *M. iliopsoas* on the femur (2.2) and that of the *M. triceps* surae on the calcaneus (2.2) had the most prominent scores.

Figure 37 Posterior view of the left (A) and right (B) femur from SK45, showing entheseal changes at the *M. gluteus maximus* insertion site (black arrows) and along the linea aspera (white arrows).

6.3.2.3. Correlation between OA and EC

Out of the examined individuals, 59.5% (106 out of 178) exhibited both OA and EC, whereby sex and age at death estimations were available for 83% (88 out of 106) of those. This corresponds to 53 elite individuals and 35 non-elite individuals. As with most skeletal conditions, also OA and EC tend to increase in severity with age, whereby abnormal patterns, e.g., as seen in juveniles, will be addressed more thoroughly in the discussion. Sex has been found to be a factor in the prevalence of these alterations. Correlation analyses between OA and EC were firstly performed on the mean average scores and then by correcting for age and sex to gain a more accurate representation of the relatedness of these two lesion types. By using the average OA and EC scores recorded for each individual, both elite (r_s= 0.501, p<.001) and non-elite individuals (r_s= 0.658, p<.001) exhibited a positive correlation between OA and EC.

With the assumption that the severity of OA increases with advancing age a Spearman's rank correlation test was carried out on the whole sample (r_s= 0.314, p=0.001) as well as both subgroups (Figure 38, Figure 39). The observed mutual increase between age and OA severity was positive and statistically significant for non-elite individuals (r_s =0.599, p<.001) but not for elite individuals (r_s =0.164, p=0.120).

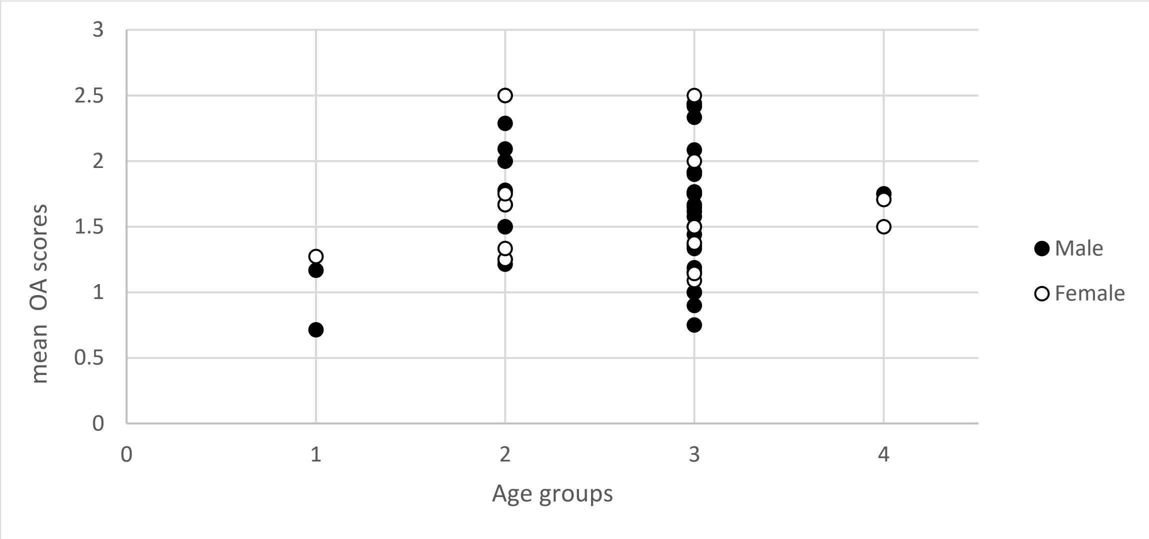

Figure 38 Relationship between mean OA scores and age (1= juvenile, 2=adult, 3=mature, 4=senile) and sex in elite individuals.

Elite individuals presented a fairly varied distribution of OA severity levels across the age groups (Figure 38). Whereas for males OA severity appeared to increase with age, females exhibited higher OA scores as adults, (1.7) than in older ages, i.e., 1.5 for mature and 1.6 for senile.

With a highly positive correlation between OA and age, non-elite individuals featured an increase in OA severity with advancing age (Figure 39). For both sexes, juveniles had the lowest scores, i.e., 0.5 for females and 0.75 for males, and mature or senile individuals displayed the highest scores, i.e., 2.2 for mature females and 1.9 and 2.3 for mature and senile males.

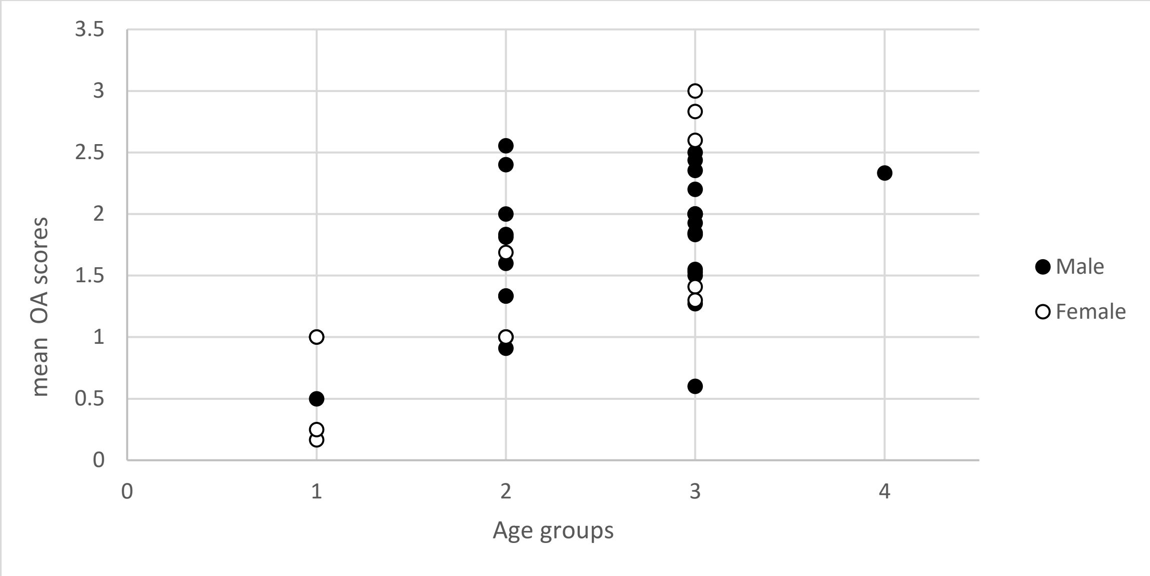

Figure 39 Relationship between mean OA scores and age (1= juvenile, 2=adult, 3=mature, 4=senile) and sex in non-elite individuals.

Also, for entheseal changes the correlation with age was assessed. In the total sample, a congruent pattern between EC severity and age was observable, which was confirmed by the performed Spearman's rank test showing a positive correlation between the two variables (r_s= 0.362, p<0.001). The elite subsample featured a slightly lower correlation between age and entheseal severity (Figure 40), yet not at a statistically significant level (r_s =0.160, p=0.127).

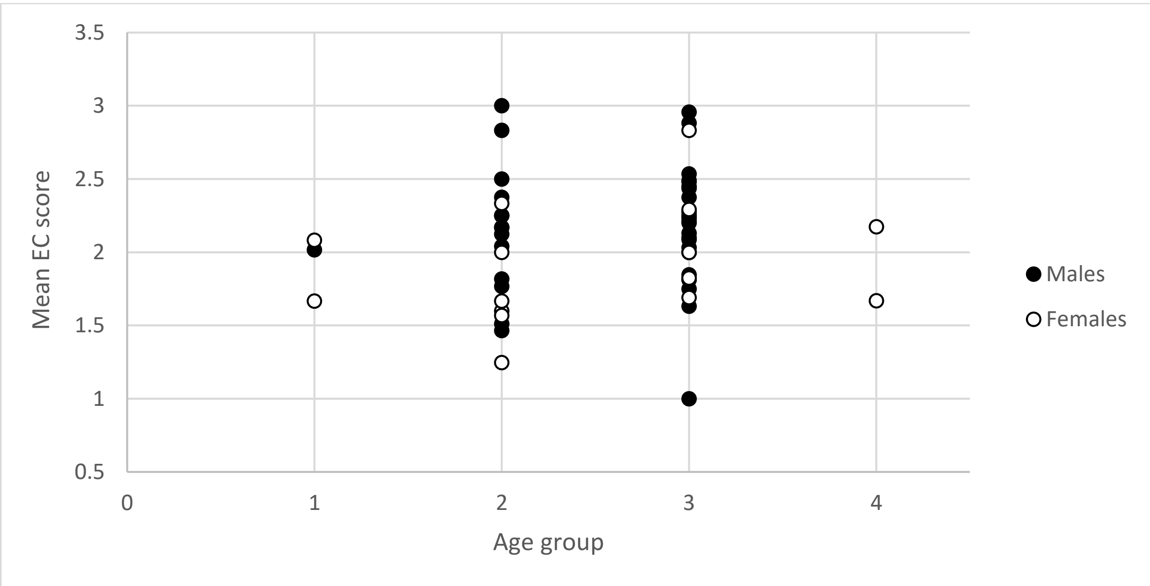

Figure 40 Relationship between mean EC scores and age (1= juvenile, 2=adult, 3=mature, 4=senile) and sex in elite individuals.

The low correlation between EC and age in the elite subsample was also reflected in the mean scores estimated for each age group in relation to sex. Males exhibited lower scores as juveniles (2) and identical mean EC scores for the adult and mature age category (2.2). In the female elite subsample, those individuals aged as adults (1.7) had the lowest mean score followed by juveniles and senile individuals (1.9, respectively), whereby mature females featured most severe entheseal alterations (2.1).

For the non-elite subsample, a more positive correlation between age and entheseal lesions was registered (Figure 41), which was also found to be statistically significant (r_s =0.536, p<.001).

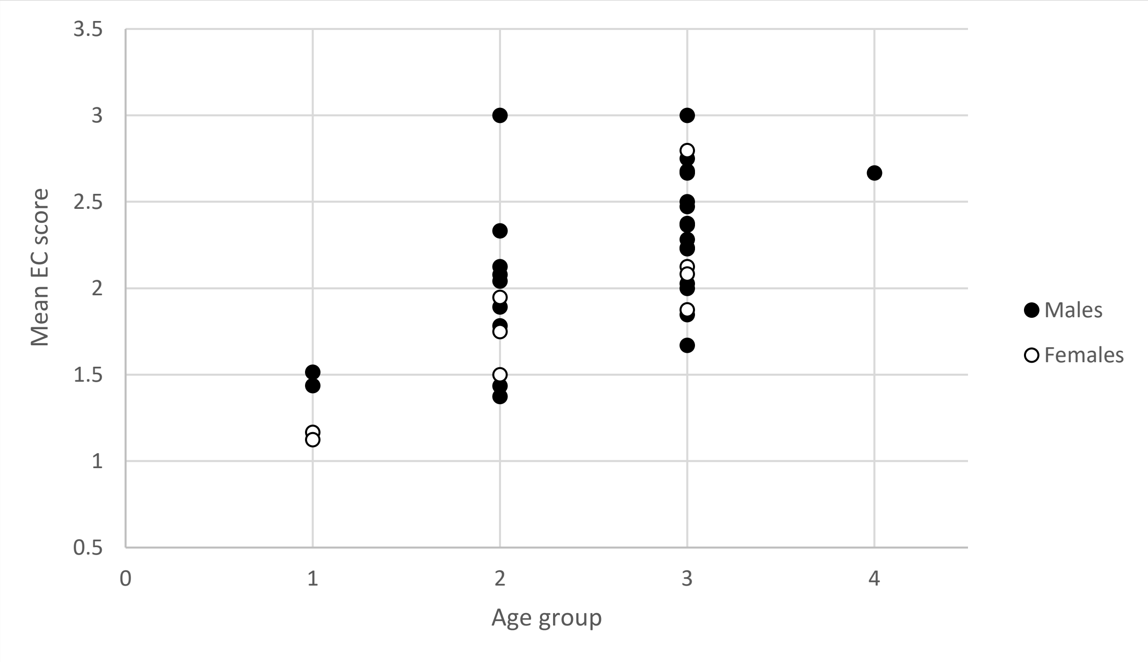

Figure 41 Relationship between mean EC scores and age (1= juvenile, 2=adult, 3=mature, 4=senile) and sex in non-elite individuals.

In both sexes of non-elite individuals, a gradual increase in EC severity was noted with advancing age. Whereby juveniles had the lowest scores, i.e., 1.2 for females and 1.5 for males, and mature and senile individuals had the highest scores, i.e., 2.2 for mature females, 2.3 for mature males and 2.7 for senile males.

When testing the correlation between the two lesions and sex, a negative relationship between sex and OA (elite individuals r_s=-0.188, p=0.178; non-elite individuals r_s= -0.152, p=0.383) and EC (elite individuals r_s= -0.336, p= 0.014; non-elite individuals r_s= -0.152, p=0.383) was found. Thus, sex did not appear to have had a major impact on the observed severity of OA and EC.

As both conditions were found to correlate with age, the OA and EC data of both the elite and non-elite subsample were corrected for age and tested again for correlation. Based on the residual data, obtained through a regression analysis, a positive relationship between OA and EC of statistical significance (r_s= 0.495, p=0.001) was found. The correlation between OA and EC did not differ greatly when splitting the sample into elite (r_s=0.441, p<.001) and non-elite individuals (r_s=0.529, p<.001).

When looking at the total sample, entheseal mean scores were generally higher than OA mean scores (Figure 42), which was expected as the scoring systems employed differed slightly (c.f. methods).

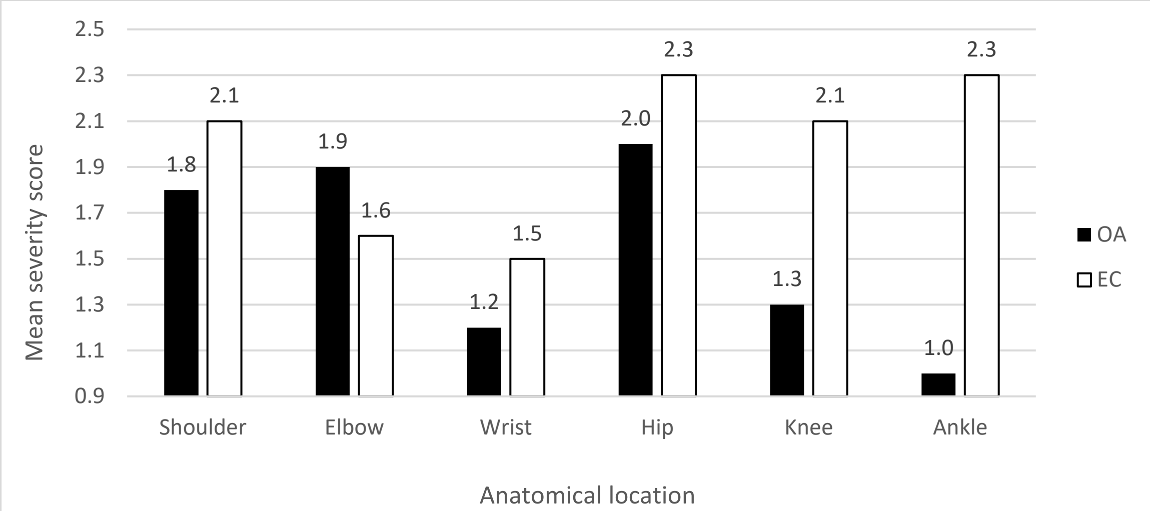

Figure 42 Mean severity scores of OA and EC of the total sample in relation to anatomical location (n=88).

Total mean scores of the shoulder, wrist and hip were very similar for both alterations. Elbow, knee, and ankle scores, on the other hand, differed quite substantially. Statistical testing on the whole sample found that all joints showed a positive correlation between their OA and EC severity scores (Table 58). The elbow, hip, and knee displayed the highest positive correlations, which were of statistical significance.

Anatomical region	**Elite † (n)**	**Non-elite † (n)**	**Total sample † (n)**
Shoulder	r_s= 0.364, p= 0.048 (30)	r_s= 0.047, p= 0.843 (20)	r_s= 0.243, p= 0.090 (50)
Elbow	r_s= 0.204, p= 0.24 (35)	r_s= 0.635, p= 0.015 (14)	r_s= 0.324, p= 0.023 (49)
Wrist	r_s= 0.084, p= 0.716 (21)	r_s= 0.0648, p= 0.017 (13)	r_s= 0.305, p= 0.079 (34)
Hip	r_s= 0.181, p= 0.245 (43)	r_s= 0.516, p= 0.007 (26)	r_s= 0.329, p= 0.006 (69)
Knee	r_s= 0.353, p= 0.051(31)	r_s= 0.592, p= 0.005 (21)	r_s= 0.464, p<0.001 (52)
Ankle	r_s= 0.048, p= 0.755 (44)	r_s= 0.3, p= 0.226 (18)	r_s= 0.127, p= 0.326 (62)

Table 58 OA and EC correlations based on anatomical location † n= number of individuals available for analysis.

In the elite subsample, the highest positive correlations were found in the shoulder, knee, elbow, and hip, however only for the shoulder the registered scores were statistically significant. Non-elite individuals featured as slightly different pattern with the elbow, knee and ankle exhibiting the highest correlations. Non-elite elbow, hip, knee and wrist correlations between OA and EC were found to be statistically significant.

6.3.2.4. *Metabolic and infectious disease*

Thirty-eight percent of the analysed population had lesions associated with metabolic disorders (n=86). With a prevalence of 43%, non-elite individuals featured more skeletal alterations linked to metabolic conditions than individuals belonging to the elite subcategory (36.8%). For both subsamples, subadults displayed a higher lesion rate than adult individuals, i.e., 37.5% versus 36.6% in elites and 53.8% versus 38.8% for non-elites. The most commonly registered conditions were *cribra cranii* (42 out of 226, 18.6%), followed by *cribra orbitalia* (38 out of 226, 16.8%), *femoralis* (35 out of 226, 15.5%) and *palatinii* (26 out of 226, 11.5%). Lower frequencies were found for *cribra humeralis* (9 out of 226, 4%). *Cribra cranii* was found to be most prevalent in the elite subsample (20.3% versus 17.2%, Figure 43), whereas *cribra orbitalia* was more common in non-elite individuals (20.4% versus 15%, Figure 44). The differences in *cribra cranii* (X^2=0.954, df=2, p=0.743) and *cribra orbitalia* (X^2=1.501, df=2, p=0.472) prevalence between the two groups was not found to be statistically significant.

Figure 43 Cranial cribra on a parietal fragment from SK153A.

Figure 44 *Cribra orbitalia* on the left orbit of SK143.

The frequencies of femoral cribra were identical for both subgroups, i.e., 16%, respectively (Figure 45), and *cribra palatinii* was recorded more often in the non-elite subsample (14% versus 10%, Figure 46).

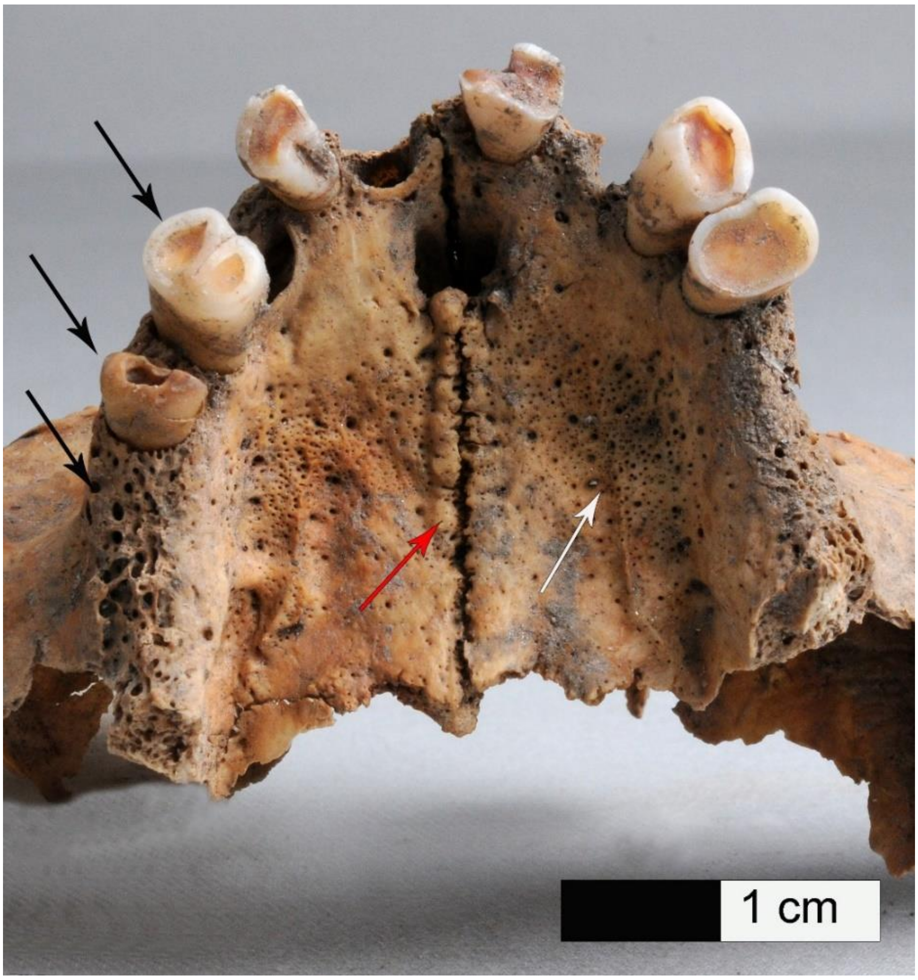

Figure 45 Inferior view of the maxilla from SK86, featuring *cribra palatinii* (white arrow), a palatine torus (red arrow), pronounced dental wear, antemortem tooth loss and caries (black arrows).

Figure 46 Right and left femur of SK52, displaying femoral cribra (black arrow) as well as entheseal alterations at the *M. iliopsoas* insertion site (white arrow).

When assessing sex and age-related differences in the occurrence of these metabolic conditions (Table 59 and 60), for *cribra cranii* and *cribra orbitalia*, it was found that the former was observed more frequently in adults and juveniles of both subgroups, i.e., 26.5% versus 2.9% in elite individuals and 18.4% versus 11.8% in non-elite individuals, whereas for the latter, subadults below the age of 13 years had a higher prevalence, 17.1% versus 14.3% in the elite group and 41.2% versus 15.8% in the non-elite group. *Cribra femoralis* was also registered more commonly in subadults (25.7% versus 12.2% in elites and 17.6% versus 15.8% in non-elites) and *cribra palatinii* was more frequent in adults (10.2% versus 8.6% in elite individuals and 14.5% versus 11.8% in non-elite individuals).

Age and sex		Cribra cranii			Cribra orbitalia			Cribra femoralis			Cribra palatinii		
		n	N	%	n	N	%	n	N	%	n	N	%
Adults and Juveniles	Females	4	22	18.2	5	22	22.7	5	22	22.7	0	22	0.0
	Males	21	51	41.2	8	51	15.7	6	51	11.8	10	51	19.6
	ND	1	25	4.0	1	25	4.0	1	25	4.0	0	25	0.0
Perinatal, Infant I and II		1	35	2.9	6	35	17.1	9	35	25.7	3	35	8.6
Total		27	133	20.3	20	133	15.0	21	133	15.8	13	133	10

Table 59 Crude prevalence rates of *cribra cranii, orbitalia, femoralis* and *palatinii* in relation to sex and age in the elite sample. † n= number of elite individuals featuring cribrotic lesions, %= percentage of N, N= total number of elite individuals.

Cribra cranii was more prevalent in elite (41.2%) and non-elite males (25.6%) than females (18.2% for elites and 17.6 for non-elites) and subadults under the age of 13 years (2.9% in the elite sample and 11.8% in the non-elite sample). C*ribra orbitalia* was registered most commonly in non-elite subadults below the age of 13 (41.2%), followed by non-elite males (25.6%), elite females (22.7%) and elite subadults under 13 years (17.1%). Elite males (15.7%) and non-elite females (5.9%) had the lowest frequencies of cribra orbitalia.

Age and sex		Cribra cranii			Cribra orbitalia			Cribra femoralis			Cribra palatinii		
		n	N	%	n	N	%	n	N	%	n	N	%
Adults and Juveniles	Females	3	17	17.6	1	17	5.9	4	17	23.5	1	17	5.9
	Males	11	43	25.6	11	43	25.6	7	43	16.3	10	43	23.3
	ND	0	16	0.0	0	16	0.0	1	16	6.3	0	16	0.0
Perinatal, Infant I and II		2	17	11.8	7	17	41.2	3	17	17.6	2	17	11.8
Total		16	93	17.2	19	93	20.4	15	93	16.1	13	93	14.0

Table 60 Crude prevalence rates of *cribra cranii, orbitalia, femoralis* and *palatinii* in relation to sex and age in the non-elite sample. † n= number of non-elite individuals featuring cribrotic lesions, %= percentage of N, N= total number of non-elite individuals.

In the elite subgroup, *cribra femoralis* was registered most often in subadults under the age of 13 years (25.7%), followed by females (22.7%), whereby males had the lowest rate (11.8%). A different pattern was found in the non-elite subsample, where females were most often affected (23.5%) and subadults under 13 years of age (17.6%) and males (16.3%) had such lesions less often. The incidence rate of *cribra palatinii* was highest in males for both the elite (19.6%) as well as the non-elite group (23.3%).

The three perinatal individuals, two in the non-elite and one elite group, did not display any signs of cribra.

Three individuals exhibited lesions associated with scurvy (SK89A, SK123, SK171) and one individual featured skeletal alterations possibly linked to rickets (SK103C). SK89A featured porotic lesions on the greater wings of the sphenoid, SK123 had *cribra orbitalia* and *humeralis*, as well as porotic lesions on the maxilla, mandible, sphenoid and endocranial surface, SK171 exhibited porosity at the mandible, on long bone diaphyses and the scapula, SK103C displayed enlargement distal epiphysis and lateral curvature of the femur and tibia. An additional three individuals (SK106, SK107A and SK146) exhibit inconclusive lesions, potentially indicating a cooccurrence of both scurvy and rickets, which is not uncommon in malnourished individuals (Ives, 2018; Schattmann et al., 2016).

All individuals, apart from SK89A, featuring lesions associated with scurvy and/or rickets belonged to the elite subsample.

In the infectious diseases' category (n=89) most individuals featured periostitis and one featured osteomyelitis (Figure 47). Although very similar in frequency, periostitis was slightly more common in non-elite individuals (29 out of 93, 31.2%) than elite individuals (39 out of 133, 29.3%). Yet, these findings were not statistically significant (X^2=6.637, df=3, p=0.084). Osteomyelitis was exclusively found in one non-elite individual. Periosteal bone reactions were mostly observed on the tibia (n=47), followed by the femur (n=21) and in only one individual also the fibula was affected. The affected bones belonged mainly to males (n=41), whereby females (n=12), undetermined adults (n=6) and subadults (n=10) had lower prevalence rates of periostitis.

Figure 47 A) Lateral view of the right tibia from SK70A, displaying extensive new bone formation identified as periostitis; B) Anterior view of the distal shaft/epiphysis of the femora from SK147, exhibiting periosteal inflammation; C) Antemortem trauma and associated osteomyelitis infection on the distal diaphysis of the left tibia from SK126 (posterior view).

6.3.2.5. *Trauma*

As outlined in the publication by Tumler et al. (2021), the crude trauma prevalence in Säben-Sabiona was 16.4% (37 out of 226), with 122 out of 8044 bones featuring a total number of 141 lesions. Tumler et al. (2021) discovered substantially higher rates of antemortem lesions, most likely linked to accidents, whereby only a small portion of the Säben-Sabiona sample featured injuries associated with the time of death, most of which were identified as sharp force injuries. In consideration of the thorough trauma analyses performed by Tumler et al. (2021) and interpretations of the observed patterns, the present section will only mention these data briefly and focuses mainly on aspects not covered in that publication as well as an interpretation of the data following the subdivision of the sample into elite and non-elite individuals. Twenty-seven elite (20.3%) and 10 non-elite individuals (10.8%) had signs of trauma. Trauma prevalence in relation to social status was not found to be statistically significant (X^2=4.885, df=3, p=0.180).

For both subgroups, males were more commonly affected by trauma than females (Table 61 and 62).

	Females			Males			ND		
Age group	n	N	%	n	N	%	n	N	%
Subadults	0	2	0.0	0	3	0.0	2	35	5.7
Adult-ND	1	3	33.3	3	3	100.0	2	20	10.0
Adult	0	7	0.0	5	15	33.3	0	3	0.0
Mature	0	8	0.0	13	29	44.8	0	2	0.0
Senile	1	2	50.0	0	1	0.0	0	0	0.0
Total	2	22	9.1	21	51	41.2	4	60	6.7

Table 61 Crude trauma prevalence rates in relation to sex and age of the elite subsample. † n= number of elite individuals featuring trauma, %= percentage of N, N= total number of elite individuals.

The elite sample was not only more often affected, but also featured most recorded lesions (n=96) that were distributed across both sexes and all age groups. The three females, two subadults (infant I, featuring one transverse fracture on a rib and a depression blunt force injury on the frontal bone) and not-determinable individuals with trauma, featured one lesion each. The remaining 89 lesions were registered on elite male skeletons. Out of the males featuring an age estimate, mature males displayed the highest crude (44.8%) and true prevalence (48 lesions) followed by adult males with 37 lesions associated with 5 individuals.

Forty-five of the registered traumatic lesions were attributable to ten non-elite individuals (Table 62). In relation to sex and age, two lesions were found on one mature female and all other lesions were found on adult (28.6%) and mature males (27.8%). In comparison to mature males, with 15 lesions, adult males had almost twice as many traumata, i.e., 28 lesions.

Age group	Females			Males			ND		
	n	N	%	n	N	%	n	N	%
Subadults	0	4	0.0	0	3	0.0	0	19	0
Adult-ND	0	3	0.0	0	7	0.0	0	5	0
Adult	0	3	0.0	4	14	28.6	0	7	0
Mature	1	7	14.3	5	18	27.8	0	2	0
Senile	0	0	0.0	0	1	0.0	0	0	0
Total	1	17	5.9	9	43	20.9	0	33	0

Table 62 Crude trauma prevalence rates in relation to sex and age of the non-elite subsample. † n= number of non-elite individuals featuring trauma, %= percentage of N, N= total number of non-elite individuals.

When assessing trauma timings of the whole population, most of the injured had antemortem characteristics, i.e., 33 individuals exhibiting 58 lesions, yet 12 skeletons displayed lesions that lacked any signs of healing, thus, were identified as perimortem trauma (83 lesions). Thirty-five percent of the recorded antemortem injuries were associated with non-elite individuals and 65.5% with the elite sample. Perimortem injuries were more commonly found in elite individuals (69.9%) than non-elite individuals (30.1%), yet this was not found to be statistically significant (X^2=3.885, df=2, p=0.143). In relation to trauma distribution, both subpopulations displayed a distinct pattern (Table 63 and 64). For both antemortem trauma (X^2=3.653, df=2, p=0.161) and perimortem trauma (X^2=3.956, df=3, p=0.266) the observed differences between the two groups were not statistically significant.

Overall, elite individuals featured an identical distribution of trauma across their skeletons (Table 63), although differences were noted for antemortem and perimortem injuries. Antemortem trauma appeared to be more commonly located on the appendicular (42.1%) and axial bones (36.8%). Perimortem lesions were mostly located in the craniofacial region (41.4%) or on bones of the axial skeleton (31%).

† (N)	Craniofacial † n (%)	Axial † n (%)	Appendicular † n (%)
Antemortem (38)	8 (21.1)	14 (36.8)	16 (42.1)
Perimortem (58)	24 (41.4)	18 (31)	16 (27.6)
Total (96)	32 (33.3)	32 (33.3)	32 (33.3)

Table 63 True prevalence of antemortem and perimortem injuries in relation to location in the elite sample. † n= number of observed lesions in the craniofacial, axial, and appendicular region of elite individuals, %= percentage of N, N= total number of lesions in elite individuals.

Furthermore, most of the registered antemortem lesions for elite individuals were either fractures or blunt force traumata (n=37) and most perimortem lesions were sharp force traumata (n=55, Figure 48). Three perimortem injuries were fractures or blunt force traumata and one antemortem lesion was identified as sharp force trauma.

Figure 48 Perimortem sharp force trauma on the distal diaphysis of the right femur from SK114.

The overall trauma distribution in non-elite individuals (Table 64), showed that axial bones were most frequently affected (46.7%), followed by those of the appendicular skeleton (37.8%). Analogous to elite individuals, the recorded antemortem lesions in the non-elite sample was highest in the appendicular (55.0%) and axial skeleton (40.0%). For perimortem injuries, the highest lesion rate was found in axial bones (52.0%), whereas craniofacial (24.0%) and appendicular bones (24.0%) showed identically low frequencies.

† (N)	Craniofacial † n (%)	Axial † n (%)	Appendicular † n (%)
Antemortem (20)	1 (5.0)	8 (40.0)	11 (55.0)
Perimortem (25)	6 (24.0)	13 (52.0)	6 (24.0)
Total (45)	7 (15.6)	21 (46.7)	17 (37.8)

Table 64 True prevalence of antemortem and perimortem injuries in relation to location in the non-elite sample. † n= number of observed lesions in the craniofacial, axial, and appendicular region of non-elite individuals, %= percentage of N, N= total number of lesions in non-elite individuals.

In terms of trauma laterality, for the whole population, most lesions were located on the left side (n=68) as opposed to the right (n=63), or centre of the body (=6). Four lesions could not be sided. The lesions examined of elite group were mostly located on the left (49 out of 96, 51.0%) than the right side (39 out of 96, 40.6%). This was true for both antemortem (47.4% versus 36.8%) and perimortem lesions (53.4% versus 43.1%). A contrary pattern was found for non-elite individuals, who had more lesions on the right side (23 out of 45, 51.1%) than the left (19 out of 45, 42.2%). However, in the non-elite subgroup, antemortem lesions were more commonly located on the left (50.0% versus 40.0%), whereas perimortem injuries were mainly observed on the right side (60.0% versus 36.0%).

Both antemortem (n=20) and perimortem lesions (n=19) were mostly identified as fractures or blunt force injuries. Only six perimortem lesions were sharp force injuries. In relation to trauma type, i.e., fractures/blunt force trauma (X^2=4.997, df=2, p=0.082) and sharp force trauma (X^2=3.924, df=2, p=0.141), the observed differences between elite and non-elite individuals was not significant.

As the archaeological record suggested that some individuals of the elite group could be identified as autochthonous, i.e., Romans, and allochthonous, i.e., Longobards or Bavarians, the trauma frequency of these individuals was also assessed. The present data suggested a low trauma prevalence for both “ethnic” groups. Despite a higher prevalence of individuals without trauma in both groups, the frequency of individuals with trauma was higher in those regarded as allochthonous (44.4%) than in those believed to be autochthonous (21.2%). Due to the small subsample size, no further statistical analyses were carried out to test for significance.

6.3.2.6. Congenital and neoplastic conditions

All congenital conditions affected the axial skeleton and included disorders such as spina bifida (four elites and three non-elites, Figure 49a), accessory vertebrae (two elite individuals and one non-elite individual, Figure 31), congenital dislocation of the hip (one elite individual), sacral deformations (one non-elite individual), lack of fusion in sacral segments (one elite individual) and sacralisation (three elite and two non-elite individuals, Figure 49b).

Figure 49 A) Posterior view of the sacrum with spina bifida from SK162 (black arrow); B) Anterior view of the sacrum from SK228, displaying sacralisation (white arrow).

For the most part neoplastic alterations were identified as benign bone tumours (n=13), most of which were button osteomas (Figure 50a). Only in one case the osseous alterations suggested a malignant tumor (SK115, Figure 50b). Three of the button osteomas were identified on three non-elite individuals, all of the other neoplastic conditions were associated with elite individuals.

Figure 50 A) Three button osteomas on the right frontal bone of SK118; B) Endocranial view of the left parietal bone from SK115, featuring a potential malignant tumor.

7. Discussion

This thesis aimed to establish, for the first time, a full bioarchaeological profile of the individuals buried within and around the church in the vineyard at Säben-Sabiona. The generated anthropological data allow a more holistic interpretation and contextualisation of the site and improve current notions on early mediaeval life in South Tyrol. Based on burial location and funerary culture, the assessed interments (n=185) could be subdivided into an elite (n=107) and non-elite subsample (n=78). For both subsamples and the whole sample, males always outnumbered females (n=94 versus n=39 in the whole sample), however a substantial amount of subadult individuals aged 0-6 years were also identified (n=38). In relation to palaeopathology, differences were observed for prevalence and severity in the elite and non-elite subsample. As most of the available comparable studies focusing on local anthropological material mainly address only the presence and/or prevalence of dental disorders, stress indicators (e.g., cribra) osteoarthrosis and trauma (Giovannini, 2003, 2002; Paladin and Zink, 2015; Renhart, 2008, 2006), comparisons with these data were often limited. As a full examination and interpretation of osteological indicators for disease, nutritional imbalances, diet, interactions with the environment and its potential risks (i.e., trauma) provide very personal and unique insights into the life experiences of an individual (see osteobiographic catalogue) as well as those of a whole group, the present study followed such an approach. Some preliminary data and more subject focused data, i.e., trauma, of the present site were already published (c.f., Tumler et al., 2021, 2019), however these data will also be incorporated and interpreted in consideration of the social status of the interred.

7.1. Bone preservation and burial practices

One of the most crucial aspects when assessing human remains and aiming to perform population analyses, i.e., reconstructing palaeodemography and palaeopathology, is the consideration of bone preservation (Bello et al., 2006; Manifold, 2012; Pinhasi and Bourbou, 2008). A lack of either qualitative and quantitative conservation or both can have tremendous impacts on the gathered results and thus affects accuracy of interpretations substantially (Lovell, 2008; Pinhasi and Bourbou, 2008).

An intact periosteal surface is an essential requirement for any palaeopathological analysis and can often be affected by taphonomy (e.g., erosion, soil pH, animal and plant activity, etc.), anthropogenic pre-deposition treatment or the excavation process (Manifold, 2012). As the Säben-Sabiona sample showed mostly good (44.2%) or very good (29.2%) levels of qualitative preservation, this ensured that even more subtle lesions, such as delicate patches of new bone formation, etc. were recordable. The good qualitative bone preservation and the fact that only a few individual burials featured animal activity, i.e., rodent gnawing, minimised the chances of registering pseudopathologies, thus, support the representativeness of the sample for palaeopathological analyses (Pinhasi and Bourbou, 2008).

Similar to qualitative preservation, bone representation can also be affected by taphonomy (e.g., soil pH and composition, oxygen availability, etc.), burial practices and the recovery process itself, whereby the latter affects particularly smaller bones, e.g., hand and foot bones or those of foetuses, neonates and infants (Bello et al., 2006; Manifold, 2012; Pinhasi and Bourbou, 2008). The completeness of the skeletons from Säben-Sabiona, out of which the majority was represented by <25% (46.5%) or 25-50% (21.2%), in conjunction with the relatively good qualitative preservation suggests that taphonomy may have had some impact on quantitative skeletal preservation. As taphonomy appears to play a more dominant role in the degradation of subadult remains (Bello et al., 2006; Manifold, 2012), the effects of which were not assessed in the present study, the actual impact of taphonomy on skeletal representativeness remains unclear. However, for the present context, low quantitative preservation may be linked to previous archaeological surveys, i.e., the skeletal remains excavated from within and around the early mediaeval church during the first excavation are untraceable. Also, the archaeological documentation of the most recent excavation (Bierbrauer and Nothdurfter, 2015), implies other causes, such as modern agricultural disturbances, for the observed lack of complete skeletons. Nevertheless, following the suggestions by Lutz (2019) data collection differentiated between features that were available for analysis and those that were not, thus, the effect of low quantitative preservation was reduced. Limited skeletal completeness inevitably leads to a decrease in reliability of the collected data, especially when examining the prevalence rates of certain pathologies, as the underrepresentation of specific skeletal elements can distort the actual frequency considerably.

Even though burial location and the presence of grave goods can have an effect on the state of preservation (Surabian, 2012), neither of them seem to have had a significant impact on periosteal quality nor quantitative preservation of the assessed sample. Further factors linked to burial practices, that may have had an effect on bone preservation are burial methods, e.g., body position, burial type and depth (Manifold, 2012). It is known that the area containing the church and cemetery was used agriculturally, i.e., as a vineyard and some graves display modern disturbance (Bierbrauer and Nothdurfter, 2015), thus soil pH may have had a negative impact on bone preservation and more superficial burials may have been more prone to be disturbed and/or damaged. A study by Manifold (2012) found that soil type and pH levels, i.e., below pH 6, as well as burial depth had a significant impact on bone preservation, i.e., acidic soils decrease hydroxyapatite survival and shallow graves were more prone to destruction, e.g., plough damage, and scattering, than deeper burials. The influence of these burial conditions on bone preservation was not examined in the present research as this would have exceeded the scope of the thesis, thus the effects of these will require further investigations. Even though the whole Säben-Sabiona mount has not been excavated yet, only a sample of the accessible skeletal remains was assessed, and preservation had an effect on the availability of osteological data, this thesis provides a first anthropological overview, providing novel information about who was interred at the site as well as the living and health conditions of the buried.

7.2. Burial practices, population composition and mortality rates

As opposed to other late antique and early mediaeval sites in the South Tyrol and Trentino regions, Säben-Sabiona differs quite substantially. These variations manifested themselves not only in the number and type of individuals interred, but also in terms of population composition, particularly the demographic structure of the sample.

Based on the number of assessed individuals from the Säben-Sabiona cemetery, the sample was estimated to represent 21 contemporaneously living individuals. Early mediaeval settlements are believed to have been composed of three to 17 farmhouses, each featuring about 10-15 individuals (Czermak, 2011; Jankuhn, 1976). This would suggest that the buried represent one to two farmhouses. Yet, as the sex ratio is so unbalanced and only the burials within and surrounding the Palaeochristian church were included in the present analysis, this interpretation needs to be taken with great caution.

With a masculinity index of 241, the sex ratio at Säben-Sabiona is not representative of a living population, which opposes the result of the mortality rate equation by Weiss (1973), according to which the sample is representative. This indicates that from an age perspective the present cemeterial population is reflective of a living population, yet when taking sex into account this changes dramatically. A potential explanation for the observed pattern might be selective burial practices. As no large settlement was identified on the mount or appears to be in direct association with Säben-Sabiona, Bierbrauer and Nothdurfter (2015) suggested already that the interred originated from different settlements along and surrounding the Eisack-Isarco valley. According to Brather and Friedrich (2013) Palaeochristian churches and cemeteries were initially solely used as burial sites of the elites. Most members of the general public were interred near their settlement and only over time did these practices shift towards cemeterial inhumations

(Brather and Friedrich, 2013; Brownlee, 2020; Sayer, 2013b). Both historical and archaeological records imply a great variability in how and where individuals were buried. Deceased individuals were being deterred following the socio-cultural and religious customs of the once living population, thus can provide insights into the perceptions, values, ideologies and relationships of the bereaved/living rather than those of the buried itself (Bourbou and Tsilipakou, 2009; Brownlee, 2020; Quinn and Beck, 2016). Most assessable burials were consistent with other early mediaeval sites from Germany (Brundke, 2018, 2016), Switzerland (Etter and Schneider, 1982) and Italy (Carrara, 2013; Nothdurfter, 1999), following typical Christian tradition, i.e., west-east orientation (73.6%), supine position (100%) with arms extended (11.9%) or flexed above the pelvis or chest (88.1%). Bierbrauer and Nothdurfter (2015) interpreted the observed burial practices and recovered grave goods, mainly consisting of iron knives and/or osseous combs with only a few individuals featuring exceptional artefacts, as means to differentiate between local Christianised Romans and pagan groups, which included Germanic individuals. As grave furniture is supplied by the living population and appears to have a strong symbolic value, rather than representing reality, numerous authors abandon the use of material culture as an indication for ethnic affiliations and are more cautious when interpreting social status/occupation of a deceased, e.g., warrior (Brownlee, 2020; Eger, 2015; Sayer, 2013a, 2013b). However, historical and bioarchaeological research has shown that individuals associated with economic power, thus, high social rank are often interred inside churches, particularly the central areas, featured elaborately build burial chambers with wealthy grave goods (Brownlee, 2020; Ferreri, 2011; López-Costas et al., 2021; Sayer, 2013b; Walter, 2008). Hence, it is not surprising that cemeterial burial sites are often organised in specific patterns according to social affiliation, status, sex and age (Brather, 2008; Etter and Schneider, 1982; Nothdurfter, 1999; Oxenham et al., 2008; Pinhasi and Bourbou, 2008). Such patterning was also observed in Säben-Sabiona. Most individuals were interred inside the church (55.8%), some of which were buried in crypts (15.9%) and/or featured exceptionally wealthy artefacts (5.7%). In terms of demographic distribution, more males and adults were located within the church as opposed to females and subadults. In comparison to the interpretations of other Italian and South Tyrolean mediaeval sites (Carrara, 2013; Ferreri, 2011; Nothdurfter, 1999; Renhart, 2008, 1991), the present data support the idea of a selective burial pattern, probably limited to local elite groups or highly esteemed individuals of the wider population. Since Säben-Sabiona was the earliest and only episcopal see of South Tyrol in the Early Middle Ages, both the archaeological and historical record suggest that the buried belonged to the upper social classes (Bierbrauer and Nothdurfter, 2015; Heitmeier, 2005). As variations in the presence of grave goods and/or the burial location were observed, the sample features an increased masculinity index, whereby the age distribution follows normal parameters, this supports the hypothesis of social stratification of the interred. More detailed interpretations of the observed palaeodemographic patterns of the elite and non-elite subgroups are attempted in the following sections.

7.2.1. Palaeodemography

When assessing palaeodemography it is essential to differentiate between the living and the cemetery population, as the former is based on dynamic processes and the latter only represents the last stage of this process, thus is static (Düring, 2017). Living populations may experience demographic fluctuations and short-term conditions more quickly and severely, whereas the impacts of these changes may not be translated directly or at all into the cemetery population. Furthermore, the right to be buried in a certain location, e.g., within a cemetery, near a settlement, etc., was determined by the still living individuals (Sayer, 2013a), of which we know little about. Selective funeral practices have shown to be particularly common for burial sites associated with violent events (e.g., Nicklisch et al., 2017; Quade and Binder, 2018) and those linked to sites of high importance, e.g., religious centres such as episcopal sees, monasteries and pilgrimage sites (Brather, 2008; Brather and Friedrich, 2013; Eggenberger et al., 1983; Etter and Schneider, 1982; Fernández-Crespo and De-la-Rúa, 2015; Ferreri, 2011; López-Costas et al., 2021). For South Tyrol, historical and ethnographic evidence suggests that the estates of religious centres were not always nearby, e.g., St. Martins church in Göflan-Covelano in the Vinschgau-Venosta valley possessed farms in the Schnals-Senales valley, thus, to be buried, the bodies of the deceased had to be transported to the respective burial site (Gorfer, 2017; Köpf, 1999). Furthermore, also the foundation of proprietary churches, which contained burials of the founders and landowners, at sites of political relevance and away from settlements, indicates social stratifications among early mediaeval populations (Nothdurfter, 1999). Hence, the interpretation of cemetery populations such as the one at Säben-Sabiona, which was a highly important religious and political centre during the early mediaeval period (Bierbrauer and Nothdurfter, 2015; Winckler, 2012), need to be approached with great caution as the buried do not reflect the actual living population. By considering all of these aspects and the available historical and archaeological information the palaeodemography of the cemetery population at Säben-Sabiona is contextualised in order to obtain insights into the once living society.

7.2.1.1. Sex distribution

The observed surplus of male individuals (70.7%, MI=241) at Säben-Sabiona is congruent with the data from other late antique and mediaeval sites, e.g., Eleutherna (71.2%) on Crete, Messene (65.7%) in Greece, Adrianapolis (61.3%) in Turkey, Elgg-Ettenbühl (60,7%) in Switzerland, Wyhl (MI=300) southwest Germay, Terlan-Terlano (68.8%) in the Etsch-Adige Valley in South Tyrol, Nomi (75%) in Trentino, Tanas (83.3%) in the Vinschgau-Venosta Valley in South Tyrol (Bagis, 2018; Bourbou, 2003; Kokkotidis, 1999; Obertová, 2008; Tumler, 2015). Also, local archaeological studies on proprietary churches discovered a similar pattern with significantly more males and subadults than females, e.g., St Georg near Kortsch-Corzes in the Vinschgau-Venosta valley (Nothdurfter, 1999).

Such a highly unbalanced sex ratio, 94 males versus 39 females in the total sample and 51 versus 22 in elites and 43 versus 17 in non-elites, indicates already some sort of bias. Even when considering all unsexed adult and juvenile individuals (N=45), a female deficit would remain. The present sex ratio does not meet the requirements for a viable and economically efficient population, which necessitates either similar numbers of both sexes or larger numbers of females (Blakey and Rankin-hill, 2009; Gautam et al., 2015). Due to a greater intrinsic vulnerability of males (Waldron, 1983), sex ratios at birth are naturally 105 or 106 males per every 100 females, (Bardsley, 2014; Chao et al., 2019; Gautam et al., 2015; Hollingshaus et al., 2019). Even though these ratios usually fluctuate slightly across different age groups, they do not deviate to the extent as seen in the Säben-Sabiona sample. Now when taking a closer look at the sex ratios at different age classes, equal numbers of both sexes are only seen in the juvenile and senile age categories. Despite increased perinatal and infant mortality rates of males, by the age of six, the sex ratio is commonly balanced again (Aghai et al., 2020; Hollingshaus et al., 2019; Sawyer, 2012; Spoorenberg, 2016). For adult (74.4%) and mature (75.8%) age groups, males strongly dominate the examined sample. Bardsley (2014) argues that sex ratios that fall below 95 or above 105 males for every female strongly indicate extrinsic causes such as warfare, gendered migration or sex-selective abortions, infanticide, and maltreatment, e.g., poor nourishment.

7.2.1.1.1. Female deficit

A population consisting of a sex ratio as observed in the present cemetery population is regarded as inviable, hence there must be other explanations for the detected female deficit. A lack of females in both, cemetery populations and historical records is not a new phenomenon, multiple authors have put various suggestions forward to explain why females are often missing, e.g., selective burial patterns, i.e., females buried in ancestral cemeteries, societal attitude towards females, active and/or passive female infanticide (Bardsley, 2014; Carrara, 2013; Czarnetzki, 1995; Czermak, 2011; Kokkotidis, 1999). For Säben-Sabiona the most plausible interpretation, which also links back to the available historical and archaeological data, is that females may have been buried elsewhere. The important role of the site in the Christianisation quest of the Alps and the presence of an episcopal see may have also had a substantial impact on where people were buried, and particularly who was allowed to be interred within the proximity of the church. From historical sources it is known that during the late mediaeval period corpses of certain individuals were denied burial on consecrated ground, e.g., murders, suicides, unbaptised infants, stillbirths, etc. (Bardsley, 2014). Yet, even though females were generally regarded as ritually impure, due to menstruation and the birth process, according to historical sources they were not to be excluded from a cemeterial burial (Bardsley, 2014; Erickson, 1976). Whether female access to a burial site was restricted by society, is not known for the earlier stages of Christianisation. However, as this period was characterised by the conversion of pagans to Christianity, excluding half of the population from certain aspects of the new religion would not have been beneficial to the Christianisation progress, thus, does not seem realistic. This is also highlighted in the notion concerning the social status of the buried, i.e., both elite and non-elite individuals had access to the cemetery and both subgroups featured a similar unbalanced sex ratio. Females are known to play a key role in preserving traditions and cultural practices, by continuing these over generations (Cicurel and Sharaby, 2007; Engels and Hunt, 2010; Gulley, 1993; Martínez et al., 2010; Mun and Chu, 2013; Sadiqi, 2007), hence this could have impacted burial customs. Even though not directly associated with early mediaeval South Tyrol, ethnographic research by Mun and Chu (2013), found that women in Malaysia continued certain traditional practices for over one thousand years regardless of modernisations, purely based on their own relevance for preserving such cultural mores. Similar behaviours have also been noted for modern day South Tyrol, where certain traditional practices are passed down through the female lineages (Bruckmüller and Sandgruber, 2002; Gorfer, 2017). Hence, early mediaeval females might have continued following pagan practices, i.e., being buried in traditional burial grounds, in cemeteries near less monumental sites, i.e., parish churches and smaller sites of worship (both pagan and Christian) or in closer proximity of where they settled. This notion might be particularly applicable to non-elite individuals, which probably represent the wider public. Early mediaeval sites that would support the view that females were buried nearby their settlements are St. Prokulus-S. Procolo in Naturns-Naturno, South Tyrol-Italy (Renhart, 1991) and Storchengasse and Münsterhof in Zürich, Switzerland (Etter and Schneider, 1982). Mays et al. (2007) suggests that in certain circumstances low sex ratios within a cemetery may be linked economic factors, such as availability of work, hence, those individuals who did not move away represented the majority of the cemetery population. As the early mediaeval period is also typified by migratory events, and females frequently transitioned between different communities for marriage they may have been interred in their ancestral burial ground rather than in the cemetery of their husbands (Düring, 2017; López-Costas et al., 2021; Sayer, 2014). This notion is also reinforced by mediaeval documents stating that females preferred to be interred near their female relatives or female saints, whereas the opposite was true for males (Andrade Cernadas, 2012; López-Costas et al., 2021). As the elite subsample potentially consists of autochthonous and allochthonous individuals, these were most likely more mobile than non-elite individuals, thus migration and burial practices associated with familial relations, cultural and/or religious affinities might be accountable in part for the observed sex ratio in the elite subsample.

Other commonly proposed reasons for unbalanced sex ratios in a skeletal assemblage are sex selective foeticide and infanticide, which has been documented since the Roman period until today and still poses a demographic issue in some modern populations (Bano et al., 2021; Bardsley, 2014; Coleman, 1976; Engels, 1980; Eshed et al., 2004a; Etter and Schneider, 1982; Hesketh and Xing, 2006; Sorta-Bilajac, 2004). As none of the individuals below the age of 13 were sexed osteologically, the proportions of female versus male subadults within the Säben-Sabiona cemetery remains unknown. Thus, would need to be investigated to assess whether female foeticide and infanticide were practiced by the local early mediaeval community. Even if such sex-selective practices were performed, it is unlikely that they would result in a sex ratio over 100% at adult age (Fernández-Crespo and De-la-Rúa, 2015). Hence, especially for the present sample with such extreme proportional differences, that are limited to certain age classes, foeticide/infanticide does not suffice as a sole explanation for the observed pattern. A predisposition for bearing male children, due to the preconception environment, social and economic status of childbearing women (Bardsley, 2014; Kvasnicka and Bethmann, 2009; Norling, 2018; Pongou, 2013), in conjunction with female-selective infanticide, would have probably raised the sex ratio further, but again unlikely to the extent as seen in Säben-Sabiona. Some early mediaeval legislative texts, e.g., *Lex Salica, Lex Ribvaria* suggest a negative attitude towards female infanticide, as the “Wergeld” of killing a female infant was twelve times as high as the average (Brather, 2008; Kölbl, 2004). Thus, due to the intrinsically high rates of child mortality within the first six years of life, increased killing of infants, especially females, would have not been beneficial for the population as a whole (Bocquentin, 2003; Fernández-Crespo

and De-la-Rúa, 2015; Norling, 2018). Also, when looking at the distribution of subadult deaths for both subsamples, i.e., more subadults were classified as elite (n=40) than non-elite (n=20), the observed pattern does not add up with the current knowledge about infanticide, which shows a stronger correlation with low economic status (Haentjens, 2000; Hausfater and Hrdy, 1984; Hynes, 2011; Parmigiani and Vom Saal, 1994).
Even if female foeticide/infanticide may have had a low impact on the observed sex ratio, females may have experienced different treatments, as opposed to males, by their families and communities they lived in, i.e., passive infanticide (Sorta-Bilajac, 2004). Historical sources document that in comparison to males, females were weaned earlier, and throughout their lives they received reduced food allowances (not meeting their nutritional requirements), usually consisting of lower quality foods (Bardsley, 2014; Cullum, 1991; Czarnetzki, 1995; Klapisch-Zuber, 1985). By limiting their access to enough and high-quality foods female resistance towards disease decreases substantially (Beltran Tapia et al., 2021; Zarulli et al., 2018). Thus, leading to higher female infant mortality as well as increasing their heterogeneity, i.e., making them more susceptible to die from diseases earlier on in life. Especially in consideration of the enormous physical and nutritional requirements associated with pregnancy, i.e., 2255kcal/day, childbirth and lactation, i.e., 2635kcal/day, a weakened body and immune system are not favourable (Grischke, 2004). Out of the few female individuals available for analysis (n=39) the distribution was equal for those that died after 40 years of age (mature-senile, 43.6%) and those in their reproductive years (juvenile-adult, 43.6%). If females experienced significant disadvantages, which made them more vulnerable to premature death, a higher accumulation of female skeletons would be expected. In males, mature and senile proportions (52.1%) were higher than those of juveniles and adults (37.2%). As the differences in females were much smaller than those of males, this suggests that females had almost equally high risks of dying in young and older age, as opposed to males who commonly reached a higher age. When dividing the sample into elite and non-elite individuals, a congruent pattern as for the total sample was observed for both subgroups. This might suggest that overall societal-related sex selection may not have had such a large impact on the people buried at Säben-Sabiona, yet this topic will be discussed further in subsequent sections of this thesis.

An alternative hypothesis could be related to differentiated bone preservation, i.e., female and male preservation varies at different ages (Bello et al., 2006; Manifold, 2012). However, despite taking all badly preserved, thus unsexed, adults and juveniles into account, the male surplus remains. Thus, bone conservation may only play a limited role in explaining the sex distribution at Säben-Sabiona. Here it also needs to be mentioned that not all excavated burials were assessed, approximately another 181 burials, some of which are untraceable, lack an osteological analysis, and according to Bierbrauer and Nothdurfter (2015) the whole mount is expected to feature a total of 800-1000 burials (not scientifically proven), most of which have not been excavated yet. Hence, it is also probable that the unexamined burials feature some/all of the missing females and/or specific locations that were not excavated up until now were reserved for females, thus would balance the sex ratio again. For the burials assessed as part of this thesis no distinct pattern in terms of burial location was identified, however, females appeared to cluster in the southern side aisle within the church and the southern parts outside of the church, yet these areas were not exclusive to females. As most of the assessed females were identified outside the church in the southern parts, these burials could be reflective of a generally lower social status of early mediaeval females or simply an affiliation to lower social classes, who were less likely to be able to afford burials within the church. For those that were interred inside, a similar pattern as documented by Marti (2000) for a late antique/early mediaeval site in northern Switzerland was found, with female burial clusters mainly in the southern (47.4%) and northern (26.3%) aisle. This might suggest some sort of affiliation among these females, as grave location is often indicative for affinity, e.g., relatives, neighbours, originating from the same ancestral group/region, etc, (Brather, 2008; Brownlee, 2020; Ferreri, 2011). Based on the osteological evidence no further interpretation on relationship of these individuals can be made without the incorporation of stable isotope and/or ancient DNA analyses. However, the observed pattern clearly indicates some sort of burial organisation, which considered females, thus, the low numbers of female burials at Säben-Sabiona still raises further questions on the whereabouts of the missing female skeletons. To bring the observed sex ratio into a better context also the reasons for the male surplus need to be examined.

7.2.1.1.2. Male surplus

Various sources indicate that during the Middle Ages males outnumbered females. Evidence was found in both late mediaeval historical documents, i.e., parish records (Bardsley, 2014), and also in early mediaeval cemeteries (Carrara, 2013; Czermak, 2011; Kokkotidis, 1999; Obertová, 2008). Some of the reasons for these large numbers of male burials can be attributed to societal practices, as such sites often include violence-related burial grounds, cemeteries with selected access (e.g., monasteries, pilgrimage sites) or cemeteries associated with certain economic classes (e.g., mineworkers) (Agnew and Justus, 2014; Carrara, 2013; French, 1994; López-Costas et al., 2021).

As most mediaeval societies were patriarchies, males had a different/more elevated status than females (Singman, Jeffrey and Forgeng, 1999; Uren, 2021), thus all economic, religious and political decisions, were made by males. Males migrated frequently, settling temporarily and permanently at sites of great significance, i.e., larger settlements/cities, episcopal sees, military bases, etc., to be able to exert their professions. Increased emigratory practices have shown to be one of the major causes of sex imbalances in modern populations (Gautam et al., 2015). The locations accommodating male emigrants feature a larger male proportion and so would their cemeteries. As Säben-Sabiona is known to have been one of the most important religious, economic and political centres of the southern central Alps (Bierbrauer and Nothdurfter, 2015; Winckler, 2012), the large numbers of males may be linked to immigration or conscious selection of the burial site. According to Kokkotidis (1999) it was common for individuals who frequently changed their residence to be buried where they lived when they died, especially when their residence was near a site of religious importance. Such sites required substantial administration, which was generally carried out by bishops, clergymen and socially high-ranking individuals, thus demanding a substantial amount of people to be present (Heitmeier, 1999; Nothdurfter, 1999; Semmler, 1999). The fact that Säben-Sabiona features individuals that may have been involved in interpersonal conflict (Tumler et al., 2021, 2019), graves with rich funerary artefacts in conjunction with the burial location of some individuals, i.e., crypts and burials inside of the church, especially nave and near the relic altar (Bierbrauer and Nothdurfter, 2015; Kaufmann, 2017; Winckler, 2012), suggests that individuals of high social status were interred here.

In consideration of the encountered burial customs, the surplus of male burials within the church may exemplify the status of males within early mediaeval communities (Nothdurfter, 1999; Semmler, 1999). Yet, as the discrepancies between inside and outside male burials are relatively low and not statistically significant this may simply suggest that the selection of males interred inside the church were regarded as high-status individuals by their communities. *Ad sanctos* burials were generally reserved for individuals of great social prestige, e.g., church founders, members of elite groups or clergy (Bierbrauer and Nothdurfter, 2015; Ferreri, 2011; López-Costas et al., 2021; Passalacqua, 2012; Sayer, 2013a). Especially when considering the idea that Säben-Sabiona features selective burial patterns, i.e., only certain individuals, possibly high-ranking ones, were interred at the site, those individuals that were buried inside the church, particularly the nave may have been of even higher status. Crypt A may be an example of such a high-status burial as it is located in the nave and features exclusively mature males, or also the severely injured mature males from crypt B (nave) and D (southern side aisle) (Tumler et al., 2021). Following Eggenberger et al. (1983) and Martis' (2000) interpretations on burial practices in Palaeochristian churches of Switzerland, burials within the centre of the church, i.e., nave, choir and apsis were reserved for the founders of the church. Säben-Sabiona was an episcopal see and it is known that bishops, together with other elites, were often responsible for both sacral and profane coordination of the surrounding regions (Ferreri, 2011; Semmler, 1999; Winckler, 2012), the males interred inside the church may represent both the founders of the church and governing parties of the population.

Of course, not all the males buried at Säben-Sabiona were of high importance, based on the material culture and burial location, 51 males were classed as elites and 43 males as non-elites. The latter might represent individuals from the wider public that resided in nearby valleys and worshiped the site as a pilgrimage centre or individuals associated with the immediate household of elites. In fact, every three years since it was first mentioned in 503 A.D., males from the Gader-Badia valley pilgrim to the former episcopal see Säben-Sabiona (Craffonara, 2006). Pilgrims that travelled from Italy to southern Germany were also mentioned in Bavarian historical sources from 560 A.D. (Fehr, 2010). Similar as for other pilgrimage sites, these centres were often at distinct sacred sites, e.g., on mounts and/or near religious centres featuring relics, and were governed by selective access policies (French, 1994), e.g., males only. Thus, Säben-Sabiona' s function as a profane and sacral centre, may be directly reflected in the cemetery population, i.e., a certain number of male elite individuals were required for administrative reasons and due to its importance as a religious centre some laymen may have also chosen to be buried there. Looking at the subdivision of the sample, i.e., 51 elite males, which died mostly after their 4th decade of life (56.8%) and 43 non-elite males commonly died above 40 years of age (41.8%) or between 20-39 years (32.6%). This would clearly support the above-mentioned notions as individuals representing the upper social classes usually exhibit a higher age at death than those belonging to lower social classes (French, 1994; López-Costas et al., 2021; Mackenbach, 1995). Mediaeval sources state that clergymen and elites, but also laymen more so than their female counterparts were far more likely to choose burials in monasteries, pilgrimage sites or cemeteries associated with episcopal sees or relics of martyrs (Bardsley, 2014; Harding, 1992; Postles, 1996; Winckler, 2012).

Kuhnen (2020) suggests an association between Säben-Sabiona and mining, as some of the excavated buildings next to the church and cemetery showed evidence for iron production. As mining and metal processing are generally male dominated (Anderson, 2015; Knapp et al., 1998), in fact, some cultures even prohibit the presence of women during these activities altogether (Reid and MacLean, 1995), the observed sex distribution in conjunction with the archaeological evidence would support such a view. However, whether this hypothesis is legitimate will be examined further in the following sections concerning the age at death distribution and activity pattens of the buried, especially of the non-elite individuals as these may have been most likely involved in such practices.

As mentioned already, all available evidence indicates that the studied sample consists, probably, of a restricted group of individuals, who may have belonged to certain societal sectors (e.g., elites, clergymen, pilgrims, craftsman). The presence and frequency of such burial sites has been confirmed by various sites across Europe featuring selective burial patterns linked to sex (Fernández-Crespo and De-la-Rúa, 2015; Renhart, 2008) or social status, whereby some are even regarded as self-contained cemeteries restricted to specific members of society (Czermak, 2011; Loose and Lorenz, 1999). Research by Nothdurfter (1999) on various early mediaeval churches in the Vinschgau-Venosta valley, which he identified as private minsters of the elite, exemplify the conventionality of such customs. Thus, even though Säben-Sabiona may not represent a confined living population, the vast majority of male burials within and surrounding the early mediaeval church at Säben-Sabiona strongly support the view of a selective funerary pattern. To assess the selection criteria further and to obtain more contextualised insights into the composition of the cemetery population, also age at death may be a crucial factor that needs to be considered.

7.2.1.2. Age distribution

Age at death is an important element to be incorporated when trying to contextualise cemeterial populations. To investigate age-related mortality rates more accurately, one must comprehend, that modern social structures relating to maturity and how differently aged members of a population were seen, may not be interchangeably applicable to bioarchaeological samples. From a historical point of view, mediaeval infancy (0-7 years) was regarded as a time of growth, childhood (7-14 years) as one of play and from 14 years onwards, especially after initiation of puberty, individuals were seen as adults (Orme, 2001). Thus, mortality rates within certain age groups may point to specific biological events and/or socio-cultural practices. Furthermore, osteological age estimates relate to skeletal developmental stages, which may not be identical with biological, let alone chronological age. Yet, as the same principles apply to all bioarchaeologically assessed skeletal assemblages, it is possible to draw comparisons with these and formulate interpretations of the observed patterns.

Analogous to other local and non-local early mediaeval sites, e.g., Castelfeder-70% adults, 30% subadults (Giovannini, 2003), Pichlwiese St. Lorenzen-San Lorenzo di Sebato- 63% adults, 37% subadults (Dal Ri and Tecchiati, 2018), St. Prokulus-S. Procolo- 70% adults, 30% subadults (Renhart, 1991), Schretzheim- 70.1% adults, 29.9% subadults (Kokkotidis, 1999), Dueville- 61.6%

adults, 38.4% subadults (Carrara, 2013), the age distribution at Säben-Sabiona is with 70.8% adults and 29.2% subadults more or less consistent. This also applied when the sample was subdivided into elite (69.9% versus 30.1%) and non-elite (72% versus 28%). Even though some authors expect a subadult mortality of approximately 50% for the most hostile environments of the early mediaeval period, e.g., Västerhus in Sweden (Donat and Ullrich, 1971; Iregren and Redin, 2000; Kölbl, 2004), most studied cemeterial populations feature lower numbers, rarely exceeding 30% (Czarnetzki, 1995; Donat and Ullrich, 1971; Kokkotidis, 1999; Obertová, 2008), thus the present sample appears to be relatively well represented. Increased child mortality, especially within the first six years of age is quite common in both archaeological and modern populations (Agnew and Justus, 2014; Blakey and Rankin-hill, 2009; Bourbou and Tsilipakou, 2009; Kölbl, 2004; Kumar et al., 2016; Norling, 2018; Roser et al., 2013b). A high susceptibility of dying at a young age is also reflected in the Säben-Sabiona data, as 57.6% of all subadults died within the 0–6-year age category, with the highest probability of dying of the whole sample was between 0-4 years of age (14%), which was consistent over both subgroups. Such a proportion is relatively high for modern populations but appears to be consistent with the expected child mortality rates of early mediaeval samples (Carrara, 2013; Kölbl, 2004; Obertová, 2008; Roser et al., 2013b). Factors affecting infant mortality include congenital conditions, the nutritional status of the mother, socio-economic situation of the family, environmental elements, i.e., natural disasters, pathogenic loads etc., whereby the weaning period poses the highest mortality risk (Aheto, 2019; Blakey and Rankin-hill, 2009; Koffi et al., 2017; Kumar et al., 2016; Norling, 2018). As weaning is often associated with increased susceptibility for digestive tract disorders, i.e., weanling diarrhoea (Ashworth and Feachem, 1985; Cao et al., 2000; Kirk et al., 2017; Motarjemi et al., 1993; Singh et al., 2014), which in conjunction with other environmental factors can have a tremendous impact on infant survival, the high probability of dying within the 0–4-year age group is not surprising. As breastfeeding is crucial for infant survival, and for archaeological populations it was found that weaning was commonly initiated within the first two to three years of life (Katzenberg et al., 1996; Tsutaya and Yoneda, 2013; Wickes, 1953), the present data might indicate prolonged weaning, or weaning may only account for some of the deaths within the 0-4 age category. Following Norling (2018), infant mortality increases during a natural disaster, e.g., droughts and floods, whereby especially those who are being weaned are affected. In the past as well as in modern times, natural disasters such as mudslides, avalanches, droughts, etc., were not uncommon in the Alps (Haid and Haid, 2010; Winckler, 2012), hence could have had an effect on child mortality. Furthermore, as proven by the recovered archaeological evidence suggesting that the early mediaeval church was demolished at least twice due to fires,

possibly a Longobard attack, and mudslides (Bierbrauer and Nothdurfter, 2015; Winckler, 2012), such political and environmental factors most certainly affected the local socio-economic situation, thus may have contributed to the observed infant mortality.
Modern data shows that infant mortality rates are closely linked to life expectancy at birth, i.e., populations featuring high infant mortality rates generally also display lower life expectancies at birth (Kölbl, 2004; Roser et al., 2013b, 2013a). Even small differences in life expectancy at birth have a tremendous demographic impact on a population, however for archaeological samples, factors affecting such data, i.e., subadult deficiency, limit the estimation of the significance of the data. According to Roser et al. (2013a) life expectancy in pre-modern populations was around 30 years. Thus, with a life expectancy at birth of 33.2 years for the whole sample (31.5 for elites and 31.7 for non-elites) and a mean age at death of 32.1 years (31.7 for elites and 32.7 for non-elites), Säben-Sabiona is in line with other studies on late antique and early mediaeval sites in South Tyrol, e.g., St. Prokulus-S. Procolo (e^0_x= 28 years, mean age at death= 36 years, Renhart, 1991) and elsewhere in Europe, e.g., Dueville (e^0_x= 24 years, mean age at death=33 years, Carrara, 2013) (see also Czermak, 2011; Gadioli et al., 2018; Obertová, 2008; Slaus, 1996; Ubelaker et al., 2011). Such a pattern is also reflected when subdividing the sample according to sex, whereby mean age at death of the total sample was 32 years for females and 36 years for males, with a higher mean age at death for elites, 41.1 years for females and 40.8 years for males, than non-elites (34.5 years for females and 39.9 years for males). The increased gap in mean age at death for elite and non-elite females may be linked to living conditions and access to health care. In modern populations, poor health and limited access to health care are amongst the most common factors affecting life expectancy (Avendano and Kawachi, 2014; Luy and Minagawa, 2014). Due to their reproductive responsibilities, females are much more prone to certain conditions and premature death (Luy and Minagawa, 2014), this would have certainly increased in the early mediaeval period. As low socioeconomic status has also been found to be a contributing factor to premature death (Marmot, 2005), elite females may have had access to some sort of health care, allowing them to live longer, whereas non-elite individuals did not. Half of all assessed adult males and 38.5% of females died between 40 and 59 years of age. Male elite individuals appeared to have died more often between 40 and 59 years than any of the other groups, i.e., elite females (36.4%), non-elite males (41.9%) and non-elite females (41.2%). This might suggest that elite males have had a different lifestyle than elite females and non-elite individuals. As the data is very similar for both sexes in the non-elite sample, this might imply more congruent ways of living. Similarly, also for the adult age category, males (30.9%) died in higher numbers than females (25.6%), which is surprising as most populations feature higher

female death rates (Bardsley, 2014; Obertová, 2008; Šlaus, 1996). Yet, when assessing the adult death rates for elite and non-elite individuals a very different pattern emerges, i.e., elite females died more frequently as adults (31.8%) than males (29.4%), whereas for non-elite individuals reversed pattern was found (32.6% for males and 17.6% for females). This picture changes even more when looking at the probability of dying at different ages, both the data of the whole sample as well as for both subgroups clearly show that female chances of dying were slightly more pronounced between 15-34 years of age in contrast to males, whereby non-elite females had a 21% chance of dying at 15-19 years. Higher mortality rates for osteologically young females have also been found in other bioarchaeological studies, e.g., Privlaka in Croatia (Šlaus, 1996), and are most likely associated with the risks of pregnancy and childbirth (Bardsley, 2014; Shapland et al., 2016). Due to increased mortality risks during the childbearing periods, mediaeval females were more prone to die earlier in life than males (Bardsley, 2014; Czermak, 2011; Kokkotidis, 1999; Obertová, 2008). This pattern is particularly well illustrated in the juvenile age category, where 15.4% of females died as opposed to 6.4% of males. From the data it appears that non-elite females may have been exposed to such risks at a higher rate than elite females or males of both subgroups. Once females surpassed these years of increased vulnerability, they are expected to have a higher life expectancy than males, which was also shown in the present sample, i.e., female life expectancy was slightly higher for the 35-41 (11.9 years for females versus 11.1 years for males), 42-49 (10.1 years for females versus 8.4 years for males) and 50-57 age category(7.4 years for females versus 6.1 years for males). This pattern varies slightly when taking burial location and funerary culture into account. Elite females had the highest life expectancy across all age groups and non-elite females the lowest. More drastic discrepancies, with higher probabilities of dying for males, only started to emerge after 40 years of age. As the highest mortality rates were observed in the mature age category (41.3%), despite the low mean age at death and life expectancy at birth, this further enforces the assumption that selected individuals were buried at Säben-Sabiona. When comparing male life expectancy of the two subsamples, elite males had a slightly higher life expectancy up to about 42-49 years of age than non-elite males. Yet, between the ages 49-58 years, elite males displayed lower life expectancies than non-elite males. According to Kokkotidis (1999), individuals who belonged to a socially higher-ranking group may exhibit an increased life expectancy, up to 5 years longer, than individuals from lower social classes. The differences in life expectancy between the present elite and non-elite males was roughly 0.5-1 year. As the occupation of South Tyrol was achieved through the collaboration and appointment of the local nobility, whose lifestyle was probably very similar to that of the general public, such a low variation in life expectancy potentially implies a lower heterogeneity. In historical and modern populations, higher male death rates are usually associated with younger individuals and attributed to interpersonal violence, high-risk behaviours or occupations with a high accident/mortality risks (Blakey and Rankin-hill, 2009; Czarnetzki, 1995; Martin and Anderson, 2014; Schmidt and Schröder, 2001; Smith, 2017). For the present sample, most injured individuals belonged to the mature elite subgroup, which could be linked with the higher death rates from 42-49 years onwards. Also, the relationship between lower life expectancies of non-elites below 42 years could be linked to lifestyle patterns but ought to be assessed in more detail. As shown already by Tumler et al. (2021), violence can largely be ruled out as a cause for the observed male mortality. Even though the trauma analysis showed a relatively high rate of injured individuals (16.4%), most of which survived their injuries (Tumler et al., 2021), these may not account solely for the observed male surplus.

Thus, again the hypothesis of selective burial practices, which accommodated individuals of a certain sex and age appears to be the most rational explanation for the observed pattern. Whereby age appeared to be a discrimination factor, i.e., three out of four of the identified senile (75%), 54.4% of the estimated mature and 48.9% of the classified adult skeletons were recovered from within the church. A similar grave distribution with a higher prevalence of older males was also found in the Basilica of San Severo in Ravenna, Italy (Ferreri, 2011). Ferreri (2011) interpreted the San Severo cemetery as an upper-class burial ground, primarily used by the newly emerging elite groups in Ravenna. While some scholars argue that heterogenous Germanic and Roman groups persisted at least until the end of the 4th century (Eger, 2015), this changed thereafter with local, i.e., Roman elite groups emerging, through which a gradual cultural and physical hybridisation occurred between the two cultural groups (Bierbrauer and Nothdurfter, 2015; Kaufmann and Demetz, 2004; Maczynska, 1998; Winckler, 2012). Hence, as Bierbrauer and Nothdurfter (2015) identified rich burials of both cultures at Säben-Sabiona, the high quantity of elite male burials seems coherent with the notion of a mutual governance and eventual fusion of both cultural groups over the early mediaeval period.

Intra-cemetery grave locations are commonly viewed as reflecting status and relations, particularly clusters of inhumations, i.e., crypts, featuring at least one adult and several individuals belonging to younger age categories strongly suggest an affiliated burial site (Carr, 1995; Eggenberger et al., 1983; Ferreri, 2011; Oxenham et al., 2008). Various studies propose that burial collectives, such as crypts may have not followed modern views on traditional customs, i.e., solely family burial sites, but often signified affiliation, which could have also been political, religious, cultural, geographical, or simply personal (i.e., neighbours, friends, etc.).

Particularly for Alpine farming populations, it needs to be noted that farms were organised in certain ways, i.e., landlord and their immediate family held the highest status and mainly managed the estate, maids and farm servants, which were sometimes siblings of the landowner, performed most of the manual work (Bruckmüller and Sandgruber, 2002; Gorfer, 2017). Thus, all of these were regarded as part of one family group, even though not all of these were related. As grave location within a burial ground provides information about the status of an individual, those that were interred within stonewalled burial chambers can be expected to represent socially important individuals, i.e., founders of a church, bishops, members of the ruling classes, etc. (Nothdurfter, 1999). Those that were buried on the outskirts may belong to the extended family group, i.e., maids and farm servants. Already Bierbrauer and Nothdurfter (2015), interpreted the crypts at Säben-Sabiona as elite family tomb. The osteological record supports this notion as crypts C and E featured a more balanced adult and juvenile sex ratio and crypts B, C and D exhibited a relatively high number of infants below six years of age.

Subadult burials were not only found to be common in crypts (42.9%) but were also present in relatively high frequencies within the church (38.2%). Eggenberger et al. (1983) suggests that subadults who were buried in prestigious areas of a cemetery, i.e., within a church, close to the relics and in front of the choir were most likely the offspring of socially high-ranking individuals, who could afford such a burial. As most other Pre- and Palaeochristian cemeteries seldomly associate subadults, particularly neonates and infants, with burials within a church (Etter and Schneider, 1982; Giovannini, 2003; Renhart, 1991), the fact that an eminent institution like Säben-Sabiona displays such a large number of infant burials is extraordinary. The observed pattern might be explicable through Czermaks' (2011) suggestion that as Christianisation was initiated and dispersed through the elite, they may have buried their children at sites linked to Christianity. Another interpretation, which, however, would require a more detailed analysis of the temporospatial context of infant burials, relates to the idea that stillborn neonates, unbaptised infants and other subadults were not regarded as members of early mediaeval society (Czarnetzki, 1995; Pinhasi and Bourbou, 2008). Due to high infant mortality rates, such individuals were generally only integrated into society once they have reached a certain age, thus, featured lower risks of dying (Carroll, 2018, 2012; Pearce, 2001). These individuals were often interred at specific sites, i.e., deserted churches and cemeteries, ancient tombs and sites of worship etc. (Czarnetzki, 1995; Etter and Schneider, 1982; Fernández-Crespo and De-la-Rúa, 2015; Pinhasi and Bourbou, 2008; Sayer, 2013b). Infant burials within a cemetery or church only became a more common practice in later periods, i.e., after the 8th century A.D. in Germany and the 9th century A.D. in Switzerland (Czarnetzki, 1995; Etter and Schneider, 1982). For Säben-

Sabiona it is known that from 600 A.D. all ecclesiastical activities were moved to the new church at the top of the mount ("Heilig-Kreuz-Kirche")(Bierbrauer and Nothdurfter, 2015). Hence, if most of these infant burials dated to the later stages of the church and cemetery use the observed pattern would be congruent with the above-mentioned notion that deceased infants were treated differently.

Based on the collected osteological data, the assessed cemeterial population featured an abnormal and inviable sex ratio, yet the age distribution is compatible with the representative criteria. From a palaeodemographic point of view this signifies selective burial practices in favour of males. Cemeteries that feature only a selection of the population, which is very specific to the values and believes of the once living society, not only display skewed sex and age ratios, but often also feature a distinct cemetery organisation and funerary culture.

7.2.2. Osteological indicators for potential relatedness

In order to test the hypothesis of selective burial patterns, kinship analysis would need to be performed, especially for crypt burials. Ideally, this would also include a full molecular, i.e., aDNA, and skeletal kinship analysis, looking at congenital conditions and non-metric traits (Case et al., 2017; Cvrček et al., 2021; Juras et al., 2016; Schroeder et al., 2019). Yet, as molecular investigations would have exceeded the scope of this research project and the osteological assessment did not focus on performing a thorough skeletal kinship analysis, retrieving accurate information about the relationships of the buried at Säben-Sabiona may not be possible. However, this study provides the osteological foundation, indicating which individuals may be related, based on which further molecular analyses can build on. Rare congenital conditions as well as cranial and dental non-metric traits are often used in skeletal kinship analysis and thus, may provide rough insights into potential relationship patterns within a cemeterial population (Case et al., 2017; Coppa et al., 1997; Cvrček et al., 2018; Hauser and De Stefano, 1989). As the affected individuals did not display distinctive burial patterns, i.e., accumulations in certain areas of the burial ground, the present osteological data did not supply sufficient information to estimate osteological kinship, i.e., similar frequencies of all recorded skeletal traits in both elite and non-elite individuals. Also, as only the presence of certain cranial and dental non-metric traits was registered, and due to the low frequency of these, they were not analysed in detail, the representativeness for kinship of these traits could be uncertain.

The prevalence of congenital conditions is more or less congruent with available literature, i.e., only three authors mention the presence of such alterations (Renhart, 2008, 1991; Tumler, 2015), indicating that these are relatively rare in mediaeval South Tyrol. Both Renhart (2008,

1991) and Tumler (2015) noted cases of congenital dislocation of the hip, craniosynostoses and spina bifida. Both congenital dislocation of the hip and spina bifida in addition to other spinal deformities, e.g., sacralisation, lumbarisation, and accessory vertebrae, were also seen in 17 individuals of the Säben-Sabiona sample. Spinal deformations, such as *spina bifida occulta* and lumbosacral transitional disorders are by far the most common congenital conditions seen in modern and ancient populations (Barnes, 1994; Copp et al., 2015; Ferembach, 1963; Roberts and Manchester, 2010), e.g., lumbosacral transitional vertebrae (sacralisation and lumbarisation) have an incidence rate of 1.5-45% (Bron et al., 2007; Dharati et al., 2012; Drew and Kjellström, 2021) or spina bifida with an occurrence rate of 1 in every 1000 births (Demirci Yonguc et al., 2021; Fletcher and Brei, 2010). *Spina bifida occulta* is generally defined as a lack of fusion of the vertebral neural arches predominantly in the lumbo-sacral region (Barnes, 1994; Copp et al., 2015; Gillespie, 1949; Ntimbani et al., 2020). The prevalence of *spina bifida occulta* tends to be higher in males and appears to be caused by both genetic and environmental factors, such as vitamin and mineral deficiencies (Barnes, 1994; Fletcher and Brei, 2010). An elevated prevalence in *spina bifida occulta* in males was also represented in the present sample, with only males displaying this condition. Similarly, also the lumbosacral transitional anomalies, lumbarisation (“caudal shift”, S1 looks like L5) and sacralisation (“cranial shift”, L5 looks like S1), have a genetic origin (Barnes, 1994; Bron et al., 2007; Carapuco et al., 2005; Erken et al., 2002; Wellik and Capecchi, 2003). Generally, both *spina bifida occulta* and lumbosacral transitional malformations are assumed to have little impact on an individual’s life, however in some cases lower back pain was associated with either condition (Barnes, 1994; Bron et al., 2007; Dharati et al., 2012; Gillespie, 1949).

Non-metric traits associated with kinship analyses were also found at low prevalence rates and those that were registered were not distinct enough to infer about familial relationships among the individuals buried at Säben-Sabiona.

In relation to kinship analysis another osteological avenue, i.e., neoplasms, ought to be mentioned here. As the presence of some neoplastic conditions has been found to be linked to genetics (Benusiglio et al., 2021; Bratt, 2002; Rahner and Steinke, 2008; Wilding et al., 2012), these osteological markers could also provide information about relatedness. Even though neoplastic conditions are less frequent in archaeological populations, single cases of both benign and malignant tumours have been reported from various sites and periods (Anderson, 2000; Binder et al., 2014b; Brothwell, 2008; Roberts and Manchester, 2010). Similar as for congenital conditions, also the prevalence of bone neoplasms was fairly low and mostly of benign origin, which is congruent with the data from other early mediaeval sites in South Tyrol (Renhart, 1991;

Tumler, 2015). Like for the previously mentioned osteological alterations commonly used in kinship analysis, the prevalence of these was low and no distinct pattern in terms of burial location could be identified to associated these with each other.
Even though the osteological evidence provided inconclusive results to answer questions about relatedness, the recorded non-metric trains, and congenital and neoplastic alterations may aid the selection of samples for further molecular analyses, i.e., aDNA, which can provide a more accurate depiction of the genetic relationships within the cemetery.

7.2.3. Body size

In addition to the demographic parameters of a population, other biological attributes such as stature, osseous frame and body mass index have been found to provide useful information about the cemeterial population, e.g., health and living conditions, which in turn may help to make inferences about the living. The estimated body height of the analysed sample is consistent with the stature estimates of other late antique and/or mediaeval sites in the South Tyrol, Trentino and Veneto regions (Carrara, 2013; Corrain et al., 1983; Gadioli et al., 2018; Gallo, 1968; Renhart, 1991; Tumler, 2015). Despite the low numbers of female skeletons, the sample shows a clear sexual dimorphism, with males generally being taller (167.8cm) than females (156.8cm), whereby a congruent pattern, although not statistically significant, was also found for elite (169.1cm versus 156.2cm) and non-elite individuals (166.9cm versus 154.8cm). These findings are most congruent with those from Biverone in Veneto, i.e., 169.2cm versus 156.5cm (Gadioli et al., 2018), Terlan-Terlano in South Tyrol, i.e., 172.9cm versus 160.3cm (Tumler, 2015), Nomi in Trentino, i.e., 168.1cm versus 156.8cm (Tumler, 2015) and St. Prokulus-S. Procolo in South Tyrol (Renhart, 1991), whereby the stature estimates of St. Prokulus-S. Procolo are almost identical to those of the present sample, i.e., 168.5cm for males and 157.9cm for females. With elites being on average 1.6cm taller than non-elites and in consideration of the assumption of body height as indicator for overall health and social position (Asao et al., 2006; Bradshaw et al., 2020; Castro-Porras et al., 2018; Marciniak et al., 2022), this observation is congruent with other contemporaneous sites, which generally displayed higher body heights (roughly 3cm taller) in individuals identified as members of elevated social classes than those belonging to the general public (Siegmund, 2010). Even though this difference between elite and non-elite individuals was not found to be statistically significant, probably due to the low sample size, i.e., 52 elite and 36 non-elite individuals, the observed trend still persists. Research on stunting in modern populations found that social disadvantages leading to limited access to food materials and other physical and psychological constraints were the main causes for lower average body height (Bogin et al., 2018; Scheffler et al., 2021; Scheffler and Hermanussen, 2021). Also, subsistence and political turbulences, i.e., transition from hunting and gathering to farming and warfare, have been found to be contributing factors to lower body heights (Bogin et al., 2018; Hermanussen et al., 2015; Scheffler and Hermanussen, 2021). However, as farming was already well established by the early mediaeval period (Winckler, 2012) and osteological evidence for conflict was limited to only a few individuals buried in Säben-Sabiona (Tumler et al., 2021), these factors may have had little impacts on the body height of the population as a whole. When comparing the present stature data with that of other contemporaneous populations (c.f., Czermak, 2011; Scheffler and Hermanussen, 2021; Tumler, 2015), the yielded estimates can be considered to be within the normal ranges given the time period and location.

This notion is also supported by the body weight, BMI and OFI data. With 69.9kg for males, i.e., 70.9kg for elite and 71kg for non-elite males, and 59.1kg for females, i.e., 60.5kg for elite and 59kg for non-elite females, the estimated body weight is congruent with other early mediaeval sites, e.g., different sites in Baden-Württemberg in South-West Germany (4th-9th centuries A.D.) 71.3kg for males and 59.1kg for females (Jasch et al., 2018). Following a WHO (2005) report, BMI data can be classified into the following categories: underweight (<18.5kg/m^2), normal weight (18.5-24.9kg/m^2), overweight (25-29.9kg/m^2) and obese (>30kg/m^2). Based on this classification, the Säben-Sabiona population (BMI- 24.8kg/m^2) would fall into the upper end of the normal weight category, thus, suggests good health from an osteometric point of view (Pollmer, 2007; Stenholm et al., 2017). As both subsamples featured very similar BMI scores, i.e., 25.1kg/m^2 for elite and 24.9kg/m^2 for non-elite individuals, implies that an elevated health status regardless of social class. Witt and Bush (2005) found that muscular individuals are often misclassified using the normal BMI scoring system, whereby the consideration of the body frame index in conjunction with the BMI score would provide a better representation of body composition. As the osseous frame index poses a good alternative to the body frame index for skeletal series (Jasch et al., 2018), this data provides crucial information about the body shape of the present sample. In comparison with the data of Jasch et al. (2018), who examined early mediaeval skeletons from South-West Germany, the OFI of the total Säben-Sabiona sample (36.7 for females and 37.8 for males) as well as when subdividing the cemeterial population into elite (36.7 for females and 37.8 for males) and non-elite (36.8 for females and 38 for males) was more or less congruent with their data (35.2 for females and 37.8 for males). As both the female and male values were relatively similar, this indicates increased muscle mass for both sexes and may be interpretable as a sign for environmental adaptation. From ethnographic research it is known that certain environmental conditions entail certain physiological traits and compositions, i.e., colder climates and higher altitudes are commonly associated with organisms of small and robust body structure (Binford, 2019; Bogin et al., 2018; Johnson, 2014). Thus, the observed body size and shape may be attributable to the alpine environment, i.e., harsh, and cold climates in conjunction with mountainous landscape of the South Tyrolean Alps. This notion is supported by Ruff et al. (2006) who compared the biomechanical data of the South Tyrolean Iceman and other contemporaneous sites and interpreted the observed variations as consequences of alpine specific functional adaptations. The effects of climate and other environmental factors, e.g., terrain, on musculoskeletal morphology have been evidenced by numerous publications (Acosta et al., 2017; Czermak, 2011; Havelkova et al., 2011; James and Tallis, 2019; Pearson, 2000; Ruff, 2019; Steckel et al., 2018; Winckler, 2012). In order to assess this notion further, comparisons with other osteological collections from the local area are necessary, yet, as South Tyrol currently still lacks suitable osteometric datasets, the biomechanical context of the present sample cannot be established at this stage. Aside from changes in robusticity and stature, which are attributable to a more chronic exposure of a population to unfavorable conditions (James and Tallis, 2019; Pearson, 2000), pathological lesions on the skeleton and dentition offer insights into the short-term effects of landscape and climate on population health (Acosta et al., 2017; Steckel et al., 2018).

7.3. Living conditions and morbidity

As demonstrated in the results chapter, 80.5% of the individuals buried at Säben-Sabiona showed signs of skeletal (72.1%) and/or dental abnormalities (87.3%), whereby no major differences were recorded for elite (71% and 85.5%) and non-elite individuals (74% and 90.4%). As both subgroups featured similar frequencies of pathological alterations, this may seem to contradict the hypothesis about social stratification. Yet, it needs to be taken into account that all individuals buried at Säben-Sabiona were possibly of elevated social status (Bierbrauer and Nothdurfter, 2015; Nothdurfter, 1999), thus, social stratification within the sample may have been lower than in other populations with a more distinct separation. Furthermore, all of the assessed alterations are not necessarily a representation of overall health, e.g., dental wear, perimortem trauma, etc., thus, to gain information about the actual health status, individual alterations need to be assessed in greater detail. Regardless of this, the present palaeopathology prevalence is substantially higher than what was recorded for other early mediaeval sites in northern Italy, e.g., Biverone (34%) or Dueville (16.1%)(Carrara, 2013; Gadioli et al., 2018). When contextualising pathological lesions, it is important to consider both the demography of the assessed sample and the nature of the observed alterations. As every cemeterial population is unique, in terms of temporospatial context, extrinsic and intrinsic factors affecting body composition and health, as many of these uncontrollable variables ought to be regarded to be able to formulate meaningful interpretations. Biverone (4^{th}-5^{th} centuries A.D.) and Dueville (7^{th}-9^{th} centuries A.D.) featured a relatively young skeletal population, whereby the majority of individuals died as adults, i.e., 20-39 years (Carrara, 2013; Gadioli et al., 2018). However, as most individuals of the Säben-Sabiona assemblage belonged to the mature, i.e., 40-59 years, age category, and as the chance of developing a disease usually increases with advancing age, a higher prevalence of pathological lesions is expected.

Another much discussed concept that should be incorporated when interpreting palaeopathological lesions relates to the publication *The Osteological Paradox* by Wood et al. in 1992. According to Wood et al. (1992) demographic non-stationarity (temporal fluctuations in population size and fertility), selective mortality (cemeterial population may not be representative of the living population) and hidden heterogeneity (individual susceptibility to disease) are major contributing factors affecting the bioarchaeological contextualisation of past populations (Grauer, 2012; Wood et al., 1992). It is further argued that as part of the survival strategy, the human body can adapt and change to a certain extent as response to environmental influences (Grauer, 2012; Moore et al., 2013; Ortner, 2003; Wescott, 2013). Thus, any abnormality observable in skeletal remains may not be a sign for weakness or susceptibility for a disease, but rather a natural response to an agent affecting the physical integrity of the whole organism (DeWitte and Stojanowski, 2015; Grauer, 2012; Wood et al., 1992). Already the fact that the skeletal system is affected, and the severity of the observed disorder, evidences a chronic characteristic and a good health of the individual to live long enough to develop such severe pathological manifestations. A study by Kyle et al. in 2018 on two Sicilian late antique sites found that their civilian sample, which was typically of older age, featured a substantially higher variety and prevalence of skeletal disorders, whereas the assessed soldier sample, mostly younger individuals, displayed far less pathological lesions. Most of the observed skeletal alterations were attributable to degenerative (55%), metabolic (38%), infectious (31%) or traumatic processes (16%), with only a few related to congenital (8%) or neoplastic (6%) skeletal changes. These diseases have shown to be strongly correlated with extrinsic factors, such as climate, terrain, subsistence types, activity, and diet (Acosta et al., 2017; Kyle et al., 2018; O'Donnell et al., 2020; Ortner, 2003; Roberts and Manchester, 2010; Steckel et al., 2018). A similar pattern was also observed for dental alterations, which mainly featured lesions associated with diet and physiological stress. Thus, the vast diversity of skeletal and dental disorders in conjunction with high death rates in older age categories suggests that the individuals buried at Säben-Sabiona were often affected by disease, yet, were healthy enough to overcome any impediment, and survive up to old age. Despite the probable selective nature of the present sample, this interpretation still stands, as it is obvious from the observed pattern, which did not differ when subdividing the sample into elite and non-elite, that the interred have been of relatively good health. According to Marklein et al. (2016) individuals associated with monastic sites generally displayed both higher morbidity and increased longevity. Monastic life was characterised by improved living quality, e.g., better sanitation and water supply, access to food and shelter, which enabled longevity, but also substantial manual labour (Frazee, 1982; Marklein et al., 2016; Morton, 1852). Given the demographic distribution of the Säben-Sabiona sample and the fact that a renowned Benedictine nunnery is associated with the site such an interpretation seems plausible, even though the church in the vineyard is linked to Early Christianity. According to Frazee (1982), between the 4th to 8th centuries A.D., monasticism emerged from Christianity and was incorporated into Roman legislation. Hence, as religious leaders, e.g., bishops and other high ranking clergymen were commonly associated with the rise of monasticism (Dey, 2008; Frazee, 1982; Ullathorne, 1856), religious centres such as Säben-Sabiona could have been ideal locations for such initiations, i.e., a proto-monastery. In terms of temporospatial context, this assumption would be reasonable, as the Benedictine convent of St. Johann Müstair in Graubünden, near the Swiss-Italian border, which belonged to the episcopal see of Chur, was established around the 8th century A.D. (Sennhauser, 1999). According to Köpf (1999), mediaeval religious sites are generally divided into parish, monastic or proprietary churches, whereby all of these were founded due to political motives rather than religious ones and those that are located near important routes, often also had a pilgrimage and hospital function. To investigate these notions further and to contextualise the observed frailty to specific disorders in relation to social status, each of the identified conditions will be examined more thoroughly in the following sections.

7.3.1. Diet, stress, and infections

One fundamental way to establish subsistence strategies and living conditions includes the examination of dietary practices, the prevalence of physiological stress indicators and infectious diseases (Larsen, 2002; Steckel et al., 2018).

7.3.1.1. Diet

By assessing dietary patterns, i.e., types of foods consumed by an individual, crucial information can be obtained that helps to interpret the structure of past societies, their settlement patterns and health in these settings (Larsen, 2002). Osteological diet reconstruction relies predominantly on the analysis of disorders affecting the masticatory apparatus, which were found at a crude prevalence of 87.3% in the total Säben-Sabiona sample, whereby elite (85.5%) and non-elite individuals (90.4%) featured almost equal frequencies. These rates are much higher than what was observed in the late antique site of Biverone (16%) near Venice (Gadioli et al., 2018), yet in comparison with other early mediaeval sites in South Tyrol, e.g., Tanas (50%), Eppan-Appiano-Altenburg (50%) or Terlan-Terlano (63%) (Tumler, 2015) the recorded data was slightly more congruent.

7.3.1.1.1. Cereal consumption and processing

The most common alteration was dental wear (81.3%), for which a slightly higher prevalence was recorded for non-elite individuals (84.6%) than elite individuals (81.9%). As most anthropological studies on late antique and early mediaeval South Tyrolean site, e.g., Kapuziner Kloster- Convento dei Cappuccini in Bozen-Bolzano, Laag-Laghetti in Neumarkt- Egna, Pfatten-Vadena, Castelfeder and Elzenbaum in Freienfeld- Campo di Trens only mention the presence of dental wear, but lack information about lesion frequency, severity or its presence in relation to other variables (Giovannini, 2003, 2002; Renhart, 2006), comparisons were highly limited. Only Tumler (2015) provided raw data to estimate crude and true prevalence rates. Based on these, the sites Eppan-Appiano-Altenburg (50%) and Montan-Montagna Pinzon (83.3%) were most analogous.

Regardless of comparability with other local sites, dental wear is known to be mainly the result of either attrition, two dental surfaces rubbing against each other (e.g., bruxism), or abrasion, damage caused through mastication of rough food materials (d'Incau and Saulue, 2012; Hillson, 1996; Molnar, 1970). A study by Eshed et al., (2006) on a Natufian and Neolithic population attributed the observed dental wear to both diet, i.e., consumption of fibrous plants and other tough food materials, as well as food preparation practices, e.g., the use of pestles and mortars that polluted foods with small stone particles. According to historical and ethnographic sources, late antique and early mediaeval Alpine subsistence relied predominantly on animal husbandry and agriculture, whereby crop cultivation was most common (Bruckmüller and Sandgruber, 2002; Winckler, 2012). From the 6th century A.D. onwards, Europe experienced a climate change that favoured the expansion of agriculture and thus, also an increased cereal consumption (Czermak, 2011; Prinz, 2003). Hence, as almost half of the individuals buried at Säben-Sabiona featured signs of dental wear, which was mostly medium or low, this might suggest a frequent exposure to materials that promoted dental abrasion, particularly for non-elite individuals. As the difference in dental wear prevalence between elite (81.9%) and non-elite individuals (84.6%) was not statistically significant, the observed pattern maybe a coincidence. However, as social differences in dental wear were also observed by other scholars (Dawson and Brown, 2013;

Larsen, 2015; Miliauskienė and Jankauskas, 2015) these need to be considered here. Lower dental wear in higher social classes was associated to an increased consumption of soft textured materials, i.e., refined and processed food items (Dawson and Brown, 2013; Larsen, 2015; Miliauskienė and Jankauskas, 2015). Woolgar et al. (2006) argues that in mediaeval England, upper class diet was characterised by a high consumption of meat and more exotic foods, whereas monastic diets were mainly based on vegetables and grains. This notion is consistent with local historical sources, i.e., a transition from agriculture to a heavier reliance on animal husbandry linked to Germanic invasions (Winckler, 2012) and would also support the present data for elite and non-elite individuals.

Another important factor affecting tooth wear is enamel integrity (Babajko and Besten, 2021; König, 2000; Mobley, 2003). O'Toole and Mullan (2018) found a strong association between an increased dietary acid consumption and erosive tooth wear. Various orthodontic studies have found that acidic oral environments have a negative effect on tooth formation and mineralisation (Casas-Apayco et al., 2014; O'Toole and Mullan, 2018; Oncag et al., 2005). Dentition with a weakened enamel structure is much more susceptible to tooth abrasion and attrition, than healthy teeth with a calcium and phosphate rich enamel composition.

7.3.1.1.2. Carbohydrates and tooth decay

An indication for weakened enamel may be the presence of dental caries, as both enamel dissolution and pulp exposure through dental wear have been found to be major risk factors for the development of such lesions (König, 2000; Oncag et al., 2005; Touger-Decker and van Loveren, 2003). At Säben-Sabiona, 46.3% of the analysed sample featured at least one carious lesion, however the true caries prevalence was substantially lower (8.1%), and most individuals only featured one or two carious lesions. As expected and congruent with the dental wear data, non-elite individuals featured significantly higher crude (63.5%) and true prevalence rates (10.6%) that elite individuals (34.9% and 6%). The availability of comparable data from contemporaneous South Tyrolean sites is limited to the study by Tumler (2015) and due to a lack of contextualisation of the analysed sites a more detailed review could not be performed. The crude prevalence rates of the elite sample were mostly like those of Tanas (33%) and Eppan-Appiano-Altenburg (33.3%), whereas true prevalence rates of Nomi (6.3%) were more analogous. Caries frequencies of the non-elite subgroup were most congruent with the crude data of Montan-Montagna-Pinzon (83.3%) and true data of Tanas (10%).

As dental caries is known to be a diet-dependent disease that is primarily attributed to a high accumulation of *Streptococcus mutans* bacteria, which are associated with the digestion of carbohydrates (Hillson, 1996; König, 2000; Moye et al., 2014), the present prevalence rates, particularly for elite individuals, might suggest a low carbohydrate intake. In fact, this assumption is also supported by the previously discussed dental wear data as well as the available historical and archaeobotanical data for the central Alps, which suggest diets with a low cariogenic load (Gilck and Poschlod, 2019; Oeggl, 2009; Winckler, 2012). Thus, alpine subsistence strategies, e.g., pastoralism, animal husbandry and agriculture might offer an explanation for the observed pattern. According to Turner (1979) for populations following sedentary, e.g., agricultural (2.3-26.9%), and mixed economic subsistence strategies (0.4-10.3%), commonly exhibit higher true caries frequencies than those following mobile, i.e., hunting and gathering (0.0-5.3%) subsistence strategies, which would be consistent with the data of the present sample. Alpine pastoralism is known to have been practiced in the area at least since the Copper Age, as evidenced by the analyses of "Ötzi" the South Tyrolean ice mummy (Gilck and Poschlod, 2019; Putzer et al., 2016). As both pastoralism and farming, later also agriculture became the most common forms of subsistence for early mediaeval alpine populations (Kustatscher and Romeo, 2010; Winckler, 2012), their diet is believed to have been protein and carbohydrate rich (Mundle, 2018). This notion has also been confirmed through stable isotope analyses by Mundle (2018), who found that individuals from the Säben-Sabiona cemetery consumed predominantly animal protein in conjunction with C3 plants, e.g., wheat, rye, spelt and barley, and some C4 plants, e.g., sorghum and millet. Several orthodontic and nutritional studies showed that caries development is not solely the result of carbohydrate consumption, but can be linked to diets affecting the cariogenicity of saccharides, which is also influenced by other factors affecting the oral microbiome, e.g., fluoride proportions; saliva levels, pH, and composition; as well as plaque pH (Botelho et al., 2016; Bowen, 1994; Hillson, 1996; König, 2000; Mobley, 2003; Moye et al., 2014; Touger-Decker and van Loveren, 2003). As certain foods, such as milk, cheese, plant foods rich in phosphate and phytate, e.g., grains, legumes and certain herbs, possess cariostatic properties (Gemede, 2014; McClure, 1964; Moynihan, 2000; Moynihan et al., 1999; Philip et al., 2019), the relatively low caries prevalence in Säben-Sabiona may be explainable through such a diet. Research by Moynihan et al. (1999) and Ravishankar et al. (2012) found a close relationship between the consumption of dairy products, which have cariostatic properties, and elevated calcium and phosphorus levels in dental plaque. Thus, the relatively low caries prevalence in conjunction with the elevated dental wear pattern supports the idea of a diet rich in protein, i.e., dairy products and plant-based foods that may have been contaminated in the manufacturing process.

7.3.1.1.3. A macronutrient rich diet

Another dental disorder that is associated with increased dairy consumption is dental calculus. This condition was found at a crude prevalence rate of 53.7% for the total sample and 49.4% for elites and 59.6% for non-elites. In comparison to other local early mediaeval sites, the present frequencies were most analogous with the dental data of Eppan-Appiano-Altenburg (50%) (Tumler, 2015).

Dental calculus derives from the mineralisation of dental plaque that accumulated at the base of the tooth crown (gingival margin) and is most commonly associated with an alkaline oral environment in conjunction with poor dental hygiene (Hillson, 1996; Lieverse, 1999). Diets with a high lipid, protein and carbohydrate content, especially foods containing starch, and those that promote saliva flow, have shown to increase dental calculus development (Hardy et al., 2009; Lieverse, 1999; MacKenzie et al., 2021; Roberts and Manchester, 2010; Setiawan et al., 2021; Smith et al., 1963). Based on the crude dental calculus data, it appears that at least one third of the buried, particularly non-elite individuals, had access to food sources with an increased lipid, protein, and carbohydrate content. This aligns well with the previous interpretation of elevated dairy consumption as well as the available data from stable isotope, historical and archaeological analyses (Kustatscher and Romeo, 2010; Mundle, 2018; Winckler, 2012). Modern day ethnographic data shows that rural populations often obtain their protein requirements from dairy products, whereas meat-derived protein is more commonly associated with socially higher ranking or urban populations (Bruckmüller and Sandgruber, 2002; Darmon and Drewnowski, 2008; He et al., 2016; Murayama, 2015). Furthermore, also the fact that one case of diffuse idiopathic skeletal hyperostosis (SK230), belonging to the non-elite category, and one case of possible gout (SK151A), identified as elite, which are disorders commonly associated with protein, particularly red meat, and lipid-rich diets, obesity and diabetes mellitus (Kiss et al., 2002; Mader et al., 2013; Rogers and Waldron, 2001; Zincarelli et al., 2012), were discovered among the Säben-Sabiona skeletal assemblage suggests that only single individuals had access to a very rich diet.

7.3.1.1.4. Consequences of a macronutrient rich diet

Diets favouring dental calculus development inevitably also affect alveolar health. As an increased amount of dental calculus causes gingivitis, which will eventually lead to a resorption of the alveolus (Akcalı and Lang, 2018; Albandar et al., 1996; Hillson, 1996), the similarly high prevalence rates of periodontitis are not surprising, i.e., 53% for the total sample, 59.6% for non-elite and 48.2% for elite individuals (statistically insignificant). Similar relationships between calculus and periodontitis were also found at the late mediaeval site of St. Lorenzen-S. Sebato-

Sonnenburg (42% vs. 40%) and the early mediaeval sites of Eppan-Appiano-Altenburg (50% vs. 50%), Montan-Montagna-Pinzon (83% vs. 80%) and Tanas (33% vs 33%) (Renhart, 2008; Tumler, 2015). As St. Lorenzen-S. Sebato-Sonnenburg is a monastic site and the others are rural sites, it can be assumed that dietary habits were more or less consistent across different spatiotemporal contexts, i.e., increased consumption of food items, most likely originating from pastoralist, farming and/or agricultural activities.

Elevated levels of alveolar regression can contribute to even more severe conditions, as tooth roots are exposed and the gomphoses holding teeth in place are weakened, thus may lead to increased rates of caries infections, apical lesions and even antemortem tooth loss (Al-Shammari et al., 2005; Bignozzi et al., 2014; Hillson, 1996; López et al., 2017; Ramseier et al., 2017).

In the present sample the total crude prevalence of dental caries (46.3%) was somewhat similar to that of periodontitis (53%), however, as the true prevalence rate of carious lesions was relatively low (8.1%), a more detailed analysis of the data is required to establish how many of the actual carious lesions may be attributable to periodontitis. As true prevalence rates were only recorded for caries and periodontitis frequencies were registered based on tooth group, i.e., incisors and canines versus premolars and molars, such an analysis was not possible at this stage and necessitates reassessment of the material focusing on establishing the number of teeth affected by periodontitis.

Apical lesions were found at a crude prevalence rate of 28.4% in the total sample. In comparison to other local late antique and early mediaeval sites, e.g., Nomi (25%), Terlan-Terlano (50%), Eppan-Appiano-Altenburg (33.3%) and Montan-Montagna-Pinzon (50%), the observed total prevalence as well as that of both subgroups (24.1% for elites and 38.5% for non-elites) is on the lower end. Apical lesions are most commonly associated with a streptococcal infection of the root, which then spreads to the surrounding tissues (Oei and Hülsmann, 2018; Robertson and Smith, 2009). The exposure of the root to these bacteria, through periodontitis, dental wear and/or dental caries is the most predominant factor in the development of a dental abscess (Oei and Hülsmann, 2018). Modern studies established that a person's lifetime true prevalence of dental abscess is 5-46% (Sutherland and Matthews, 2003), thus, the present data (i.e., 4.3% for the total sample and 3.9% for elites and 4.8% for non-elites) fall within the lower end of what is common in modern datasets.

Advancement of these dental disorders ultimately leads to premature tooth loss (Delgado-Darias et al., 2006; Fujita et al., 2013; Hillson, 1996; Mayes, 2016). When interpreting the prevalence rates of these disorders it is crucial to consider antemortem tooth loss frequencies. With a crude prevalence of 44.8% (39.8% for elites and 51.9% for non-elites), and a true prevalence of 12.4%

(11.2% for elites and 20.1% for non-elites), antemortem tooth loss was relatively high for the present sample. In comparison with the true prevalence rates of other local sites, i.e., Montan-Montagna-Pinzon (4.6%), Nomi (12.3%), Eppan-Appiano-Altenburg (17.4%) and Tanas (18%), the present data is congruent with the general pattern. High antemortem tooth loss rates imply that the true dental disorder frequencies, i.e., caries (8.1% for the total sample, 6.4% for elites and 10.6% for non-elites), may have been substantially higher than what was recordable from the available teeth. To assess the impact of premature tooth loss on the registered dental disease prevalence rates, i.e., caries and wear, further analyses, including a correction calculation, would be required (Lukacs, 1995; Trombley et al., 2019). However, as true prevalence data were only recorded for caries and antemortem tooth loss, but not for dental wear, which is a factor that needs to be considered, the correction calculation could not be performed. Regardless of this, as antemortem tooth loss is most commonly the result of dental disorders (Delgado-Darias et al., 2006; Fujita et al., 2013; Hillson, 1996), the high rates as seen in the Säben-Sabiona sample further reinforce the assumption that these individuals regularly consumed food items that had a negative effect on their oral health.

Data from modern populations and clinical research reported a significant relationship between poor oral health, an increased mortality risk and a low socioeconomic status of the affected individual/population (Chandra Shekar and Reddy, 2011; Dye and Thornton-Evans, 2010; Hobdell et al., 2003; Jansson et al., 2001; Kim et al., 2013; Park et al., 2016; Paula et al., 2012). As higher disease frequencies were recorded in non-elite than elite individuals, this might point towards a slightly lower socioeconomic status of non-elites in comparison to the present elite sample. Even though a statistically significant difference was only observed for caries, the present prevalence rates still indicate worse oral health for the non-elite sample. A study on the late mediaeval site of Villamagna in Italy, for which only dietary practices were held responsible for the observed dental diseases, showed substantially higher true prevalence rates of caries (18.3%-21.9%) and antemortem tooth loss (16.3%-18.7%), and lower periapical lesions frequencies (3.3%-2.3%) (Trombley et al., 2019), than what were observed in the total sample. In consideration of the evidence available for the Säben-Sabiona sample, both sites appear to be fairly similar in terms of the socioeconomic context, i.e., rural populations that relied on a mixed-farming subsistence strategy and were associated with a religious estate (Trombley et al., 2019). Multiple sources report that monastic populations and those linked to religious and/or political centres generally displayed distinct disease patterns at higher frequencies (Agnew and Justus, 2014; Belcastro et al., 2007; Marklein et al., 2016). For the present sample, such a trend could only be noted in the non-elite sample, which had higher dental disease frequencies than the elite group. With alpine farming and pastoralism, probably, being the main form of subsistence during the early mediaeval period, only wealthy members of the society could afford foods of high nutritional value (Kustatscher and Romeo, 2010; Winckler, 2012). At Säben-Sabiona, the zooarchaeological and stable isotope analyses suggest that the buried had access to such rich food sources, as bones of cattle, pigs, red deer, sheep and chickens were recovered, and the nitrogen and carbon ratios also indicate subsistence practices containing mainly C3 plants, a minor contribution of C4 plants and animal protein (Mundle, 2018). Hence, both subsamples may have had access to the same/similar foods, yet it is likely that social differences in food processing and selective access to high quality products may be the main reason for the observed low differences and statistically insignificant results for most dental alterations apart from caries. To investigate this notion further stable isotope analyses considering this assumption need to be performed.

7.3.1.1.5. Sex and age-related dietary differences

Differences between the sexes in relation to social status and age groups were noticed, although as lower prevalence rates were recorded for all subadults (implying good subadult health) and unsexed adults, these will not be discussed in further detail. For the remainder of the sample, quite a distinct picture in relation to sexual division in food consumption and dietary behaviour emerged. As opposed to the wider literature (Bardsley, 2014; Eidissen, 2020; Geber and Murphy, 2018; Trombley et al., 2019; Ubelaker et al., 2011) for most conditions, males featured substantially higher crude prevalence rates of dental alterations than females, e.g., 79.4% versus 55% for dental calculus, 75% versus 65% for periodontitis, 64.7% versus 55% for caries, 97.1% versus 80% for dental wear. A somewhat consistent pattern was also found when subdividing the sample into elite and non-elite individuals, whereby slightly larger differences between the sexes in the prevalence of dental wear, calculus, antemortem tooth loss and dental caries were noted for non-elite individuals. In most bioarchaeological samples, females feature worse dental heath than males, and this has been mainly attributed to biological factors, i.e., hormones, mineral metabolism during gestation, or differentiated dietary practices among a population (Bardsley, 2014; Eidissen, 2020; Oziegbe and Schepartz, 2021; Trombley et al., 2019). However, as the Säben-Sabiona males displayed significantly more dental disorders, which are not attributable to increased hormonal fluctuations due to pregnancy and menstruation as in females, this pattern might suggest sexually differentiated access to certain foods and/or consumption of these. Mundle (2018) found significant differences between the male and female isotope ratios. Yet, as isotopic sources were not established, i.e., the exact animal protein content cannot be quantified, the anthropological data was not processed and interpreted at the time and the isotopic sex ratios were not assessed in detail, the degree of sex-related dietary practices, from a stable isotope perspective, remain obscure. Looking at the supplemented isotopic raw data it appears that the Säben-Sabiona females had slightly higher nitrogen values than males. To further assess this notion, the now available osteological evidence can be used to propose interpretations.

The increased dental disease rates in males might be linked to the quantity of food consumption, as it is known that more frequent exposure to carbohydrate- and protein-rich food sources can have a substantial impact on the development of dental caries and calculus (Grimoud et al., 2011; Hillson, 1996; Lingström et al., 2000; Moynihan, 2000; Ravishankar et al., 2012), which in turn would also increase the occurrence of associated dental conditions, i.e., periodontitis, periapical lesions, antemortem tooth loss (Hillson, 1996; Silva Junior et al., 2019). Alpine agriculture, farming and pastoralism as well as hunting on such uneven terrain and mining are regarded as highly strenuous activities (Weisdorf, 2009; Zellweger et al., 1993) that require a substantial caloric intake on a regular basis (Eli and Li, 2015; Maughan, 2000). Hence, as activities outside the immediate household are commonly the sole subsistence responsibility of males (Larsen, 2015; Winckler, 2012), the observed dental disease pattern may just be the result of that, i.e., an increased food consumption to meet their caloric requirements. As the elite subsample features higher differences in the frequencies of dental wear (97.5% in males versus 83.3% in females), calculus (77.5% in males versus 58.3% in females), periodontitis (75% in males versus 66.7% in females), periapical lesions (40% in males versus 25% in females) and caries (52.5% in males versus 41.7% in females) between the sexes than non-elite individuals (i.e., wear- 92.6% versus 77.8%, calculus- 77.8% versus 44.4%, periodontitis- 74.1% versus 66.7%, periapical lesions-50% versus 62.5% and caries 82.1% versus 62.5%) this might be an indication for more prominent sexual division of food consumption and behaviour in elite individuals. More detailed insights into the sex and/or status related differences can be obtained by looking at the assessed true prevalence rates, i.e., caries, periapical lesions and antemortem tooth loss.

The observed sex related bias in terms of dental disease distribution was also reflected in the true prevalence rates of caries for the total sample (11.4% for males versus 7.5% for females) and for elite individuals (9% for males versus 4% for females), yet not for non-elite individuals (16.4% for males and 22.4% for females). As already addressed earlier, the observed true caries prevalence rate in elite individuals is very unusual, as in most osteoarchaeological studies, females featured higher caries rates than males, due to earlier dental eruption, increased oestrogen levels and continuous hormonal fluctuations, as well as pregnancy and lactation, which have been shown to have a negative effect on female oral health (Eidissen, 2020; Ferraro and Vieira, 2010; Geber and Murphy, 2018; Larsen, 2015; Trombley et al., 2019). Furthermore, in most bioarchaeological contexts, males are associated with high-protein-content diets and females with diets containing more plant-based foods, i.e., carbohydrates, which increase caries prevalence rates (Larsen, 2015; Miliauskienė and Jankauskas, 2015). The patterns recorded for the non-elite subsample are consistent with the general consensus, yet, the lower true caries prevalence rates in elite females might suggest that they consumed food items of lower cariogenicity than elite males. This assumption is also supported by the similar patterns seen for periapical lesions, with elite individuals featuring higher crude and true prevalence rates in males (40% and 6.1%) than females (25% and 1.7%), whereby a less distinct but opposite distribution was seen for non-elite individuals, i.e., 50% and 7.1% in males, and 62.5% and 8.1% in females. Thus, the present data may indicate specific sex-related dietary practices and behaviours that are linked to the social status of an individual, e.g., dairy versus meat protein, food items of lower nutritional quality, etc. Furthermore, modern studies have found that oral health of males is substantially poorer than that of females, predominantly due to a lack of oral hygiene and negligence of already developed disorders (Bencosme, 2016; Lipsky et al., 2021). This in conjunction with an increased intake of food items favouring tooth decay might be a reason for the observed pattern.

High rates of dental disorders also increase the chance of premature tooth loss, this in turn also affects the number of teeth available to assess the prevalence of dental disorders. Thus, increased consumption of foods leading to dental disorders as seen in males, would inevitably also lead to higher numbers of antemortem tooth loss. This, however, was not the case for the Säben-Sabiona sample, where both, crude and true prevalence of premature tooth loss was significantly higher in females than males, i.e., crude prevalence rate of 75% versus 58.8% and true prevalence rates of 26.7% versus 13.9%. Increased female antemortem tooth loss was also consistent over both the elite and non-elite subsample. Two major hypotheses regarding the elevated rates of antemortem tooth loss in females can be proposed, dietary and/or reproductive factors. Due to the higher rates of premature tooth loss, it is possible that females consumed similar amounts of food as their male counterparts, yet this was not discernible from the present data as those teeth may have been lost whilst alive as a consequence of such a diet. Reproduction poses a considerable risk factor contributing to premature tooth loss in females, as the physiological, metabolic and nutritional demands of gestation and lactation have been shown to have a negative effect on female dental health (Gabel et al., 2018; Oziegbe and Schepartz, 2021; Silk et al., 2008). A study by Oziegbe and Shepartz (2021) found that high parity women exhibited significantly increased frequencies of tooth loss, than women who had less children despite poor oral hygiene and dental care practices. As the presence of a preauricular sulcus simply indicates physiological loading onto the pelvic girdle, thus does not inform about parturition or the quantity of births (Waltenberger et al., 2022), this cannot be confirmed, yet, given the high incidence rate of antemortem tooth loss, such an assumption is still valid. In consideration of the high numbers of subadults, this notion appears plausible, despite the lack of female skeletons. A divergence between the sexes in relation to antemortem tooth loss was particularly evident in the mature and senile age category, where females exhibited substantially higher true prevalence rates than males (33.3% versus 20.2% and 62.5% versus 6.7%). This was consistent over both subgroups, although mature non-elite females (46.2%) had a higher rate than elite females (18.8%). Senile data were only available for elite females; thus, no comparisons could be made. Higher frequencies in older females may be attributable to hormonal changes taking place during menopause, which has been positively associated with increased rates of dental disorders, particularly antemortem tooth loss (Buencamino et al., 2009; Pan et al., 2019). As females are generally more prone to be affected by antemortem tooth loss due to continuous hormonal fluctuations, initially due to menstruation, pregnancy and lactation, and then at later ages due menopausal decrease of hormone production (Suri and Suri, 2014), such high premature tooth loss rates in older females can be expected. Although, hormonal changes may not be the sole culprit here, especially in consideration of the social status of the assessed sample, i.e., non-elite females displaying higher rates of antemortem tooth loss. Some clinical studies found that lifestyle, socioeconomic status and age or a combination of all of these factors may increase the prevalence of antemortem tooth loss in females (Alves et al., 2015; Castro Alves et al., 2013). Thus, for the Säben-Sabiona sample the increased rates of antemortem tooth loss in the elite female group may be more likely to be primarily attributable to hormonal/biological factors, whereas for non-elite females, their socioeconomic status may have caused an additional burden impacting alveolar and tooth health.

7.3.1.2. Stress and infections

Aside from providing information about diet and nutrition, dental markers, i.e., linear enamel hypoplasia, in combination with other skeletal lesions (e.g., cribra and porotic hyperostosis) are often used to assess the exposure to stress, which in turn can potentially provide insights into some aspects of overall health of a population (Goodman and Armelagos, 1985; Goodman and Rose, 1990; Hillson, 1996; Reitsema and McIlvaine, 2014; Steckel et al., 2018; Wood et al., 1992). The World Health Organisation defines health as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity" (WHO, 1999), hence, the health status as such can never be fully established from a past population (Reitsema and McIlvaine, 2014). Without the availability of the wider context, the examination of stress markers on dental and skeletal remains can only provide partial information about the physiological health of an individual and/or a population. In consideration of these aspects, the following discussion concerning the observed dental and skeletal stress markers solely attempts the elucidation of physiological health of the present sample.

Linear enamel hypoplasias mark an episode of amelogenetic arrest that is most commonly associated with exposure to chronic stress (Hillson, 1996; Reid and Dean, 2000). With a crude prevalence of 11.9%, i.e., 9.6% for elites and 15.4% for non-elites, such lesions were relatively uncommon in the Säben-Sabiona sample. Again, due to a lack of comparable data from local sites, i.e., mostly limited to the presence of LEH (c.f., Giovannini, 2002; Paladin and Zink, 2015), more contextualised confrontations were not possible. Regardless of this, the recorded data can still be interpreted using a more holistic approach. Two explanations can be proposed here, either that the ones who experienced subadult hardship, died younger as a consequence of these circumstances, thus could not develop any physical evidence indicating such an exposure and/or that early mediaeval life in this area of the Alps was characterised by low rates of physiological stress. The former hypothesis is supported by current research suggesting a greater selective pressure on the frailest individuals of a group, promoting survivorship of the fittest (DeWitte, 2014; Wood et al., 1992). Low physiological stress rates are also reasonable, since no evidence was found to suggest that the Eisack-Isarco valley was influenced significantly by other factors, aside from the continuous changes in leadership linked to mass migration, which would not have impacted physiological health so dramatically (Bierbrauer and Nothdurfter, 2015; Tumler et al., 2021; Winckler, 2012). In fact, historical studies suggest that political fluctuations had a greater impact on elite individuals than the general public, who was rarely affected (Winckler, 2012). Research has found that agricultural populations display higher rates of linear enamel hypoplasia as opposed to foraging societies (Larsen, 1995; Starling and Stock, 2007). However, as individuals inhabiting the South Tyrolean Alps have a long history of a mixed subsistence strategy, mainly relying on agriculture but also high alpine pastoralism, transhumance and hunting (Kustatscher and Romeo, 2010; Putzer et al., 2016; Winckler, 2012), this may account for the low incidence of these dental defects. More flexible subsistence strategies in conjunction with improved climatic conditions, favouring agricultural yield (Czermak, 2011; Prinz, 2003; Winckler, 2012), would have had a beneficial impact on the accessibility and availability of food resources.

Despite this, an age- and sex-related bias in the prevalence of linear enamel hypoplasias was clearly discernible from the present data, whereby females, particularly those aged 20-40 years of age, featured the highest rates in both subgroups, i.e., 33.3% in elite females versus 5% in elite males, and 25% in non-elite females versus 14.3% in non-elite males. The observed pattern may point towards an increased exposure to chronic physiological stress of females during childhood. This could be explained by a previously mentioned notion that females may have been treated differently than males regardless of social status, i.e., weaned earlier, reduced food allowances consisting of low-quality foods (Bardsley, 2014; Cullum, 1991; Czarnetzki, 1995; Klapisch-Zuber, 1985), which in combination with reproductive impacts, increased the risk of dying substantially (Bartlett et al., 2005; Beltran Tapia et al., 2021; Rahman et al., 2015; Romero-Gutiérrez et al., 2007). However, as only six females, out of 39, displayed signs of linear enamel hypoplasia, this explanation may only apply to these individuals but not the remaining female sample. As those females could be categorised into the elite and non-elite subgroups, specific status-related causes for LEH in Säben-Sabiona can be ruled out. To elucidate the wider bioarchaeological context of these individuals also other stress markers, such as those linked to metabolic conditions, need to be considered.

Skeletal indicators for systemic stress have been found in 38.1% of the sample, i.e., 37% in elites and 43% in non-elites, whereby more subadults (37.5% in the elite sample and 53.8% in the non-elite sample) than adults (36.6% for elites and 38.8% for non-elites) exhibited such lesions. As most studies focusing on early mediaeval sites in South Tyrol only refer to cribrotic lesions, e.g., Laag-Laghetti, Pfatten-Vadena, Castelfeder, Elzenbaum, Langhütten-Gand and St. Prokulus- S. Procolo (Giovannini, 2003, 2002; Paladin and Zink, 2015; Renhart, 2006, 1991) and/or the prevalence rates of different skeletal alterations linked to metabolic conditions are not clearly differentiated, comparisons with the present data were highly limited. The Säben-Sabiona sample featured mostly abnormal porosity on the ectocranial vault, i.e., *cribra cranii* or porotic hyperostosis (18.6%), and the orbital roof, i.e., *cribra orbitalia* (16.8%), followed by femoral cribra (15.5%), *cribra palatinii* (11.5%) and humeral cribra (4%). Metabolic lesions have been found in 36.8% of the elite sample and 43% of the non-elite group, whereby again, more subadults (37.5% for elites, 53.8% for non-elites) than adults (36.6% for elites and for non-elites 38.8%) exhibited such osseous defects. These frequencies are slightly higher but consistent with what has been recorded in early mediaeval (27% versus 25%) and 17th century (30% versus 20%) St. Prokulus-S. Procolo in Naturns-Naturno (Renhart, 1991). Furthermore, the observed differences between elite and non-elite individuals, even though not statistically significant, are consistent with other skeletal assemblages representing socially stratified populations (c.f.,Fowler et al., 1999; Larsen, 2015; Parham and Scott, 1980; Powell, 1992, 1988; Shimada et al., 2004), suggesting an adverse health effect based on the socioeconomic status of the individual, i.e., higher stress rates and lower quality of life for laymen individuals. Cribrotic alterations are most commonly associated with a chronic response to various metabolic diseases, such as iron deficiency anaemia, scurvy and rickets, but also congenital conditions affecting haematopoiesis, trauma and/or infections, e.g., parasites (Brickley, 2018; Buikstra, 2019; Gowland and Western, 2012; Schats, 2015; Smith-Guzman, 2015; Walker et al., 2009). In fact, a more thorough osteological analysis identified seven subadult skeletons (six elites and one non-elite individual), which featured a combination of lesions that indicate scurvy, rickets, or both. Scurvy, i.e., vitamin C deficiency, is most commonly associated with inadequate consumption of fresh fruits and vegetables, whereas rickets is caused by an insufficient exposure to sunlight and/or following a diet, which lacks naturally occurring vitamin D (Brickley and Ives, 2008; Buikstra, 2019; Roberts and Manchester, 2010). Evidence for the presence of such severe metabolic conditions in early mediaeval South Tyrol, has already been established by Renhart (2006), Tumler (2015) and Paladin et al. (2018). As the historical and osteological evidence suggests that the individuals buried at Säben-Sabiona relied mainly on alpine farming and agriculture, which resulted in a diet predominantly consisting of animal protein, C3 plants and some C4 plants (Kustatscher and Romeo, 2010; Mundle, 2018; Winckler, 2012), their diet should have been fairly balanced. However, an elevated consumption of plant foods that are rich in phytate, which includes grains, legumes, tubers, nuts and seeds, may have had an adverse effect on mineral bioavailability. Phytate rich foods have been found to cause a significant reduction in the absorption of calcium, iron, zinc and magnesium (Al Hasan et al., 2016; Huss-Ashmore et al., 1982; Lynch and Cook, 1980), hence, a lack of these minerals in conjunction with depleted vitamin D and vitamin C levels would have had a negative impact on osteoid mineralisation, cardiovascular health and immunocompetence in general (Ahmadieh and Arabi, 2011; Brickley and Ives, 2008; Cherayil, 2010; Ives, 2018; Pasricha et al., 2021; Sauberlich, 1994).

Clinical research showed that vitamin C, vitamin D, iron and calcium deficiencies are commonly comorbid with other nutrient deficiencies and underlying physiological conditions, e.g., digestive disorders, infections, etc. (Bermejo and García-López, 2009; Bikle, 2007; Hahn et al., 2019; Kaitha et al., 2015; Pasricha et al., 2021). Infections, such as those of parasites have been found to be highly common in past populations, as established through research of coprolites from latrines and cesspits (Gonçalves et al., 2003; Graff et al., 2020; Knorr et al., 2019; Mitchell, 2015; Mitchell et al., 2011), intestinal samples of mummies (Seo et al., 2007) and soil samples from the pelvic area (Wang et al., 2022). Skeletal evidence associated with infections, includes a high prevalence of non-specific subperiosteal new bone formations, e.g., periostitis (Grauer, 1993) or cribra (Newfield, 2017; Setzer, 2014; Smith-Guzman, 2015; Smith-Guzmán, 2015). Periostitis was found frequently and at an almost identical prevalence in elites (29.3%) and non-elites (31.2%). Due to the non-specific nature, multifactorial aetiology of this skeletal lesion (Buikstra, 2019; Roberts and Manchester, 2010) as well as the fact that all recorded periosteal lesions were localised, direct links between periostitis and a parasitic infection cannot be made.

Both *cribra cranii* and *cribra orbitalia* have been associated with respiratory infections, and *cribra orbitalia* was frequently encountered in individuals with heart conditions and parasitic infections (Brickley, 2018; Cole and Waldron, 2019; Gowland and Western, 2012; O'Donnell et al., 2020; Schats, 2021, 2015). As the Säben-Sabiona site features archaeological evidence for ore mining and processing (Kuhnen, 2020), which is known to affect respiratory health, and *cribra cranii* (18.6%) and *cribra orbitalia* (16.8%) were the most prevalent types of porous cranial lesions, this might indicate that some of these individuals, i.e., particularly of the non-elite group, were involved in such activities. This notion is investigated more thoroughly in the relevant subsequent chapters on palaeopathology.

As different localities are often dominated by certain age and/or sex groups, the examination of age and sex of the affected individuals might provide further insights aiding the contextualisation of the observed conditions. When broken down into sex and age a very distinct pattern emerges. In the elite sample, adult and juvenile males featured higher rates of *cribra cranii* (41.2%) yet, adult and juvenile females displayed *cribra orbitalia* more commonly (22.7%). A slightly different pattern was found for non-elite individuals, the rate of *cribra cranii* was also highest in adult and juvenile males (25.6%), but for *cribra orbitalia*, subadults (41.2%) outnumbered males (25.6%) and females (5.9%). The *cribra cranii* pattern suggests that males, regardless of their social rank, must have experienced chronic physiological stress more commonly than females and subadults. The prevalence rates of *cribra orbitalia* are in agreement with the findings of most other studies, who report significantly higher rates for females and subadults (Jatautis et al., 2011; Kyle et al., 2020; Šlaus, 1996). Many authors attribute porotic cranial lesions mainly to malnutrition in conjunction with the burdens of the female reproductive system, i.e., excessive iron loss during menstruation and hormonal fluctuations affecting nutrient absorption (Bardsley, 2014; Braun, 2005; Johnson-Wimbley and Graham, 2011; Šlaus, 1996). Thus, elite females appear to have been more frequently exposed to intrinsic and extrinsic factors that favoured the development of *cribra orbitalia*. A study by Wapler et al. (2004) found a strong association between *cribra orbitalia* and inflammatory processes, e.g., scurvy, rickets and trauma-related haematomas, and osteoporosis. As hormonal imbalances are known to have a substantial impact on nutrient metabolism and absorption (Ko and Kim, 2020; Macdonald et al., 2012; Pugh et al., 2022), these might be an explanation for the high *cribra orbitalia* rate in elite females. Even though females might be more susceptible to such conditions, in the present sample, males were the ones to display *cribra cranii* more often. This might suggest that males, particularly non-elite males, were more commonly exposed to environmental conditions, which had a negative effect on their health. As a comorbidity of *cribra cranii* and *cribra orbitalia* has been associated with respiratory infections (O'Donnell et al., 2020) and it is reported that in the mediaeval mining industry, males mainly worked inside tunnels, whereas females were involved in ore sorting and processing outside of these (Krause, 2013; Oberhofer, 2005), the observed pattern may be an indication for the involvement in mining. Furthermore, also the high prevalence of periostitis in the sample (29.3%, elite; 31.2%, non-elite), which is caused by a non-specific infection, commonly associated with micro-trauma (Buikstra, 2019; Roberts and Manchester, 2010), may support this notion. The anterior shaft of the tibia is particularly vulnerable to such lesions due to limited osseous protection by muscle mass, hence, injury prevalence, i.e., periostitis development, is frequently seen at this location. Moving around in dark and confined spaces, that might have even been waterlogged, provide the ideal environment for infections and injuries in the lower legs, thus, this may account for the high prevalence of periostitis in the tibiae. As ore mining inside the tunnels was dominated by males and historical sources of the Prettau-Predoi mine in the Ahrn-Aurina Valley report that habitual involvement in ore mining posed high health as well as death risks (Oberhofer, 2005), the high rates of cribra and periostitis in the present sample may be attributable to such activities.

However, as in the elite sample, females (22.7%), and in the non-elite sample, subadults (41.2%), featured the highest frequencies of *cribra orbitalia*, also other factors, i.e., early mediaeval living conditions, ought to be considered. Historical sources report that in the past, the main means to prepare food and to generate heat involved indoor wood burning (Winckler, 2012), which ultimately would have affected indoor air quality (Christensen and Ryhl-Svendsen, 2015). Increased air pollution, especially in enclosed areas, e.g., through wood burning, has been found to be a significant contributing factor for the development of severe pneumonia (Dherani et al., 2008; Harris et al., 2011; Schümann and Hunder, 1997; Troeger et al., 2018). Even though osteological evidence for severe pneumonia was not found in the present sample, indoor air pollution may still have had a substantial impact on respiratory and cardiovascular health of the affected individuals. Hence, every individual that was frequently exposed to such environments, i.e., settings with limited ventilation and increased carbon monoxide and particulate matter levels, was increasingly vulnerable and susceptible to respiratory infections (Christensen and Ryhl-Svendsen, 2015; Riddervold et al., 2012). Even though specific analyses for respiratory infections, i.e., sinusitis, were not part of the scope of this research, at least one case of *concha bullosa* (see appendix 22), which is commonly associated with a sinus inflammation (Pittore et al., 2011), was recorded. The risks of respiratory inflammations may have been particularly elevated in colder periods (Mäkinen et al., 2009; Mourtzoukou and Falagas, 2007), also as individuals may have alternated between indoor and outdoor workspaces. As females and subadults, especially those under six years of age, probably spent most of their lives in such environments, this might account for the recorded rates of *cribra orbitalia*. Furthermore, modern studies have found a significant correlation between indoor air pollution and respiratory inflammation in infants (Noonan et al., 2020; Smith et al., 2000), hence, the higher rates of *cribra orbitalia* in non-elite subadults might be linked to smaller living spaces, which were most likely also used for both sleeping and living.

Šlaus (1996) who found a similar *cribra orbitalia* distribution, i.e., 47% of subadults, 25% of males and 19% of females, interpreted these lesions as indicators for frequent episodes of anaemia during childhood. As no differentiation between active versus healed lesions was made and marrow expansion was not assessed in the present study, more detailed explanation of the data is not possible at this stage. However, the presence of such lesions does suggest that these individuals suffered from some sort of chronic inflammation, infection and/or malnutrition, which may have contributed to their premature death. Due to the ongoing development of the immune system, children are generally regarded as more vulnerable. Thus, frequent exposure to environmental stresses in combination with depleted nutrient levels, increases their frailty and risk of dying throughout childhood significantly (Gracey, 2004; Katona and Katona-Apte, 2008; Wood et al., 1992). As already mentioned in previous sections, subadult mortality was relatively high in the Säben-Sabiona sample, i.e., for both subsamples, and even though not all of the deceased infants displayed porous cranial lesions, this does not necessarily dismiss this conjecture. In fact, the development of skeletal lesions requires a condition to be chronic, hence, all acute disorders are not captured on osseous remains (Buikstra, 2019; Roberts and Manchester, 2010; Wood et al., 1992). Many infections, e.g., respiratory conditions, are characterised by an acute disease progression (Graham, 1990; Liu et al., 2014; Prina et al., 2015) and only those individuals that survived long enough to develop skeletal alterations would be available to evidence these conditions osteologically. Despite advanced medical care, pneumonia accounts for the highest morbidity and mortality rates in modern populations, especially for children under the age of five (Johnstone et al., 2008; McAllister et al., 2019; Prina et al., 2015). A global clinical study by Caulfield et al. (2004), found that pneumonia and undernutrition accounted for 52.3% and 53% of all registered child deaths. In an early mediaeval setting these values can be expected to be substantially higher. Elevated frequencies of porous cranial and postcranial lesions were recorded in early mediaeval Schloss Tirol-Castel Tirolo, where 59% of the subadult sample displayed lesions associated with scurvy, rickets or both (Paladin et al., 2018). Paladin et al. (2018) interpreted the observed nutritional deficiencies to be linked to food availability, which might have been particularly low during winter periods, as well as the socio-economic status of the population. If seasonal-related nutritional stress was the main factor causing the observed skeletal alterations, then similarly high rates would be expected for the Säben-Sabiona sample, yet this was not the case. The composition of the cemetery population may explain some of the noted statistically insignificant differences, but as both elites and non-elites featured fairly similar rates of cribrotic lesions, social status may be ruled out as a major contributing factor. As the Säben-Sabiona sample appears to contain a group of high-status individuals, which most likely consumed more processed foods (Larsen, 2015; Winckler, 2012), thus, contained reduced nutrient yield (Hailemariam and Wudineh, 2020; S. Lee et al., 2017), these together with their offspring might have experienced a nutritional disadvantage through these practices. Another explanation, might be the political situation of both sites, as the Schloss Tirol-Castel Tirolo was occupied by the Franks-Alemanni, which was characterised by increasing social turbulence, whereas Säben-Sabiona experienced Bavarian and/or Longobard occupation that was described as more peaceful (Kustatscher and Romeo, 2010; Winckler, 2012). Variations in the socio-economic status, i.e., impacts of these political fluctuations, and possibly also different subsistence strategies, could account for the discrepancies in the systemic stress prevalence rates between these two sites. Given the uniqueness of each cemeterial population, a vast variety of factors can influence the presence of certain conditions, thus, one needs to comprehend that the observed patterns may be true for the given sample, but may not be population specific.

7.3.2. Activity patterns and trauma

Activity reconstruction from past populations has been attempted in numerous studies (c.f., Becker, 2013; Foster et al., 2014; Gestsdottir, 2014; Havelkova et al., 2011; Henderson et al., 2013; Myszka et al., 2019), with the majority utilising degenerative joint diseases, i.e., OA, spondyloarthrosis and Schmorl's nodes, EC and long bone dimensions, i.e., robusticity indices and cross-sectional geometry, as indicators for habitual occupations (Blakey and Rankin-hill, 2009;

Eng, 2016; Larsen, 2015; Palmer et al., 2014; Schrader, 2019; Stirland, 2002; Wells, 1964; Wilczak et al., 2009).

A high prevalence of OA, spondyloarthrosis and Schmorl's' nodes has been associated with episodes of repeated micro-traumatic stress to the skeleton (Wells, 1964), whereby individuals involved in farming activities have been shown to exhibit higher levels of appendicular OA and individuals exposed to excessive workload and axial weight bearing frequently displayed spondyloarthrosis and Schmorl's nodes. Thus, the use of OA, spondylarthrosis and Schmorl's' nodes as activity markers has been justified (Larsen, 2015; Sandmark et al., 2000; Schrader, 2019; Stirland, 2002; Stirland and Waldron, 1997; Wilczak et al., 2009; Woo and Pak, 2013). However, studies utilising EC to reconstruct occupations and those testing the correlation between EC and activity on skeletal reference collections or in combination with other traits known to affect bone remodelling established variable results (Alves Cardoso and Henderson, 2013; Milella et al., 2012; Palmer and Waters-Rist, 2019; Schrader, 2019). Nikita et al. (2019) demonstrated a low effectiveness of EC in expressing activity when other contributing factors, such as age and body size were taken into account. Alternatively, research by Villotte et al. (2010) on four identified skeletal collections validated the correlation between some EC and physical activity, thus a link between EC and activity must exist. If the presence of both, OA and EC, is associated with the exposure to physical activity, both osseous alterations are expected to correlate in severity and location (Palmer et al., 2014). In the Säben-Sabiona sample a positive correlation between OA and EC was established, which was statistically significant and persisted even after correcting for age (r_s=0.495, p=0.001). Sex was not found to be correlated. In comparison to Palmer et al. (2014), who only examined 69 skeletons from a 19th century Dutch cemetery and found a correlation of both alterations in the upper limbs (r_s=0.242, p=0.045), the correlation in the present data was found to be higher when considering the whole body (r_s=0.501, p<0.001, elites; r_s=0.658, p<0.001, non-elites). Low correlations between OA and EC have been suggested to indicate different types of activity, i.e., low load accumulated over time versus explosive force (Palmer et al., 2014; Woo and Pak, 2013), thus high correlations could potentially indicate the opposite. The multifactorial nature of the two variables, i.e., OA and EC, is a major factor influencing lesion expression, thus also their relationship patterns (Milella et al., 2012; Weiss and Jurmain, 2007). As the correlation between OA and EC was quite moderate in both subsamples, even after correcting for age, i.e., r_s=0.441, p<0.001, elites; r_s=0.529, p<0.001, non-elites, other factors such as genetic predisposition or in fact activity may account for the observed distribution.

A cofounding factor may be the concept of "bone-formers" and "bone-losers", in which the tendency for bone formation and resorption has been shown to vary on an individual basis (Mays, 2016; Rogers and Waldron, 1995). The shape of the periosteum and endosteum, where bone formation and resorption occurs, has been shown to be highly affected by hormonal, mechanical, age-related and other influences (Gosman et al., 2011; Palastanga and Soames, 2012; Szulc and Seeman, 2009). Hence, the same tendency for bone remodelling may exist for the different anatomical regions. In Säben-Sabiona, all muscle/joint groups displayed a positive correlation between OA and EC, which was significant at the elbow, hip and knee when looking at the total sample and non-elite individuals. Even though still positive, yet overall elite individuals featured lower and non-significant correlations as opposed to non-elite individuals. Some studies on OA claim that alterations in enarthrosis joints, e.g., shoulder and hip are generally more correlated with age than activity, while the opposite is true for trochoid (pivot joint) and ginglymus joints (hinge joint), such as elbow and knee (Bridges, 1992; Jurmain, 1991). Elbow OA appeared to be more severe than entheseal deterioration at this site and the opposite was true for the knee with a substantially higher EC score. Not only do these results support the assumption of distinct underlying biomechanical processes of OA and EC development, but may also suggest a different response to external factors such as mechanical loading. As the severity of hip OA and EC was similar and significantly correlated, whereby this data was not corrected for age, the observed pattern may in fact display more age-related changes as opposed to activity. In addition to the findings of the present study also research by Molnar et al. (2011) found a positive correlation between the prevalence of OA (eburnation) and elevated EC with age.

Findings concerning the relationship between OA and/or EC and activity have been mixed (Leiberman et al., 2001; Schrader, 2019; Weiss and Jurmain, 2007; Zumwalt, 2006). Particularly research on animal models disproves a link between activity patterns and entheseal morphology (Rabey et al., 2015; Wallace et al., 2017; Zumwalt, 2006). On the other hand, clinical research proposed that a correlation between OA and EC development is due to an inflammatory process, whereby soft tissue injury leads to an inflammation at the enthesis that are mostly adjacent to the synovial membrane and joint cartilage (Benjamin and McGonagle, 2007; Binks et al., 2015; Schulze-Tanzil, 2019). In fact, exposure to mechanical loading that exceeds the physiological limits has already been associated with joint damage (Andersen et al., 2012; Holmberg et al., 2004; Walker-Bone and Palmer, 2002), but it appears to affect the whole muscular-skeletal system (Acosta et al., 2017; Lieverse et al., 2007; Wright, 2015). If repetitive overloading was the major factor for EC development, then, as shown in the present sample, a higher deterioration would be expected in the lower limbs than the upper limbs. The observed pattern would also be in agreement with the assumption that EC develop as response to immediate damage through excessive strain exposure, while the effects on joints would become more prominent later in life. Thus, the present data indicates that both, OA and EC, can be used to gain information about activity patterns, yet similar internal and/or external factors may cause slightly different osseous responses. Furthermore, this highlights the importance of utilising a multifactorial analysis approach to be able to reconstruct the complex synergy of musculoskeletal movement. The following sections will follow this concept, providing suggestions of potential occupations and activities, which align with the osteological, archaeological, and historical evidence.

7.3.2.1. Osteoarthrosis and entheseal changes

The frequency and severity patterns of these conditions were also assessed for the Säben-Sabiona sample, yet as analogous investigations for South Tyrolean sites are highly limited, the ability to draw comparisons was restricted, especially for EC. As more detailed analyses of entheseal changes, especially in respect to activity reconstruction, are a rather new scientific approach, most of the older bioarchaeological studies concerning South Tyrolean sites focused mainly on bone robusticity and merely mention alterations at entheses (Giovannini, 2003; Renhart, 2008, 2006). Only a few publications address the presence of degenerative joint lesions (Giovannini, 2002; Paladin and Zink, 2015; Renhart, 2006) and mention robusticity values and entheses in conjunction with activity reconstruction (Giovannini, 2003; Renhart, 2008). Recently, Paladin and Zink (2015) were some of the first to utilise entheseal data together with OA and certain non-metric traits as evidence for horseback riding in an individual from Langhütten-Gand in Eppan-Appiano. A more detailed and extensive study focusing on the severity of OA and EC in relation to sex and lesion location was performed by Tumler (2015), yet due to a lack of differentiation among the various sites and scarce contextualisation of the data, knowledge about the frequency and severity of these conditions on a population level of a confined site is still highly limited. Also, the absence of raw data addressing these points further limits current knowledge of OA, spondyloarthrosis, Schmorl’s nodes and EC prevalence and severity in early mediaeval South Tyrol, which in turn hinders any attempts to investigate activity patterns for this region. Therefore, the present research provides novel data, not only to elucidate workload and lifestyle of the individuals buried at Säben-Sabiona, but also to form a foundation to draw comparisons from and to better contextualise subsistence and behaviour of early mediaeval South Tyrolean peoples. Furthermore, due to the standardised data collection approach, confrontations with sites from other spatiotemporal contexts can be made for the first time.

Overall body robusticity, expressed through the osseous frame index (37.2, elites; 37.4, non-elites) was found to be consistent with other early mediaeval data, i.e., normal ranges from 34.3 to 38.6 (Jasch et al., 2018). Regardless of sex or social status, the calculated osseous frame indices indicate an intermediate robust cemeterial population, i.e., 35.2-41.8 in females and 38.4-43.6 in males is regarded as medium robust in modern samples (Hermanussen, 2013). Even though South Tyrol lacks comparable data, the publications mentioning robusticity always refer to very robust individuals (Giovannini, 2003; Renhart, 2008, 2006). In contrast to other sites across Europe, such as the mediaeval sites of Skeljastaðir (32%) and Barton (19%) in Iceland (Gestsdottir et al., 2006) or the pre-mediaeval site of Epidamnus (59%) in Albania (Wright, 2015), Säben-Sabiona had a higher OA prevalence (69.7%, total sample; 64.7%, elites; 67.1%, non-elites). For EC, the total sample exhibited a prevalence of 63.5%. Similarly high rates of OA and EC were also found by Tumler (2015) on different early mediaeval sites across the South Tyrol-Trentino region (72%, OA; 72.5%, EC) or by Sperduti (1997) on the Roman site Lucus Feroniae, where 76% of the studied sample had OA and 63.2% had EC. Increased robusticity, OA and EC levels throughout the body, as seen in the present sample, are often associated with physically demanding lifestyles, which include extensive walking and heavy lifting (Andersen et al., 2012; Cooper et al., 1994; Havelkova et al., 2011; Lieverse et al., 2007; Videman et al., 1990; Wilczak et al., 2009). Yet, as both subgroups, i.e., OFI=37.2, 64.7% OA and 63.7% EC in elites and OFI= 37.4, 67.1% OA and 63.2% EC in non-elites, featured a high OFI scores and prevalence rates of OA and EC, and rather elevated general degenerative scores (1.5 and 2.1, elites; 1.6 and 2.1, non-elites), this may indicate an overall exposure to high levels of physical strain, regardless of social status. To explore this notion further, also the sex, age at death and lesion distribution ought to be taken into account.

In correspondence with other research (Larsen, 2015; Palmer et al., 2014; Salo, 2016; Santana-Cabrera et al., 2015; Sperduti, 1997; Williams et al., 2019), for most of the present sample males had higher OA and EC frequencies and severity scores than females. Only for EC, elite females exhibited higher frequencies than males (81.8% versus 78.4%), yet, severity scores were higher in elite males again. Even though other aetiological factors such as genetics have been proposed, such sex differences are often interpreted as an indication for the involvement in more and heavier labour activities of males (Bridges, 1992; Wilczak et al., 2009; Williams et al., 2019; Zhang et al., 2017). Also, skeletal robusticity, which was found to be greater in males (37.8, elites; 38.0, non-elites) than females (36.7, elites; 36.8, non-elites) of both subsamples, indicates higher rates of osseous responses to physiological stress in males, particularly non-elite males.

According to Wolff's law, bone structure and shape will adapt to the exposed mechanical loading, thus, remodel based on these strains (Hoyte and Enlow, 1966; Pearson and Lieberman, 2004; Ruff, 2019). Hence, greater morphological bone remodelling equals to excessive and prolonged subjectivity to mechanical forces. Slight but clear differences between the sexes and subgroups were recorded for humerus, femur and tibia robusticity, whereby males always had greater scores than females and non-elite individuals featured higher humerus and femur robusticity. In comparison to the osteometric data of other early mediaeval sites in southern Germany (Czermak, 2011), the present robusticity values are consistent and suggest a highly active lifestyle.
Especially, increased rates and severity levels of hip OA and EC are linked to high demanding ways of living (Andersen et al., 2012; Jensen, 2008; Montes and Subirà, 2018; Rossignol, 2005; Schrader, 2012; Waldron, 1995). In comparison to hip OA rates of other sites, e.g., Archaic (50.5%) and Diaguita (48%) period in Chile (DiGangi and Gruenthal-Rankin, 2019); Greek (50%) and Roman (29%) occupation of Epidamnus in Albania (Wright, 2015); or mediaeval Hrísbrú (56%) in Iceland (Eng, 2014), the present prevalence was substantially higher when considering the total sample (70.2%), yet much more congruent when dividing the cemetery population by social status, i.e., 51.0% in elites and 46.1% in non-elites. Research by Andersen et al. (2012) and Jensen (2008) found that regular and long-term exposure to the biomechanical strains linked to farming activities, such as heavy lifting and other strenuous labour, was a high-risk factor for developing hip OA. However, as elite females (77.3%) featured higher prevalence rates of hip OA than elite males (64.7) and the opposite was recorded for non-elite individuals, i.e., 35.3% in females and 65.1% in males, the data might suggest less pronounced sexual division of labour in the elite sample, with females more frequently involved in activities leading to increased hip degeneration. An alternative hypothesis relates to pregnancy and/or hormonal changes associated with menopause, which might be linked to increased hip OA. As nine out of seventeen of the assessable elite females were estimated being over 40 years of age, and hip OA is known to increase from 40 years onwards (Arden and Nevitt, 2006), this may only partially account for such a high prevalence in elite females. From a clinical perspective, OA prevalence tends to increase for both sexes after 40 years of age, and no correlations between reproductive factors and hip OA have been recorded (Arden and Nevitt, 2006; Hussain et al., 2018; Jørgensen et al., 2011). Most of these studies attribute hip OA with lifestyle patterns (Arden and Nevitt, 2006; Jørgensen et al., 2011). Another component influencing hip modification may have been locomotion on uneven alpine terrain, which certainly affects both hip and lower limb movement and degeneration (Becker, 2020; Franz and Kram, 2012; Williams et al., 2019). As a rule, lower

body degeneration follows a specific pattern, i.e., the first to be affected is commonly the knee, followed by the hips and then the lower back (Arden and Nevitt, 2006). Both sexes, regardless of social status had pronounced *M. gluteus maximus entheses* (elites- 2.8 in males, 2.5 in females; non-elites- 2.7 in males, 2.6 in females), which is the most powerful hip extensor of the human body and whose main function is the abduction, extension and lateral rotation of the hip (Paulsen and Waschke, 2013, Figure 52). Actions such as climbing or running are linked to *gluteus maximus* activation, whereas during normal walking this muscle is less often engaged (Lewis et al., 2015; Lieberman, 2006; Moore et al., 2013). The increased gluteus expression in both elite and non-elite males and females may be most likely attributable to habitual movement in mountainous environments, although the slightly higher score for elite males may indicate a more frequent involvement in such activities.

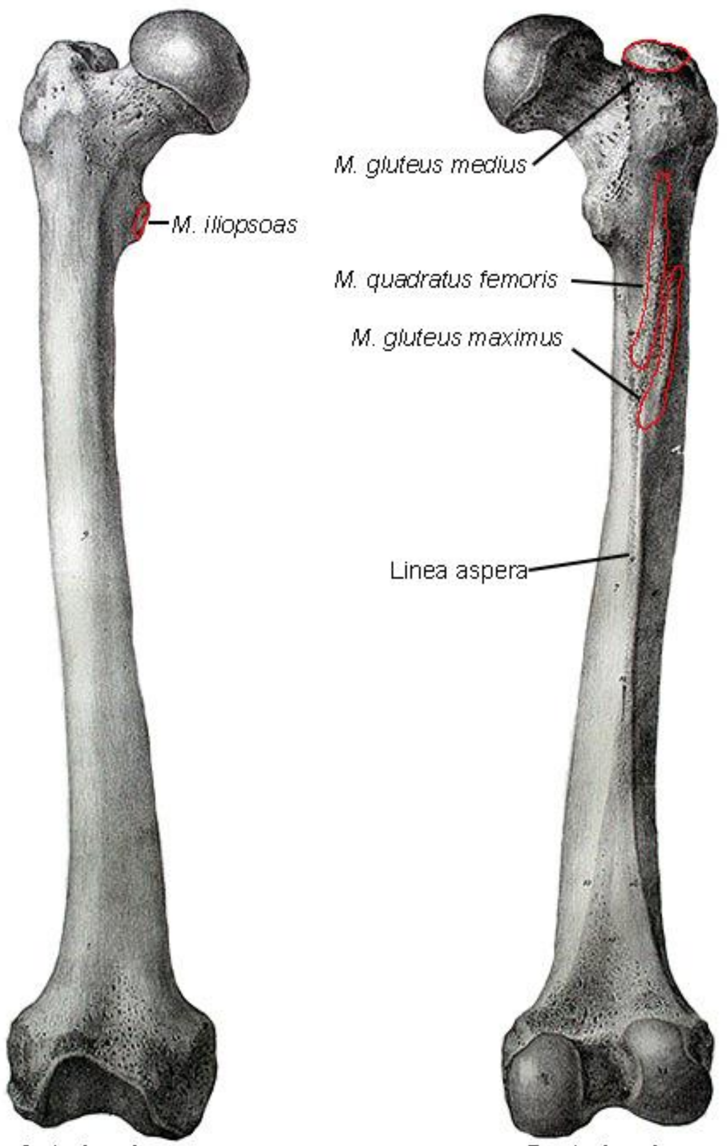

Figure 52 Anterior and posterior view of the right femur outlining the location of the assessed muscle insertion sites.

Elite (2.7) and non-elite males (2.5) also showed elevated alterations on the *M. vastus medialis*, *M. adductor magnus*, *M. adductor longus* and *M. iliopsoas*. These are involved in the extension of the leg at the knee joint, such as in walking and running activities, flexion of the hip, e.g., sitting, maintaining erect body posture or bending the trunk forward, medial rotation and adduction of the femur, such as when climbing or horseback riding (Arbanas et al., 2009; Moore et al., 2013; Paulsen and Waschke, 2013; Sajko and Stuber, 2009; Tyler et al., 2014; Wheeless, 2019). In fact, the sample also featured osteological markers for horseback riding, include the presence of Poirier's facets, which were found at a prevalence of 16.5% in elites and 21.5% in non-elites, as well as higher levels of hip and lumbar spine OA (Andelinović et al., 2015; Berthon et al., 2019; Djukic et al., 2018; Palfi and Dutour, 1996). As the use of horses for traction and military operations has been documented historically and ethnographically (Bruckmüller and Sandgruber, 2002; Gorfer, 2017; Winckler, 2012), some of the observed musculoskeletal alterations at the lower spine, hip and legs might be attributable to horseback riding. As males had higher mean scores than females (2.1, elites; 1.7, non-elites) for muscles utilised in leg extension, this might be solely related to intrinsically higher muscle mass in males than females, or that they have engaged more frequently in activities involving walking, running, bending, and climbing in the alpine terrain. Also the fact that males (2.6, elites; 2.4, non-elites) had elevated *M. biceps femoris*, *M. semimembranosus* and *M. semitendinosus* entheses, which are involved in flexion and extension of the knee joint, such as standing up, climbing stairs or jumping (Palastanga and Soames, 2012), suggests frequent engagement uphill and downhill exercise (Franz and Kram, 2012).

Similar as for the hip, also the prevalence of knee (62.9%, total sample; 47.1%, elites; 38.2%, non-elites) and ankle (61.3%, total sample; 47.1%, elites; 46.1%, non-elites) OA was greater in Säben-Sabiona than in studies on populations from similar spatiotemporal contexts, i.e., mediaeval Hrísbrú (43%) in Iceland or Greek (33%) and Roman (29%) Epidamnus in Albania (Eng, 2014; Wright, 2015). Especially the larger discrepancies between the prevalence rates of OA between non-elite males (58.1%, knee; 67.4%, ankle) and females (17.6%, knee; 39.4% ankle) as opposed to the elite sample, which featured more analogous frequencies (knee- 64.7% in males and 63.6% in females; ankle-62.7% in males and 64.6% in females), may point to social differences in mechanical loading. In the clinical literature such high rates of knee OA in conjunction with elevated frequencies of hip OA have been associated with farming activities, which often include regular heavy lifting, squatting or knee bending, kneeling and jumping (Andersen et al., 2012; Holmberg et al., 2004; Sandmark et al., 2000). Thus, higher rates of knee

OA would have been expected for the non-elite sample, which engaged most likely in alpine farming and agricultural or even mining activities on a regular basis, yet elite individuals had higher OA prevalence rates. As elite males exhibited the highest frequency and severity of knee OA (64.7% and 1.7) in conjunction with elevated ankle OA (62.7% and 1.3), this indicates increased exposure to physiological strains of these joints. As also nine out of ten osteochondrosis dissecans cases in the tibia belonged to elite individuals, this further proves increased physiological strain that even led to injury. Also, the previously mentioned notion about involvement in horseback riding ought to be continued here. Although a rare injury in modern industrialised populations, proximal tibiofibular dislocations, which affect both the knee and ankle joint, are commonly associated with falls, such as from horses (Horan and Quin, 2006; Petter and Davidson, 2004). Proximal tibiofibular dislocations seldomly leave direct osseous traces, yet they can manifest themselves in increased levels of muscular and joint alterations around the ankle. Another line of osteological evidence to support this assumption is the relatively high prevalence of lateral squatting facets (16.5%) in elite individuals, which is identical to the prevalence of Poirier's facets in this subgroup. A further potential indicator for frequent involvement in horseback riding in elite males is the increased ankle EC frequency (62.7%), particularly the elevated modifications at the *M. triceps surae* enthesis (2.4). Permanent dorsi-flexion of the ankle causes the *M. triceps surae* to contract, thus, pushes the weight of the whole body upwards, e.g., in galloping or jumping positions (Cejudo et al., 2020; Djukic et al., 2018; Moore et al., 2013; Palastanga and Soames, 2012). When comparing an agricultural and a horse rider population, Djukic et al. (2018) even found a 100% EC prevalence at the *M. triceps surae* insertion site for the horse rider sample. Another major contributing factor to increased lower limb and hip OA, may have been locomotion and the performance of farming and agricultural activities in mountainous terrain, which has been shown to increase both trauma risks, causing secondary OA, and deterioration of the joints (Becker, 2020; Gestsdottir, 2014; Valderrabano et al., 2006; Williams et al., 2019). An example is ankle OA, which is commonly associated with a preceding ankle sprain, mostly caused through running, jumping (Gestsdottir, 2014; Valderrabano et al., 2006) or other daily accidents, e.g., slipping (Dogan & Demirci, 2012; Otte & Haasper, 2007), whose risks would certainly increase on uneven ground. Non-elite males featured the highest rates of ankle OA (67.4%), followed by elite females (64.6%), elite males (62.7%) and non-elite females (39.4%), which suggests that non-elite males and elite females participated more commonly in activities that caused excessive ankle joint strain, i.e., more frequent involvement in day-to-day activities necessitating locomotion on uneven terrain. As mentioned previously, early mediaeval subsistence in South Tyrol, not only relied on farming, but also pastoralism and hunting, hence, the lower rate of knee OA, but higher rate of ankle OA in non-elite males might represent such a lifestyle. The increased prevalence of EC at the ankle joint and more severe changes *M. triceps surae* entheses in non-elite males (60.5%, 2.2) and elite females (68.2%, 2.2) can also be an indicator for habitual movement on uneven ground. This muscle activates significant amount of force during locomotion, pushing the weight of the body upwards (Moore et al., 2013; Palastanga and Soames, 2012), which would be significantly more strenuous when walking or running uphill. In fact, dorsal calcaneal spurs have been found to be quite common in long-distance runners (Reule and Alt, 2011), hunter-gatherers (Weiss, 2012) and mobile pastoralists (Gresky et al., 2016). The presence of such alterations in the ankle, which was quite prevalent in Säben-Sabiona, particularly in the elite subsample, can be interpreted as evidence for intensive physical mobility, either in the form of locomotion or horseback riding (Maffulli et al., 2004; Reule and Alt, 2011; Weiss, 2012). As the prevalence rates of ankle OA (67.4% in males versus 39.4% in females) and EC (60.5% in males and 29.4% in females) differed more between the sexes in non-elite individuals, this probably points to more significant variations in labour, or work areas bearing different corporal demands in socially lower ranking individuals. Non-elite males may have been involved in transhumance and mobile pastoralism, hence, the higher EC and OA rates, whereas non-elite females were most likely responsible for animal product processing, which posed lower risks of developing elevated levels of OA and EC. Various biomechanical studies argue that increased mobility in mountainous terrain, e.g., through transhumance, pastoral farming, big and small game hunting lead to increased mechanical loading, which inevitably causes osteological changes (Marchi, 2008; Marchi et al., 2011, 2006; Ruff, 2019; Ruff et al., 2006). Habitual activity, especially adaptation to certain environments, manifests itself on bone in the form of increased robusticity and changes in shape (Becker, 2020; Foster et al., 2014; Myszka and Piontek, 2012; Rabey et al., 2015; Ruff, 2019; Schrader, 2019; Williams-Hatala et al., 2016; Zumwalt, 2006). The relatively high femoral and tibial robusticity scores of both subgroups, as well as biomechanical research on osteological traces of subsistence of the late Neolithic/Copper Age Iceman, i.e., transhumance and seasonal migration across higher and lower elevations (Ruff et al., 2006), imply intensified mobility.

More accurate and informative data to assess mobility can be obtained through the examination of the platymeric index of the femur and platycnemic index of the tibia. The platymeric index describes the flattening of the upper part of the femoral shaft, which tends to be more pronounced, i.e., smaller index, in highly mobile individuals (Ari et al., 2005; Brothwell, 1981; Czermak, 2011; Herrmann et al., 1990). Following the classification of the platymeric index, i.e., hyperplatymeric <75; platymeric=75-84; eumeric=85-99; stenomeric<100, the present proximal femoral shafts of elites were predominantly eumeric and those of non-elites platymeric. As these measured femoral changes are believed to result from chronic femoral overloading, starting already early in an individual's life when the osseous response is the greatest (Lieberman, 1997; Townsley, 1948), the present data implies greater mobility and overloading in non-elites. Looking at the differences between male and female platymeric indices, for the elite sample, males display slightly lower values than females and the opposite pattern was found for non-elite individuals, suggesting higher mobility of elite males and non-elite females. Another line of evidence for increased mobility is provided by the estimated platycnemic index, which describes the degree of tibial flattening at the nutrient foramen (Ari et al., 2005; Brothwell, 1981; Czermak, 2011; Herrmann et al., 1990). Similar as the platymeric index, also the platycnemic index can be classified into hyperplatycnemic<54; platycnemic=55-62; mesocnemic=63-69 and eurycnemic<70. Based on this classification, elite (74.5, right; 73.7, left) and non-elite individuals (79.6, right; 80.6, left) display eurycnemic *tibiae*, whereby in both subsamples, females had higher values. As platycnemy is associated with increased activation of the *M. soleus* and deep plantar flexors of the feet, increased tibial flattening at the nutrient foramen is frequently attributed to walking and running on rough terrain (Kennedy, 1989; Marchi et al., 2011; Thomson, 1889). Thus, the diaphyseal shape of males, particularly elite males, suggests a higher level of mobility than non-elite males and elite and non-elite females. A study by Marchi et al. (2011), on a Ligurian Neolithic sample also found low diaphyseal shape ratios in conjunction with high levels of tibial robusticity, which they linked to excessive mobility on uneven terrain whilst carrying heavy loads. Modern research on long distance runners and hockey players found that, due to repeated directional changes, hockey players featured significantly greater tibial and fibular robusticity (Marchi and Shaw, 2011). As similar patterns were registered for the present sample, especially for elite males, this indicates habitual and excessive locomotion on mountainous topography. In addition to normal mobility as part of daily occupations, one activity that could be proposed here, as it is known to have been restricted to the upper social class (Lorenz, 1999), is hunting and even hunting on horseback, which would have required frequent directional changes whilst moving up and downhill.

Due to the increased impact of locomotion and terrain on the development of OA and EC in the hip and lower limbs, more reliable data about activity patterns are usually obtained through the assessment of upper body alterations (Milella et al., 2015; Palmer et al., 2014). However, looking at the OA and EC prevalence within both subsamples, clear discrepancies between the two alterations are discernible. In the elite sample, OA was most frequent in the wrist (43.1%), followed by the elbow (40.2%) and shoulder (33.3%), whereby EC were registered most often in the shoulder (42.2%), then elbow (41.2%) and wrist (26.5%). A similar pattern was registered for non-elite individuals, where OA was highest in the wrist (35.5%), followed by the shoulder (28.9%) and elbow (27.6%) as opposed to EC, where higher frequencies were found in the shoulder (44.7%), then the elbow (32.9%) and wrist (22.4%). A congruent inconsistency between upper limb OA and EC frequencies was also encountered by Palmer et al. (2014), who assessed the use and correlation of OA and EC to reconstruct activity. As suggested by Palmer et al. (2014), this pattern may indicate different aetiological factors leading to the development of OA and EC, which might have a stronger influence than activity alone, thus, highlights the multifactorial nature of these alterations (Milella et al., 2012; Palmer et al., 2014; Weiss and Jurmain, 2007). However, gross joint movement is commonly achieved through one or two major muscles, e.g., *M. deltoideus* and *M. latissimus dorsi* move the arm at the shoulder joint and, whereby variations in these movements are yielded through the activation of other muscles, e.g., *M. pectoralis* moves the arm medially (Paulsen and Waschke, 2013; Tillmann, 2016, Figure 53). As all of these muscle actions involve the same joint, i.e., shoulder joint for the mentioned muscles, more complex synergies of muscles may leave prominent skeletal changes at the joint level but not at individual enthesis. Increased mechanical strain exposure, which has been found to be an eminent factor in the development of osseous modifications (Schrader, 2019; Schulte et al., 2017; Zumwalt, 2006), would enhance these differences even more. Thus, as lower limbs experience continuous strain through axial loading, whereas the effects of body mass are not as great in the upper limbs, the combination of lower weight bearing and joint/muscle coaction during movement might explain the observed discrepancies in upper limb OA and EC.

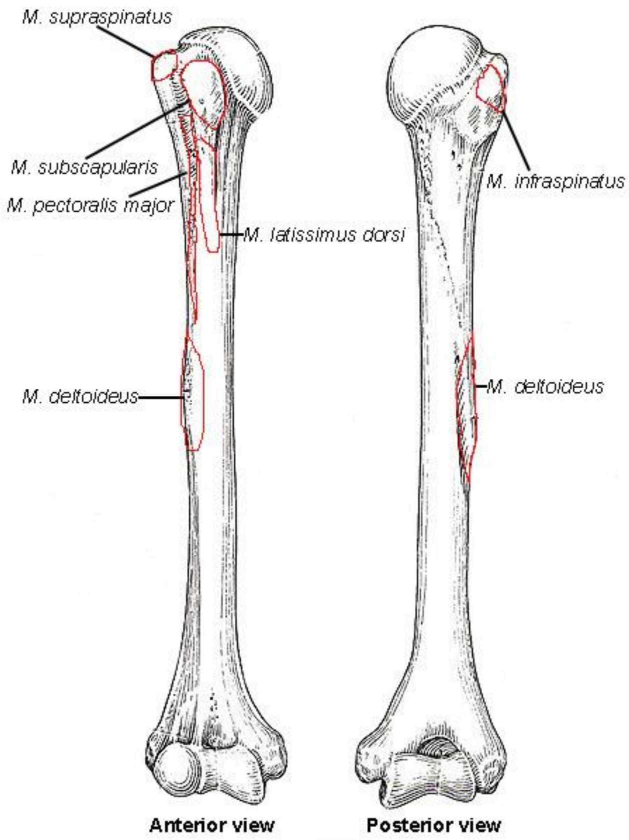

Figure 53 Anterior and posterior view of the right humerus outlining the location of the assessed muscle insertion sites.

Regardless of these variations, overall OA and EC was still found to correlate in the upper limb, and also when looking at the samples as a whole, clear differences between the two social groups and sexes of these were registered. In both subgroups, males featured higher frequencies of OA and EC than females, however, the discrepancies between the sexes were greater in the non-elite sample, suggesting that division of labour may have been more pronounced in the non-elite sample. Even though both subsamples featured similarly high frequencies of OA and EC, i.e., implying a more homologous strain exposure of the upper limb, elite females had substantially higher prevalence rates than their non-elite counterparts. To explain these patterns further and in consideration of the previously mentioned inconsistency of OA and EC frequency, joint OA and individual muscle EC will be discussed in greater depth to establish potential habitual movements that may account for the differences between the social groups and/or sexes of these. For both subgroups the highest OA prevalence in the upper limb was registered in the wrist (43.1%, elites; 35.5%, non-elites). Montes and Subirà (2018) interpreted increased wrist OA in their mediaeval monastic sample as indicator for the involvement in agriculture, craftwork, and other fine motor movement. Of course, agriculture would not only require wrist movement, but also put high loads of physical strain onto the shoulder and elbow, especially for ploughing, carrying, and lifting activities (Becker and Goldstein, 2018; Crubezy et al., 2002; Domett et al., 2017; Lai and Lovell, 1992; Myszka et al., 2019). In terms of shoulder and elbow prevalence rate, elite (33.3%, shoulder; 40.2%, elbow) and non-elite individuals (28.9%, shoulder; 27.6%, elbow) displayed diverging patterns, which might be linked to a distinctive exposure of mechanical loading. As OA prevalence rates for all joints were higher in the elite sample, this further implies that joints of elite individuals were more damaged, i.e., used than those of non-elite individuals. Explanations for this pattern might be identified looking at the frequencies of the sexes. In non-elite males the differences in the prevalence rates were much higher (51.2%, wrist; 41.9%, shoulder; 37.2%, elbow), whereas for elite males, all joints had similar prevalence rates (58.8 %, elbow; 58.8%, wrist; 52.9%, shoulder). This might point towards a higher variety of activities that involve the use of all joints more frequently in elite as opposed to non-elite males. For females, the non-elite sample displayed more analogous frequencies across the upper limb joints (23.5%, wrist; 23.5%, elbow; 17.6%, shoulder) than the elite sample (50%, wrist; 36.4%, elbow; 31.8% shoulder), thus, suggesting that elite females may have engaged in monotonous activities more commonly than non-elite females. To investigate this notion further, individual muscle attachment sites can provide useful information about the types of movements that were frequently exercised. Elite males and females displayed the highest frequencies of EC at the *M. pectoralis major* (49%, 40.9%), *M. deltoideus* (47.1%, 36.4%), *M. biceps brachii* (47.1%, 31.8%) and *M. subscapularis* (47.1%, 36.4%) insertion sites. These muscles are predominantly used to adduct, abduct, flex, rotate and antevert the shoulder joint and to flex the elbow joint (Paulsen and Waschke, 2013; Tillmann, 2016). The observed EC distribution is typical for high load physical activities and implies the application of substantial stress onto the entire structure of the extremity. Based on the results of Rhode (2006) on Andean fishing and farming populations, the entheseal frequency and severity pattern would be consistent with high workload farming activities. This is further supported by Milella et al. (2015), who found that individuals involved in farming and agriculture had substantially higher rates of EC than other occupational groups. As entheseal changes are commonly associated with tendon microtrauma due to overloading (Y. K. Lee et al., 2017; Manske and Prohaska, 2007; Moore et al., 2013), both elite males and females appear to have engaged in similar activities, applying excessive strain on these muscles. Oestrogen has been shown to have positive impacts on tissue remodelling (Aydin et al., 2013; Circi et al., 2009; Torricelli et al., 2013), whereby a negative effect was found for testosterone (Marqueti et al., 2011; Miller et al., 2005), thus, it could be that both sexes engaged in similar activities with males simply displaying signs of slower microtrauma recovery. Musculoskeletal overloading is commonly caused during weightlifting activities, multiple repetitions of the same movement as well as when exceeding normal range of motion in an abrupt manner, i.e., injury (Y. K. Lee et al., 2017; Manske and Prohaska, 2007; Moore et al., 2013; Truszczyńska et al., 2016). The *M. pectoralis* enthesis featured the highest mean severity score in the elite sample (2.6, males; 2.3, females), thus, activities involving this muscle may have been practiced most frequently. *M. pectoralis major* is the most important muscle for shoulder/arm adduction and anteversion (Paulsen and Waschke, 2013; Tillmann, 2016), which are movements commonly employed in a vast variety of activities including scything, ploughing as well as when guiding plow-pulling animals, pulling carts and sledges. Even though elite individuals may have held a higher social status, they may have still engaged in such activities in order to secure their subsistence, in fact, they may have owned larger estates, which required more hard work. As the skeletal sample of Säben-Sabiona predates the establishment of feudalism, social-division of labour as seen in later mediaeval and modern periods may have not been as distinct during the Early Middle Ages. Historical sources report that only high ranking individuals could afford larger animals (Bruckmüller and Sandgruber, 2002; Winckler, 2012), such as cows, oxen and horses, and especially in agriculture, access to new technology or plow-pulling animals would have been revolutionary, thus, limited to upper social classes. Such tasks were probably completed by males, whereas females may have engaged in activities associated with food processing, e.g., grinding grains, wool and hide processing, etc. (Bruckmüller and Sandgruber, 2002). The use of technology may have reduced the strenuosity of labour, yet the repetitiveness of these activities remained the same. Research by Eshed et al. (2004b) associated elevated *M. deltoideus* entheses, in their female Natufian Hunter-Gatherer sample, with activities requiring heavy use of the arms, i.e., probably related to pounding of grain with a stone or wood pestle. In elite females, the *M. deltoideus* enthesis was amongst the most severely affected insertion sites (2.1), thus, such activities may have also been performed on a habitual basis by elite females. Even though traditional perceptions associate females more with activities linked to their domicile and males with occupations outside the immediate household, modern data suggests that in the absence of males, females took over and also completed typical male tasks (Bruckmüller and Sandgruber, 2002; Duby, 1977; Jogna, 2010; Judd and Roberts, 1999). Especially in consideration of the nature of the site, i.e., profane and sacral centre, which certainly required elite males to perform different constitutional tasks outside their estates (Loose and Lorenz, 1999), a significant amount of organisational farming responsibilities and workload would have been attributed to elite females. Socio-anthropological research on modern populations in Austria found that field work was generally carried out by both males and females, whereby females were more commonly engaged in manual activities than males, who were regularly involved in operating mechanical equipment (Bruckmüller and Sandgruber, 2002; Jogna, 2010). For early mediaeval South Tyrol, today's mechanical equipment may correspond to farming tools and animals, thus, especially for agricultural work males may have performed more dangerous tasks, i.e., dealing with working animals, whereas females may have been responsible for less dangerous but equally demanding manual tasks (Bruckmüller and Sandgruber, 2002; Duby, 1977; Judd and Roberts, 1999). Analogous sexual division of labour was still actively practiced in recent alpine farming settings, an example is hay harvesting, where males drove hay carts and females and children performed most manual tasks, e.g., hay raking and turning and compiling hay to form haystacks for drying (Bruckmüller and Sandgruber, 2002; Gorfer, 2017; Hessenberger, 2013). In the absence of males, elite females may have had to undertake the duties of their partners in addition to their own chores. Modern data from Austria shows that women contributed significantly to the management of farms, in fact, in 1999, 40% of farms were solely managed by women (Bruckmüller and Sandgruber, 2002). While direct evidence for this hypothesis is not available, the high rates of shoulder and elbow entheseal changes in males may point towards such an assumption, i.e., the frequent absence of males, as the same muscles are also frequently employed during horseback riding and combat activities. Due to the importance of the *M. pectoralis* and *M. biceps brachii* in anteversion of the arm and flexion and supination of the elbow (Paulsen and Waschke, 2013; Tillmann, 2016), these may have been exercised significantly, i.e., when tightening and loosening the reins during horseback riding or during combat. As a vast range of shoulder and arm movements is also employed in fencing (Tsolakis et al., 2010; Williams and Walmsley, 2000) and according to Tumler et al. (2019, 2021) at least some of the individuals buried at Säben-Sabiona were involved in interpersonal violence, the frequency of entheseal lesions may have been reinforced through such activities.

In the non-elite subsample, both males and females displayed slightly different frequencies of muscles affected. For males, the highest EC prevalence rates were seen for the *Lig. costoclavicularis* (39.5%), *M. deltoideus* (39.5%) and *M. biceps brachii* (34.9%). The *Lig. costoclavicularis* has more of a protective function, i.e., limiting clavicle elevation and anteroposterior movement of the arm, rather than causing motion (Shane Tubbs et al., 2009). Thus, elevated prevalence rates of EC at the *Lig. costoclavicularis* insertion site might be linked to frequent movement beyond the normal range of motion or trauma, e.g., falls onto the shoulder (Marchese and Bordoni, 2021). Together with the *M. deltoideus*, the most important muscle for shoulder adduction and abduction, and the *M. biceps brachii*, which is the main muscle for elbow flexion and supination with flexed elbow, EC in the non-elite males appear to be most consistent with lifting motions utilising an extended or flexed arm. Excessive use of these muscles was also evidenced in the high mean severity scores of these entheses (2, *Lig. costoclavicularis*; 2.1, *M. deltoideus*; 2.3, M. *biceps brachii*). Prominent *M. biceps brachii* entheses are often linked to stress or overuse injuries, especially those that involve throwing, beating and lifting actions (Capasso et al., 1999; Moore et al., 2013; Palmer, 2012). Raising and lowering the arm in flexed and/or extended position, e.g., hoeing, chopping wood, would be an example of a movement involving all of these three muscles (Mays, 1999; Sung and Freivalds, 2014), and as crop cultivation as well as mining and construction commonly require such movements, it is highly likely that non-elite males frequently engaged in such activities.

Non-elite females on the other hand, displayed the highest EC prevalence rates at the insertion sites of the *M. pectoralis major* (35.3%), *M. deltoideus* (35.3%) and *M. pronator teres* (35.3%). These muscles are the most important ones to adduct, abduct and antevert the shoulder and to pronate the lower arm (Paulsen and Waschke, 2013; Tillmann, 2016). As these muscles also displayed some of the most elevated severity scores, i.e., 2.7 for *M. pectoralis major*, 1.7 for *M. deltoideus* and 1.5 for *M. pronator teres*, the data support the notion of excessive or repetitive arm movements towards the centre of the body. Tasks requiring such motions, i.e., pulling and pushing actions in combination with lower arm pronation, may include milking, weaving, grinding grain, gardening, sweeping and raking (Kumar and Cheng, 1991; Lundqvist et al., 2021; Masci et al., 2020; Molleson, 1994; Park et al., 2014; Rok Chang et al., 1999). As the *M. pronator teres* is the main muscle for wrist rotation, i.e., pronation, non-elite females may have participated in activities which necessitated such a movement on a regular basis, e.g., stirring during cooking, knitting, or crocheting (personal communication Katharina Ennemoser, Physiotherapist, Quellenhof-St. Martin in Passeier, 20th July 2022).

According to Bridges (1989) early agricultural populations generally display greater sexual division of labour and, as the differences between males and females were more pronounced in non-elite individuals, this might suggest more involvement in sex-specific tasks of non-elites. Elite individuals experienced entheseal alterations more frequently than non-elites, but non-elite individuals were more severely affected. This might relate to activity repetitiveness and variation. As mentioned, elite males may have been responsible for different types of work at their estate as well as occasional military operations (Loose, 1999), hence, their increased entheseal lesion prevalence. Due to the absence of males, elite females may have experienced additional workload in combination with task variation, which would explain the elevated EC frequencies and similar pattern as seen in elite males. Loose (1999) argues that elite individuals commonly possessed larger estates, which they rarely sustained themselves, but let these as a whole or partially to family members or other devoted personnel. In fact, historical sources dated to the 8th and 9th centuries A.D. report the donation of forests, fields, waters, and all associated rights with these, i.e., hunting and fishing rights to Säben-Sabiona, which supports the view of the need for a well organised land-owning regiment. As non-elite individuals probably lived a much more consistent life, their daily tasks were similar, i.e., very monotonous, and highly strenuous. Everyday work for non-elites may have only fluctuated based on seasonal demands but was generally fairly invariable in terms of physiological strain, i.e., constantly high demanding, hence, the elevated severity values (Judd and Roberts, 1999; Mays, 1999).

Agricultural activities are characterised by exposing the body to excessive mechanical loading and/or maintaining similar postures for prolonged time, which has been positively associated with spondylarthrosis and Schmorl's nodes (Cho et al., 2015; Hansson, 1995; Kramer, 2006; Palfi and Dutour, 1996; Peck, 2009; Rossignol, 2005; Teraguchi et al., 2014). Both subgroups exhibited the highest rates of spondyloarthrosis and Schmorl's nodes in the thoracic (41.2% and 24.5%, elites; 36.8% and 25.0%, non-elites) and lumbar spine (37.3% and 14.7%, elites; 32.9% and 14.5%, non-elites). Particularly for non-elite individuals, weight loading on the thoracic spine appears to have been pronounced due to the elevated spondyloarthrosis severity scores in this section, i.e., 2.05. This is a rather unusual pattern, as for most populations the spondyloarthrosis prevalence rates tend to be highest in the lumbar spine, followed by the cervical spine and due to lower degree of movement, the thoracic section should be the least affected (Bridges, 1994; Gunness-Hey, 1980; Klaus et al., 2009; Larsen, 2015; Waldron, 1993). The pattern of Schmorl's nodes is consistent with other research, e.g., thoracic prevalence of Schmorl's nodes in 16th century military recruits from the Mary Rose was as high as 26.7% (Stirland, 2002), and reinforces the above mentioned notion about excessive mechanical loading of the thoracic spine. Elite individuals featured such osseous lesions more frequently in these regions than non-elite individuals. Only for spondyloarthrosis in the cervical vertebrae, non-elite individuals were more often affected (26.5%, elites; 30.3%, non-elites). This might suggest that elite individuals engaged regularly in activities favouring the development of spondyloarthrosis in the mid and lower back, whereby non-elite individuals appeared to expose their neck, i.e., cervical spine, to such strains. Yet, from a spondyloarthrosis severity point of view, cervical vertebrae of elites (2.35) were more severely affected than those of non-elite individuals (2.1). Based on these data, both groups appear to have been frequently involved in activities causing changes in the cervical spine, yet non-elites engaged in such tasks slightly more often, but in terms of physical demand, elite individuals seem to have been exposed to greater loading, hence, the higher severity scores. As spondyloarthrosis in the cervical spine has been frequently observed in populations carrying heavy loads on their head (Larsen, 2015; Levy, 1968; Lovell, 1994; Molleson, 1994), one would also expect higher rates of Schmorl's nodes, however, even though non-elite individuals displayed prominent spondyloarthrosis rates, Schmorl's node prevalence was substantially lower (2.6%) than what would be expected if they had engaged in such practices on regular basis. As thoracic and lumbar vertebrae showed the highest prevalence of spondyloarthrosis, particularly those of elite individuals, it is likely to assume that holding the same body posture, lifting, and carrying weights may have been carried out habitually by these individuals. The present frequencies are very similar as those found by DiGangi and Gruenthal-Rankin (2019) in their Archaic sample from Chile, who also featured higher rates of thoracic (37.9%) and lumbar spondyloarthrosis (37.9%) than cervical spondyloarthrosis (31.6%). For this population it is known that their subsistence relied predominantly on seasonal migration, which was accompanied by a hunting element of both terrestrial and marine animals (DiGangi and Gruenthal-Rankin, 2019). Historical, archaeological and the present osteological data also support similar interpretations, i.e., a highly mobile population (Putzer et al., 2016; Winckler, 2012), for early mediaeval South Tyrol. Based on these data, elite individuals appear to have subjected their mid- and lower back to heavy loads and have been more mobile than non-elite individuals, as also suggested by the lower limb robusticity and platymeric and platycnemic index data as well as the higher rate of vertebral osteochondrosis dissecans. For both subgroups, males exhibited higher spondyloarthrosis rates than females, whereby the differences between the sexes were much more pronounced in the elite subsample, e.g., thoracic vertebrae 60.8% in males, 36.4% in females. Also, the rate of Schmorl's nodes in the thoracic and lumbar region was higher in males than females for both subgroups, suggesting a more frequent involvement of males in strenuous labour leading to such injuries. Deviations of this pattern were only observed in the frequency and expression of cervical spondyloarthrosis, particularly in non-elites. The higher difference between male and female spondyloarthrosis rates and severity of the cervical spine in non-elite individuals, i.e., 46.5% and 2.3 in males and 17.6% and 1.8 in females, clearly supports the previously mentioned notion about high demanding non-elite lifestyles, particularly of males. As frequent upper body movements which involve heavy weightlifting or repeated bending and twisting of the neck have a significant impact on cervical spine health (Ariful Islam et al., 2015), non-elite males seem to have engaged in such activities at a greater scale than non-elite females. Although for Schmorl's nodes, non-elite females (5.9%) were more often affected than non-elite males (2.3%). Schmorl's nodes are commonly associated with excessive weight bearing, thus, as both sexes in the non-elite sample appear to have lived a highly laborious life, higher rates of Schmorl's nodes in non-elite females may be related to biological factors, i.e., males featuring more muscle mass, thus, strength than females, increasing the injury risk of the latter. Higher expressions of cervical spondyloarthrosis in elite individuals, with females featuring slightly higher rates of degeneration (i.e., 2.5 versus 2.2), might be linked to repetitive exposure to mechanical loading affecting this section of the spine. Another very common factor affecting joint health is the age of the individual, i.e., similar as any other degenerative disease, also spondyloarthrosis and osteoarthrosis worsens with age.

The aetiopathogenesis of OA and EC has been shown to correlate with age (Acosta et al., 2017; Mariotti et al., 2004; Montes and Subirà, 2018; Niinimäki and Baiges Sotos, 2013; Salo, 2016; Sperduti, 1997; Weiss and Jurmain, 2007), which was also found in Säben-Sabiona with the oldest age category featuring both the highest frequency and severity. For older individuals, elevated levels of OA and EC were expected due to the pathogenesis of these conditions, which tends to intensify over one's lifetime (Cheverko and Hubbe, 2017; Rogers and Waldron, 1995; Weiss and Jurmain, 2007; Williams et al., 2019). However, the presence of OA and elevated frequency and severity of EC in younger individuals suggests that these may have been exposed to extensive mechanical loading already during childhood to develop such lesions in early adulthood (Becker and Goldstein, 2018; Milella et al., 2012; Schrader, 2019; Villotte and Knüsel, 2013; Wilczak et al., 2009). Looking at OA, which is commonly found in individuals over the age of 45 (Buikstra, 2019; Roberts and Manchester, 2010; Shane Anderson and Loeser, 2010), the non-elite sample featured higher rates in their juvenile age category (75%, females; 66.7%, males) than elites (50%, females, 33.3% males). For both subgroups, female juveniles (50% in elites, 75% in non-elites) had higher rates than male juveniles (33.3% elites and 66.7% in non-elites). This pattern may imply that those females that died as juveniles may have been involved more frequently in highly strenuous activities, favouring the development of OA at such a young age, than males who died around the same age. The entheseal data supports such a view only for the elite sample, with a 100% EC prevalence in females as opposed to 33.3% elite males, but not for the non-elite sample (50%, females; 66.7%, males). The slightly higher rates of EC in non-elite juvenile males (66.7%) than females (50%) may be related to the sex-related labour differences and the increased involvement of males in activities posing high tendon injury risks. Elite adult males displayed higher OA and EC rates (93.3%, respectively) than adult females (71.4%, OA; 85.7%, EC), which aligns well with the notion that in an agricultural setting, adult males were probably the ones exposed to the greatest workload. Yet, as all of the examined non-elite adult females displayed EC and only 64.3% of non-elite adult males had such lesions (most of which were moderate or severe), whereas the difference in OA rates was lower and reversed (78.6%, males; 66.7%, females) this might indicate that adults of the non-elite sample experienced the greater or similar levels of physiological strain, regardless of sex.

The high frequencies and severity scores of OA and EC in juveniles and adults may represent a general tendency for a high demanding lifestyle. Even though comparable OA and EC data from local sites are not available, thus it is not possible to establish whether the observed pattern is consistent with a spatiotemporal trend, other studies can be considered to contextualise the collected data. Similar patterns with high rates of severe joint degeneration in juveniles and early adults were recorded by Wilczak et al. (2009), who examined the New York African Burial Ground. As the examined cemeterial population consisted of enslaved individuals, which were most definitely subjected to significant workload, Wilczak et al. (2009) linked the elevated OA and EC data in younger individuals to early and habitual exposure to intense physiological strains. Especially in consideration of the environmental constraints of the Alps as well as the political instabilities of the Early Middle Ages (Maczynska, 1998; Winckler, 2012), survival may have been challenging for both the local elite and non-elite population. Thus, engagement in extensive mechanical loading throughout life, which was most likely initiated already during childhood, may have been a necessity. Various studies point towards non-exclusive subsistence strategies, i.e., alpine manufacture was mainly based on subsistence economy, including alpine pastoralism, farming, mining and hunting (Leonardi, 2009; Meyer, 1998, 1992; Mundle, 2018; Renhart, 1991; Winckler, 2012). In most societies, children and juveniles are regularly required to help adults to acquire the necessary life skills, e.g., herding smaller animals, crop harvesting, gathering fruits and vegetables, etc. (Bugarin, 2008; Hawkes et al., 1995; Kim et al., 1991). High rates of EC are commonly associated with highly mobile subsistence strategies, e.g., hunter-gatherers, mobile pastoralists etc. (Capasso et al., 1999; Franz and Kram, 2012; Geere et al., 2010; Henderson, 2013; Shatrugna et al., 2008). Thus, the examined individuals may have engaged in a variety of physically demanding activities, regardless of their background, i.e., clerics, farmers, miners, etc., which in conjunction with the hilly environment, imposed significant mechanical strain on the whole body already since childhood. Also, the fact that most interred individuals were less than 60 years of age, and the onset of visible osseous degeneration is usually at around 45 years of age strongly supports the notion of a highly laborious lifestyle, especially in consideration of the severity of some of the observed alterations in younger age categories.

To sum up, the high prevalence and distribution of OA and EC, as well as the gathered osteometric data indicate long-term engagement in strenuous activities at a young age. The whole sample displays skeletal alterations and robusticity scores consistent with habitual movement on uneven terrain, transportation and lifting of heavy loads on the upper back and limb, whereby the activities of non-elites appeared to have been more versatile and demanding. Due to the nature of the present sample, i.e., a selected population, the observed joint alterations might not be attributable to a single type of activity. Yet, as mobile pastoralism and alpine farming and agriculture is known to have played a dominant part in the subsistence at this locality, whether from a peasant or cleric social status, also the collected data confirm this, it is highly likely that those buried at the Säben-Sabiona cemetery relied on such subsistence strategies. To explore this notion further, the assessment of trauma may provide more detailed information about the types of activities.

7.3.2.2. Trauma

The assessment of skeletal trauma can provide a substantial amount of information on human behaviour and bio-sociological and cultural contexts, e.g., hazards associated with daily activities, interpersonal aggression, torture, structural violence and combat dynamics, the reoccurrence and types of conflicts as well as possible medical treatments (Gerhards, 2007; Gilmour et al., 2015; Kjellström, 2005; Nicklisch et al., 2017; Rodríguez-Martín, 2006; Šlaus et al., 2012, 2010; Smith, 2017). For early mediaeval South Tyrol, most of the earlier studies (c.f., Giovannini, 2003; Renhart, 2008, 2006), but also some of the more recent ones (c.f., Paladin and Zink, 2015; Tumler, 2015) mentioned the presence of trauma in their sample but did not provide a thorough trauma analysis, which would be required to be able to understand more complex sociocultural practices and contexts. Some of these publications also yield data about the type and/or timing of the observed lesions (Renhart, 1991; Tumler, 2015), yet, again this information lacks a differential diagnosis and contextualisation. Up to now, only two studies on South Tyrolean skeletal remains, i.e., from the Säben-Sabiona sample, that assess trauma prevalence and pattern thoroughly, are available (Tumler et al., 2021, 2019). Tumler et al. (2019, 2021) performed a detailed trauma analysis discussing the aetiology and potential contexts of the lesions. Most of the assessed individuals featured antemortem injuries, particularly fractures that were most likely the result of accidents associated with daily activities, whereby only a selected number of individuals exhibited signs of intentional violence, e.g., SK63 (Tumler et al., 2021, 2019). These publications clearly outline the vast amount of information that can be gained through such investigations, i.e., lifestyle and the sociocultural impacts of the constantly changing political and economic situation throughout the early mediaeval period. While these publications provide a systematic investigation at the population and aetiological level of the observed trauma, there remains a paucity of contextualisation in relation to the social status and burial pattern of the injured at Säben-Sabiona. As mentioned by Tumler et al. (2021), the total Säben-Sabiona sample features a similar trauma prevalence (16.4%) as other European late antique and mediaeval sites. When subdividing the sample into elite and non-elite individuals, it became apparent that the elite subgroup (20.3%) exhibited a substantially higher trauma prevalence than the non-elite sample (9.3%). In both subsamples, males were more frequently affected. Numerous studies on trauma frequency illustrate a higher proportion of males being affected by bone injuries (Giuffra et al., 2015; Nicklisch et al., 2017; Šlaus et al., 2012; Šlaus and Novak, 2006). Males tend to have higher trauma risks due to their involvement in more difficult and hazardous activities associated with daily labour, e.g., through agricultural activities such as ploughing, working with large farming animals, etc., as well as their predisposition for more aggressive behaviour and their frequent engagement in conflict situations (Carré et al., 2017; Carré and Archer, 2018; Gerhards, 2007; Gilmour et al., 2015; Šlaus et al., 2012). The demographic profile of the injured elite and non-elite individuals displays similar patterns with a high trauma prevalence in males (41.2%, elites; 20.9%, non-elites) as opposed to females (9.1%, elites; 5.9%, non-elites) and subadults (5.7%, elites; none in non-elites). As elite individuals displayed higher rates of trauma regardless of sex and age group, this might indicate involvement in activities, which posed an elevated injury risk. Social status-related inconsistencies in trauma prevalence have been found to be a strong indicator for differentiated lifestyles, whereby elevated injury rates in high status individuals are commonly associated with interpersonal conflict (Lahren and Berryman, 1984; Larsen, 2015; Quinn and Beck, 2016; Smith, 2017). Here, the age distribution of the injured individuals might provide clues to elucidate this notion further.

As, in the elite sample, senile females (one out of two) featured the highest trauma frequencies followed by mature (13 out of 29) and adult (5 out of 15) males, two interpretations can be proposed. For females it is know that trauma risks increase following menopause due to a sharp drop in hormone levels, thus a higher vulnerability to osteoporosis. For males, on the other hand, a slightly different distribution was observed in non-elites (28.6%, adults; 27.8%, mature) as opposed to elites. A very similar trauma distribution between males aged 20-40 years and those above 40 points towards an increased injury risk in both younger and older adult males. However, as mature elites featured higher trauma rates than adult elites and the non-elite individuals were mostly affected as adults rather than later on in life, this might suggest an increased involvement of non-elite individuals in activities with elevated injury risk. The fact that elite males above forty years of age displayed more injuries than those between 20-40 years could be linked to the aging, i.e., like any other pathological condition also trauma accumulates with age. Even though sex and age of the injured provides essential information, more so does the type, location, and timing of trauma, which are crucial elements to distinguish among differences in trauma distribution between elite and non-elite individuals.

It is known that injuries resulting from sharp force trauma, particularly in cases of polytrauma, and/or fractures located above or within the hat brim line are generally associated with exposure to intentional violence, whereas fractures on the postcranium are often, but not always, linked to accidents (Constantinescu et al., 2017; Gerhards, 2007; Gilmour et al., 2015; Judd and Redfern, 2012; Kremer et al., 2008; Larsen, 2015; Mant, 2019; Myszka et al., 2012). The elite sample featured substantially more sharp forced injuries (n=55), than non-elite individuals (n=6), whereby all individuals with multiple injuries were elites. A similar pattern was observed for trauma timing with perimortem (69.9%), mostly in the craniofacial region (41.4% versus 21.1%), being more common in elite individuals than antemortem lesions (65%), which were mostly located in the axial (36.8% vs 31%) and appendicular skeleton (42.1% vs 27.6%). Most injuries in elite individuals, regardless of trauma timing, were located on the left side. In consideration of the analyses by Tumler et al. (2021, 2019) as well as those by other scholars (e.g., Boucherie et al., 2017; Fiorato et al., 2007; Kjellström, 2005; Larsen, 2015), such a trauma distribution, i.e., elevated rates of perimortem trauma, sharp force polytrauma, injury focalisation in the craniofacial region and a dominance of lesions on the left side (associated with right handed attacker), are highly indicative for the involvement in interpersonal conflict. Reasons for increased evidence implying greater exposure to intentional violence of elite individuals can be explained by looking at the sociocultural contexts of early mediaeval South Tyrol. Numerous historical sources illustrate the dangers and cruelty associated with the adaptation of Christianity, which is assumed to have been completed by around 600 A.D (Roschmann, 1751; Sarti, 2013; Sparber, 1942; Winckler, 2012). The attempts of early clerics to Christianise pagan individuals, both autochthonous and allochthonous groups, may have posed an increased death risk and dying as a martyr might have been rewarded with a more prestigious burial (Sarti, 2013). The historical literature features many examples of missionaries that were killed in the quest of Christianisation, e.g., Marinus from Gallia was burned alive when trying to convert pagan individuals in Irschenberg near Miesbach in Bavaria, Germany, yet they also mention the relocation of a martyr burial to a Christian site (Semmler, 1999). During these early periods of the Middle Ages, clergymen and bishops, who initially originated mainly from local elite groups, functioned as mediators between the local population and the invading groups, thus, they played a major role in exercising profane duties, such as military protection of important key locations (Kustatscher and Romeo, 2010; Sarti, 2013). As Säben-Sabiona was an episcopal see, thus, in essence a political centre, and historical records evidence the involvement of Ingenuinus, the bishop of Säben-Sabiona, in the negotiations to save the inhabitants of the *castrum Ferruge* during the Frank invasion in 590 A.D. (Dudley, 2003; Gleirscher, 1986; Hammer, 2011; Kustatscher and Romeo, 2010; Winckler, 2012), it is likely that some of the injured elite individuals participated in small scale military operations associated with the continuous variations of power and frontiers. Territories close to the frontiers were frequently raided, whereby churches and whole villages were burned to the ground, local Roman elites and even priests were killed (Kustatscher and Romeo, 2010; Winckler, 2012). According to Bierbrauer and Nothdurfter (2015) the church in the vineyard was destroyed at least once by a fire and given the age distribution of the elite individuals with trauma, also the osteological evidence would support such a notion. However, due to the lack of carbon 14 data for the present skeletal assemblage an association between specific historically documented violent events and the individuals featuring trauma cannot be established. Especially in the present setting, if C14 data were available for the injured, these could function as a direct osteological witness for historically recorded events. Thus, carbon 14 dating should be incorporated in future anthropological analyses to improve the contextualisation of the data. Despite not being able to link the injured to specific historical occurrences, the present anthropological data still provides a good overview of the early mediaeval living conditions. Raids and other types of small scale conflicts were most commonly employed as means for institutionalised oppression and to express power (Elema, 2012; Quinn and Beck, 2016; Šlaus et al., 2010; Smith, 2017), thus, mature elite males, who probably held leading positions may have been of higher risks to be subjects of such violence. The exertion of such tactical assaults might be evidenced in the higher trauma prevalence in individuals featuring typical Germanic (44.4%) material culture than those featuring artefacts representing Roman traditions (21.2%). As life expectancy was rather low for individuals that were regularly involved in interpersonal aggression, engagement in military activities might account for the high trauma rates in adult elite males. Research by Nicklisch et al. (2017) on the battle of Lützen found that most males killed were between 20-30 years of age, which is an age group that was often specifically targeted by military recruiters. A similar trend was observed for the age at death data of late mediaeval battle sites, i.e., Towton (26-35 years), Uppsala (25-34 years) and Sandbjerget (30-40 years) (Bennike et al., 2006; Boucherie et al., 2017; Kjellström, 2005; Novak, 2007). Historical and archaeological sources report that the employment of border guards, specialised for the alpine terrain, i.e., *auctoribus montani*, was common during periods of increased hostility (Gietl, 2004; Winckler, 2012), thus, those that lost their lives during such defence procedures might have also been interred at Säben-Sabiona.

Even though the location of Säben-Sabiona, i.e., at one of the major trade routes between Italy and Northern Europe, made this site prone to continuous political instability, not everyone may have been affected as drastically by these changes (Albertoni, 2005; Giostra and Lusuardi Siena, 2004; Kustatscher and Romeo, 2010; Winckler, 2012). Winckler (2012) suggests that most of the rural population in South Tyrol was largely unaffected by border controls as well as other military activities. This would also explain the findings of Tumler et al. (2021), i.e., only a small proportion of the Säben-Sabiona sample displayed multiple injuries associated with the time of death. These interpretations appear to be consistent with other mediaeval studies, e.g., Giecz (11^{th}-12^{th} century A.D.) in Poland (Agnew and Justus, 2014). Analogous with Säben-Sabiona, Giecz was a major centre of political, economic, and religious power, featuring a strong military presence consisting of elite individuals (clergymen, bishops, etc.). In Giecz, adult trauma prevalence was substantially higher (49%) than in Säben-Sabiona (21.9%, total sample; 26.9%, elites; 14.9%, non-elites), but for both sites lesions associated with intentional violence were relatively low (Agnew and Justus, 2014; Tumler et al., 2021). Thus, like most of the common residents of Giecz, especially non-elite individuals buried at Säben-Sabiona engaged most likely in physically demanding and hazardous lifestyles, which account for the high prevalence of non-intentional injuries. The individuals buried at Säben-Sabiona are believed to have derived from the surrounding area and relied predominantly on alpine farming, occasional fishing and hunting (Bierbrauer and Nothdurfter, 2015; Kaufmann, 2017). Following the publication by Kuhnen (2020), the archaeological record also evidences potential involvement in mining and associated forestry. Habitual engagement in strenuous labour is also supported by the collected osteoarthrosis, entheseal and robusticity data. Clinical and osteoarchaeological research found that lower social classes, particularly those engaging in animal farming and agriculture, display axial and appendicular trauma more often than higher social classes (Dogan and Demirci, 2012; Karttunen and Rautiainen, 2013; Larsen, 2015; Loder, 2008; Roberts and Cox, 2003; Tucker et al., 2017). A congruent pattern was recorded for the non-elite sample, with a higher prevalence of axial (46.7%) and appendicular injuries (37.8%) than craniofacial trauma (15.6%). Also lesion laterality, i.e., overall, more injuries on the right side, with a higher prevalence of antemortem trauma on the left and perimortem trauma on the right, does not follow a homogeneous pattern as seen in cases of intentional violence (Boucherie et al., 2017; Fiorato et al., 2007; Larsen, 2015; Tumler et al., 2019), thus, points more towards less consistent behaviours and biomechanical mechanisms leading to trauma. Ethnographic research reports that agriculture and forestry are among the most dangerous occupations in modern day Austria (Bruckmüller and Sandgruber, 2002). In fact, from 1929 to 1937 falls and trips (10,747 cases), accidents with tools (6,184 cases), injuries caused through means of transportation (7,023 cases), animal-related accidents (5,897 cases) and building collapses/falling of other items have been found to be the most common causes for lethal and non-lethal injuries (Bruckmüller and Sandgruber, 2002). Thus, as discussed already in depth by Tumler et al. (2021), the trauma pattern associated with accidents rather than intentional violence, which was mostly attributable to the non-elite subsample is congruent with strenuous manual labour featuring immense injury risks, e.g., high alpine agriculture, farming, pastoralism, forestry and/or mining (Gilmour et al., 2015; Judd and Roberts, 1999; Karttunen and Rautiainen, 2013; Mant, 2019; Oberhofer, 2005; Šlaus et al., 2012). Overall, the trauma distribution between elite and non-elite individuals is congruent with all of the other osteological and historical evidence implying general hardship, whereby elite individuals were more likely to be exposed to interpersonal aggression.

8. Conclusion and outlook

The present study aimed to establish a full biological and palaeopathological profile of the individuals interred around and within the church of the vineyard at Säben-Sabiona, Italy, to gain information about the quality of life in early mediaeval South Tyrol. Even though the analysed population only forms a portion of a larger skeletal collection, the selected sample has been shown to be representative of the individuals buried at Säben-Sabiona and opens research into the living conditions and health of individuals living during a period marked by continuous cultural and political transformation. As this is the first anthropological study ever conducted on the skeletal sample of Säben-Sabiona, novel data has been generated and by utilising a holistic approach to contextualise these findings, a better depiction of the living conditions during this spatiotemporal context was yielded.

Based on the historical and archaeological evidence known to date, as well as on the results of the present research, it can be proposed that Säben-Sabiona was a selective burial site, where only certain high-ranking members of the early mediaeval society were interred. The demographic profile suggests that with a relatively normal age distribution, such an extreme overrepresentation of males, as seen in the present cemeterial population, can only be explained by selective inhumation practices. As no distinct sex- or age-related burial patterns could be established, the data strongly implies that females have been buried elsewhere, i.e., in areas not yet excavated or in a completely different location. The high number of male burials may be associated with the political and religious function of the site. Clear status-related discrepancies in mean age at death and life expectancy at birth were observed in the present sample, with non-elite individuals living longer. In terms of body height, weight and form, the data of both subgroups was consistent with that from other local and non-local early mediaeval sites, displaying average sizes of 167.8cm for males and 156.8cm for females, a normal body mass index and fairly robust skeletal structure. Skeletal and dental disorders were distributed almost equally between both subgroups, yet, for most conditions the non-elite sample was more frequently and/or more severely affected. Both groups appear to have had access to a similar macronutrient rich diet, although the foods consumed by non-elite individuals may have been of lower quality, i.e., less processed. Also, sex-related differences were observed, implying that males may have consumed the same food items as females, but at a higher quantity, hence causing increased dental deterioration. Sexual and social differences in relation to chronic stress exposure continued to persist, with females, subadults and non-elite males most often affected, whereby rough living and working conditions may be determining factors. This was again reflected in the osteoarthrosis, entheseal and robusticity data, which showed that non-elite individuals engaged in more monotonous, but highly strenuous activities, with a clear sexual division of labour. Whereas the elite subsample displayed more variability in terms of movements, low rates of sexual division of labour and more trauma, particularly those associated with the time of death. Based on the available historical, archaeological, and anthropological data, it can be assumed that those classed as elites, may have belonged to a ruling and/or cleric group, which commonly possessed fields, estates and sometimes even forests, and may have actively engaged in daily activities similar of those classed as non-elites. Those categorised as non-elites may have been affected by hardship slightly more, i.e., as shown in the low differences of osteological data. The present data show that even though the archaeological evidence implies social stratification, all individuals buried at Säben-Sabiona displayed fairly similar prevalence rates in dental and skeletal alterations. Due to the lack of statistically significant data, from an osteological perspective, the hypothesis of a clear social stratification cannot be proven. One explanation for the observed lack of variation between the two subsamples, may be related to sample size and bone preservation, i.e., underrepresentation of certain bone elements or limited bone surface quality, another more likely reason might be the nature of the sample. It appears that regardless of supposed social status, all lived a very physically demanding lifestyle, which was evidenced by the osteological data, i.e., OA, EC and robusticity data. As the archaeological record also suggests that the cemetery population at Säben-Sabiona was probably composed of individuals deriving from different locations along the Eisack-Isarco valley, thus, form a selected sample that were exposed to similar environments, the low osteological variations between elite and non-elite might be explained by that. It needs to be pointed out that the present samples did not derive from two distinct populations, i.e., which would be expected to show higher rates of variation, but most likely from several groups from nearby areas. Hence, as distinct extrinsic and/or intrinsic factors form the basis of skeletal variation, the present sample may have simply been too similar to show osteological differences for the differentiation between elite and non-elite individuals. To explore this notion further, stable isotope analyses looking at dietary differences based on the present anthropological and archaeological data should be performed, in order to gain a better understanding of the sociocultural context of the sample. Moreover, the collection of additional osteological data for South Tyrol, utilising such a standardised approach, would also help to contextualise the osteological data, i.e., whether the Säben-Sabiona sample/subsamples correspond to the spatiotemporal trend or not.

To conclude, this research used a holistic osteoarchaeological approach to investigate population structure, diet, and health, of the individuals buried at Säben-Sabiona, providing an insight into several aspects of the living conditions and lifestyle of early mediaeval individuals. As the first biocultural study of this cemeterial population, this thesis provides a solid foundation for future anthropological and molecular research on early mediaeval populations residing in South Tyrol.

9. References

Acosta, M.A., Henderson, C.Y., Cunha, E., 2017. The Effect of Terrain on Entheseal Changes in the Lower Limbs. Int. J. Osteoarchaeol. 27. https://doi.org/10.1002/oa.2597

Acsádi, G.Y., Nemeskéri, J., 1970. History of human life span and mortality. Akademiai Kiado, Budapest.

Agarwal, S.C., 2016. Bone Morphologies and Histories: Life Course Approaches in Bioarchaeology. Am. J. Phys. Anthropol. 159, 130–149.

Aghai, Z.H., Goudar, S.S., Patel, A., Saleem, S., Dhaded, S.M., Kavi, A., Lalakia, P., Naqvi, F., Hibberd, P.L., McClure, E.M., Nolen, T.L., Iyer, P., Goldenberg, R.L., Derman, R.J., 2020. Gender variations in neonatal and early infant mortality in India and Pakistan: a secondary analysis from the Global Network Maternal Newborn Health Registry. Reprod. Health 17, 178. https://doi.org/10.1186/s12978-020-01028-0

Agnew, A.M., Justus, H.M., 2014. Preliminary Investigations of the Bioarchaeology of Medieval Giecz (XI-XII C.): Examples of Trauma and Stress. Anthropol. Rev. 77, 189–203. https://doi.org/10.2478/anre-2014-0015

Aheto, J.M.K., 2019. Predictive model and determinants of under-five child mortality: evidence from the 2014 Ghana demographic and health survey. BMC Public Health 19, 64. https://doi.org/10.1186/s12889-019-6390-4

Ahmadieh, H., Arabi, A., 2011. Vitamins and bone health: beyond calcium and vitamin D. Nutr. Rev. 69, 584–598. https://doi.org/10.1111/j.1753-4887.2011.00372.x

Akcalı, A., Lang, N.P., 2018. Dental calculus: the calcified biofilm and its role in disease development. Periodontol. 2000 76, 109–115. https://doi.org/10.1111/prd.12151

Akinyamoju, A.O., Gbadebo, S.O., Adeyemi, B.F., 2014. Periapical lesions of the jaws: a review of 104 cases in ibadan. Ann. Ibadan Postgrad. Med. 12, 115–9.

Al-Shammari, K.F., Al-Khabbaz, A.K., Al-Ansari, J.M., Neiva, R., Wang, H.-L., 2005. Risk Indicators for Tooth Loss Due to Periodontal Disease. J. Periodontol. 76, 1910–1918. https://doi.org/10.1902/jop.2005.76.11.1910

Al Hasan, S.M., Hassan, M., Saha, S., Islam, M., Billah, M., Islam, S., 2016. Dietary phytate intake inhibits the bioavailability of iron and calcium in the diets of pregnant women in rural Bangladesh: a cross-sectional study. BMC Nutr. 2, 24. https://doi.org/10.1186/s40795-016-0064-8

Albandar, J.M., Brown, L.J., Brunelle, J.A., Löe, H., 1996. Gingival State and Dental Calculus in Early-Onset Periodontitis. J. Periodontol. 67, 953–959. https://doi.org/10.1902/jop.1996.67.10.953

Albanese, J., Tuck, A., Gomes, J., Cardoso, H.F. V, 2016. An alternative approach for estimating stature from long bones that is not population- or group-specific. Forensic Sci. Int. 259. https://doi.org/10.1016/j.forsciint.2015.12.011

Alberti, A., Dal Ri, L., Marzoli, C., Tecchiati, U., 2004. Evidenze relative al X, IX, VIII sec. a. C. nell ambito dell alto bacino del fiume Adige (Cultura di Luco- Meluno). Mediterr. Quad. Annu. dell Ist. di Stud. sulle civilta Ital. e del Mediterr. antico del Cons. Naz. delle richerche.

Albertoni, G., 2005. Romani e Germani come questione storiografica, in: Romani e Germani Nel Cuore Delle Alpi Tra V e VIII Secolo. Saggi, Bozen, pp. 17–27.

Alfsdotter, C., Kjellström, A., 2019. The Sandby Borg Massacre: Interpersonal Violence and the Demography of the Dead. Eur. J. Archaeol. 22, 210–231. https://doi.org/10.1017/eaa.2018.55

Alfsdotter, C., Papmehl-Dufay, L., Victor, H., 2018. A moment frozen in time: evidence of a late fifth-century massacre at Sandby borg. Antiquity 92, 421–436. https://doi.org/10.15184/aqy.2018.21

Algee-Hewitt, B.F.B., Coelho, C., Navega, D., Cunha, E., 2020. Statistical approaches to ancestry estimation: New and established methods for the quantification of cranial variation for forensic casework, in: Obertová, Z., Stewart, A., Cattaneo, C. (Eds.), Statistics and Probability in Forensic Anthropology. Elsevier Inc., London, pp. 227–248.

AlQahtani, S.J., Hector, M.P., Liversidge, H.M., 2010. Brief communication: The London atlas of human tooth development and eruption. Am. J. Phys. Anthropol. 142, 481–490. https://doi.org/10.1002/ajpa.21258

Alt, K.W., 1997. Odontologische Verwandtschaftsanalyse- Individuelle Charakteristika der Zähne in ihrer Bedeutung für Anthropologie, Archäologie und Rechtsmedizin. Gustav Fischer Verlag, Stuttgart.

Alt, K.W., Rösing, F.W., Teschler-Nicola, M., 1998. Dental Anthropology. Springer Vienna, Vienna. https://doi.org/10.1007/978-3-7091-7496-8

Alves Cardoso, F., Henderson, C., 2013. The Categorisation of Occupation in Identified Skeletal Collections: A Source of Bias? Int. J. Osteoarchaeol. 23. https://doi.org/10.1002/oa.2285

Alves, R.C., Félix, S.A., Rodriguez-Archilla, A., Oliveira, P., Brito, J., Dos Santos, J.M., 2015. Relationship between menopause and periodontal disease: a cross-sectional study in a Portuguese population. Int. J. Clin. Exp. Med. 8, 11412–9.

Andelinović, Anterić, I., Škorić, E., Bašić, 2015. Skeleton changes induced by horse riding on medieval skeletal remains from croatia. Int. J. Hist. Sport. https://doi.org/10.1080/09523367.2015.1038251

Andersen, S., Thygesen, L.C., Davidsen, M., Helweg-Larsen, K., 2012. Cumulative years in occupation and the risk of hip or knee osteoarthritis in men and women: a register-based follow-up study. Occup. Environ. Med. 69, 325–330. https://doi.org/10.1136/oemed-2011-100033

Anderson, T., 2000. Congenital conditions and neoplastic disease in British Palaeopathology, in: Cox, M.J., Mays, S. (Eds.), Human Osteology in Archaeology and Forensic Science. Cambridge University Press, Cambridge, pp. 199–226.

Anderson, W.P., 2015. Gender and Metallurgy: An Ethnoarchaeological response to a disappearing craft in Eastern Africa. University of Wisconsin- La Crosse.

Andrade Cernadas, J.M., 2012. Los testamentos como reflejo de los cambios de actitud ante la muerte en la Galicia del siglo XIV.

Arbanas, J., Starcevic Klasan, G., Nikolic, M., Jerkovic, R., Miljanovic, I., Malnar, D., 2009. Fibre type composition of the human psoas major muscle with regard to the level of its origin. J. Anat. 215, 636–641.

Arcini, C., 2005. The vikings bare their filed teeth. Am. J. Phys. Anthropol. 128, 727–733. https://doi.org/10.1002/ajpa.20164

Arden, N., Nevitt, M., 2006. Osteoarthritis: Epidemiology. Best Pract. Res. Clin. Rheumatol. 20, 3–25. https://doi.org/10.1016/j.berh.2005.09.007

Ari, I., Kafa, M.I., Sendemir, E., 2005. Anthropometric measurements of femur and tibia on the Byzantine skeletons of Nicea remains (13th century A.D.). Anthropologie 43, 45–49. https://doi.org/10.2307/26292712

Ariful Islam, M., Hossen, M., Hauque, M., Uddin Ahmad, F., Amin Ahmed, F., Rahman Khan, M., 2015. Review journal of Cervical Spondylosis (Cervical Osteoarthritis; Arthritis-neck; Neck-arthritis; Chronic neck pain of elderly). J. Bangladesh Orthop. Soc. 30, 141–143.

Asao, K., Kao, W.H.L., Baptiste-Roberts, K., Bandeen-Roche, K., Erlinger, T.P., Brancati, F.L., 2006. Short Stature and the Risk of Adiposity, Insulin Resistance, and Type 2 Diabetes in Middle Age. Diabetes Care 29, 1632–1637. https://doi.org/10.2337/dc05-1997

Ashworth, A., Feachem, R.C., 1985. Interventions for the control of diarrhoeal diseases among young children: weaning education. Bull. World Health Organ. 63, 1115–1127.

Aufderheide, A.C., Rodríguez-Martín, C., 1998. The Cambridge Encyclopedia of Human Paleopathology. Cambridge University Press, Cambridge.

Avendano, M., Kawachi, I., 2014. Why Do Americans Have Shorter Life Expectancy and Worse Health Than Do People in Other High-Income Countries? Annu. Rev. Public Health 35, 307–325. https://doi.org/10.1146/annurev-publhealth-032013-182411

Babajko, S., Besten, Pamela Den, 2021. Environmental Factors and Enamel/Dentin Defects, in: Goldberg, M., Den Besten, P. (Eds.), Extracellular Matrix Biomineralization of Dental Tissue Structures. Biology of Extracellular Matrix. Springer, Cham, pp. 295–305. https://doi.org/10.1007/978-3-030-76283-4_12

Bach, H., 1965. Zur Berechnung der Körperhöhe aus den langen Gliedmaßenknochen weiblicher Skelette. Anthropol. Anzeiger 29, 12–21.

Bagis, N., 2018. Prevalence of tooth loss in Adrianapolis historical population. Bull. Int. Assoc. Paleodont. 12, 18–22.

Baldoni, M., Nardi, A., Muldner, G., Lelli, R., Gnes, M., Ferraresi, F., Meloni, V., Cerino, P., Greco, S., Manenti, G., Angle, M., Rickards, O., Martínez-Labarga, C., 2016. Archaeo-biological reconstruction of the Italian medieval population of Colonna (8th–10th centuries CE). J. Archaeol. Sci. Reports 10, 483–494. https://doi.org/10.1016/j.jasrep.2016.11.013

Bano, N., Beg, A., Kumari, A., Dahiya, R., 2021. A critical review : Problem of female feoticide and female infanticide in India. Pharma Innov. J. 10, 243–248.

Bardsley, S., 2014. Missing Women: Sex Ratios in England, 1000-1500. J. Br. Stud. 53, 273–309.

Barnes, E., 2012. Atlas of Developmental Field Anomalies of the Human Skeleton: A Paleopathology Perspective, 1st ed. Wiley-Blackwell, Hoboken. https://doi.org/10.1002/9781118430699

Barnes, E., 1994. Developmental defects of the axial skeleton in paleopathology. University Press of Colorado, Niwot, Colo.

Bartlett, L.A., Mawji, S., Whitehead, S., Crouse, C., Dalil, S., Ionete, D., Salama, P., 2005. Where giving birth is a forecast of death: maternal mortality in four districts of Afghanistan, 1999–2002. Lancet 365, 864–870. https://doi.org/https://doi.org/10.1016/S0140-6736(05)71044-8

Bass, W.M., 1995. Human Osteology: A laboratory field manual of the human skeleton, 4th ed.

Missouri Archaeological Society, Columbia.

Baxarias, J., Herrerin, J., 2008. The handbook atlas of paleopathology. Portico Libros, Zaragoza.

Becker, S.K., 2020. Osteoarthritis, entheses, and long bone cross-sectional geometry in the Andes: Usage, history, and future directions. Int. J. Paleopathol. 29, 45–53. https://doi.org/10.1016/j.ijpp.2019.08.005

Becker, S.K., 2013. Labor and the rise of the Tiwanaku State (AD 500-1100): A Bioarchaeological Study of Activity Patterns. University of North Carolina.

Becker, S.K., Goldstein, P.S., 2018. Evidence of osteoarthritis in the Tiwanaku Colony, Moquegua, Peru (<scp>AD</scp> 500-1100). Int. J. Osteoarchaeol. 28, 54–64. https://doi.org/10.1002/oa.2634

Belcastro, G., Rastelli, E., Mariotti, V., Consiglio, C., Facchini, F., Bonfiglioli, B., 2007. Continuity or Discontinuity of the Life-Style in central Italy during the Roman Imperial Age-Early Middle Ages Transition: Diet, Health and Behaviour. Am. J. Phys. Anthropol. 132, 381–394. https://doi.org/10.1002/ajpa

Bello, S.M., Thomann, A., Signoli, M., Dutour, O., Andrews, P., 2006. Age and sex bias in the reconstruction of past population structures. Am. J. Phys. Anthropol. 129, 24–38. https://doi.org/10.1002/ajpa.20243

Beltran Tapia, F.J., Szoltysek, M., Ogorek, B., Gruber, S., 2021. Inferring " missing girls " from child sex ratios in European historical census. Econ. Hist. 82.

Bencosme, J., 2016. Sex-Based Differences in Oral Health. Dimens. Dent. Hyg. 14, 33–34.

Benjamin, M., Kumai, T., Milz, S., Boszczyk, B.M., Boszczyk, A.A., Ralphs, J.R., 2002. The skeletal attachment of tendons - Tendon “entheses.” Comp. Biochem. Physiol. - A Mol. Integr. Physiol. 133, 931–945. https://doi.org/10.1016/S1095-6433(02)00138-1

Benjamin, M., McGonagle, D., 2007. Histopathologic changes at “synovio-entheseal complexes” suggesting a novel mechanism for synovitis in osteoarthritis and spondyloarthritis. Arthritis Rheumatol. 56, 3601–3609.

Benjamin, M., Toumi, H., Ralphs, J.R., Bydder, G., Best, T.M., Milz, S., 2006. Where tendons and ligaments meet bone: attachment sites ('entheses’) in relation to exercise and/or mechanical load. J. Anat. 208, 471–490. https://doi.org/10.1111/j.1469-7580.2006.00540.x

Bennike, P., Otto, T., Thrane, H., Vandkilde, H., 2006. Rebellion, combat and massacre: a medieval mass grave at Sandbjerg near Naestved in Denmark, in: Warfare and Society. Archaeological and Social Anthropological Perspectives. Aarhus Universitetsforlag, Aarhus, pp. 305–318.

Benusiglio, P.R., Fallet, V., Sanchis-Borja, M., Coulet, F., Cadranel, J., 2021. Lung cancer is also a hereditary disease. Eur. Respir. Rev. 30, 210045. https://doi.org/10.1183/16000617.0045-2021

Berbesque, J.C., Hoover, K.C., 2018. Frequency and developmental timing of linear enamel hypoplasia defects in Early Archaic Texan hunter-gatherers. PeerJ 6, e4367. https://doi.org/10.7717/peerj.4367

Berbesque, J.C., Marlowe, F.W., Pawn, I., Thompson, P., Johnson, G., Mabulla, A., 2012. Sex Differences in Hadza Dental Wear Patterns. Hum. Nat. 23, 270–282. https://doi.org/10.1007/s12110-012-9145-9

Bermejo, F., García-López, S., 2009. A guide to diagnosis of iron deficiency and iron deficiency anemia in digestive diseases. World J. Gastroenterol. 15, 4638. https://doi.org/10.3748/wjg.15.4638

Berthon, W., Tihanyi, B., Kis, L., Révész, L., Coqueugniot, H., Dutour, O., Pálfi, G., 2019. Horse riding and the shape of the acetabulum: Insights from the bioarchaeological analysis of early Hungarian mounted archers (10th century). Int. J. Osteoarchaeol. 29, 117–126. https://doi.org/10.1002/oa.2723

Betsinger, T.K., 2007. The Biological Consequences of Urbanization in Medieval Poland. Ohio State University.

Bierbrauer, V., 2006. Sabiona- Säben: Archäologie und Geschichte. Akad. Publ. 3, 56–62.

Bierbrauer, V., 2005a. Romanen und Germanen im 5.-8. Jahrhundert aus archäologischer Sicht, in: Landi, W. (Ed.), Romanan Und Germanen Im Herzen Der Alpen. Athesia, Bozen, pp. 215–240.

Bierbrauer, V., 2005b. Die Ausgrabungen im spätantik-frühmittelalterlichen Bischofssitz von Sabiona-Säben, in: Landi, W. (Ed.), Romanan Und Germanen Im Herzen Der Alpen. Athesia, Bozen, pp. 331–350.

Bierbrauer, V., Nothdurfter, H., 2015. Säben I- Die Ausgrabungen im Spätantik-Frühmittelalterlichen Bischofssitz Sabiona-Säben in Südtirol I. Verlag C.H. Beck München, München.

Bignozzi, I., Crea, A., Capri, D., Littarru, C., Lajolo, C., Tatakis, D.N., 2014. Root caries: a periodontal perspective. J. Periodontal Res. 49, 143–163. https://doi.org/10.1111/jre.12094

Bikle, D.D., 2007. Vitamin D Insufficiency/Deficiency in Gastrointestinal Disorders. J. Bone Miner. Res. 22, V50–V54. https://doi.org/10.1359/jbmr.07s208

Binder, M., Quade, L., 2018. Death on a Napoleonic battlefield – Peri-mortem trauma in soldiers from the Battle of Aspern 1809. Int. J. Paleopathol. 22, 66–77. https://doi.org/10.1016/j.ijpp.2018.05.007

Binder, M., Roberts, C., Spencer, N., Antoine, D., Cartwright, C., 2014a. On the antiquity of cancer: Evidence for metastatic carcinoma in a young man from ancient Nubia (c. 1200bc). PLoS One 9. https://doi.org/10.1371/journal.pone.0090924

Binder, M., Roberts, C., Spencer, N., Antoine, D., Cartwright, C., 2014b. On the Antiquity of Cancer: Evidence for Metastatic Carcinoma in a Young Man from Ancient Nubia (c. 1200BC). PLoS One 9, e90924. https://doi.org/10.1371/journal.pone.0090924

Binford, L.R., 2019. Constructing Frames of Reference: An Analytical Method for Archaeological Theory Building Using Ethnographic and Environmental Data Sets, 1st ed. University of California Press, Los Angeles.

Binks, D.A., Gravallese, E.M., Bergin, D., Hodgson, R.J., Tan, A.L., Matzelle, M.M., McGonagle, D., Radjenovic, A., 2015. Role of vascular channels as a novel mechanism for subchondral bone damage at cruciate ligament entheses in osteoarthritis and inflammatory arthritis. Ann. Rheum. Dis. 74, 196–203. https://doi.org/10.1136/annrheumdis-2013-203972

Bitschnau, M., Obermair, H., 2009. Tiroler Urkundenbuch, II. Abteilung: Die Urkunden zur Geschichte des Inn-, Eisack-, und Pustertals, Band 1: Bi. ed. Universitätsverlag Wagner, Innsbruck.

Bittles, A.H., 2012. Consanguinity in Context. Cambridge University Press, Cambridge. https://doi.org/10.1017/CBO9781139015844

Black, S., Ferguson, E., 2011. Forensic Anthropology 2000-2010. CRC Press, London.

Blakey, M.L., Rankin-hill, L.M., 2009. The Skeletal Biology of the New York African Burial Ground Part 1, Part 1. ed. Howard University Press, Washington D.C.

Block, J.A., Shakoor, N., 2010. Lower limb osteoarthritis: biomechanical alterations and implications for therapy. Curr. Opin. Rheumatol. 22, 544–550. https://doi.org/10.1097/BOR.0b013e32833bd81f

Bocquentin, F., 2003. Pratiques funéraires, paramètres biologiques et identités culturelles au Natoufien : une analyse archéo-anthropologique. Universite de Bordeaux I.

Bocquet-Appel, J.-P., Masset, C., 1977. Estimateurs en paleodemographie. L'Homme 17, 65–90.

Bogin, B., 1999. Patterns of Human Growth. Cambridge University Press, Cambridge.

Bogin, B., Varea, C., Hermanussen, M., Scheffler, C., 2018. Human life course biology: A centennial perspective of scholarship on the human pattern of physical growth and its place in human biocultural evolution. Am. J. Phys. Anthropol. 165, 834–854. https://doi.org/10.1002/ajpa.23357

Bonfiglioli, B., Brasili, P., Belcastro, M.G., 2003. Dento-alveolar lesions and nutritional habits of a Roman Imperial age population (1st-4th c. AD): Quadrella (Molise, Italy). Homo 54, 36–56. https://doi.org/http://dx.doi.org/10.1078/0018-442X-00055

Botelho, J.N., Villegas-Salinas, M., Troncoso-Gajardo, P., Giacaman, R.A., Cury, J.A., 2016. Enamel and dentine demineralization by a combination of starch and sucrose in a biofilm – caries model. Braz. Oral Res. 30. https://doi.org/10.1590/1807-3107BOR-2016.vol30.0052

Boucherie, A., Jørkov, M.L., Smith, M., 2017. Wounded to the bone: Digital microscopic analysis of traumas in a medieval mass grave assemblage (Sandbjerget, Denmark, AD 1300–1350). Int. J. Paleopathol. 19, 66–79. https://doi.org/10.1016/j.ijpp.2017.10.005

Bourbou, C., 2003. Health patterns of proto-Byzantine populations (6th-7th centuries AD) in south Greece: the cases of Eleutherna (Crete) and Messene (Peloponnese). Int. J. Osteoarchaeol. 13, 303–313. https://doi.org/10.1002/oa.702

Bourbou, Chryssi, Tsilipakou, A., 2009. Investigating the Human Past of Greece during the 6th-7th centuries A.D., in: Schepartz, L.A., Fox, S.., Bourbou, C. (Eds.), New Directions Int the Skeletal Biology of Greece. The Americal School of Classical Studies at Athens, New Jersey, pp. 121–136.

Bowen, W.H., 1994. Food Components and Caries. Adv. Dent. Res. 8, 215–220. https://doi.org/10.1177/08959374940080021301

Bradshaw, R., Eliopoulos, C., Borrini, M., 2020. Septal Aperture of the Humerus: Etiology and Frequency Rates in Two European Populations. Anat. Rec. 303, 1821–1830. https://doi.org/10.1002/AR.24290

Brather, S., 2008. Zwischen Spätantike und Frühmittelalter Archäologie des 4. bis 7. Jahrhunderts im Westen, in: Beck, H., Geuenich, D., Steuer, H. (Eds.), Ergänzungsbände Zum Reallexikon Der Germanischen Altertumskunde. Walter de Gruyter, Berlin, pp. 237–273.

Brather, S., Friedrich, M., 2013. Das Brigachtal im frühen Mittelalter, in: Alt, K.W., Brather, S., Deible, J., Eckert, H., Friedrich, M., Klug-Treppe, J., Krohn, N., Scheunemann, A., Wieners, T.H.T. (Eds.), Das Brigachtal Im Frühen Mittelalter. Landesamt für Denkmalpflege im Regierungspräsidium Stuttgart, Stuttgart, pp. 9–27.

Bratt, O., 2002. Hereditary Prostate Cancer: Clinical Aspects. J. Urol. 168, 906–913. https://doi.org/10.1016/S0022-5347(05)64541-7

Braun, S., 2005. Cribra orbitalia- Makroskopische Evaluation eines Stressors in der Skelettserie Spitalfriedhof St. Johann in Basel. Bull. la Soc. Suisse d'Anthropologie 10.

Breitinger, E., 1937. Zur Berechnung der Körperhöhe aus den langen Gliedmaßenknochen. Anthropol. Anzeiger 14, 249–274.

Brickley, M., Ives, R., 2008. The Bioarchaeology of Metabolic Bone Disease. Academic Press, Ox.

Brickley, M.B., 2018. Cribra orbitalia and porotic hyperostosis: A biological approach to diagnosis. Am. J. Phys. Anthropol. 167, 896–902. https://doi.org/10.1002/ajpa.23701

Bridges, P.S., 1994. Vertebral arthritis and physical activities in the prehistoric Southeastern United States. Am. J. Phys. Anthropol. 93, 83–93. https://doi.org/10.1002/ajpa.1330930106

Bridges, P.S., 1992. Prehistoric arthritis in the Americas. Annu. Rev. Anthropol. 21, 67–91.

Bridges, P.S., 1989. Changes in Activities with the Shift to Agriculture in the Southeastern United States. Curr. Anthropol. 30, 385–394.

Bron, J.L., Van Royen, B.J., Wuisman, P.I.J.M., 2007. The clinical significance of lumbosacral transitional anomalies. Acta Orthop. Belg. 73, 687–695.

Brooks, S., Suchey, J.M., 1990. Skeletal age determination based on the os pubis: A comparison of the Acsadi-Nemeskeri and Suchey-Brooks methods. Hum. Evol. 5, 227–238.

Brothwell, D.R., 2008. Tumours and Tumour-like Processes, in: Pinhasi, R., Mays, S. (Eds.), Advances in Human Palaeopathology. John Wiley & Sons Ltd., Chichester, pp. 253–281.

Brothwell, D.R., 1989. The relationship of tooth wear to aging, in: Age Markers in the Human Skeleton. C. C. Thomas, Springfield, pp. 303–316.

Brothwell, D.R., 1981. Digging up Bones: The excavation, treatment, and study of human skeletal remains. Cornell University Press.

Brownlee, E.C., 2020. The Dead and their Possessions: The Declining Agency of the Cadaver in Early Medieval Europe. Eur. J. Archaeol. 23, 406–427. https://doi.org/10.1017/eaa.2020.3

Bruckmüller, E., Sandgruber, R., 2002. Politik, Geschichte, Wirtschaft: Geschichte der österreichischen Land- und Forstwirtschaft im 20. Jahrhundert., 1st ed. Carl Überreuter Verlag, Wien.

Brundke, N., 2018. Die Bestattungen des ausgehenden Frühmittelalters auf dem Oberleiserberg (Niederösterreich), in: Pieler, F., Laussegger, A. (Eds.), Archäologische Forschungen in Niederösterreich. Edition Donau-Universität Krems, Wien, pp. 150–158.

Brundke, N., 2016. Ein Gräberfeld des späten Frühmittelalters auf dem Oberleiserberg, in: Lauermann, E., Trebsche, P. (Eds.), Beiträge ZumTag Der Niederösterreichischen Landesarchäologie 2016. Edition Donau-Universität Krems, Wien, pp. 69–76.

Buckberry, J.L., Chamberlain, A.T., 2002. Age estimation from the auricular surface of the ilium: A revised method. Am. J. Phys. Anthropol. 119, 231–239. https://doi.org/10.1002/ajpa.10130

Buencamino, M.C.A., Palomo, L., Thacker, H.L., 2009. How menopause affects oral health, and what we can do about it. Cleve. Clin. J. Med. 76, 467–475. https://doi.org/10.3949/ccjm.76a.08095

Bugarin, F.T., 2008. Constructing an Archaeology of Children: Studying Children and Child Material Culture from the African Past. Archeol. Pap. Am. Anthropol. Assoc. 15, 13–26. https://doi.org/10.1525/ap3a.2005.15.13

Buikstra, J., Ubelaker, D., 1994. Standards for data collection from human skeletal remains. Proc. a Semin. F. Museum Nat. Hist. Organ. by Jonathan Haas.

Buikstra, J.E., 2019. Ortner's Identification of Pathological Conditions in Human Skeletal Remains, 3rd ed. Elsevier, London. https://doi.org/10.1016/C2011-0-06880-1

Buzon, M.R., 2012. The Bioarchaeological Approach to Paleopathology, in: Grauer, A. (Ed.), A Companion to Paleopathology. Blackwell Publishing Inc., Chichester, pp. 58–75. https://doi.org/10.1002/9781444345940.ch4

Byers, S.N., 2017. Introduction to Forensic Anthropology, 5th Editio. ed. Routledge, Boston.

Campanacho, V., Santos, A.L., 2013. Comparison of the Entheseal Changes of the os coxae of Portuguese Males (19th-20th centuries) with Known Occupation. Int. J. Osteoarchaeol. 23, 229–236. https://doi.org/10.1002/oa.2297

Cao, X., Rawalai, K., Thompson, A.J., Hartel, G., Thompson, S., Paterson, J.H., Chusilp, K., 2000. Relationship between Feeding Practices and Weanling Diarrhoea in Northeast Thailand. J. Heal. Popul. Nutr. 18, 85–92.

Capasso, L.K., Kennedy, A.R., Wilczak, C.A., 1999. Atlas of occupational marker on human remains. J. Paleopathol. 3.

Capitanio, M., 1993. Notizie antropologiche sugli scheletri di trento, del VI-VIII sec. D.C. Atti Accad. Roveretania Agiati VII, 29–56.

Capitanio, M., 1981. Anthropologische Bemerkungen über die spätromischer Bestattungen von Pfatten-Haimburg (Vadena). Der Schlern 55, 189–196.

Carapuco, M., Novoa, A., Bobola, N., Mallo, M., 2005. Hox genes specify vertebral types in the presomitic mesoderm. Genes Dev. 19, 2116–2121. https://doi.org/10.1101/gad.338705

Carazo, M.S., 2017. Application of the maxillary suture obliteration method for estimation of the age at death in prisners in the Valdenoceda francoist prison, in: Bioarheologija Na Balkanu. Markeri Okupacionog Stresa I Druge Studije. Srpsko arheolosko drustvo, Belgrad.

Carr, C., 1995. Mortuary Practices: Their Social, Philosophical-Religious, Circumstantial, and Physical Determinants. J. Archaeol. Method Theory 2, 105–200.

Carrara, N., 2013. The Lombard necropolis of Dueville (Northeast Italy, 7th-9th c. AD): burial rituals, paleodemography, anthropometry and paleopathology. Antrocom Online J. Anthropol. 9, 259–271.

Carroll, M., 2018. Infancy and Earliest Childhood in the Roman World, 1st ed. Oxford University Press, Oxford. https://doi.org/10.1093/oso/9780199687633.001.0001

Carroll, M., 2012. No part in earthy things. The death, burial and commemoration of newborn children and infants in Roman Italy, in: Harlow, M., Larsson Loven, L. (Eds.), Families in the Roman and Late Antique World. Bloomsbury Publishing, New York, pp. 42–63.

Carson, S.A., 2022. Nutrition within the household: 18th through early 20 th century female and male statures. J. Biosoc. Sci. 54, 583–604. https://doi.org/10.1017/S0021932021000250

Casas-Apayco, L.C., Dreibi, V.M., Hipolito, A.C., Graeff, M.S.Z., Rios, D., Magalhaes, A.C., Buzalaf, M.A.R., Wang, L., 2014. Erosive cola-based drinks affect the bonding to enamel surface: an in vitro study. J. Appl. Oral Sci. 22, 434–441. https://doi.org/10.1590/1678-775720130468

Case, D.T., Jones, L.B., Offenbecker, A.M., 2017. Skeletal Kinship Analysis Using Developmental Anomalies of the Foot. Int. J. Osteoarchaeol. 27, 192–205. https://doi.org/10.1002/oa.2529

Caselitz, P., 1998. Caries-Ancient plague of humankind, in: Alt, K.W., Rösing, F.W., Teschler-Nicola, M. (Eds.), Dental Anthropology. Springer, Vienna, pp. 203–226.

Castro-Porras, L. V, Rojas-Russell, M.E., Aedo-Santos, Á., Wynne-Bannister, E.G., López-Cervantes, M., 2018. Stature in adults as an indicator of socioeconomic inequalities in Mexico. Rev. Panam. Salud Pública 42, 1–9. https://doi.org/10.26633/RPSP.2018.29

Castro Alves, R., Antunes Félix, S., Rodriguez Archilla, A., 2013. Is menopause associated with an increased risk of tooth loss in patients with periodontitis? Rev. Port. Estomatol. Med. Dentária e Cir. Maxilofac. 54, 210–216. https://doi.org/10.1016/j.rpemd.2013.09.005

Caulfield, L.E., de Onis, M., Blössner, M., Black, R.E., 2004. Undernutrition as an underlying cause of child deaths associated with diarrhea, pneumonia, malaria, and measles. Am. J. Clin. Nutr. 80, 193–198. https://doi.org/10.1093/ajcn/80.1.193

Cejudo, A., Ginés-Díaz, A., Sainz de Baranda, P., 2020. Asymmetry and Tightness of Lower Limb Muscles in Equestrian Athletes: Are They Predictors for Back Pain? Symmetry (Basel). 12, 1679. https://doi.org/10.3390/sym12101679

Chandra Shekar, B., Reddy, C., 2011. Oral health status in relation to socioeconomic factors among the municipal employees of Mysore city. Indian J. Dent. Res. 22, 410. https://doi.org/10.4103/0970-9290.87063

Chao, F., Gerland, P., Cook, A.R., Alkema, L., 2019. Systematic assessment of the sex ratio at birth for all countries and estimation of national imbalances and regional reference levels. Proc. Natl. Acad. Sci. 116, 9303–9311. https://doi.org/10.1073/pnas.1812593116

Cherayil, B.J., 2010. Iron and Immunity: Immunological Consequences of Iron Deficiency and Overload. Arch. Immunol. Ther. Exp. (Warsz). 58, 407–415. https://doi.org/10.1007/s00005-010-0095-9

Cheverko, C.M., Hubbe, M., 2017. Comparisons of statistical techniques to assess age-related skeletal markers in bioarchaeology. Am. J. Phys. Anthropol. https://doi.org/10.1002/ajpa.23206

Cho, H.J., Morey, V., Kang, J.Y., Kim, K.W., Kim, T.K., 2015. Prevalence and Risk Factors of Spine, Shoulder, Hand, Hip, and Knee Osteoarthritis in Community-dwelling Koreans Older Than Age 65 Years. Clin. Orthop. Relat. Res. 473, 3307–3314. https://doi.org/10.1007/s11999-015-4450-3

Christ, K., 1955. Die Militärgeschichte der Schweiz in römischer Zeit. Schweizer Zeitschrift für Geschichte 5.

Christensen, J.M., Ryhl-Svendsen, M., 2015. Household air pollution from wood burning in two reconstructed houses from the Danish Viking Age. Indoor Air 25, 329–340. https://doi.org/10.1111/ina.12147

Churchill, S.E., Morrs, A.G., 1998. Muscle marking morphology and Labour intensity in prehistoric

Khoisan foragers. Int. J. Osteoarchaeol. 8, 390–411.

Cicurel, I., Sharaby, R., 2007. Women in the menstruation huts: Variations in preserving purification customs among Ethiopian immigrants. J. Fem. Stud. Relig. 23, 69–84. https://doi.org/10.2979/FSR.2007.23.2.69

Claudepierre, P., Voisin, M.C., 2005. The entheses: Histology, pathology, and pathophysiology. Jt. Bone Spine 72, 32–37. https://doi.org/10.1016/j.jbspin.2004.02.010

Cole, G., Waldron, T., 2019. Cribra orbitalia: Dissecting an ill-defined phenomenon. Int. J. Osteoarchaeol. 29. https://doi.org/10.1002/oa.2757

Coleman, E., 1976. Infanticide in the Early Middle Ages, in: Stuard, S.M. (Ed.), Women in Medieval Society. University of Pennsylvania Press, Philadelphia, pp. 47–70. https://doi.org/10.9783/9780812207675

Constantinescu, M., Gavrilă, E., Greer, S., Soficaru, A., Ungureanu, D., 2017. Fighting to the Death: Weapon Injuries in a Mass Grave (16th–17th Century) from Bucharest, Romania. Int. J. Osteoarchaeol. 27, 106–118. https://doi.org/10.1002/oa.2450

Conzato, A., Marzoli, C., Rizzi, J., 2009. An Early Metal Age multiple burial from South Tyrol Italy, A taphonomic and anthropological approach, in: Societe d Anthropologie de Paris.

Cooper, C., McAlidon, T., Coggon, D., Egger, P., Dieppe, P., 1994. Occupational activity and osteoarthritis of the knee. Ann. Rheum. Dis. 53, 90–93.

Copp, A.J., Adzick, N.S., Chitty, L.S., Fletcher, J.M., Holmbeck, G.N., Shaw, G.M., 2015. Spina bifida. Nat. Rev. Dis. Prim. 1, 15007. https://doi.org/10.1038/nrdp.2015.7

Coppa, A., Cucina, A., Hoogland, M.L.P., Lucci, M., Luna Calderón, F., Panhuysen, R.G.A.M., Tavarez María, G., Valcárcel Rojas, R., Vargiu, R., 2008. New evidence of two different migratory waves in the circum-Caribbean area during the pre-Columbian period from the analysis of dental morphological traits, in: Crossing the Borders: New Methods and Techniques in the Study of Archaeological Materials from the Caribbean. The University of Alabama Press, Alabama, pp. 195–213.

Coppa, A., Cucina, A., Mancinelli, D., Vargiu, R., 1997. Biological relationships of Etruscan-culture communities. Etruscan Stud. 4, 87–102.

Corrain, C., 1985. Reperti osteologici paleocristiani e medioevali nel Trentino. Atti Accad. Roveretana degli Agiati 6, 49–52.

Corrain, C., Colombo, M., Monastra, G., 1983. Resti scheletri da tombe romane III-IV sec d C di Riva del Garda. Atti dell Accad. Roveretana degli Agiati 23, 49–67.

Couoh, L.R., 2017. Differences between biological and chronological age-at-death in human skeletal remains: A change of perspective. Am. J. Phys. Anthropol. https://doi.org/10.1002/ajpa.23236

Coussens, A., Anson, T., Norris, R.M., Henneberg, M., 2002. Sexual dimorphism in the robusticity of long bones of infants and young children. Prz. Antropol. Rev. 65, 3–16.

Cox, M.J., Mays, S., 2000. Human Osteology In Archaeology and Forensic Science, 1st ed. Cambridge University Press, Cambridge.

Craffonara, L., 2006. Jì en Jeunn: Die Wallfahrt der Gadertaler Pfarreien nach Säben- Geschichte und Mythos. Museum Ladin, San Martin de Tor.

Crubezy, E., Goulet, J., Bruzek, J., Jelinek, J., Rouge, D., Ludes, B., 2002. Epidemiology of osteoarthritis and enthesopathies in a European population dating back 7700 years. Jt. Bone Spine 69, 580–588.

Cullum, P.H., 1991. Cremetts and Corrodies: Care of the Poor and Sick at St Leonard's Hospital, York, in the Middle Ages. Borthwick Publications, York.

Cvrček, J., Kuželka, V., Jor, T., Dupej, J., Horák, M., Naňka, O., Brůžek, J., Velemínský, P., 2021. Familial occurrence of skeletal developmental anomalies as a reflection of biological relationships in a genealogically documented Central European sample (19th to 20th centuries). J. Anat. joa.13499. https://doi.org/10.1111/joa.13499

Cvrček, J., Velemínský, P., Dupej, J., Vostrý, L., Brůžek, J., 2018. Kinship and morphological similarity in the skeletal remains of individuals with known genealogical data (Bohemia, 19th to 20th centuries): A new methodological approach. Am. J. Phys. Anthropol. 167, 541–556. https://doi.org/10.1002/ajpa.23683

Czarnetzki, A., 1995. Das Kleinkinderdefizit der Merowingerzeit in Südwestdeutschland im Spiegel medizinhistorischer Ergebnisse. Bull. la Soc. Suisse d'Anthropologie 1, 89–103.

Czermak, A.M., 2011. Soziale Stratifizierung im frühen Mittelalter- Aussage und Nachweismöglichkeiten anhand von biologischen Indikatoren. Ludwigs-Maximillians Universität München.

Czerniak, B., 2016. Dorman and Cyerniak's Bone Tumors, 2nd ed. Saunders Elsevier, Philadelphia.

d'Incau, E., Saulue, P., 2012. Understanding dental wear. J. Dentofac. Anomalies Orthod. 15, 104. https://doi.org/10.1051/odfen/2011404

Dal Ri, L., 2010. Archäologie des Frühmittelalters in Südtirol: einige neue Daten, in: Kreisel, W., Ruffini, F.V., Reeh, T., Pörtge, K.H. (Eds.), Südtirol Alto Adige, Eine Landschaft Auf Dem Prüfstand. Tappeiner AG, Bozen, pp. 235–257.

Dal Ri, L., Tecchiati, U., 2018. Sankt Lorenzen Pichlwiese Ein römerzeitliches Gräberfeld im Pustertal, in: Dal Ri, L., Tecchiati, U. (Eds.), Forschungen Zur Denkmalpflege in Südtirol- Band 7/Beni Culturali in Alto Adige-Studi e Richerche- Volume 7. Athesia, Bozen, pp. 631–686.

Darmon, N., Drewnowski, A., 2008. Does social class predict diet quality? Am. J. Clin. Nutr. 87, 1107–1117. https://doi.org/10.1093/ajcn/87.5.1107

Dawes, C., 2006. Why does supragingival calculus form preferentially on the lingual surface of the 6 lower anterior teeth? J. Can. Dent. Assoc. 72, 923–926.

Dawson, H., Brown, K.R., 2013. Exploring the relationship between dental wear and status in late medieval subadults from England. Am. J. Phys. Anthropol. 150, 433–441. https://doi.org/10.1002/ajpa.22221

Dayal, M.R., 2009. Polymorphism of cranial suture obliteration in adult crania. University of Adelaide.

Deheeger, M., Bellisle, F., Rolland-Cachera, M.F., 2002. The French longitudinal study of growth and nutrition: data in adolescent males and females. J. Hum. Nutr. Diet. 15, 429–438. https://doi.org/10.1046/j.1365-277X.2002.00396.x

Delgado-Darias, T., Velasco-Vázquez, J., Arnay-de-la-Rosa, M., Martín-Rodríguez, E., González-Reimers, E., 2006. Calculus, periodontal disease and tooth decay among the prehispanic population from Gran Canaria. J. Archaeol. Sci. 33, 663–670.

https://doi.org/10.1016/j.jas.2005.09.018

Demirci, M., Tuncer, S., Yuceokur, A.A., 2010. Prevalence of caries on individual tooth surfaces and its distribution by age and gender in university clinic patients. Eur. J. Dent. 4, 270–9.

Demirci Yonguc, G.N., Sayhan, S., Cirpan, S., Bulut, B., Guvencer, M., Naderi, S., 2021. Posterior wall defect of sacrum: an anatomical study of sacral spina bifida. Turk. Neurosurg. 31, 339–347. https://doi.org/10.5137/1019-5149.JTN.29180-20.3

Dennis, G., 2018. Can examples of ancient human bone neoplasms inform current biomedical bone cancer research ? Hum. Voyag. 2, 1–6.

DeWitte, S.N., 2014. Health in post-black death London (1350-1538): Age patterns of periosteal new bone formation in a post-epidemic population. Am. J. Phys. Anthropol. https://doi.org/10.1002/ajpa.22510

DeWitte, S.N., Stojanowski, C.M., 2015. The Osteological Paradox 20 Years Later: Past Perspectives, Future Directions. J. Archaeol. Res. 23. https://doi.org/10.1007/s10814-015-9084-1

Dey, H.W., 2008. Diaconiae, xenodochia, hospitalia and monasteries: 'social security' and the meaning of monasticism in early medieval Rome. Early Mediev. Eur. 16, 398–422. https://doi.org/10.1111/j.1468-0254.2008.00236.x

Dharati, K., Nagar, S.K., Ojaswini, M., Dipali, T., Paras, S., Sucheta, P., 2012. A study of sacralisation of fifth lumbar vertebra in Gujarat. Natl. J. Med. Res. 2, 211–213.

Dherani, M., Pope, D., Mascarenhas, M., Smith, K.R., Weber, M., Bruce, N., 2008. Indoor air pollution from unprocessed solid fuel use and pneumonia risk in children aged under five years: a systematic review and meta-analysis. Bull. World Health Organ. 86, 390–398. https://doi.org/10.2471/BLT.07.044529

DiGangi, E.A., Gruenthal-Rankin, A., 2019. SKELETAL STRESS MARKERS AND SUBSISTENCE STRATEGY IN PREHISTORIC CHILEAN POPULATIONS OF THE SEMI-ARID NORTH. Chungara Rev. Antropol. Chil. 51, 613–626. https://doi.org/10.4067/S0717-73562019005002201

DiGangi, E.A., Hefner, J.T., 2013. Ancestry Estimation, in: DiGangi, E.A., Moore, M.K. (Eds.), Research Methods in Human Skeletal Biology. Elsevier, Oxford. https://doi.org/10.1016/B978-0-12-385189-5.00005-4

DiMaio, V.J., DiMaio, D., 2001. Forensic Pathology, 2nd ed. CRC Press, New York.

Djukic, K., Miladinovic-Radmilovic, N., Draskovic, M., Djuric, M., 2018. Morphological appearance of muscle attachment sites on lower limbs: Horse riders versus agricultural population. Int. J. Osteoarchaeol. 28, 656–668. https://doi.org/10.1002/oa.2680

Dogan, H.K., Demirci, S., 2012. Livestock-Handling Related Injuries and Deaths, in: Javed, K. (Ed.), Livestock Production. InTech. https://doi.org/10.5772/50834

Domett, K., Evans, C., Chang, N., Tayles, N., Newton, J., 2017. Interpreting osteoarthritis in bioarchaeology: Highlighting the importance of a clinical approach through case studies from prehistoric Thailand. J. Archaeol. Sci. Reports 11, 762–773. https://doi.org/10.1016/j.jasrep.2016.12.030

Donat, P., Ullrich, H., 1971. Einwohnerzahl und Siedlungsgröße der Merowingerzeit. Zeitschrift für Archäologie 5, 235–265.

Drew, R., Kjellström, A., 2021. Sacralization in the Mary Rose and Kronan assemblages: An inconsistently recorded anomaly. Int. J. Osteoarchaeol. 0–2. https://doi.org/10.1002/oa.2982

Duby, G., 1977. Krieger und Bauern. Die Entwicklung von Wirtschaft und Gesellschaft im frühen Mittelalter. Syndikat Verlag, Frankfurt am Main.

Dudley, F.W., 2003. History of the Lombards. Paul the Deacon. University of Pennsylvania, Philadelphia.

Düring, A., 2017. From Individuals to Settlement Patterns. Bridgning the Gap Between the Living and the Dead in Early Medieval Populations Using an Agent-Based Demographic Model. University of Oxford.

Dwight, T., 1894. Methods of estimating the height from part of the skeleton. Med. Rec. 46, 293–296.

Dye, B.A., Thornton-Evans, G., 2010. Trends in Oral Health by Poverty Status as Measured by Healthy People 2010 Objectives. Public Health Rep. 125, 817–830. https://doi.org/10.1177/003335491012500609

Egaña, S., Turner, S., Doretti, M., Bernardi, P., Ginarte, A., 2008. Commingled Remains and Human Rights Investigations, in: Recovery, Analysis, and Identification of Commingled Human Remains. Humana Press, Totowa, NJ, pp. 57–80. https://doi.org/10.1007/978-1-59745-316-5_4

Eger, C., 2015. Zur Deutung reich ausgestatteter Männergräber des Mittleren 5. Jhs. im Mittelmeerraum, in: Rance, P., Blay, A., Koncz, I., Samu, L. (Eds.), Romania Gothica II, The Frontier World- Romans, Barbarians and Military Culture. Tivadar vida, Budapest, pp. 237–286.

Eggenberger, P., Ulrich-Bochsler, S., Schäublin, E., 1983. Beobachtungen an Bestattungen in und um Kirchen im Kanton Bern aus archäologischer und anthropologischer Sicht Beobachtungen an Bestattungen in und um Kirchen im Kanton Bern aus archäologischer und anthropologischer Sicht. Zeitschrift für schweizerische Archäologie und Kunstgeschichte 40, 221–240.

Eidissen, A.H., 2020. “You Are What You Eat”- A regional study on late medieval diet, and how it differs between sexes. University of Leiden.

Elema, A., 2012. Trial by Battle in France and England. University of Toronto.

Eli, S., Li, N., 2015. Caloric Requirements and Food Consumption Patterns of the Poor. Cambridge, MA. https://doi.org/10.3386/w21697

Eng, J.T., 2016. A bioarchaeological study of osteoarthritis among populations of northern China and Mongolia during the Bronze Age to Iron Age transition to nomadic pastoralism. Quat. Int. 405, 172–185. https://doi.org/10.1016/J.QUAINT.2015.07.072

Eng, J.T., 2014. Bioarchaeological evidence of stress and activity in the medieval Hrisbru cemetery in the Mosfell Valley, Iceland., in: Zori, D., Byock, J. (Eds.), Viking Archaeology in Iceland- Mosfell Archaeological Project. Brepols.

Engels, D., 1980. The Problem of Female Infanticide in the Greco-Roman World. Class. Philol. 75, 112–120. https://doi.org/10.1086/366548

Engels, F., Hunt, T., 2010. The Origin of the Family, Private Property and the State. Penguin Classics, London.

Erickson, C., 1976. The Medieval Vision: Essays in History and Perception. Oxford University Press, Oxford.

Erken, E., Ozer, H.T.E., Gulek, B., Durgun, B., 2002. The Association Between Cervical Rib and Sacralization. Spine (Phila. Pa. 1976). 27, 1659–1664. https://doi.org/10.1097/00007632-200208010-00013

Esclassan, R., Grimoud, A.M., Ruas, M.P., Donat, R., Sevin, A., Astie, F., Lucas, S., Crubezy, E., 2009. Dental caries, tooth wear and diet in an adult medieval (12th-14th century) population from mediterranean France. Arch. Oral Biol. 54, 287–297. https://doi.org/10.1016/j.archoralbio.2008.11.004

Eshed, V., Gopher, A., Gage, T.B., Hershkovitz, I., 2004a. Has the transition to agriculture reshaped the demographic structure of prehistoric populations? New evidence from the Levant. Am. J. Phys. Anthropol. 124, 315–329. https://doi.org/10.1002/ajpa.10332

Eshed, V., Gopher, A., Galili, E., Hershkovitz, I., 2004b. Musculoskeletal stress markers in Natufian hunter-gatherers and Neolithic farmers in the Levant: The upper limb. Am. J. Phys. Anthropol. 123, 303–315. https://doi.org/10.1002/ajpa.10312

Eshed, V., Gopher, A., Hershkovitz, I., 2006. Tooth wear and dental pathology at the advent of agriculture: New evidence from the Levant. Am. J. Phys. Anthropol. 130, 145–159. https://doi.org/10.1002/ajpa.20362

Etches, V., Frank, J., Ruggiero, E. Di, Manuel, D., 2006. MEASURING POPULATION HEALTH: A Review of Indicators. Annu. Rev. Public Health 27, 29–55. https://doi.org/10.1146/annurev.publhealth.27.021405.102141

Etter, H.F., Schneider, J.E., 1982. Zur Stellung von Kind und Frau im Frühmittelalter : eine archäologisch- anthropologische Synthese. Zeitschrift für schweizerische Archäologie und Kunstgeschichte 39.

Facchini, F., Rastelli, E., Brasili, P., 2004. Cribra orbitalia and cribra cranii in Roman skeletal remains from the Ravenna area and Rimini (I-IV century AD). Int. J. Osteoarchaeol. 14, 126–136. https://doi.org/10.1002/oa.717

Fazekas, I.G., Kosa, F., 1978. Forensic fetal osteology. Akademiai Kiado, Budapest.

Fehr, H., 2010. Am Anfang war das Volk ? Die Entstehung der bajuwarischen Identität als archäologisches und interdisziplinäres Problem, in: Pohl, W., Mehofer, M. (Eds.), Archaeology of Identity- Archäologie Der Identität. VÖAW, Wien, pp. 211–232.

Ferembach, D., 1963. Frequency of Spina Bifida Occulta in Prehistoric Human Skeletons. Nature 199, 100–101.

Ferembach, D., Schwidetzky, I., Stloukal, M., 1979. Empfehlungen für die Alters- und Geschlechtsdiagnose am Skelett. Homo 30, 1–32.

Fernández-Crespo, T., De-la-Rúa, C., 2015. Demographic evidence of selective burial in megalithic graves of northern Spain. J. Archaeol. Sci. 53, 604–617. https://doi.org/10.1016/j.jas.2014.11.015

Ferraro, M., Vieira, A.R., 2010. Explaining Gender Differences in Caries: A Multifactorial Approach to a Multifactorial Disease. Int. J. Dent. 2010, 1–5. https://doi.org/10.1155/2010/649643

Ferreri, D., 2011. Spazi cimiteriali, pratiche funerarie e identità nella città di Classe. Archeol. Mediev. 38, 59–74. https://doi.org/10.1400/215653

Finnegan, M., 1978. Non-metric variation of the infracranial skeleton. J. Anat. 125, 23–37.

Fiorato, V., Boylston, A., Knüsel, C., 2007. Blood Red Roses the archaeology of a mass grave from the battle of Towton AD 1461, 2nd ed. Oxbow Books, Oxford.

Fletcher, J.M., Brei, T.J., 2010. Introduction: Spina bifida-A multidisciplinary perspective. Dev. Disabil. Res. Rev. 16, 1–5. https://doi.org/10.1002/ddrr.101

Foreman, K.J., Marquez, N., Dolgert, A., Fukutaki, K., Fullman, N., McGaughey, M., Pletcher, M.A., Smith, A.E., Tang, K., Yuan, C.W., Brown, J.C., Friedman, J., He, J., Heuton, K.R., Holmberg, M., Patel, D.J., Reidy, P., Carter, A., Cercy, K., Chapin, A., Douwes-Schultz, D., Frank, T., Goettsch, F., Liu, P.Y., Nandakumar, V., Reitsma, M.B., Reuter, V., Sadat, N., Sorensen, R.J.D., Srinivasan, V., Updike, R.L., York, H., Lopez, A.D., Lozano, R., Lim, S.S., Mokdad, A.H., Vollset, S.E., Murray, C.J.L., 2018. Forecasting life expectancy, years of life lost, and all-cause and cause-specific mortality for 250 causes of death: reference and alternative scenarios for 2016–40 for 195 countries and territories. Lancet 392, 2052–2090. https://doi.org/10.1016/S0140-6736(18)31694-5

Fornaciari, G., Giuffra, V., 2013. The "Gout of the Medici": Making the modern diagnosis using paleopathology. Gene. https://doi.org/10.1016/j.gene.2013.04.056

Forsom, E., Warner Thorup Boel, L., Jaque, B., Mollerup, L., 2017. The death of a medieval Danish warrior. A case of bone trauma interpretation. Scand. J. Forensic Sci. Nord. rettsmedisin 23, 1–8. https://doi.org/10.1515/sifs-2017-0001

Foster, A., Buckley, H., Tayles, N., 2014. Using Enthesis Robusticity to Infer Activity in the Past: A Review. J. Archaeol. Method Theory 21, 511–533. https://doi.org/10.1007/s10816-012-9156-1

Fowler, M.L., Rose, J., Vander Leest, B., Ahler, S.R., 1999. The Mound 72 Area: Dedicated and Sacred Space in Early Cahokia. Springfield.

Franz, J.R., Kram, R., 2012. The effects of grade and speed on leg muscle activations during walking. Gait Posture 35, 143–147. https://doi.org/10.1016/j.gaitpost.2011.08.025

Frazee, C.A., 1982. Late Roman and Byzantine Legislation on the Monastic Life from the Fourth to the Eighth Centuries. Church Hist. 51, 263–279. https://doi.org/10.2307/3167117

Freemont, A., Hoyland, J., 2007. Morphology, mechanisms and pathology of musculoskeletal ageing. J. Pathol. 211, 252–259. https://doi.org/10.1002/path.2097

Freeth, C., 2000. Dental Health in British Antiquity, in: Cox, M.J., Mays, S. (Eds.), Human Osteology in Archaeology and Forensic Science. Cambridge University Press, Cambridge, pp. 227–238.

French, D.R., 1994. Ritual, Gender and Power Strategies: Male Pilgrimage to Saint Patrick's Purgatory. Religion 24, 103–115.

Fujita, H., Suzuki, T., Shoda, S., Kawakubo, Y., Ohno, K., Giannakopoulou, P., Harihara, S., 2013. Contribution of Antemortem Tooth Loss (AMTL) and Dental Attrition to Oral Palaeopathology in the Human Skeletal Series from the Yean-Ri Site, South Korea. Int. J. Archaeol. 1, 1–5. https://doi.org/10.11648/j.ija.20130101.11

Funari, P.P.A., 1998. The archaeology of ethnicity. Constructing identities in the past and present. Rev. Antropol. 41. https://doi.org/10.1590/S0034-77011998000100009

Gabel, F., Jürges, H., Kruk, K.E., Listl, S., 2018. Gain a child, lose a tooth? Using natural experiments to distinguish between fact and fiction. J. Epidemiol. Community Health 72, 552–556. https://doi.org/10.1136/jech-2017-210210

Gadioli, G., Scaggion, C., Carrara, N., 2018. Anthropological analysis and paleo-demographic study of human skeletal remains from the late ancient necropolis of Biverone (4th-5th c.AD), San Stino Di Livenza (Venice, Italy). Anthropol. Rev. 81, 66–80. https://doi.org/10.2478/anre-2018-0006

Gallo, P., 1968. Reperti scheletrici romani e medievali di Padova. Boll. del Mus. Civ. di Padova 57, 1–8.

Gamble, J.A., Boldsen, J.L., Hoppa, R.D., 2017. Stressing out in medieval Denmark: An investigation of dental enamel defects and age at death in two medieval Danish cemeteries. Int. J. Paleopathol. 17, 52–66. https://doi.org/10.1016/j.ijpp.2017.01.001

Garcin, V., Veleminsky, P., Trefny, P., Bagousse, A.A. Le, Lefebvre, A., Bruzek, J., 2010. Dental health and lifestyle in four early mediaeval juvenile populations: Comparisons between urban and rural individuals, and between coastal and inland settlements. HOMO- J. Comp. Hum. Biol. 61, 421–439. https://doi.org/10.1016/j.jchb.2010.06.004

Garvin, H.M., Passalacqua, N. V., Uhl, N.M., Gipson, D.R., Overbury, R.S., Cabo, L.L., 2012. Developments in Forensic Anthropology: Age at Death Estimation, in: Dirkmaat, D.C. (Ed.), A Companion to Forensic Anthropology. Blackwell PUblishing Ltd.

Gautam, R.K., Jhariya, J., Kumar, P., 2015. Globally Declining Population of Women Folk Causing Sex Imbalance Is a Serious Concern: An Analysis of Sex Ratio around the Globe. J. Anthropol. 2015, 1–8. https://doi.org/10.1155/2015/431458

Geber, J., Murphy, E., 2018. Dental markers of poverty: Biocultural deliberations on oral health of the poor in mid-nineteenth-century Ireland. Am. J. Phys. Anthropol. 167, 840–855. https://doi.org/10.1002/ajpa.23717

Geere, J.-A.L., Hunter, P.R., Jagals, P., 2010. Domestic water carrying and its implications for health: a review and mixed methods pilot study in Limpopo Province, South Africa. Environ. Health 9, 52. https://doi.org/10.1186/1476-069X-9-52

Gemede, H.F., 2014. Potential Health Benefits and Adverse Effects Associated with Phytate in Foods. Food Sci. Qual. Manag. 27, 45–55.

Gerhards, G., 2007. Traumatic lesions in human osteological remains from the Daugava area (7th to 17th centuries AD). Archaeol. Balt. 8, 360–367.

Gestsdottir, H., 2014. Osteoarthritis in Iceland An archaeological study. University of Iceland.

Gestsdottir, H., Jonsson, H., Rogers, J., Thorsteinsson, J., 2006. Osteoarthritis in the skeletal population from Skeljastaðir Iceland ; a reassessment. Archaeol. Islandica 5, 75–81.

Gietl, R., 2004. Die römer auf den pässen der ostalpen. Free Software Foundation, Boston.

Gilck, F., Poschlod, P., 2019. The origin of alpine farming: A review of archaeological, linguistic and archaeobotanical studies in the Alps. The Holocene 29, 1503–1511. https://doi.org/10.1177/0959683619854511

Gillespie, H.W., 1949. The Significance of Congenital Lumbo-Sacral Abnormalities. Br. J. Radiol. 22, 270–275. https://doi.org/10.1259/0007-1285-22-257-270

Gilmour, R.J., Gowland, R., Roberts, C., Bernert, Z., Kiss, K.K., Lassányi, G., 2015. Gendered Differences in Accidental Trauma to Upper and Lower Limb Bones at Aquincum, Roman Hungary. Int. J. Paleopathol. 11, 75–91. https://doi.org/10.1016/j.ijpp.2015.08.004

Giostra, G., Lusuardi Siena, S., 2004. Le popolazioni germaniche in Italia: Le testimonianze di epoca alteomedievale a sud dello spartiacque alpino, in: Gleirscher, P., Marzartico, F. (Eds.), Guerrieri Principi Ed Eroi Fra Il Danubio e Il Po Della Preistoria All Alto Medioevo. Museo Castello Buonconsiglio, Trento, pp. 513–527.

Giovannini, F., 2003. Skelettfunde auf Castelfeder (9.-10. Jahrhundert nach Christus), in: Montan. Schützenkompanie Montan, Montan.

Giovannini, F., 2002. Studi di resti scheletri umani d eta tardoantica rinvenuti in Alto Adige malattie, alimentazione, aspetti demografici ed etnici, in: Dal Ri, L., Di Stefano, S., Constantini, R., Samadelli, M. (Eds.), Forschungen Zur Denkmalpflege in Südtirol- Band 1/Beni Culturali in Alto Adige-Studi e Richerche- Volume 1. Amt für Bodendenkmäler Bozen/ Ufficio Beni Archeologici Bolzano, Bozen.

Gleirscher, P., 1986. Säben- Von der Spätantike ins frühe Mittelalter Stand der archäologischen Forschung. Der Schlern 9, 552–562.

Gleirscher, P., Nothdurfter, H., 1987. Die Kirchengrabung von St. Georg bei Völlan, Lana. Der Schlern 61, 267–305.

Godde, K., Taylor, R.W., 2013. Distinguishing body mass and activity level from the lower limb: Can entheses diagnose obesity? Forensic Sci. Int. https://doi.org/10.1016/j.forsciint.2013.01.027

Göhring, A., Hölzl, S., Joachimski, M., Mayr, C., Grupe, G., 2020. Multi-isotope fingerprint of humans, animals, and environmental samples from Karacamirli, in: Kaniuth, K. (Ed.), Karacamirli- Tepe 5 A Multi-Period Necropolis in Western Azerbaijan. PeWe Verlag, Gladbeck, pp. 217–244.

Goncalves, D., Campanacho, V., Cardoso, H.F.V., 2011. Reliability of the lateral angle of the internal auditory canal for sex determination of subadult skeletal remains. J. Forensic Leg. Med. 18, 121–124. https://doi.org/10.1016/j.jflm.2011.01.008

Gonçalves, M.L.C., Araújo, A., Ferreira, L.F., 2003. Human intestinal parasites in the past: new findings and a review. Mem. Inst. Oswaldo Cruz 98, 103–118. https://doi.org/10.1590/S0074-02762003000900016

Goodman, A.H., Armelagos, G.J., 1985. the Chronological Distribution in Human Permanent Canine Teeth of Enamel Incisor and Canine Teeth. Arch. Oral Biol. 30, 503–507.

Goodman, A.H., Martinez, C., Chavez, A., 1991. Nutritional supplementation and the development of linear enamel hypoplasias in children from Tezonteopan. Am. J. Clin. Nutr. 53, 773–781.

Goodman, A.H., Rose, J.C., 1990. Assessment of systemic physiological perturbations from dental enamel hypoplasias and associated histological structures. Am. J. Phys. Anthropol. 33, 59–110. https://doi.org/10.1002/ajpa.1330330506

Gorfer, A., 2017. Die Erben der Einsamkeit- Reise zu den Bergbauernhöfen Südtirols, 7th ed. Tappeiner, Verona.

Gosman, J.H., Stout, S.D., Larsen, C.S., 2011. Skeletal biology over a life span: A view from the surfaces. Yearb. Phys. Anthropol. 146, 86–98.

Gowland, R.L., Western, A.G., 2012. Morbidity in the marshes: Using spatial epidemiology to investigate skeletal evidence for malaria in Anglo-Saxon England (AD 410-1050). Am. J. Phys. Anthropol. 147, 301–311. https://doi.org/10.1002/ajpa.21648

Gracey, M., 2004. Orphaned and vulnerable to infection, undernutrition and early death: increasing threats to infants and children. Acta Paediatr. 93, 8–9. https://doi.org/10.1080/08035250310021479

Graff, A., Bennion-Pedley, E., Jones, A.K., Ledger, M.L., Deforce, K., Degraeve, A., Byl, S., Mitchell, P.D., 2020. A comparative study of parasites in three latrines from Medieval and Renaissance Brussels, Belgium (14th–17th centuries). Parasitology 147, 1443–1451. https://doi.org/10.1017/S0031182020001298

Graham, N.M.H., 1990. The Epidemiology of acute respiratory infections in children and adults: A global perspective. Epidemiol. Rev. 12, 149–178. https://doi.org/10.1093/oxfordjournals.epirev.a036050

Grauer, A., 2012. A Companion to Paleopathology. Blackwell Publishing Inc., Oxford.

Grauer, A.L., 1993. Patterns of anemia and infection from medieval York, England. Am. J. Phys. Anthropol. 91, 203–213. https://doi.org/10.1002/ajpa.1330910206

Graw, M., Wahl, J., Ahlbrecht, M., 2005. Course of the meatus acusticus internus as criterion for sex differentiation. Forensic Sci. Int. 147, 113–117. https://doi.org/10.1016/j.forsciint.2004.08.006

Gresky, J., Wagner, M., Schmidt-Schultz, T.H., Schwarz, L., Wu, X., Aisha, A., Tarasov, P.E., Schultz, M., 2016. ‘You must keep going’ – Musculoskeletal system stress indicators of prehistoric mobile pastoralists in Western China. Quat. Int. 405, 186–199. https://doi.org/10.1016/j.quaint.2015.04.035

Grimoud, A.-M., Lucas, S., Sevin, A., Georges, P., Passarrius, O., Duranthon, F., 2011. Frequency of Dental Caries in Four Historical Populations from the Chalcolithic to the Middle Ages. Int. J. Dent. 2011, 1–7. https://doi.org/10.1155/2011/519691

Grischke, E.-M., 2004. Empfehlungen zur Ernährung in der Schwangerschaft. Ernährung & Medizin 19, 165–168. https://doi.org/10.1055/s-2004-837278

Grupe, G., Christiansen, K., Schröder, I., Wittwer-Backofen, U., 2005. Anthropologie. Ein einführendes Lehrbuch, Anthropologie. Springer-Verlag, Berlin, Heidelberg, New York. https://doi.org/10.1007/b137685

Grupe, G., Harbeck, M., McGlynn, G.C., 2015. Prähistorische Anthropologie. Springer Berlin Heidelberg, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-55275-5

Gulley, H.E., 1993. Women and the Lost Cause: preserving a Confederate identity in the American Deep South. J. Hist. Geogr. 19, 125–141. https://doi.org/10.1006/JHGE.1993.1009

Gunness-Hey, M., 1980. The Koniag Eskimo presacral vertebral column: variations, anomalies, and pathologies. Ossa 7, 99–118.

Haas-Gebhard, B., 2004. A nord delle alpi: Franchi, Alamanni e Baiuvari, in: Gleirscher, P., Marzartico, F. (Eds.), Guerrieri Principi Ed Eroi Fra Il Danubio e Il Po Della Preistoria All Alto Medioevo. Museo Castello Buonconsiglio, Trento, pp. 529–540.

Haentjens, A.M.E., 2000. Reflections on Female Infanticide in the Greco-Roman World. Antiq. Class. 69, 261–264. https://doi.org/10.3406/antiq.2000.2440

Hagemayer, O., 1967. Die Benediktinerinnenabtei Säben in Südtirol. Erbe im Auftrag 43, 493–498.

Hahn, T., Adams, W., Williams, K., 2019. Is vitamin C enough? A case report of scurvy in a five-year-old girl and review of the literature. BMC Pediatr. 19, 74. https://doi.org/10.1186/s12887-019-1437-3

Haid, H., Haid, B., 2010. Naturkatastrophen in den Alpen. Haymon Verlag, Innsbruck.

Hailemariam, G.A., Wudineh, T.A., 2020. Effect of Cooking Methods on Ascorbic Acid Destruction of Green Leafy Vegetables. J. Food Qual. 2020, 8908670. https://doi.org/10.1155/2020/8908670

Hamanishi, C., Kawabata, T., Yosii, T., Tanaka, S., 1994. Schmorl's Nodes on Magnetic Resonance Imaging. Spine (Phila. Pa. 1976). 19, 450–453. https://doi.org/10.1097/00007632-199402001-00012

Hammer, C.I., 2011. Early Merovingian Bavaria: A Late Antique Italian Perspective. J. Late Antiq. 4.2, 217–244.

Hansson, P.-A., 1995. Analysis of biomechanical load when working with manually handled shaft tools. Uppsala.

Harding, G.T., Dunbar, M.J., Hubley-Kozey, C.L., Stanish, W.D., Astephen Wilson, J.L., 2016. Obesity is associated with higher absolute tibiofemoral contact and muscle forces during gait with and without knee osteoarthritis. Clin. Biomech. 31, 79–86. https://doi.org/10.1016/j.clinbiomech.2015.09.017

Harding, V., 1992. Burial choice and burial location in later medieval London, in: Basset, S.R. (Ed.), Death in Towns, Urban Responses to the Dying and the Dead, 100-1600. Leicester University Press, Leicester, pp. 119–135.

Hardy, K., Blakeney, T., Copeland, L., Kirkham, J., Wrangham, R., Collins, M., 2009. Starch granules, dental calculus and new perspectives on ancient diet. J. Archaeol. Sci. 36, 248–255. https://doi.org/10.1016/j.jas.2008.09.015

Harris, A.M., Sempértegui, F., Estrella, B., Narváez, X., Egas, J., Woodin, M., Durant, J.L., Naumova, E.N., Griffiths, J.K., 2011. Air pollution and anemia as risk factors for pneumonia in ecuadorian children: a retrospective cohort analysis. Environ. Heal. 10, 93. https://doi.org/10.1186/1476-069X-10-93

Harth, S., Obert, M., Ramsthaler, F., Reuß, C., Traupe, H., Verhoff, M.A., 2009. Estimating age by assessing the ossification degree of cranial sutures with the aid of Flat-Panel-CT. Leg. Med. 11, S186–S189. https://doi.org/10.1016/J.LEGALMED.2009.01.091

Hartung von Hartungen, C., 2005. Romanen und Germanen im nationalen Spannungsfeld Tirols, in: Landi, W. (Ed.), Romanan Und Germanen Im Herzen Der Alpen. Athesia, Bozen, pp. 161–211.

Hauptfeld, G., 1982. Die Gentes im Vorfeld von Ostgoten und Franken im sechsten Jahrhundert, in: Wolfram, H., Schwarcz, A., Friesinger, H., Falko, D. (Eds.), Die Bayern Und Ihre Nachbarn. Berichte Des Symposiums Der Kommission Für Frühmittelalterforschung Vom 25. Bis 28. Oktober 1982 Im Stift Zwettl, Niederösterreich. Denkschriften. Österreichische Akademie der Wissenschaften, Philosophisch-Historische Klasse /179-180 Veröffentlichungen der Kommision für Frühmittelalterforschung/ 8-9, Wien, pp. 121–134.

Hauser, G., De Stefano, G.F., 1989. Epigenetic Variants of the Human Skull. Schweizerbart, Stuttgart.

Hausfater, G., Hrdy, S.B., 1984. Infanticide Comparative and Evolutionary Perspectives, 1st ed.

Routledge, New York. https://doi.org/10.4324/9780203788608

Havelkova, P., Villotte, S., Veleminsky, P., Polacek, L., Dobisikova, M., 2011. Enthesopathies and activity patterns in the Early Medieval Great Moravian population: Evidence of division of labour. Int. J. Osteoarchaeol. 21, 487–504. https://doi.org/10.1002/oa.1164

Hawkes, K., O'Connell, F., Blurton Jones, N.G., 1995. Hadza Children's Foraging: Juvenile Dependency, Social Arrangements, and Mobility among Hunter-Gatherers. Curr. Anthropol. 36, 688–700.

He, Y., Yang, X., Xia, J., Zhao, L., Yang, Y., 2016. Consumption of meat and dairy products in China: a review. Proc. Nutr. Soc. 75, 385–391. https://doi.org/10.1017/S0029665116000641

Heitmeier, I., 2005. Baiern im Inn-, Eisack- und Pustertal? Frühmittelalterliche Machtpolitik und die Frage der Siedlugnsentwicklung im Tiroler Alpenraum, in: Landi, W. (Ed.), Romanan Und Germanen Im Herzen Der Alpen. Athesia, Bozen, pp. 45–68.

Heitmeier, I., 1999. Zur Kontinuität der Raumorganisation in Nordtirol von der Spätantike bis ins hohe Mittelalter, in: Loose, R., Lorenz, S. (Eds.), König, Kirche, Adel- Herrschaftsstrukturen Im Mittleren Alpenraum Und Angrenzenden Gebieten (6.-13. Jahrhundert). Tappeiner, Bozen, pp. 267–290.

Henderson, C., 2013. Subsistence strategy changes: The evidence of entheseal changes. HOMO- J. Comp. Hum. Biol. 64, 491–508. https://doi.org/10.1016/j.jchb.2013.08.002

Henderson, C.Y., Craps, D.D., Caffell, A.C., Millard, A.R., Gowland, R., 2013. Occupational Mobility in 19th Century Rural England: The Interpretation of Entheseal Changes. Int. J. Osteoarchaeol. 23. https://doi.org/10.1002/oa.2286

Hermanussen, M., 2013. Auxology Studying Human Growth and Development. Schweizerbart, Stuttgart.

Hermanussen, M., Scheffler, C., Groth, D., Aßmann, C., 2015. Height and skeletal morphology in relation to modern life style. J. Physiol. Anthropol. 34, 41. https://doi.org/10.1186/s40101-015-0080-4

Herrmann, B., Grupe, G., Hummel, S., Piepenbrink, H., Schutkowski, H., 1990. Prähistorische Anthropologie- Leitfaden der Feld und Labormethoden. Springer, Berlin.

Hershkovitz, I., Latimer, B., Dutour, O., Jellema, L.M., Wish-Baratz, S., Rothschild, C., Rothschild, B.M., 1997. Why Do We Fail in Aging the Skull From the Sagittal Suture. Am. J. Phys. Anthropol. 103, 393–399.

Hesketh, T., Xing, Z.W., 2006. Abnormal sex ratios in human populations: Causes and consequences. Proc. Natl. Acad. Sci. 103, 13271–13275. https://doi.org/10.1073/pnas.0602203103

Hessenberger, E., 2013. Erzählen vom Leben im 20. Jahrhundert Erinnerungspraxis und Erzähltraditionen in lebensgeschichtlichen Interviews am Beispiel der Region Montafon-Vorarlberg. Studienverlag Ges.m.b.H., Innsbruck.

Heuberger, R., 1932. Rätien im Altertum und Frühmittelalter, Forschungen und Darstellung, 1st ed. Wagner, Innsbruck.

Hillson, S., 1996. Dental Anthropology. Cambridge University Press, Cambridge.

Hillson, S., Bond, S., 1997. Relationship of enamel hypoplasia to the pattern of tooth crown growth: A discussion. Am. J. Phys. Anthropol. 104, 89–103. https://doi.org/10.1002/(SICI)1096-8644(199709)104:1<89::AID-AJPA6>3.0.CO;2-8

Hobdell, M.H., Oliveira, E.R., Bautista, R., Myburgh, N.G., Lalloo, R., Narendran, S., Johnson, N.W., 2003. Oral diseases and socio-economic status (SES). Br. Dent. J. 194, 91–96. https://doi.org/10.1038/sj.bdj.4809882

Holl, M., 1884. Über die in Tirol vorkommenden Schädelformen. Berger, Innsbruck.

Hollingshaus, M., Utz, R., Schacht, R., Smith, K.R., 2019. Sex ratios and life tables: Historical demography of the age at which women outnumber men in seven countries, 1850–2016. Hist. Methods A J. Quant. Interdiscip. Hist. 52, 244–253. https://doi.org/10.1080/01615440.2019.1605863

Holmberg, S., Thelin, A., Thelin, N., 2004. Is there an increased risk of knee osteoarthritis among farmers? A population-based case?control study. Int. Arch. Occup. Environ. Health 77, 345–350. https://doi.org/10.1007/s00420-004-0518-1

Holst, M., 2010. Osteological Analysis Coppergate York. York.

Horan, J., Quin, G., 2006. Proximal tibiofibular dislocation. Emerg. Med. J. 23, e33–e33. https://doi.org/10.1136/emj.2005.032144

Hoyte, D.A.N., Enlow, D.H., 1966. Wolff's law and the problem of muscle attachment on resorptive surfaces of bone. Am. J. Phys. Anthropol. 24, 205–213. https://doi.org/10.1002/ajpa.1330240209

Hug, L., Sharrow, D., Zhong, K., You, D., 2018. Levels and Trends in Child Mortality.

Huss-Ashmore, R., Goodman, A.H., Armelagos, G.J., 1982. Nutritional Inference from Paleopathology. Adv. Archaeol. Method Theory 5, 395–474.

Hussain, S.M., Cicuttini, F.M., Alyousef, B., Wang, Y., 2018. Female hormonal factors and osteoarthritis of the knee, hip and hand: a narrative review. Climacteric 21, 132–139. https://doi.org/10.1080/13697137.2017.1421926

Hynes, L., 2011. Routine Infanticide by Married Couples? An Assessment of Baptismal Records from Seventeenth Century Parma. J. Early Mod. Hist. 15, 507–530. https://doi.org/10.1163/157006511X600828

Iregren, E., Redin, L., 2000. Assemblages of children´s bones in a medieval churchyard in Sweden: Results of epidemics, warfare, infanticide or simply disturbed graves?, in: Varela, T.A. (Ed.), Investigaciones En Bioversidad Humana Universidade de Santiago de Compostela. Universidad de Santiago de Compostela, Santiago de Compostela, p. 13.

Irish, J.D., Morez, A., Girdland Flink, L., Phillips, E.L.W., Scott, G.R., 2020. Do dental nonmetric traits actually work as proxies for neutral genomic data? Some answers from continental- and global-level analyses. Am. J. Phys. Anthropol. 172, 347–375. https://doi.org/10.1002/ajpa.24052

Ives, R., 2018. Rare paleopathological insights into vitamin D deficiency rickets, co-occurring illnesses, and documented cause of death in mid-19th century London, UK. Int. J. Paleopathol. 23, 76–87. https://doi.org/10.1016/j.ijpp.2017.11.004

Jacobs, K., 1992. Estimating femur and tibia length from fragmentary bones: an evaluation of Steele's (1970) method using a prehistoric European sample. Am. J. Phys. Anthropol. 89, 333–345.

James, R.S., Tallis, J., 2019. The likely effects of thermal climate change on vertebrate skeletal muscle mechanics with possible consequences for animal movement and behaviour. Conserv. Physiol. 7. https://doi.org/10.1093/conphys/coz066

Jankuhn, H., 1976. Archäologie und Geschichte, Beiträge zur siedlungsarchäologischen Forschung. DeGruyter, Berlin.

Jansson, L., Lavstedt, S., Frithiof, L., Theobald, H., 2001. Relationship between oral health and mortality in cardiovascular diseases. J. Clin. Periodontol. 28, 762–768. https://doi.org/10.1034/j.1600-051X.2001.280807.x

Jantsch, M., 1972. Holl, Moritz. Neue Dtsch. Biogr. 2, 533.

Jasch, I., Langer, A., Boley, M., Mumm, R., Riesenberg, M., Mann, R., Wahl, J., 2018. Osseous Frame Index calculations of the early medieval South-West Germany. Anthropol. Anzeiger 74, 431–443. https://doi.org/10.1127/anthranz/2018/0822

Jatautis, Š., Mitokaite, I., Jankauskas, R., 2011. Analysis of cribra orbitalia in the earliest inhabitants of medieval Vilnius. Anthropol. Rev. 74, 57–68. https://doi.org/10.2478/v10044-010-0006-z

Jensen, L.K., 2008. Hip osteoarthritis: influence of work with heavy lifting, climbing stairs or ladders, or combining kneeling/squatting with heavy lifting. Occup. Environ. Med. 65, 6–19. https://doi.org/10.1136/oem.2006.032409

Jogna, E., 2010. Geschlechterspezifische Disparitäten in Bezug auf die Arbeitsteilung in Agrarbetrieben in St. Georgen am Walde. University of Vienna.

Johnson-Wimbley, T.D., Graham, D.Y., 2011. Diagnosis and management of iron deficiency anemia in the 21st century. Therap. Adv. Gastroenterol. 4, 177–184. https://doi.org/10.1177/1756283X11398736

Johnson, A.L., 2014. Exploring Adaptive Variation among Hunter-gatherers with Binford’s Frames of Reference. J. Archaeol. Res. 22, 1–42. https://doi.org/10.1007/s10814-013-9068-y

Johnstone, J., Eurich, D.T., Majumdar, S.R., Jin, Y., Marrie, T.J., 2008. Long-Term Morbidity and Mortality After Hospitalization With Community-Acquired Pneumonia. Medicine (Baltimore). 87, 329–334. https://doi.org/10.1097/MD.0b013e318190f444

Jørgensen, K.T., Pedersen, B.V., Nielsen, N.M., Hansen, A.V., Jacobsen, S., Frisch, M., 2011. Socio-demographic factors, reproductive history and risk of osteoarthritis in a cohort of 4.6 million Danish women and men. Osteoarthr. Cartil. 19, 1176–1182. https://doi.org/10.1016/j.joca.2011.07.009

Judd, M.A., Redfern, R.C., 2012. Trauma, in: Grauer, A.L. (Ed.), A Companion to Paleopathology. Blackwell Publishing Inc., Oxford, pp. 359–379.

Judd, M.A., Roberts, C.A., 1999. Fracture trauma in a medieval British farming village. Am. J. Phys. Anthropol. 109, 229–243. https://doi.org/10.1002/(SICI)1096-8644(199906)109:2<229::AID-AJPA7>3.0.CO;2-Y

Juras, A., Chyleński, M., Krenz-Niedbała, M., Malmström, H., Ehler, E., Pospieszny, Ł., Łukasik, S., Bednarczyk, J., Piontek, J., Jakobsson, M., Dabert, M., 2016. Investigating kinship of Neolithic post-LBK human remains from Krusza Zamkowa, Poland using ancient DNA. Forensic Sci. Int. Genet. 0, 30–39. https://doi.org/10.1016/j.fsigen.2016.10.008

Jurmain, R., 1991. Degenerative changes in peripheral joints as indicators of mechanical stress: Opportunities and limitations. Int. J. Osteoarchaeol. 1, 247–252.

Kacki, S., Villotte, S., Knüsel, C.J., 2011. Baastrup's sign (kissing spines): A neglected condition in paleopathology. Int. J. Paleopathol. 1, 104–110. https://doi.org/10.1016/j.ijpp.2011.09.001

Kahl, K.E., Ostendorf Smith, M., 2000. The pattern of spondylosis deformans in prehistoric samples from west-central New Mexico. Int. J. Osteoarchaeol. 10, 432–446. https://doi.org/10.1002/1099-1212(200011/12)10:6<432::AID-OA535>3.0.CO;2-V

Kaifu, Y., Kasai, K., Townsend, G.C., Richards, L.C., 2003. Tooth wear and the design of the human dentition: A perspective from evolutionary medicine. Am. J. Phys. Anthropol. 122, 47–61. https://doi.org/10.1002/ajpa.10329

Kaitha, S., Bashir, M., Ali, T., 2015. Iron deficiency anemia in inflammatory bowel disease. World J. Gastrointest. Pathophysiol. 6, 62. https://doi.org/10.4291/wjgp.v6.i3.62

Karakostis, F.A., Wallace, I.J., Konow, N., Harvati, K., 2019. Correction: Experimental evidence that physical activity affects the multivariate associations among muscle attachments (entheses) (doi:10.1242/jeb.213058). J. Exp. Biol. 222. https://doi.org/10.1242/jeb.220210

Karttunen, J.P., Rautiainen, R.H., 2013. Distribution and characteristics of occupational injuries and diseases among farmers: A retrospective analysis of workers' compensation claims. Am. J. Ind. Med. 56, 856–869. https://doi.org/10.1002/ajim.22194

Katherine Spradley, M., Jantz, R.L., 2016. Ancestry Estimation in Forensic Anthropology: Geometric Morphometric versus Standard and Nonstandard Interlandmark Distances. J. Forensic Sci. 61, 892–897. https://doi.org/10.1111/1556-4029.13081

Katona, P., Katona-Apte, J., 2008. The Interaction between Nutrition and Infection. Clin. Infect. Dis. 46, 1582–1588. https://doi.org/10.1086/587658

Katzenberg, A.M., Herring, A.D., Saunders, S.R., 1996. Weaning and infant mortality: Evaluating the skeletal evidence. Am. J. Phys. Anthropol. 101, 177–299.

Kaufmann, G., 2017. Ein Meilenstein. Der Schlern 91, 73–87.

Kaufmann, G., 2012. Von Burg Mais zur Zenoburg. ARX Burgen und Schlösser Bayern, Österreich und Südtirol 2, 43–51.

Kaufmann, G., Demetz, S., 2004. Dal riparo alla citta. Cenni sulla preistoria e sulla prima storia di Bressanone, in: Bressanone I. La Storia. Athesia/Tappeiner, Lana, pp. 29–88.

Kennedy, K.A.R., 1989. Skeletal markers of occupational stress, in: Iscan, M.Y., Kennedy, K.A.R. (Eds.), Reconstruction of Life from the Skeleton. Liss, New York, pp. 129–160.

Kerley, E.R., 1965. The microscopic determination of age in human bone. Am. J. Phys. Anthropol. 23, 149–163.

Kerley, E.R., Ubelaker, D.H., 1978. Revisions in the microscopic method of estimating age at death in human cortical bone. Am. J. Phys. Anthropol. 49, 545–546.

Kerr, N.W., 1991. Prevalence and natural history of periodontal disease in Scotland-the medieval period (900-1600 A.D.). J. Periodontal Res. 26, 346–354.

Kim, J.K., Baker, L.A., Davarian, S., Crimmins, E., 2013. Oral health problems and mortality. J. Dent. Sci. 8, 115–120. https://doi.org/10.1016/j.jds.2012.12.011

Kim, S.W., Kashiwazaki, H., Imai, H., Moji, K., Orias-Rivera, J., 1991. Food consumption and energy expenditure of Aymara in a herding community of the Bolivian Altiplano. J. Hum. Ergol. 20, 181–97. https://doi.org/10.11183/jhe1972.20.181

Kimmerle, E.H., Baraybar, J.P., 2008. Skeletal Trauma Identification of injuries resulting from human rights abuse and armed conflict. CRC Press, New York.

Kirk, M.D., Angulo, F.J., Havelaar, A.H., Black, R.E., 2017. Diarrhoeal disease in children due to contaminated food. Bull. World Health Organ. 95, 233–234. https://doi.org/10.2471/BLT.16.173229

Kiss, C., O'Neill, T.W., Mituszova, M., Szilagyi, M., Donath, J., Poor, G., 2002. Prevalence of diffuse idiopathic skeletal hyperostosis in Budapest, Hungary. Rheumatology 41, 1335–1336. https://doi.org/10.1093/rheumatology/41.11.1335

Kjellström, A., 2005. A sixteenth-century warrior grave from Uppsala, Sweden: the Battle of Good Friday. Int. J. Osteoarchaeol. 15, 23–50. https://doi.org/10.1002/oa.746

Klapisch-Zuber, C., 1985. Women, Family, and Ritual in Renaissance Italy. The University of Chicago Press, Chichago.

Klaus, H.D., Spencer Larsen, C., Tam, M.E., 2009. Economic intensification and degenerative joint disease: Life and labor on the postcontact north coast of Peru. Am. J. Phys. Anthropol. 139, 204–221. https://doi.org/10.1002/ajpa.20973

Knapp, B.A., 2001. Archaeology and ethnicity: a dangerous liaison. Archaeol. Cypria 4, 29–46.

Knapp, B.A., Pigott, V.C., Herbert, E.W., 1998. Social Approaches to an Industrial Past, 1st ed. Routledge, London. https://doi.org/10.4324/9780203068922

Knorr, D.A., Smith, W.P.W., Ledger, M.L., Peña-Chocarro, L., Pérez-Jordà, G., Clapés, R., de Fátima Palma, M., Mitchell, P.D., 2019. Intestinal parasites in six Islamic medieval period latrines from 10th–11th century Córdoba (Spain) and 12th–13th century Mértola (Portugal). Int. J. Paleopathol. 26, 75–83. https://doi.org/10.1016/j.ijpp.2019.06.004

Knüsel, C.J., Göggel, S., Lucy, D., 1997. Comparative Degenerative Joint Disease of the Vertebral Column in the Medieval Monastic Cemetery of the Gilbertine Priory of St. Andrew, Fishergate, York, England. Am. J. Phys. Anthropol. 103, 481–495.

Knüsel, C.J., Smith, M.J., 2014. The Routledge Handbook of the Bioarchaeology of Human Conflict. Routledge Taylor & Francis Group, London.

Ko, S.-H., Kim, H.-S., 2020. Menopause-Associated Lipid Metabolic Disorders and Foods Beneficial for Postmenopausal Women. Nutrients 12, 202. https://doi.org/10.3390/nu12010202

Koffi, A.K., Wounang, R.S., Nguefack, F., Moluh, S., Libite, P., Kalter, H.D., 2017. Sociodemographic, behavioral, and environmental factors of child mortality in Eastern Region of Cameroon: results from a social autopsy study. J. Glob. Health 7. https://doi.org/10.7189/jogh.07.010601

Kokkotidis, G.K., 1999. Von der Wiege bis zur Bahre: Untersuchungen zur Paläodemografie der Alamannen des Frühen Mittelalters. Untersuchungen zur Paläodemografie der Alamannen des Frühen Mittelalters. Universität zu Köln.

Kölbl, S., 2004. Das Kinderdefizit im fruehen Mittelalter - Realitaet oder Hypothese? - Zur Deutung demographischer Strukturen in Graeberfeldern. Eberhard-Karls-Universität Tübingen.

Komar, D., Buikstra, J., 2009. Forensic Anthropology. Contemporary Theory and Practice. Oxford University Press, Oxford.

König, K.G., 2000. Diet and oral health. Int. Dent. J. 50, 162–174. https://doi.org/10.1111/j.1875-595X.2000.tb00555.x

Köpf, U., 1999. Christliche Kultorte als Zeugen der älteren Kirchengeschichte des Vinschgaus, in: Loose, R., Lorenz, S. (Eds.), König, Kirche, Adel- Herrschaftsstrukturen Im Mittleren Alpenraum Und Angrenzenden Gebieten (6.-13. Jahrhundert). Tappeiner, Bozen, pp. 53–96.

Kramer, P.A., 2006. Prevalence and Distribution of Spinal Osteoarthritis in Women. Spine (Phila. Pa. 1976). 31, 2843–2848.

Krause, R., 2013. Mittelalterlicher Bergbau auf dem Kristberg im Montafon , Vorarlberg (Österreich). Verlag Dr. Rudolf Habelt GmbH, Bonn.

Kremer, C., Racette, S., Dionne, C.-A., Sauvageau, A., 2008. Discrimination of Falls and Blows in Blunt Head Trauma: Systematic Study of the Hat Brim Line Rule in Relation to Skull Fractures. J. Forensic Sci. 53, 716–719. https://doi.org/10.1111/j.1556-4029.2008.00725.x

Krogman, W.M., Iscan, M.Y., 1986. The Human Skeleton in Forensic Medicine, 2nd ed. Charles C Thomas, Springfield.

Kuhnen, H.-P., 2020. Mehr als nur ein Bischofssitz: Sabiona-Säben, Gem. Klausen (Südtirol) und sein siedlungsarchäologisches Umfeld, in: Cavada, E., Zagermann, M. (Eds.), Alpine Festungen 400-1000 Chronologie, Räume Und Funktionen, Netzwerke, Interpretationen. Verlag C.H. Beck München, München, pp. 149–450.

Kumar, S., Cheng, C., 1991. Biomechanical analysis of raking and comparison of two rakes. Int. J. Ind. Ergon. 7, 31–39. https://doi.org/10.1016/0169-8141(91)90056-R

Kumar, S., Molitor, R., Vollmer, S., 2016. Drought and Early Child Health in Rural India. Popul. Dev. Rev. 42, 53–68.

Kustatscher, E., Romeo, C., 2010. Übergänge und Perspektiven- Grundzüge der Landesgeschichte- Der Tiroler Raum von der Frühgeschichte bis ins späte Mittelalter, 1st ed. Athesia, Bozen.

Kvasnicka, M., Bethmann, D., 2009. Why are More Boys Born During War?: Evidence from Germany at Mid Century. Ruhr Econ. Pap. 154, 3–12. https://doi.org/10.2139/ssrn.1514383

Kyle, B., Reitsema, L.J., Tyler, J., Fabbri, P.F., Vassallo, S., 2018. Examining the osteological paradox: Skeletal stress in mass graves versus civilians at the Greek colony of Himera (Sicily). Am. J. Phys. Anthropol. 167, 161–172. https://doi.org/10.1002/ajpa.23624

Kyle, B., Shehi, E., Koçi, M., Reitsema, L.J., 2020. Bioarchaeological reconstruction of physiological stress during social transition in Albania. Int. J. Paleopathol. 30, 118–129. https://doi.org/10.1016/j.ijpp.2020.06.003

Lahren, C.H., Berryman, H.E., 1984. Fracture Patterns and Status at Chucalissa (40SY1): a Biocultural Approach. Tennessee Anthropol. 9, 15–21.

Lai, P., Lovell, N.C., 1992. Skeletal markers of occupational stress in the fur trade: a case study from Hudson's Bay Company fur trade post. Int. J. Osteoarchaeol. 2, 221–234.

Lambacher, N., Gerdau-Radonic, K., Bonthorne, E., Valle de Tarazaga Montero, F.J., 2016. Evaluating three methods to estimate the number of individuals from a commingled context. J. Archaeol. Sci. Reports 10, 674–683. https://doi.org/10.1016/j.jasrep.2016.07.008

Lamendin, H., Baccino, E., Humbert, J.F., Tavernier, J.C., Nossintchouk, R.M., Zerilli, A., 1992. A simple technique for age estimation in adult corpses: the two criteria dental method. J. Forensic Sci. 37, 1373–9.

Landi, W., 2005. Romanen und Germanen im Herzen der Alpen zwischen 5. und 8. Jahrhundert. Athesia, Bozen.

Larentis, O., 2017. San Martino di Lundo (Trento) Grave 1. Case study of an individual introducing possibilities markers of horse riding. Med. Hist. 1, 103–110.

Larsen, C.S., 2015. Bioarchaeology Interpreting Behavior from the Human Skeleton, 2nd ed. Ohio State University, Ohio.

Larsen, C.S., 2002. Bioarchaeology: The lives and lifestyles of past people. J. Archaeol. Res. 10, 119–166. https://doi.org/10.1023/A:1015267705803

Larsen, C.S., 1995. Biological Changes in Human Populations with Agriculture. Annu. Rev. Anthropol. 24, 185–213. https://doi.org/10.1146/annurev.an.24.100195.001153

Larsen, C.S., Hutchinson, D.L., 1992. Dental evidence for physiological disruption: Biocultural interpretations from the Eastern Spanish Borderlands, U.S.A., in: Goodman, A.H., Capasso, L.L. (Eds.), Recent Contributions to the Study of Enamel Development Defects. Journal of Paleopathology Monographic Publications 2, Edigrafital Teramo, Chieti, pp. 151–169.

Lavallo, G., 2013. Variation In Non-Metric Traits of the Pelvis Between Whites, Blacks, and Hispanics. Texas State University- San Marcos.

Lee, S., Choi, Y., Jeong, H.S., Lee, J., Sung, J., 2017. Effect of different cooking methods on the content of vitamins and true retention in selected vegetables. Food Sci. Biotechnol. 27, 333–342. https://doi.org/10.1007/s10068-017-0281-1

Lee, Y.K., Skalski, M.R., White, E.A., Tomasian, A., Phan, D.D., Patel, D.B., Matcuk, G.R., Schein, A.J., 2017. US and MR Imaging of Pectoralis Major Injuries. RadioGraphics 37, 176–189. https://doi.org/10.1148/rg.2017160070

Leiberman, D.E., Devlin, M.J., Pearson, O.M., 2001. Articular area response to mechanical loading: effects of exercise, age, and skeletal location. Am. J. Phys. Anthropol. 116, 266–277.

Leonard, W.R., Katzmarzyk, P.T., 2010. Body Size and Shape: Climatic and Nutritional Influences on Human Body Morphology, in: Muehlenbein, M.P. (Ed.), Human Evolutionary Biology. Cambridge University Press, Cambridge, pp. 157–169. https://doi.org/10.1017/CBO9780511781193.014

Leonardi, A., 2009. 1809-2009 Südtiroler Landwirtschaft zwischen Tradition und Innovation. Athesia, Bozen.

Levy, L.F., 1968. Porter's Neck. BMJ 2, 16–19. https://doi.org/10.1136/bmj.2.5596.16

Lewis, J., Freisinger, G., Pan, X., Siston, R., Schmitt, L., Chaudhari, A., 2015. Changes in lower extremity peak angles, moments and muscle activations during stair climbing at different speeds. J. Electromyogr. Kinesiol. 25, 982–989. https://doi.org/10.1016/j.jelekin.2015.07.011

Lewis, M., Shapland, F., Watts, R., 2016. On the threshold of adulthood: A new approach for the use of maturation indicators to assess puberty in adolescents from medieval England. Am. J. Hum. Biol. 28. https://doi.org/10.1002/ajhb.22761

Lieberman, D.E., 2006. The human gluteus maximus and its role in running. J. Exp. Biol. 209, 2143–2155. https://doi.org/10.1242/jeb.02255

Lieberman, D.E., 1997. Making Behavioral and Phylogenetic Inferences from Hominid Fossils: Considering the Developmental Influence of Mechanical Forces. Annu. Rev. Anthropol. 26, 185–210. https://doi.org/10.1146/annurev.anthro.26.1.185

Lieverse, A.R., 1999. Diet and the aetiology of dental calculus. Int. J. Osteoarchaeol. 9, 219–232. https://doi.org/10.1002/(SICI)1099-1212(199907/08)9:4<219::AID-OA475>3.0.CO;2-V

Lieverse, A.R., Weber, A.W., Bazaliiskiy, V.I., Goriunova, O.I., Savel'ev, N.A., 2007. Osteoarthritis in Siberia's Cis-Baikal: Skeletal indicators of hunter-gatherer adaptation and cultural change. Am. J. Phys. Anthropol. 132, 1–16. https://doi.org/10.1002/ajpa.20479

Lieverse, A.R., Weber, A.W., Goriunova, O.I., 2006. Human taphonomy at Khuzhir-Nuge XIV, Siberia: a new method for documenting skeletal condition. J. Archaeol. Sci. 33, 1141–1151. https://doi.org/10.1016/j.jas.2005.12.001

Lilienthal, G., 1984. Zum Anteil der Anthropologie an der NS-Rassenpolitik. Medizinhist. J. 19, 148–160.

Lingström, P., van Houte, J., Kashket, S., 2000. Food starches and dental caries. Crit. Rev. Oral Biol. Med. 11, 366–380.

Lipsky, M.S., Su, S., Crespo, C.J., Hung, M., 2021. Men and Oral Health: A Review of Sex and Gender Differences. Am. J. Mens. Health 15, 155798832110163. https://doi.org/10.1177/15579883211016361

Liu, W.K., Liu, Q., Chen, D.H., Liang, H.X., Chen, X.K., Chen, M.X., Qiu, S.Y., Yang, Z.Y., Zhou, R., 2014. Epidemiology of Acute Respiratory Infections in Children in Guangzhou: A Three-Year Study. PLoS One 9, e96674. https://doi.org/10.1371/journal.pone.0096674

Loder, R.T., 2008. The Demographics of Equestrian-Related Injuries in the United States: Injury Patterns, Orthopedic Specific Injuries, and Avenues for Injury Prevention. J. Trauma Inj. Infect. Crit. Care 65, 447–460. https://doi.org/10.1097/TA.0b013e31817dac43

Loose, R., 1999. Der Vintschgau im frühen und hohen Mittelalter (bis ca. 1250), in: Loose, R., Lorenz, S. (Eds.), König, Kirche, Adel- Herrschaftsstrukturen Im Mittleren Alpenraum Und Angrenzenden Gebieten (6.-13. Jahrhundert). Tappeiner, Bozen, pp. 9–34.

Loose, R., Lorenz, S., 1999. König, Kirche, Adel- Herrschaftsstrukturen im Mittleren Alpenraum und angrenzenden Gebieten (6.-13. Jahrhundert). Tappeiner, Bozen.

López-Costas, O., Müldner, G., Lidén, K., 2021. Biological histories of an elite: Skeletons from the Royal Chapel of Lugo Cathedral (NW Spain). Int. J. Osteoarchaeol. 0–2. https://doi.org/10.1002/oa.3011

López, R., Smith, P.C., Göstemeyer, G., Schwendicke, F., 2017. Ageing, dental caries and periodontal diseases. J. Clin. Periodontol. 44, S145–S152. https://doi.org/10.1111/jcpe.12683

Lorenz, S., 1999. Von der "forestis" zum "Wildbann": Die Forsten in der hochmittelalterlichen Geschichte Südtirols, in: Loose, R., Lorenz, S. (Eds.), König, Kirche, Adel-Herrschaftsstrukturen Im Mittleren Alpenraum Und Angrenzenden Gebieten (6.-13. Jahrhundert). Tappeiner, Bozen, pp. 151–170.

Lovejoy, C.O., 1985. Dental Wear in the Libben Population: Its Functional Pattern and Role in the Determination of Adult Skeletal. Age at Death. Am. J. Phys. Anthropol. 68, 47–56.

https://doi.org/10.1002/ajpa.1330680105

Lovejoy, C.O., Meindl, R.S., Pryzbeck, T.R., Mensforth, R.P., 1985. Chronological Metamorphosis of the Auricular Surface of the Ilium: A New Method for the Determination of Adult Skeletal Age at Death. Am. J. Phys. Anthropol. 68, 15–28. https://doi.org/10.1002/ajpa.1330680103

Lovell, N.C., 2008. Analysis and interpretation of skeletal trauma, in: Katzenberg, M.A., Saunders, S.R. (Eds.), Biological Anthropology of the Human Skeleton. Wiley, Hoboken, pp. 341–386.

Lovell, N.C., 1997. Trauma Analysis in Paleopathology. Yearb. Phys. Anthropol. 40, 139–170. https://doi.org/10.1002/(SICI)1096-8644(1997)25+<139::AID-AJPA6>3.0.CO;2

Lovell, N.C., 1994. Spinal arthritis and physical stress at Bronze Age Harappa. Am. J. Phys. Anthropol. 93, 149–164. https://doi.org/10.1002/ajpa.1330930202

Lozanoff, S., Sciullit, P.W., Schneidert, K.N., 1985. Third trochanter incidence and metric trait covariation in the human femur. J. Anat. 143, 149.

Lukacs, J.R., 2007. Dental trauma and antemortem tooth loss in prehistoric Canary Islanders: prevalence and contributing factors. Int. J. Osteoarchaeol. 17, 157–173. https://doi.org/10.1002/oa.864

Lukacs, J.R., 1995. The 'caries correction factor': A new method of calibrating dental caries rates to compensate for antemortem loss of teeth. Int. J. Osteoarchaeol. 5, 151–156. https://doi.org/10.1002/oa.1390050207

Lukacs, J.R., 1989. Dental paleopathology: Methods for reconstructing dietary patterns, in: Iscan, Y.M., Kennedy, K.A.R. (Eds.), Reconstruction of Life from the Skeleton. Liss, New York, pp. 261–286.

Lundqvist, P., Stå, M., Pinzke, S., 2021. Ergonomics of Cow Milking in Sweden, in: Donham, K.J., Rautiainen, R., Schumann, S.H., Lay, J. (Eds.), Agricultural Health and Safety: Recent Advances. CRC Press, Boca Raton, pp. 169–176. https://doi.org/10.1201/9781003248958-25

Lunz, R., 2006. Archäologische Streifzüge durch Südtirol: Etschtal vom Reschen bis zur Salurner Klause, 2nd ed. Athesia, Bozen.

Lunz, R., 2004. Archäologische Streifzüge durch Südtirol: Pustertal und Eisacktal, 1st ed. Athesia, Bozen.

Lutz, A., 2019. Zum Umgang mit defekten Daten in der Osteologie. Ludwig Maximilian University of Munich.

Luy, M., Minagawa, Y., 2014. Gender gaps- Life expectancy and proportion of life in poor health. Heal. Reports 25, 12–19.

Lynch, S.R., Cook, J.D., 1980. INTERACTION OF VITAMIN C AND IRON. Ann. N. Y. Acad. Sci. 355, 32–44. https://doi.org/10.1111/j.1749-6632.1980.tb21325.x

Macdonald, H.M., Hardcastle, A.C., Jugdaohsingh, R., Fraser, W.D., Reid, D.M., Powell, J.J., 2012. Dietary silicon interacts with oestrogen to influence bone health: Evidence from the Aberdeen Prospective Osteoporosis Screening Study. Bone 50, 681–687. https://doi.org/10.1016/j.bone.2011.11.020

Mackenbach, J.P., 1995. Social inequality and death as illustrated in late-medieval death dances. Am. J. Public Health 85, 1285–1292. https://doi.org/10.2105/AJPH.85.9.1285

MacKenzie, L., Speller, C.F., Holst, M., Keefe, K., Radini, A., 2021. Dental calculus in the industrial age: Human dental calculus in the Post-Medieval period, a case study from industrial Manchester. Quat. Int. https://doi.org/10.1016/j.quaint.2021.09.020

Maczynska, M., 1998. Die Völkerwanderung- Geschichte einer ruhelosen Epoche. Artemis & Winkler Verlag, Düsseldorf/Zürich.

Mader, R., Verlaan, J.-J., Buskila, D., 2013. Diffuse idiopathic skeletal hyperostosis: clinical features and pathogenic mechanisms. Nat. Rev. Rheumatol. 9, 741–750. https://doi.org/10.1038/nrrheum.2013.165

Maffulli, N., Testa, V., Capasso, G., Sullo, A., 2004. Calcific Insertional Achilles Tendinopathy. Am. J. Sports Med. 32, 174–182. https://doi.org/10.1177/0363546503258923

Mäkinen, T.M., Juvonen, R., Jokelainen, J., Harju, T.H., Peitso, A., Bloigu, A., Silvennoinen-Kassinen, S., Leinonen, M., Hassi, J., 2009. Cold temperature and low humidity are associated with increased occurrence of respiratory tract infections. Respir. Med. 103, 456–462. https://doi.org/10.1016/j.rmed.2008.09.011

Manifold, B.M., 2012. Intrinsic and Extrinsic Factors Involved in the Preservation of Non-Adult Skeletal Remains in Archaeology and Forensic Science. Bull. Int. Assoc. Paleodont. 6, 51–64.

Mann, R.W., Hunt, D.R., 2019. Non-metric traits and anatomical variants that can mimic trauma in the human skeleton. Forensic Sci. Int. 301, 202–224. https://doi.org/10.1016/J.FORSCIINT.2019.05.039

Mann, R.W., Hunt, D.R., 2012. Photographic Regional Atlas of Bone Disease- A guide to Pathologic and Normal Variation in the Human Skeleton, 3rd ed. Charles C. Thomas Publisher, Springfield.

Mann, R.W., Hunt, D.R., Lozanoff, S., 2016. Photographic Regional Atlas of Non-Metric Traits and Anatomical Variants in the Human Skeleton. Charles C. Thomas Publisher, Springfield.

Mann, R.W., Jantz, R.L., Bass, W.M., Willey, P.S., 1991. Maxillary Suture Obliteration: A Visual Method for Estimating Skeletal Age. J. Forensic Sci. 36, 781–791.

Manske, R.C., Prohaska, D., 2007. Pectoralis major tendon repair post surgical rehabilitation. North Am. J. Sport. Phys. Ther. 2, 22–33.

Mant, M., 2019. Time after time: individuals with multiple fractures and injury recidivists in long eighteenth-century (c. 1666–1837) London. Int. J. Paleopathol. 24, 7–18. https://doi.org/10.1016/J.IJPP.2018.08.003

Marchese, R.M., Bordoni, B., 2021. Anatomy, Shoulder and Upper Limb, Coracoclavicular Joint (Coracoclavicular Ligament), in: StatPearls. StatPearls Publishing, Treasure Island.

Marchi, D., 2008. Relationships between lower limb cross-sectional geometry and mobility: The case of a Neolithic sample from Italy. Am. J. Phys. Anthropol. 137, 188–200. https://doi.org/10.1002/ajpa.20855

Marchi, D., Shaw, C.N., 2011. Variation in fibular robusticity reflects variation in mobility patterns. J. Hum. Evol. 61, 609–616. https://doi.org/10.1016/j.jhevol.2011.08.005

Marchi, D., Sparacello, V.S., Holt, B.M., Formicola, V., 2006. Biomechanical approach to the reconstruction of activity patterns in Neolithic Western Liguria, Italy. Am. J. Phys. Anthropol. 131, 447–455. https://doi.org/10.1002/ajpa.20449

Marchi, D., Sparacello, V.S., Shaw, C., 2011. Mobility and lower limb robusticity of a pastoralist

Neolithic population from north-western Italy., in: Pinhasi, R., Stock, J.T. (Eds.), Human Bioarchaeology of the Transition to Agriculture. Wiley Blackwell, Chichester, pp. 317–346.

Marciniak, S., Bergey, C.M., Silva, A.M., Hałuszko, A., Furmanek, M., Veselka, B., Velemínský, P., Vercellotti, G., Wahl, J., Zariņa, G., Longhi, C., Kolář, J., Garrido-Pena, R., Flores-Fernández, R., Herrero-Corral, A.M., Simalcsik, A., Müller, W., Sheridan, A., Miliauskienė, Ž., Jankauskas, R., Moiseyev, V., Köhler, K., Király, Á., Gamarra, B., Cheronet, O., Szeverényi, V., Kiss, V., Szeniczey, T., Kiss, K., Zoffmann, Z.K., Koós, J., Hellebrandt, M., Maier, R.M., Domboróczki, L., Virag, C., Novak, M., Reich, D., Hajdu, T., von Cramon-Taubadel, N., Pinhasi, R., Perry, G.H., 2022. An integrative skeletal and paleogenomic analysis of stature variation suggests relatively reduced health for early European farmers. Proc. Natl. Acad. Sci. 119. https://doi.org/10.1073/pnas.2106743119

Maresh, M.M., 1955. Linear Growth of long bones of extremities from Infancy Through Adolescence. Am. J. Dis. Child. 89, 725–742.

Mariotti, V., Facchini, F., Belcastro, M.G., 2004. Enthesopathies--proposal of a standardized scoring method and applications. Coll. Antropol. 28, 145–159.

Marklein, K.E., Leahy, R.E., Crews, D.E., 2016. In sickness and in death: Assessing frailty in human skeletal remains. Am. J. Phys. Anthropol. 161, 208–225. https://doi.org/10.1002/ajpa.23019

Marmot, M., 2005. Status Syndrome: How Your Social Standing Directly Affects Your Health and Life Expectancy, 1st ed. Holt Paperbacks, New York.

Marques, C., Matos, V., Meinzer, N.J., 2019. Proliferative Periosteal Reactions, in: Steckel, R.H., Larsen, C.S., Roberts, C.A., Baten, J. (Eds.), The Backbone of Europe: Health, Diet, Work, and Violence over Two Millenia. Cambridge University Press, Cambridge, pp. 137–174.

Marti, R., 2000. Zwischen Römerzeit und Mittelalter: Forschungen zur frühmittelalterlichen Siedlungsgeschichte der Nordwestschweiz (4.-10. Jahrhundert). Archäologie und Kantonmuseum BL, Basel.

Martin, D.L., Anderson, C.P., 2014. Bioarchaeological and Forensic Perspectives on Violence-How Violent Death is Interpreted from Skeletal Remains. Cambridge University Press, Cambridge.

Martin, M., 1996. Die Menschen im Frühmittelalter, in: Furger, A., Vontobel, H. (Eds.), Die Schweiz Zwischen Antike Und Mittelalter: Archäologie Und Geschichte Des 4. Bis 9. Jahrhundert. Neue Zürcher Zeitung (Archäologie und Kulturgeschichte der Schweiz), Zürich, pp. 185–212.

Martin, R., 1928. Lehrbuch der Anthropologie. Verlag von Gustav Fischer, Jena.

Martin, R., Saller, K., 1957. Lehrbuch der Anthropologie. In systematischer Darstellung mit besonderer Berücksichtigung der anthropologischen Methoden, 3rd ed. Gustav Fischer Verlag, Stuttgart.

Martínez, C., Paterna, C., Yago, C., Masson, S., 2010. Le discours des femmes sur la répartition des tâches domestiques et de soins. Nouv. Quest. Féministes Vol. 29, 94–114. https://doi.org/10.3917/nqf.291.0094

Marzoli, C., Bombonato, G., Rizzi, G., 2009. Nuovi dati Archeologici sull' insediamento tardo antico-alto medievale della valle dell Adige tra la conca di Merano e Salorno. Atti Accad. Roveretania Agiati IX.

Masci, F., Rosecrance, J., Mixco, A., Cortinovis, I., Calcante, A., Mandic-Rajcevic, S., Colosio, C., 2020. Personal and occupational factors contributing to biomechanical risk of the distal upper limb among dairy workers in the Lombardy region of Italy. Appl. Ergon. 83, 102796. https://doi.org/10.1016/j.apergo.2018.12.013

Masset, C., 1989. Age estimation on the basis of cranial sutures, in: Iscan, Y.M. (Ed.), Age Markers in the Human Skeleton. Charles C. Thomas, Springfield, pp. 71–103.

Maughan, R., 2000. Nutrition in Sport, Nutrition in Sport. Blackwell Science Ltd, Oxford.

Mayes, A.T., 2016. Spiro Mounds, Oklahoma: Dental Evidence for Subsistence Strategies. Int. J. Osteoarchaeol. 26, 749–758. https://doi.org/10.1002/oa.2472

Mays, S., 2016. Bone-formers and bone-losers in an archaeological population. Am. J. Phys. Anthropol. https://doi.org/10.1002/ajpa.22912

Mays, S., 1999. A biomechanical study of activity patterns in a medieval human skeletal assemblage. Int. J. Osteoarchaeol. 9, 68–73. https://doi.org/10.1002/(SICI)1099-1212(199901/02)9:1<68::AID-OA468>3.0.CO;2-M

Mays, S., Harding, C., Heighway, C.M., 2007. The Churchyard. University of York, York.

McAllister, D.A., Liu, L., Shi, T., Chu, Y., Reed, C., Burrows, J., Adeloye, D., Rudan, I., Black, R.E., Campbell, H., Nair, H., 2019. Global, regional, and national estimates of pneumonia morbidity and mortality in children younger than 5 years between 2000 and 2015: a systematic analysis. Lancet Glob. Heal. 7, e47–e57. https://doi.org/10.1016/S2214-109X(18)30408-X

McClure, F.J., 1964. Cariostatic Effect of Phosphates. Science (80-.). 144, 1337–1338. https://doi.org/10.1126/science.144.3624.1337

McNaught, 2006. A clinical and archaeological study of Schmorls Nodes using clinical data to understand the past. Durham University.

Meindl, R.S., Bedford, M.E., Russell, K.F., Lovejoy, C.O., Simpson, S.W., 1995. Testing the Test of the Multifactorial Aging Method: A reply to Fairgrieve and Oost. Am. J. Phys. Anthropol. 97, 85–87.

Meindl, R.S., Lovejoy, C.O., 1985. Ectocranial suture closure: a revised method for the determination of skeletal age at death based on the lateral-anterior sutures. Am. J. Phys. Anthropol. 68, 57–66. https://doi.org/10.1002/ajpa.1330680106

Melzer, D., Hurst, A.J., Frayling, T., 2007. Genetic Variation and Human Aging: Progress and Prospects. Journals Gerontol. Ser. A Biol. Sci. Med. Sci. 62, 301–307. https://doi.org/10.1093/gerona/62.3.301

Menghin, O., 1964. Ergänzende historische Bemerkungen zu den Funden von: Pfaffenhofen im Oberinntal. Veröffentlichungen des Museum Ferdinandeum 44, 211–236.

Meyer, W., 1998. Besiedlung und wirtschaftliche Nutzung hochalpiner Zonen in der mittelalterlichen Schweiz, in: Spindler, K. (Ed.), Mensch Und Natur Im Mittelalterlichen Europa. Wieser, Friesach, pp. 231–260.

Meyer, W., 1992. Rodung, Ackerbau und Viehwirtschaft. Archäologische Beiträge zur Besiedlung und zur Geschichte der landwirtschaftlichen Technologien in den Alpen des Mittelalters, in: Bergier, J.-F., Guzzi, S. (Eds.), Die Entdeckung Der Alpen. Actes Du Colloque Latsis 1990 Zurich, 1er-2 Novembre 1990. Schwabe & Co. AG, Basel, pp. 117–129.

Michalowski, A., 2002. Romanen und Bajuwaren im Inntal. Folia Praehist. Posnaniensia 10/11.

Milella, M., Alves Cardoso, F., Assis, S., Perréard Lopreno, G., Speith, N., 2015. Exploring the relationship between entheseal changes and physical activity: A multivariate study. Am. J. Phys. Anthropol. 156. https://doi.org/10.1002/ajpa.22640

Milella, M., Giovanna Belcastro, M., Zollikofer, C.P.E., Mariotti, V., 2012. The effect of age, sex, and physical activity on entheseal morphology in a contemporary Italian skeletal collection. Am. J. Phys. Anthropol. 148, 379–388. https://doi.org/10.1002/ajpa.22060

Miliauskienė, Ž., Jankauskas, R., 2015. Social differences in oral health: Dental status of individuals buried in and around Trakai Church in Lithuania (16th–17th c.c.). Anthropol. Anzeiger 72, 89–106. https://doi.org/10.1127/anthranz/2014/0407

Mitchell, P.D., 2015. Human Parasites in Medieval Europe: Lifestyle, Sanitation and Medical Treatment, in: De Baets, K., Littlewood, D.T.J. (Eds.), Advances in Parasitology. Academic Press, London, pp. 389–420. https://doi.org/10.1016/bs.apar.2015.05.001

Mitchell, P.D., Anastasiou, E., Syon, D., 2011. Human intestinal parasites in crusader Acre: Evidence for migration with disease in the medieval period. Int. J. Paleopathol. 1, 132–137. https://doi.org/10.1016/j.ijpp.2011.10.005

Mobley, C.C., 2003. Nutrition and dental caries. Dent. Clin. North Am. 47, 319–336. https://doi.org/10.1016/S0011-8532(02)00102-7

Mole, C.G., Heyns, M., Cloete, T., 2015. How hard is hard enough? An investigation of the force associated with lateral blunt force trauma to the porcine cranium. Leg. Med. 17, 1–8. https://doi.org/10.1016/j.legalmed.2014.07.008

Molleson, T., 1994. The Eloquent Bones of Abu Hureyra. Sci. Am. 271, 70–75. https://doi.org/10.1038/scientificamerican0894-70

Molnar, P., Ahlstrom, T.P., Leden, I., 2011. Osteoarthritis and activity-an analysis of the relationship between eburnation, Musculoskeletal Stress Markers (MSM) and age in two Neolithic hunter-gatherer populations from Gotland, Sweden. Int. J. Osteoarchaeol. 21, 283–291. https://doi.org/10.1002/oa.1131

Molnar, S., 1972. Tooth wear and culture: A survey of tooth function among some prehistoric populations. Curr. Anthropol. 13, 511–526.

Molnar, S., 1971. Human tooth wear, tooth function, and cultural variability. Am. J. Phys. Anthropol. 34, 175–190.

Molnar, S., 1970. Human tooth wear, tooth function and cultural variability. Am. J. Phys. Anthropol. 34, 175–189. https://doi.org/10.1016/B978-0-7506-7897-1.00006-6

Montes, N., Subirà, M.E., 2018. Monasticism and activity patterns: Evaluating osteoarthritis distribution and entheseal changes in a feminine monastic community (Santa Maria de Vall Santa, Spain). Ann. Univ. Apulensis Ser. Hist. 22, 151–178. https://doi.org/10.29302/auash.2018.22.1.7

Moore, K.L., Agur, A.M.R., Dalley, A.F., 2013. Clinical Oriented Anatomy, 7th ed. Lippincott Williams & Wilkins, Philadelphia.

Moore, M.K., 2013. Sex Estimation and Assessment, in: DiGangi, E.A., Moore, M.K. (Eds.), Research Methods in Human Skeletal Biology. Elsevier, Oxford, pp. 91–116. https://doi.org/10.1016/B978-0-12-385189-5.00004-2

Morton, J., 1852. The Ancren Riwle: A Treatise on the Rules and Duties of Monastic life. Camden Society, London.

Moser, S.-K., 1992. Säben. Tappeiner, Bozen.

Moskowitz, R.W., Kelly, M.A., Lewallen, D.G., 2004. Understanding osteoarthritis of the knee: causes and effects. Am. J. Orthop. 33, 5–9.

Motarjemi, Y., Kaferstein, F., Moy, G., Quevedo, F., 1993. Contaminated weaning food: A major risk factor for diarrhoea and associated malnutrition. Bull. World Health Organ. 71, 79–92.

Mourtzoukou, E.G., Falagas, M.E., 2007. Exposure to cold and respiratory tract infections. Int. J. Tuberc. Lung Dis. 11, 938–943.

Moye, Z.D., Zeng, L., Burne, R.A., 2014. Fueling the caries process: carbohydrate metabolism and gene regulation by Streptococcus mutans. J. Oral Microbiol. 6, 24878. https://doi.org/10.3402/jom.v6.24878

Moynihan, P., 2000. Foods and factors that protect against dental caries. Nutr. Bull. 25, 281–286. https://doi.org/10.1046/j.1467-3010.2000.00033.x

Moynihan, P.J., Ferrier, S., Jenkins, G.N., 1999. The cariostatic potential of cheese: cooked cheese-containing meals increase plaque calcium concentration. Br. Dent. J. 187, 664–667. https://doi.org/10.1038/sj.bdj.4800362

Mumm, R., Reimann, A., Scheffler, C., 2021. Estimation of percentage of body fat in field studies – a method based on relative elbow breadth (Frame Index) and BMI. Hum. Biol. Public Heal. 1, 1–12. https://doi.org/10.52905/hbph.v1.3

Mun, C.Y., Chu, W.M., 2013. Preserving Tradition with a purpose: Interpreting Zuo Yuezi in Malaysia. J. Chinese Lit. Cult. 1, 1–15.

Mundle, L., 2018. Subsistence strategies and mobility patterns in Early Medieval Italian Alps through stable carbon, nitrogen and sulphur isotope analysis. Ludwig Maximilian University Munich.

Murail, P., Bruzek, J., Houët, F., Cunha, E., 2005. DSP: A tool for probabilistic sex diagnosis using worldwide variability in hip-bone measurements. Bull. Mémoires la Société d’Anthropologie Paris 17, 167–176.

Murayama, N., 2015. Effects of Socioeconomic Status on Nutrition in Asia and Future Nutrition Policy Studies. J. Nutr. Sci. Vitaminol. (Tokyo). 61, S66–S68. https://doi.org/10.3177/jnsv.61.S66

Murphy, M.S., Gaither, C., Goycochea, E., Verano, J.W., Cock, G., 2010. Violence and weapon-related trauma at Puruchuco-Huaquerones, Peru. Am. J. Phys. Anthropol. 142, 636–649.

Myszka, A., Krenz-Niedbała, M., Tomczyk, J., Zalewska, M., 2019. Osteoarthritis: A problematic disease in past human populations. A dependence between entheseal changes, body size, age, sex, and osteoarthritic changes development. Anat. Rec. ar.24316. https://doi.org/10.1002/ar.24316

Myszka, A., Piontek, J., 2013. The effect of age on external bone morphology properties in adults. Anthropologie 1, 409–420.

Myszka, A., Piontek, J., 2012. Variation of Musculoskeletal Stress Markers in the Medieval Population from Cedynia (Poland) – Proposal of Standardized Scoring Method Application. Coll. Antropol. 36, 1009–1017.

Myszka, A., Piontek, J., Milosz, E., 2012. Traumatic Injuries in the Late Medieval and Early Modern Population from Lekno, Poland. Interdiscip. Archaeol. Nat. Sci. Archaeol. 3, 237–243.

Navazo, B., Oyhenart, E., Dahinten, S., Mumm, R., Scheffler, C., 2020. Decrease of external skeletal robustness (Frame Index) between two cohorts of school children living in Puerto Madryn, Argentina at the beginning of the 21st century. Anthropol. Anzeiger 77, 405–413. https://doi.org/10.1127/anthranz/2020/1182

Newfield, T.P., 2017. Malaria and malaria-like disease in the early Middle Ages. Early Mediev. Eur. 25, 251–300. https://doi.org/10.1111/emed.12212

Nicklisch, N., Ramsthaler, F., Meller, H., Friedrich, S., Alt, K.W., 2017. The face of war: Trauma analysis of a mass grave from the Battle of Lützen (1632). PLoS One 12, 1–30. https://doi.org/https://doi.org/10.1371/journal.pone.0178252

Niinimäki, S., Baiges Sotos, L., 2013. The Relationship Between Intensity of Physical Activity and Entheseal Changes on the Lower Limb. Int. J. Osteoarchaeol. 23. https://doi.org/10.1002/oa.2295

Nikita, E., Xanthopoulou, P., Bertsatos, A., Chovalopoulou, M., Hafez, I., 2019. A three-dimensional digital microscopic investigation of entheseal changes as skeletal activity markers. Am. J. Phys. Anthropol. ajpa.23850. https://doi.org/10.1002/ajpa.23850

Noonan, C.W., Semmens, E.O., Ware, D., Smith, P., Boyer, B.B., Erdei, E., Hopkins, S.E., Lewis, J., Ward, T.J., 2020. Wood stove interventions and child respiratory infections in rural communities: KidsAir rationale and methods. Contemp. Clin. Trials 89, 105909. https://doi.org/10.1016/j.cct.2019.105909

Norén, A., Lynnerup, N., Czarnetzki, A., Graw, M., 2005. Lateral angle: a method for sexing using the petrous bone. Am. J. Phys. Anthropol. 128, 318–323. https://doi.org/10.1002/AJPA.20245

Norling, J., 2018. Natural Disasters, Mortality, Fertility, and Educational Attainment in Africa.

Nothdurfter, H., 1999. Archäologische Hinweise auf Adel und Raumorganisation des 7./8. Jahrhunderts im westlichen Südtirol, in: Loose, R., Lorenz, S. (Eds.), König, Kirche, Adel-Herrschaftsstrukturen Im Mittleren Alpenraum Und Angrenzenden Gebieten (6.-13. Jahrhundert). Tappeiner, Bozen, pp. 97–124.

Nothdurfter, H., 1991. Sonderaustellung in Schloß Tirol-St. Prokulus in Naturns- Ergrabene Geschichte von den Menschen des Frühmittelalters und der Pestzeit. Südtiroler Landesmuseum für Archäologie, Schloß Tirol.

Novak, A.S., 2007. Battle-related trauma, in: Fiorato, V., Boylston, A., Knüsel, C. (Eds.), Blood Red Roses. Oxbow Books, Oxford.

Ntimbani, J., Kelly, A., Lekgwara, P., 2020. Myelomeningocele - A literature review. Interdiscip. Neurosurg. 19, 100502. https://doi.org/10.1016/j.inat.2019.100502

O'Donnell, L., Hill, E.C., Anderson, A.S.A., Edgar, H.J.H., 2020. Cribra orbitalia and porotic hyperostosis are associated with respiratory infections in a contemporary mortality sample from New Mexico. Am. J. Phys. Anthropol. 173, 721–733. https://doi.org/10.1002/ajpa.24131

O'Sullivan, D., 2013. Burial of the Christian Dead in the Later Middle Ages, in: Stutz, N., Tarlow, S. (Eds.), The Oxford Handbook of the Archaeology of Death and Burial. Oxford University

Press. https://doi.org/10.1093/oxfordhb/9780199569069.013.0015

O'Toole, S., Mullan, F., 2018. The role of the diet in tooth wear. Br. Dent. J. 224, 379–383. https://doi.org/10.1038/sj.bdj.2018.127

Oberhofer, M.A., 2005. Häuer – Holzer – Schmelzer: Unfälle und Krankheiten im Bergbau Prettau. Eine Auswertung der Krankengeschichten des Südtiroler Landarztes Dr. Franz von Ottenthal (1818–1899)., in: Ingenhaeff, W., Bair, J. (Eds.), Bergvolk Und Medizin. 3. Internationales Bergbausymposiume Schwaz 2004, Innsbruck, pp. 251–268.

Obermair, H., 2005. Das Recht der tirolisch-tridentinischen "Regio" zwischen Spätantike und Frühmittelalter, in: Landi, W. (Ed.), Romanan Und Germanen Im Herzen Der Alpen. Athesia, Bozen, pp. 121–134.

Obertová, Z., 2008. The Early Medieval Alamannic Population at Horb-Altheim (450-510 A.D.), Bioarchaeo. ed. Verlag Marie Leidorf GmbH, Rahden.

Oeggl, K., 2009. The significance of the Tyrolean Iceman for the archaeobotany of Central Europe. Veg. Hist. Archaeobot. 18, 1–11. https://doi.org/10.1007/s00334-008-0186-2

Oei, A., Hülsmann, M., 2018. The acute apical abscess: Aetiology, microbiology, treatment and prognosis. Endod. Pract. Today 12, 75–85.

Olivier, G., Aaron, C., Fully, G., Tissier, G., 1978. New estimations of stature and cranial capacity in modern man. J. Hum. Evol. 7, 513–518.

Oncag, G., Tuncer, A.V., Tosun, Y.S., 2005. Acidic Soft Drinks Effects on the Shear bond Strength of Orthodontic Brackets and a Scanning Electron Microscopy Evaluation of the Enamel. Angle Orthod. 75, 247–253.

Oomman, N., Ganatra, B.R., 2002. Sex Selection: The Systematic Elimination of Girls. Reprod. Health Matters 10, 184–188. https://doi.org/10.1016/S0968-8080(02)00029-0

Orme, N., 2001. Medieval Children. Yale University Press, New Haven & London.

Ortner, D., 2003. Identification of Pathological Conditions in Human Skeletal Remains, 2nd ed, Identification of Pathological Conditions in Human Skeletal Remains. Academic Press, New York.

Ousley, S.D., Jantz, R.L., 2014. Fordsic 3 and Statistical Methods for Estimating Sex and Ancestry, in: Dirkmaat, D. (Ed.), A Companion to Forensic Anthropology. John Wiley & Sons Ltd., pp. 311–329.

Ousley, S.D., Jantz, R.L., 1996. FORDISC 2.0. Personal computer forensic discriminant functions.

Oxenham, M., Matsumura, H., Domett, K., Kim Thuy, N., Kim Dung, N., Lan Cuong, N., Huffer, D., Muller, S., 2008. Childhood in Late Neolithic Vietnam: Bio-Mortuary Insights into an Ambiguous Life Stage, in: Bacvarov, K. (Ed.), Babies Reborn: Infant/Child Burials in Pre- and Protohistory, International Union For Prehistoric and Protohistoric Sciences, Proceedings of the XV World Congress (Lisbon, 4-9 September 2006). Archaeopress, Lisbon, pp. 123–136.

Oziegbe, E.O., Schepartz, L.A., 2021. Association between parity and tooth loss among northern Nigerian Hausa women. Am. J. Phys. Anthropol. 174, 451–462. https://doi.org/10.1002/ajpa.24197

Paladin, A., Moghaddam, N., Stawinoga, A.E., Siebke, I., Depellegrin, V., Tecchiati, U., Lösch, S., Zink, A., 2020. Early medieval Italian Alps: reconstructing diet and mobility in the valleys. Archaeol. Anthropol. Sci. 12, 82. https://doi.org/10.1007/s12520-019-00982-6

Paladin, A., Wahl, J., Zink, A., 2018. Evidence of probable subadult scurvy in the Early Medieval cemetery of Castel Tirolo, South Tyrol, Italy. Int. J. Osteoarchaeol. 28, 714–726. https://doi.org/10.1002/oa.2694

Paladin, A., Zink, A., 2015. Studio antropologico e paleopatologico dei resti scheletrici umani altomedievali del sito di Appiano-Eppan localitá Langhütten-Gand (bolzano), in: Kaufmann, G. (Ed.), Archäologie Des Überetsch. pp. 391–403.

Palamenghi, A., Borlando, A., De Angelis, D., Sforza, C., Cattaneo, C., Gibelli, D., 2021. Exploring the potential of cranial non-metric traits as a tool for personal identification: the never-ending dilemma. Int. J. Legal Med. 135, 2509–2518. https://doi.org/10.1007/s00414-021-02654-4

Palastanga, N., Soames, R., 2012. Anatomy and Human Movement: Structure and Function, 6th ed. Churchill Livingstone, London.

Palfi, G., Dutour, O., 1996. Activity-induced Skeletal Markers in Historical Anthropological Material. Int. J. Anthropol. 11, 41–55.

Palmer, J., 2012. Busy Bones- Osteoarthritis and musculoskeletal markers as evidence of physical activity and social differentiation in post-medieval the Netherlands. University of Leiden.

Palmer, J.L.A., Hoogland, M.H.L., Waters-Rist, A.L., 2014. Activity reconstruction of post-medieval dutch rural villagers from upper limb osteoarthritis and entheseal changes. Int. J. Osteoarchaeol. https://doi.org/10.1002/oa.2397

Palmer, J.L.A., Waters-Rist, A.L., 2019. Acts of life: Assessing entheseal change as an indicator of social differentiation in postmedieval <scp>Aalst</scp> (<scp>Belgium</scp>). Int. J. Osteoarchaeol. 29, 303–313. https://doi.org/10.1002/oa.2740

Pan, Hsieh, Chen, Chen, 2019. Factors Associated with Tooth Loss in Postmenopausal Women: A Community-Based Cross-Sectional Study. Int. J. Environ. Res. Public Health 16, 3945. https://doi.org/10.3390/ijerph16203945

Parham, K.R., Scott, G.T., 1980. Porotic hyperostosis: A study of disease and culture at Toqua (40MR6), a late Mississippian site in eastern Tennessee, in: Willey, P., Smith, F.H. (Eds.), The Skeletal Biology of Aboriginal Populations in the Southeastern United States. Anthropological Association, Miscellaneous Paper, Tennessee, pp. 39–51.

Park, J.-B., Han, K., Park, Y.-G., Ko, Y., 2016. Association between socioeconomic status and oral health behaviors: The 2008–2010 Korea national health and nutrition examination survey. Exp. Ther. Med. 12, 2657–2664. https://doi.org/10.3892/etm.2016.3679

Park, S.-A., Lee, A.-Y., Kim, J.-J., Lee, K.-S., So, J.-M., Son, K.-C., 2014. Electromyographic Analysis of Upper and Lower Limb Muscles during Gardening Tasks. Korean J. Hortic. Sci. Technol. 32, 710–720. https://doi.org/10.7235/hort.2014.14059

Parmigiani, S., Vom Saal, F.S., 1994. Infanticide and Parental Care, 1st ed. Routledge Taylor & Francis Group, London. https://doi.org/10.1002/(sici)1098-2337(1996)22:6<466::aid-ab8>3.3.co;2-7

Pasricha, S.-R., Tye-Din, J., Muckenthaler, M.U., Swinkels, D.W., 2021. Iron deficiency. Lancet 397, 233–248. https://doi.org/10.1016/S0140-6736(20)32594-0

Passalacqua, N. V., 2012. Bioarchaeological Investigations of Health and Demography in Medieval Asturias, Spain. Michigan State University.

Passalacqua, N. V., Rainwater, C.W., 2015. Skeletal Trauma analysis. Wiley-Blackwell, New York.

Passarino, G., De Rango, F., Montesanto, A., 2016. Human longevity: Genetics or Lifestyle? It takes two to tango. Immun. Ageing 13, 12. https://doi.org/10.1186/s12979-016-0066-z

Paula, J.S., Leite, I.C., Almeida, A.B., Ambrosano, G.M., Pereira, A.C., Mialhe, F.L., 2012. The influence of oral health conditions, socioeconomic status and home environment factors on schoolchildren's self-perception of quality of life. Health Qual. Life Outcomes 10, 6. https://doi.org/10.1186/1477-7525-10-6

Paulsen, F., Waschke, J., 2013. Sobotta Atlas of Human Anatomy- Tables of Muscles, Joints and Nerves, 1st ed. Elsevier Urban & Fischer, München.

Pearce, J., 2001. Infants, Cemeteries and Communities in the Roman Provinces, in: Davies, G., Gardner, A., Lockyear, K. (Eds.), Theoretical Roman Archaeology Journal. Oxbow Books, Oxford, pp. 125–142. https://doi.org/10.16995/TRAC2000_125_142

Pearson, K., 1899. On the reconstruction of the stature of prehistoric races. Mathematical contributions to the theory of evolution. Philos. Trans. R. Soc. London 192, 169–244.

Pearson, K., Bell, J., 1917. The study of the long bones of the English skeleton. Cambridge University Press, London.

Pearson, O.M., 2000. Activity, Climate, and Postcranial Robusticity. Curr. Anthropol. 41, 569–607. https://doi.org/10.1086/317382

Pearson, O.M., Buikstra, J.E., 2006. Behavior and the bones, in: Buikstra, J.E., Beck, L.A. (Eds.), Bioarchaeology: The Contextual Analysis of Human Remains. Academic Press, London, pp. 207–226.

Pearson, O.M., Lieberman, D.E., 2004. The aging of Wolff's "law": ontogeny and responses to mechanical loading in cortical bone. Yearb. Phys. Anthropol. 47, 63–99.

Peck, J.J., 2013. Status, health, and lifestyle in Middle Iron Age Britain: A bioarcheological study of elites and non-elites from East Yorkshire, Northern England. Int. J. Paleopathol. 3, 83–94. https://doi.org/10.1016/j.ijpp.2013.03.005

Peck, J.J., 2009. The biological impact of culture contact a bioarchaeological study of Roman colonialism in Britain. Ohio State University.

Perréard Lopreno, G., Alves Cardoso, F., Assis, S., Milella, M., Speith, N., 2013. Categorization of Occupation in Documented Skeletal Collections: Its Relevance for the Interpretation of Activity-Related Osseous Changes. Int. J. Osteoarchaeol. 23, 175–185. https://doi.org/10.1002/oa.2301

Petter, A., Davidson, J., 2004. An unusual knee injury: Isolated tibiofibular dislocation. Emerg. Med. Australas. 16, 172–173. https://doi.org/10.1111/j.1742-6723.2004.00572.x

Pfirrmann, C.W.A., Resnick, D., 2001. Schmorl Nodes of the Thoracic and Lumbar Spine: Radiographic-Pathologic Study of Prevalence, Characterization, and Correlation with Degenerative Changes of 1,650 Spinal Levels in 100 Cadavers. Radiology 219, 368–374. https://doi.org/10.1148/radiology.219.2.r01ma21368

Phenice, T., 1967. A Newly Developed Visual Method of Sexing the Os Pubis. Am. J. Phys. Anthropol. 30, 297–302.

Philip, N., Leishman, S., Walsh, L., 2019. Potential Role for Natural Products in Dental Caries Control. Oral Heal. Prev. Dent. 17, 479–485. https://doi.org/10.3290/j.ohpd.a42741

Pinhasi, R., Bourbou, C., 2008. How Representative Are Human Skeletal Assemblages for

Population Analysis, in: Pinhasi, R., Mays, S. (Eds.), Advances in Human Palaeopathology. John Wiley & Sons Ltd., pp. 32–44.

Pinhasi, R., Mays, S., 2008. Advances in Human Palaeopathology. John Wiley & Sons Ltd., Chichester.

Pittore, B., Al-Safi, W., Jarvis, S.J., 2011. Concha bullosa of the inferior turbinate:an unusual cause of nasal obstruction. Acta Otorhinolaryngol. Ital. 31, 47.

Pollmer, U., 2007. Esst endlich normal! Piper Verlag GmbH, München.

Pomeroy, E., Macintosh, A., Wells, J.C.K., Cole, T.J., Stock, J.T., 2018. Relationship between body mass, lean mass, fat mass, and limb bone cross-sectional geometry: Implications for estimating body mass and physique from the skeleton. Am. J. Phys. Anthropol. 166, 56–69. https://doi.org/10.1002/ajpa.23398

Pongou, R., 2013. Erratum to: Why Is Infant Mortality Higher in Boys Than in Girls? A New Hypothesis Based on Preconception Environment and Evidence From a Large Sample of Twins. Demography 50, 445–446. https://doi.org/10.1007/s13524-012-0183-z

Postles, D., 1996. Monastic Burials of Non-Patronal Lay Benefactors. J. Ecclesiast. Hist. 47, 620–637. https://doi.org/10.1017/S0022046900014640

Powell, M.L., 1992. In the best of health? Disease and trauma among the Mississippian elite, in: Barker, A.W., Pauketat, T.R. (Eds.), Lords of the Southeast: Social Inequality and the Native Elites of the Southeastern North America. Archaeological Papers of teh American Archaeological Association, U.S.A., pp. 81–97.

Powell, M.L., 1988. Status and Health in Prehistory: A case study of the Moundville Chiefdom. Smithsonian Institution Press, Washington D.C.

Prina, E., Ranzani, O.T., Torres, A., 2015. Community-acquired pneumonia. Lancet 386, 1097–1108. https://doi.org/10.1016/S0140-6736(15)60733-4

Prinz, F., 2003. Deutschlands Frühgeschichte. Klett-Cotta, Stuttgart.

Pugh, J.N., Lydon, K.M., O'Donovan, C.M., O'Sullivan, O., Madigan, S.M., 2022. More than a gut feeling: What is the role of the gastrointestinal tract in female athlete health? Eur. J. Sport Sci. 22, 755–764. https://doi.org/10.1080/17461391.2021.1921853

Putzer, A., Festi, D., Oeggl, K., 2016. Was the Iceman really a herdsman? The development of a prehistoric pastoral economy in the Schnals Valley. Antiquity 90, 319–336. https://doi.org/10.15184/aqy.2015.185

Quade, L., Binder, M., 2018. Life on a Napoleonic battlefield: A bioarchaeological analysis of soldiers from the Battle of Aspern, Austria. Int. J. Paleopathol. 22, 23–38. https://doi.org/10.1016/j.ijpp.2018.03.006

Quetelet, A., 1871. Anthropométrie ou mesure des différentes facultés de l'homme. Muquardt, C., Brussels.

Quinn, C.P., Beck, J., 2016. Essential tensions: A framework for exploring inequality through mortuary archaeology and bioarchaeology. Open Archaeol. 2, 18–41. https://doi.org/10.1515/opar-2016-0002

Rabey, K.N., Green, D.J., Taylor, A.B., Begun, D.R., Richmond, B.G., McFarlin, S.C., 2015. Locomotor activity influences muscle architecture and bone growth but not muscle attachment site morphology. J. Hum. Evol. 78.

https://doi.org/10.1016/j.jhevol.2014.10.010

Ragsdale, B.D., Campbell, R.A., Kirkpatrick, C.L., 2018. Neoplasm or not? General principles of morphologic analysis of dry bone specimens. Int. J. Paleopathol. 21. https://doi.org/10.1016/j.ijpp.2017.02.002

Rahman, M.M., Abe, S.K., Kanda, M., Narita, S., Rahman, M.S., Bilano, V., Ota, E., Gilmour, S., Shibuya, K., 2015. Maternal body mass index and risk of birth and maternal health outcomes in low- and middle-income countries: a systematic review and meta-analysis. Obes. Rev. 16, 758–770. https://doi.org/10.1111/obr.12293

Rahner, N., Steinke, V., 2008. Hereditary Cancer Syndromes. Dtsch. Arztebl. Int. https://doi.org/10.3238/arztebl.2008.0706

Ramseier, C.A., Anerud, A., Dulac, M., Lulic, M., Cullinan, M.P., Seymour, G.J., Faddy, M.J., Bürgin, W., Schätzle, M., Lang, N.P., 2017. Natural history of periodontitis: Disease progression and tooth loss over 40 years. J. Clin. Periodontol. 44, 1182–1191. https://doi.org/10.1111/jcpe.12782

Ravishankar, T.L., Yadav, V., Tangade, P.S., Tirth, A., Chaitra, T.R., 2012. Effect of consuming different dairy products on calcium, phosphorus and pH levels of human dental plaque: A comparative study. Eur. Arch. Paediatr. Dent. 13, 144–148. https://doi.org/10.1007/BF03262861

Raybould, A., 1921. The Tyrol: Past and Present. Irish Mon. 49, 57–63.

Redfern, R.C., 2016. Injury and trauma in bioarchaeology: Interpreting violence in past lives, Injury and Trauma in Bioarchaeology: Interpreting Violence in Past Lives. https://doi.org/10.1017/9780511978579

Reher, D., 1995. Wasted Investments: Some economic Implications of Childhood Mortality Patterns. Popul. Stud. (NY). 49, 519–536.

Reid, A., MacLean, R., 1995. Symbolism and the social contexts of iron production in Karagwe. World Archaeol. 27, 144–161. https://doi.org/10.1080/00438243.1995.9980298

Reid, D.J., Dean, M.C., 2000. Brief communication: the timing of linear hypoplasias on human anterior teeth. Am. J. Phys. Anthropol. 113, 135–139. https://doi.org/10.1002/1096-8644(200009)113:1<135::AID-AJPA13>3.0.CO;2-A

Reinecke, P., 1941. Zu Grabfunden langobardischer Zeit aus Italien. Ger. Anzeiger der Römisch-Germanischen Kommission des Dtsch. Archäologischen Instituts 25, 42–47.

Reitsema, L.J., McIlvaine, B.K., 2014. Reconciling “stress” and “health” in physical anthropology: What can bioarchaeologists learn from the other subdisciplines? Am. J. Phys. Anthropol. 155. https://doi.org/10.1002/ajpa.22596

Renhart, S., 2008. Anthropologische Analyse der Bestattungen aus der Stiftskirche von St. Lorenzen- Kloster Sonnenburg (Pustertal). Atti Accad. Roveretania Agiati VIII, 431–477.

Renhart, S., 2006. Anthropologische Untersuchungen von 11 Frühmittelalterlichen Baumsargbestattungen aus Elzenbaum (Gem. Freienfeld, Südtirol), Grabungsjahr 1996. Atti Accad. Roveretania Agiati VIII, 363–387.

Renhart, S., 1991. Anthropologie: den Menschen von St. Prokulus auf der Spur, in: Nothdurfter, H. (Ed.), Sonderaustellung in Schloß Tirol-St. Prokulus in Naturns- Ergrabene Geschichte von Den Menschen Des Frühmittelalters Und Der Pestzeit. Südtiroler Landesmuseum für Archäologie, Schloß Tirol, pp. 153–190.

Resnick, D., Niwayama, G., 1978. Intravertebral Disk Herniations: Cartilaginous (Schmorl's) Nodes. Radiology 126, 57–65. https://doi.org/10.1148/126.1.57

Reule, C.A., Alt, W.W., 2011. Individuelle Risikofaktoren für Achillessehnenbeschwerden bei laufbetonten Sportarten. Dtsch. Z. Sportmed. 62, 150–154.

Rhine, J.S., 1990. Non-metric skull racing, in: Gill, G., Rhine, S. (Eds.), Skeletal Attribution of Race: Methods for Forensic Anthropology. University of New Mexico, New Mexico.

Rhode, M.P., 2006. Habitual subsistence practices among prehistoric Andean populations : fishers and farmers. University of Missouri--Columbia. https://doi.org/10.32469/10355/4374

Riddervold, I.S., Bønløkke, J.H., Olin, A.-C., Grønborg, T.K., Schlünssen, V., Skogstrand, K., Hougaard, D., Massling, A., Sigsgaard, T., 2012. Effects of wood smoke particles from wood-burning stoves on the respiratory health of atopic humans. Part. Fibre Toxicol. 9, 12. https://doi.org/10.1186/1743-8977-9-12

Robbins, G., Mushrif Tripathy, V., Misra, V.N., Mohanty, R.K., Shinde, V.S., Gray, K.M., Schug, M.D., 2009. Ancient skeletal evidence for leprosy in India (2000 B.C.). PLoS One 4, 1–8. https://doi.org/10.1371/journal.pone.0005669

Roberts, C., Manchester, K., 2010. The Archaeology of Disease, 3rd ed. The History Press, Stroud.

Roberts, C.A., Cox, M.J., 2003. Health and Disease in Britain: From Prehistory to the Present Day. Sutton Publishing, Stroud.

Robertson, D., Smith, A.J., 2009. The microbiology of the acute dental abscess. J. Med. Microbiol. 58, 155–162. https://doi.org/10.1099/jmm.0.003517-0

Rodríguez-Martín, C., 2006. Identification and differential diagnosis of traumatic lesions of the skeleton. Forensic Anthropol. Med. Complement. Sci. From Recover. to Cause Death 197–221. https://doi.org/10.1007/978-1-59745-099-7_8

Rogers, J., Waldron, T., 2001. DISH and the monastic way of life. Int. J. Osteoarchaeol. 11, 357–365. https://doi.org/10.1002/oa.574

Rogers, J., Waldron, T., 1995. Field Guide to Joint Disease. John Wiley & Sons Ltd., Chichester.

Rok Chang, S., Park, S., Freivalds, A., 1999. Ergonomic evaluation of the effects of handle types on garden tools. Int. J. Ind. Ergon. 24, 99–105. https://doi.org/10.1016/S0169-8141(98)00091-2

Romero-Gutiérrez, G., Espitia-Vera, A., Ponce-Ponce de León, A.L., Huerta-Vargas, L.F., 2007. Risk Factors of Maternal Death in Mexico. Birth 34, 21–25. https://doi.org/10.1111/j.1523-536X.2006.00142.x

Roschmann, A., 1751. De episcopatu Sabionensi S. Cassiani martyris deque S. Ingenuini eiusdem urbis episcopi actis Hieronymi. Wagner, Ulm.

Rosen, C., Glowacki, J., Bilzenkian, J.P., 1999. The Aging Skeleton. Academic Press, San Diego.

Roser, M., Ortiz-Ospina, E., Ritchie, H., 2013a. Life Expectancy [WWW Document]. Our World Data. URL https://ourworldindata.org/life-expectancy

Roser, M., Ritchie, H., Dadonaite, B., 2013b. Child and Infant Mortality [WWW Document]. Our World Data. URL https://ourworldindata.org/child-mortality

Rossignol, M., 2005. Primary osteoarthritis of hip, knee, and hand in relation to occupational exposure. Occup. Environ. Med. 62, 772–777. https://doi.org/10.1136/oem.2005.020057

Rouge-Maillart, C., Vielle, B., Jousset, N., Chappard, D., Telmon, N., Cunha, E., 2009. Development of a method to estimate skeletal age at deat in adults using the acetabulum and the auricular surface on a Portuguese population. Forensic Sci. Int. 188, 91–95. https://doi.org/10.1016/j.forsciint.2009.03.019

Ruff, C., 2019. Biomechanical Analyses of Archaeologicla Human Skeletons, in: Katzenberg, A.M., Grauer, A. (Eds.), Biological Anthropology of the Human Skeleton. John Wiley & Sons Ltd., Oxford, pp. 189–224.

Ruff, C., 2002. Variation in Human Body Size and Shape. Annu. Rev. Anthropol. 31, 211–232. https://doi.org/10.1146/annurev.anthro.31.040402.085407

Ruff, C.B., Garofalo, E., Holmes, M.A., 2013. Interpreting skeletal growth in the past from a functional and physiological perspective. Am. J. Phys. Anthropol. https://doi.org/10.1002/ajpa.22120

Ruff, C.B., Holt, B.M., Sládek, V., Berner, M., Murphy, W.A., zur Nedden, D., Seidler, H., Recheis, W., 2006. Body size, body proportions, and mobility in the Tyrolean "Iceman." J. Hum. Evol. 51, 91–101. https://doi.org/10.1016/j.jhevol.2006.02.001

Sadiqi, F., 2007. The Role of Moroccan Women in Preserving Amazigh Language and Culture. Museum Int. 59, 26–33. https://doi.org/10.1111/j.1468-0033.2007.00620.x

Sajko, S., Stuber, K., 2009. Psoas Major: a case report and review of its anatomy, biomechanics, and clinical implications. J. Can. Chiropr. Assoc. 53, 311–318.

Salo, K., 2016. Health in Southern Finland Bioarchaeological analysis of 555 skeletons excavated from nine cemeteries (11th-19th century AD). University of Helsinki.

Salo, K., 2005. What Ancient Human Teeth Can Reveal ? Demography , Health , Nutrition and Biological Relations in Luistari. University of Helsinki.

Salter, D.M., 2002. Degenerative joint disease. Curr. Diagnostic Pathol. 8, 11–18. https://doi.org/10.1054/cdip.2001.0090

Saluja, G., Fitzpatrick, K., Bruce, M., Cross, J., 1986. Schmorl's nodes (intravertebral herniations of intervertebral disc tissue) in two historic British populations. J. Anat. 145, 87–96.

Sandmark, H., Hogstedt, C., Vingard, E., 2000. Primary osteoarthrosis of the knee in men and women as a result of lifelong physical load from work. Scand. J. Work. Environ. Health 26, 20–25.

Santana-Cabrera, J., Velasco-Vázquez, J., Rodríguez-Rodríguez, A., 2015. Entheseal changes and sexual division of labor in a North-African population: The case of the pre-Hispanic period of the Gran Canaria Island (11th-15th c. CE). HOMO- J. Comp. Hum. Biol. 66. https://doi.org/10.1016/j.jchb.2014.10.005

Sarti, L., 2013. Perceiving War and the Military in Early Christian Gaul (ca. 400-700 A.D.). Brill, Leiden.

Sauberlich, H.E., 1994. Pharmacology of Vitamin C. Annu. Rev. Nutr. 14, 371–391. https://doi.org/10.1146/annurev.nu.14.070194.002103

Sauer, N.J., 1998. The timing of injuries and manner of death: distinguishing among antemortem, perimortem and postmortem trauma., in: Reich, K. (Ed.), Forensic Osteology: Advances in the Identification of Human Remains. Charles C Thomas, Springfield, pp. 321–332.

Sauer, N.J., 1992. Forensic anthropology and the concept of race: If races don't exist, why are forensic anthropologists so good at identifying them? Soc. Sci. Med. 34, 107–111. https://doi.org/10.1016/0277-9536(92)90086-6

Saul, F.P., Saul, J.M., 1989. Osteobiography: A Maya Example, in: Iscan, M.Y., Kennedy, K.A.R. (Eds.), Reconstruction of Life from the Skeleton. Alan R. Liss, New York, pp. 287–302.

Sauser, G., 1938. Die Ötztaler- Anthropologie und Anatomie einer Tiroler Talschaft. Naturwissenschaftlich-medizinischer Verein, Innsbruck.

Sawyer, C.C., 2012. Child Mortality Estimation: Estimating Sex Differences in Childhood Mortality since the 1970s. PLoS Med. 9, e1001287. https://doi.org/10.1371/journal.pmed.1001287

Sayer, D., 2014. 'Sons of athelings given to the earth': Infant Mortality within Anglo-Saxon Mortuary Geography. Mediev. Archaeol. 58, 78–103. https://doi.org/10.1179/0076609714Z.00000000032

Sayer, D., 2013a. Investigating the Social Aspects Early Medieval Mortuary Practice. Hist. Compass 11, 147–162. https://doi.org/10.1111/hic3.12030

Sayer, D., 2013b. Christian Burial Practice in the Early Middle Ages: Rethinking the Anglo-Saxon Funerary Sphere. Hist. Compass 11, 133–146. https://doi.org/10.1111/hic3.12028

Schats, R., 2021. Cribriotic lesions in archaeological human skeletal remains. Prevalence, co-occurrence, and association in medieval and early modern Netherlands. Int. J. Paleopathol. 35, 81–89. https://doi.org/10.1016/j.ijpp.2021.10.003

Schats, R., 2015. Malaise and mosquitos: osteoarchaeological evidence for malaria in the medieval Nehterlands. Analecta Praehist. Leiden 45, 133–140.

Schattmann, A., Bertrand, B., Vatteoni, S., Brickley, M., 2016. Approaches to co-occurrence: Scurvy and rickets in infants and young children of 16-18th century Douai, France. Int. J. Paleopathol. 12, 63–75. https://doi.org/10.1016/j.ijpp.2015.12.002

Scheffler, C., 2011. The change of skeletal robustness of 6-12 years old children in Brandenburg (Germany) - Comparison of body composition 1999-2009. Anthropol. Anzeiger 68, 153–165. https://doi.org/10.1127/0003-5548/2011/0095

Scheffler, C., Hermanussen, M., 2021. Stunting is the natural condition of human height. Am. J. Hum. Biol. e23693. https://doi.org/10.1002/ajhb.23693

Scheffler, C., Hermanussen, M., Soegianto, S.D.P., Homalessy, A.V., Touw, S.Y., Angi, S.I., Ariyani, Q.S., Suryanto, T., Matulessy, G.K.I., Fransiskus, T., Safira, A.V.C., Puteri, M.N., Rahmani, R., Ndaparoka, D.N., Payong, M.K.E., Indrajati, Y.D., Purba, R.K.H., Manubulu, R.M., Julia, M., Pulungan, A.B., 2021. Stunting as a Synonym of Social Disadvantage and Poor Parental Education. Int. J. Environ. Res. Public Health 18, 1350. https://doi.org/10.3390/ijerph18031350

Scheuch, M., 1994. Österreich- Provinz, Weltreich, Republik. Ein historischer Atlas. Das Beste, Wien.

Scheuer, L., Black, S., 2004. The Juvenile Skeleton. Elsevier, Oxford.

Scheuer, L., Black, S., 2000. Developmental Juvenile Osteology. Academic Press (Elsevier), Oxford.

Scheuer, L., Black, S., Christie, A., 2000. Developmental Juvenile Osteology, Developmental Juvenile Osteology. Academic Press (Elsevier), London. https://doi.org/10.1016/B978-

012624000-9/50015-0

Schlecht, S.H., 2012. Understanding Entheses: Bridging the Gap Between Clinical and Anthropological Perspectives. Anat. Rec. Adv. Integr. Anat. Evol. Biol. 295, 1239–1251. https://doi.org/10.1002/ar.22516

Schmidt, R.A., Schröder, I.W., 2001. Anthropology of Violence and Conflict. Taylor & Francis Group, London.

Schmitt, A., Cunha, E., Pinheiro, J., 2006. Forensic Anthropology and Medicine Complementary Sciences From Recovery to Cause of Death. Humana Press, New Jersey.

Schrader, S., 2019. Bioarchaeological Approaches to Activity Reconstruction, in: Martin, D. (Ed.), Activity, Diet and Social Practice. Springer, pp. 55–126. https://doi.org/10.1007/978-3-030-02544-1_3

Schrader, S.A., 2012. Activity patterns in New Kingdom Nubia: An examination of entheseal remodeling and osteoarthritis at Tombos. Am. J. Phys. Anthropol. 149, 60–70. https://doi.org/10.1002/ajpa.22094

Schroeder, H., Margaryan, A., Szmyt, M., Theulot, B., Włodarczak, P., Rasmussen, S., Gopalakrishnan, S., Szczepanek, A., Konopka, T., Jensen, T.Z.T., Witkowska, B., Wilk, S., Przybyła, M.M., Pospieszny, Ł., Sjögren, K.G., Belka, Z., Olsen, J., Kristiansen, K., Willerslev, E., Frei, K.M., Sikora, M., Johannsen, N.N., Allentoft, M.E., 2019. Unraveling ancestry, kinship, and violence in a Late Neolithic mass grave. Proc. Natl. Acad. Sci. U. S. A. 166. https://doi.org/10.1073/pnas.1820210116

Schulte, F.A., Ruffoni, D., Lambers, F.M., Christen, D., Webster, D.J., Kuhn, G., Müller, R., 2017. Local Mechanical Stimuli Regulate Bone Formation and Resorption in Mice at the Tissue-Level, in: Calloway, R. (Ed.), Biomechancis Bones and Joints. Hayle Medical, New York, pp. 34–45.

Schulze-Tanzil, G., 2019. Intraarticular Ligament Degeneration Is Interrelated with Cartilage and Bone Destruction in Osteoarthritis. Cells 8, 990. https://doi.org/10.3390/cells8090990

Schümann, K., Hunder, G., 1997. Die anthropogene Bleibelastung und ihre Risiken. Pharm. Unserer Zeit 26, 143–151. https://doi.org/10.1002/pauz.19970260307

Semmler, J., 1999. Zum Wirken von Mönchen und Bischöfen aus dem Merowingerreich im südöstlichen Vorfeld, in: Loose, R., Lorenz, S. (Eds.), König, Kirche, Adel-Herrschaftsstrukturen Im Mittleren Alpenraum Und Angrenzenden Gebieten (6.-13. Jahrhundert). Tappeiner, Bozen, pp. 35–52.

Sennhauser, H.R., 2003. Frühe Kirchen im östlichen Alpengebiet- Von der Spätantike bis in ottonische Zeit, 1st ed. Bayerische Akademie der Wissenschaften, München.

Sennhauser, H.R., 1999. Kloster Müstair, Gründungszeit und Kalstradition, in: Loose, R., Lorenz, S. (Eds.), König, Kirche, Adel- Herrschaftsstrukturen Im Mittleren Alpenraum Und Angrenzenden Gebieten (6.-13. Jahrhundert). Tappeiner, Bozen, pp. 125–150.

Seo, M., Guk, S.-M., Kim, J., Chai, J.-Y., Bok, G.D., Park, S.S., Oh, C.S., Kim, M.J., Yi, Y.S., Shin, M.H., Kang, I.U., Shin, D.H., 2007. Paleoparasitological report on the stool from a medieval child mummy in Yangju, Korea. J. Parasitol. 93, 589–592. https://doi.org/10.1645/GE-905R3.1

Setiawan, I., Lesmana, D., Marhaeni Diah Herawati, D., Sufiawati, I., Widyaputra, S., 2021. Correlation between the Macronutrient Content of Dental Calculus and the FFQ-Based

Nutritional Intake of Obese and Normal-Weight Individuals. Int. J. Dent. 2021, 1–8. https://doi.org/10.1155/2021/5579208

Setzer, T.J., 2014. Malaria detection in the field of paleopathology: A meta-analysis of the state of the art. Acta Trop. 140, 97–104. https://doi.org/10.1016/j.actatropica.2014.08.010

Shane Anderson, A., Loeser, R.F., 2010. Why is osteoarthritis an age-related disease? Best Pract. Res. Clin. Rheumatol. 24, 15–26. https://doi.org/10.1016/j.berh.2009.08.006

Shane Tubbs, R., Shah, N.A., Marchase, N.D., Cömert, A., Acar, H.I., Tekdemir, I., Loukas, M., Shoja, M.M., 2009. The costoclavicular ligament revisited: A functional and anatomical study. Rom. J. Morphol. Embryol. 50, 475–9.

Shapland, F., Lewis, M., Watts, R., 2016. The Lives and Deaths of Young Medieval Women: The Osteological Evidence. Mediev. Archaeol. 59, 272–289. https://doi.org/10.1080/00766097.2015.1119392

Shatrugna, V., Kulkarni, B., Kumar, P.A., Balakrishna, N., Rani, K.U., Reddy, G.C., Rao, G.V.N., 2008. Relationship between women's occupational work and bone health: a study from India. Br. J. Nutr. 99, 1310–1315. https://doi.org/10.1017/S0007114507868504

Shimada, I., Shinoda, K., Farnum, J., Corruccini, R., Watanabe, H., 2004. An Integrated Analysis of Pre-Hispanic Mortuary Practices. Curr. Anthropol. 45, 369–402. https://doi.org/10.1086/382249

Sick, J., 2021. Entheseal Changes: Benefits, Limitations and Applications in Bioarchaeology. Pathways 2, 14–35. https://doi.org/10.29173/pathways25

Siegmund, F., 2010. Die Körpergröße der Menschen in der Ur- und Frühgeschichte Mitteleuropas und ein Vergleich ihrer anthropologischen Schätzmethoden. Books on Demand Gmbh, Norderstedt.

Siegmund, F., Papageorgopoulou, C., 2011. Body Mass and Body Mass Index estimation in medieval Switzerland. Bull. der Schweizerischen Gesellschaft für Anthropol. 17, 35–44.

Silk, H., Douglass, A.B., Douglass, J.M., Silk, L., 2008. Oral health during pregnancy. Am. Fam. Physician 77, 1139–44.

Silva Junior, M.F., Batista, M.J., de Sousa, M. da L.R., 2019. Risk factors for tooth loss in adults: A population-based prospective cohort study. PLoS One 14, e0219240. https://doi.org/10.1371/journal.pone.0219240

Singh, S.P., Sinha, S., Choudhary, S.K., Sarker, G., Kumar, P., Shahnawaz, K., 2014. Diarrhoea and its association with the time of weaning and dietary habits of children. J. Evol. Med. Dent. Sci. 3, 10047–10052. https://doi.org/10.14260/jemds/2014/3302

Singman, Jeffrey, L., Forgeng, J.L., 1999. Daily Life in Medieval Europe. Greenwood Publishing Group, Westport.

Sjöstrand, P.A., 2015. Origins and Adaptation in Humans a Case Study of Taste and Lifestyle. Uppsala University.

Skalic, C., 2018. A critical approach to ancestry in Forensic Anthropology: An Assessment of Fordisc 3.1 and AncesTrees. University of Windsor.

Skinner, M.F., Skinner, M.M., Pilbrow, V.C., Hannibal, D.L., 2016. An Enigmatic Hypoplastic Defect of the Maxillary Lateral Incisor in Recent and Fossil Orangutans from Sumatra (Pongo abelii) and Borneo (Pongo pygmaeus). Int. J. Primatol. 37, 548–567.

https://doi.org/10.1007/s10764-016-9920-2

Šlaus, M., 1996. Demography and disease in the Early Medieval site of Privlaka. Opvscvla Archaeol. Rad. Arheol. zavoda-Opuscula Archaeol. Pap. Dep. Archaeol. 20, 141–149.

Šlaus, M., Novak, M., Bedic, Z., Strinovic, D., 2012. Bone Fractures as Indicators of Intentional Violence in the Eastern Adriatic From the Antique to the Late Medieval Period (2nd-16th century AD). Am. J. Phys. Anthropol. 149, 26–38.

Šlaus, M., Novak, M., Vyroubal, V., Bedic, Z., 2010. The harsh life of the 15th century Croatia-Ottoman Empire Military Border: Analyzing and Identifying the Reasons for the Massacre in Cepin. Am. J. Phys. Anthropol. 141, 358–372.

Šlaus, M., Pećina-Šlaus, N., Brkić, H., 2004. Life stress on the Roman limes in continental Croatia. HOMO-Journal Comp. Hum. … 54, 240–263. https://doi.org/10.1078/0018-442X-00072

Smith-Guzman, N.E., 2015. The skeletal manifestation of malaria: An epidemiological approach using documented skeletal collections. Am. J. Phys. Anthropol. 158, 624–635. https://doi.org/10.1002/ajpa.22819

Smith-Guzmán, N.E., 2015. Cribra orbitalia in the ancient Nile Valley and its connection to malaria. Int. J. Paleopathol. 10, 1–12. https://doi.org/10.1016/j.ijpp.2015.03.001

Smith, K.R., Samet, J.M., Romieu, I., Bruce, N., 2000. Indoor air pollution in developing countries and acute lower respiratory infections in children. Thorax 55, 518 LP – 532. https://doi.org/10.1136/thorax.55.6.518

Smith, L.W., Baer, P.N., King, C.T.G., White, C.L., 1963. Studies on Experimental Calculus Formation in the Rat III. Calculus Formation as Influenced by High Fat, High Carbohydrate Diets, and Sucrose in the Drinking Water. J. Periodontol. 34, 327–329. https://doi.org/10.1902/jop.1963.34.4.327

Smith, M., 2017. Mortal Wounds- The Human Skeleton as Evidence for Conflict in the Past. Pen & Sword Military, Barnsley.

Smith, M.O., Dorsz, J.R., Betsinger, T.K., 2013. Diffuse idiopathic skeletal hyperostosis (DISH) in pre-Columbian North America: Evidence from the eastern Tennessee River Valley. Int. J. Paleopathol. 3, 11–18. https://doi.org/10.1016/j.ijpp.2013.03.001

Snoddy, A.M.E., Buckley, H.R., Elliott, G.E., Standen, V.G., Arriaza, B.T., Halcrow, S.E., 2018. Macroscopic features of scurvy in human skeletal remains: A literature synthesis and diagnostic guide. Am. J. Phys. Anthropol. 167, 876–895. https://doi.org/10.1002/ajpa.23699

Sorta-Bilajac, I., 2004. Indian Bioethics: the Issue of Female Feoticide and Infanticide. A Sikh Perspective. Ethics Polit. 6, 1–8.

Sparber, A., 1942. Das Bistum Sabiona in seiner geschichtlichen Entwicklung. Tipografia A. Wegner, Bressanone.

Spatola, B.F., 2015. Atypical gunshot and blunt force injuries: wounds along the biomechanical continuum, in: Passalacqua, N. V., Rainwater, C.W. (Eds.), Skeletal Trauma Analysis. Wiley-Blackwell, New York.

Sperduti, A., 1997. Life Conditions of a Roman Imperial Age Population: Occupational Stress Markers and Working Activities in Lucus Feroniae (Rome, 1st- 2nd cent. AD). Hum. Evol. 12, 253–267.

Spoorenberg, T., 2016. On the masculinization of population: The contribution of demographic development -- A look at sex ratios in Sweden over 250 years. Demogr. Res. 34, 1053–1062. https://doi.org/10.4054/DemRes.2016.34.37

Spradley, K.M., Jantz, R.L., 2011. Sex estimation in forensic anthropology: Skull versus postcranial elements. J. Forensic Sci. 56, 289–296.

Starling, A.P., Stock, J.T., 2007. Dental indicators of health and stress in early Egyptian and Nubian agriculturalists: A difficult transition and gradual recovery. Am. J. Phys. Anthropol. 134, 520–528. https://doi.org/10.1002/ajpa.20700

Steckel, R., Larsen, C., Sciulli, P., Walker, P., 2006. Data collection codebook, The global history of health project. Ohio State University, Ohio.

Steckel, R.H., 2005. Young adult mortality following severe physiological stress in childhood: Skeletal evidence. Econ. Hum. Biol. 3, 314–328. https://doi.org/10.1016/j.ehb.2005.05.006

Steckel, R.H., Larsen, C.S., Roberts, C.A., Baten, J., 2018. The Backbone of Europe, 1st ed. Cambridge University Press, Cambridge. https://doi.org/10.1017/9781108379830

Steckel, R.H., Rose, J.C., 2002. The backbone of History Health and Nutrition in the Western Hemisphere. Cambridge University Press, Cambridge.

Stenholm, S., Head, J., Aalto, V., Kivimäki, M., Kawachi, I., Zins, M., Goldberg, M., Platts, L.G., Zaninotto, P., Magnusson Hanson, L.L., Westerlund, H., Vahtera, J., 2017. Body mass index as a predictor of healthy and disease-free life expectancy between ages 50 and 75: a multicohort study. Int. J. Obes. 41, 769–775. https://doi.org/10.1038/ijo.2017.29

Stewart, T.D., 1979. Essentials of Forensic Anthropology. C.C. Thomas, Springfield.

Stewart, T.D., 1958. The rate of development of vertebral osteoarthritis in American whites and its significance in skeletal age identification. Leech 28, 144–151.

Stinson, S., Bogin, B., O'Rourke, D.H., 2012. Human Biology: An Evolutionary and Biocultural Perspective, 2nd ed. Wiley-Blackwell, New Jersey.

Stirland, A.J., 2002. Raising the dead: The Skeleton Crew of King Henry VIII's Great Ship, the Mary Rose. John Wiley & Sons, Ltd, Chichester.

Stirland, A.J., Waldron, T., 1997. Evidence for Activity Related Markers in the Vertebrae of the Crew of the Mary Rose. J. Archaeol. Sci. 24, 329–335. https://doi.org/10.1006/jasc.1996.0117

Sture, J.F., 2001. Biocultural Perspectives on Birth Defects in Medieval Urban and Rural English Populations. Durham University.

Sung, K., Freivalds, A., 2014. Evaluating both Physiological and Biomechanical Strains in Women Using Different Hoe Handle Designs. Proc. Hum. Factors Ergon. Soc. Annu. Meet. 58, 1795–1799. https://doi.org/10.1177/1541931214581374

Surabian, D., 2012. Preservation of buried human remains in soil. U.S Dep. Agric. Nat. Resour. Conserv. Serv. 1–54.

Suri, Vanita, Suri, Varun, 2014. Menopause and oral health. J. Midlife. Health 5, 115. https://doi.org/10.4103/0976-7800.141187

Sutherland, S., Matthews, D.C., 2003. Emergency management of acute apical periodontitis in the permanent dentition: a systematic review of the literature. J. Can. Dent. Assoc. 69, 160.

Szulc, P., Seeman, E., 2009. Thinking inside and outside the envelopes of bone. Osteoporos. Int. 20, 1281–1288. https://doi.org/10.1007/s00198-009-0994-y

Tanchev, P., 2017. Osteoarthritis or Osteoarthrosis: Commentary on Misuse of Terms. Reconstr. Rev. 7. https://doi.org/10.15438/rr.7.1.178

Tappeiner, F., 1883. Studien zur Anthropologie und der Sette Comuni. Wagner, Meran.

Tawha, T., Dinkele, E., Mole, C., Gibbon, V.E., 2020. Assessing zygomatic shape and size for estimating sex and ancestry in a South African sample. Sci. Justice. https://doi.org/10.1016/J.SCIJUS.2020.01.003

Teraguchi, M., Yoshimura, N., Hashizume, H., Muraki, S., Yamada, H., Minamide, A., Oka, H., Ishimoto, Y., Nagata, K., Kagotani, R., Takiguchi, N., Akune, T., Kawaguchi, H., Nakamura, K., Yoshida, M., 2014. Prevalence and distribution of intervertebral disc degeneration over the entire spine in a population-based cohort: the Wakayama Spine Study. Osteoarthr. Cartil. 22, 104–110. https://doi.org/10.1016/j.joca.2013.10.019

Terrenato, N., 2019. The Early Roman Expansion into Italy- Elite Negotiation and Family Agendas. Cambridge University Press, Cambridge.

Terzer, C., 2005. Die langobardischen Gräber von Civezzano. Zur Problematik von Altfunden und deren Interpretation, in: Landi, W. (Ed.), Romanan Und Germanen Im Herzen Der Alpen. Athesia, Bozen, pp. 297–313.

Thomson, A., 1889. The influence of posture on the form of the articular surfaces of the tibia and astragalus in the different races of man and the higher apes. J. Anat. Physiol. 23, 616–639.

Tillmann, B.N., 2016. Atlas der Anatomie des Menschen, Springer-Lehrbuch. Springer Berlin Heidelberg, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-49288-8

Todd, T.W., 1920. Age Changes in the Pubic Bone I the male white pubis. Am. J. Phys. Anthropol. Ill, 285–328. https://doi.org/10.1002/ajpa.1330030301

Todd, T.W., Lyon, J.D.W., 1924. Endocranial suture closure. Part I. Adult males of white stock. Am. J. Phys. Anthropol. 7, 325–384.

Torroni, A., Rengo, C., Guida, V., Cruciani, F., Sellitto, D., Coppa, A., Calderon, F.L., Simionati, B., Valle, G., Richards, M., Macaulay, V., Scozzari, R., 2001. Do the Four Clades of the mtDNA Haplogroup L2 Evolve at Different Rates? Am. J. Hum. Genet 69, 1348–1356. https://doi.org/10.1086/324511

Touger-Decker, R., van Loveren, C., 2003. Sugars and dental caries. Am. J. Clin. Nutr. 78, 881S-892S. https://doi.org/10.1093/ajcn/78.4.881S

Towle, I., Irish, J.D., 2019. A probable genetic origin for pitting enamel hypoplasia on the molars of Paranthropus robustus. J. Hum. Evol. 129, 54–61. https://doi.org/10.1016/j.jhevol.2019.01.002

Townsley, W., 1948. The influence of mechanical factors on the development and structure of bone. Am. J. Phys. Anthropol. 6, 25–46. https://doi.org/10.1002/ajpa.1330060109

Troeger, C., Blacker, B., Khalil, I.A., Rao, P.C., Cao, J., Zimsen, S.R.M., Albertson, S.B., Deshpande, A., Farag, T., Abebe, Z., Adetifa, I.M.O., Adhikari, T.B., Akibu, M., Al Lami, F.H., Al-Eyadhy, A., Alvis-Guzman, N., Amare, A.T., Amoako, Y.A., Antonio, C.A.T., Aremu, O., Asfaw, E.T., Asgedom, S.W., Atey, T.M., Attia, E.F., Avokpaho, E.F.G.A., Ayele, H.T., Ayuk, T.B., Balakrishnan, K., Barac, A., Bassat, Q., Behzadifar, Masoud, Behzadifar, Meysam, Bhaumik, S., Bhutta, Z.A., Bijani, A., Brauer, M., Brown, A., Camargos, P.A.M., Castañeda-Orjuela, C.A., Colombara, D., Conti, S., Dadi, A.F., Dandona, L., Dandona, R., Do, H.P., Dubljanin, E., Edessa, D., Elkout, H., Endries, A.Y., Fijabi, D.O., Foreman, K.J., Forouzanfar, M.H., Fullman, N., Garcia-Basteiro, A.L., Gessner, B.D., Gething, P.W., Gupta, R., Gupta, T., Hailu, G.B., Hassen, H.Y., Hedayati, M.T., Heidari, M., Hibstu, D.T., Horita, N., Ilesanmi, O.S., Jakovljevic, M.B., Jamal, A.A., Kahsay, A., Kasaeian, A., Kassa, D.H., Khader, Y.S., Khan, E.A., Khan, M.N., Khang, Y.-H., Kim, Y.J., Kissoon, N., Knibbs, L.D., Kochhar, S., Koul, P.A., Kumar, G.A., Lodha, R., Magdy Abd El Razek, H., Malta, D.C., Mathew, J.L., Mengistu, D.T., Mezgebe, H.B., Mohammad, K.A., Mohammed, M.A., Momeniha, F., Murthy, S., Nguyen, C.T., Nielsen, K.R., Ningrum, D.N.A., Nirayo, Y.L., Oren, E., Ortiz, J.R., PA, M., Postma, M.J., Qorbani, M., Quansah, R., Rai, R.K., Rana, S.M., Ranabhat, C.L., Ray, S.E., Rezai, M.S., Ruhago, G.M., Safiri, S., Salomon, J.A., Sartorius, B., Savic, M., Sawhney, M., She, J., Sheikh, A., Shiferaw, M.S., Shigematsu, M., Singh, J.A., Somayaji, R., Stanaway, J.D., Sufiyan, M.B., Taffere, G.R., Temsah, M.-H., Thompson, M.J., Tobe-Gai, R., Topor-Madry, R., Tran, B.X., Tran, T.T., Tuem, K.B., Ukwaja, K.N., Vollset, S.E., Walson, J.L., Weldegebreal, F., Werdecker, A., West, T.E., Yonemoto, N., Zaki, M.E.S., Zhou, L., Zodpey, S., Vos, T., Naghavi, M., Lim, S.S., Mokdad, A.H., Murray, C.J.L., Hay, S.I., Reiner, R.C., 2018. Estimates of the global, regional, and national morbidity, mortality, and aetiologies of lower respiratory infections in 195 countries, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet Infect. Dis. 18, 1191–1210. https://doi.org/10.1016/S1473-3099(18)30310-4

Trombley, T.M., Agarwal, S.C., Beauchesne, P.D., Goodson, C., Candilio, F., Coppa, A., Rubini, M., 2019. Making sense of medieval mouths: Investigating sex differences of dental pathological lesions in a late medieval Italian community. Am. J. Phys. Anthropol. 169, 253–269. https://doi.org/10.1002/ajpa.23821

Trotter, M., Gleser, G., 1958. A Re-Evaluation O F Estimation O F Stature Based on Measurements of Stature Taken During Life and of Long Bones After Death. Am. J. Phys. Anthropol. 16, 79–123. https://doi.org/10.1002/ajpa.1330160106

Trotter, M., Gleser, G.C., 1977. Corrigenda to “Estimation of stature from long limb bones of American Whites and Negroes”, in: American Journal Physical Anthropology (1952). Am. J. Phys. Anthropol. 47, 355–356. https://doi.org/10.1002/ajpa.1330470216

Trotter, M., Gleser, G.C., 1952. Estimation of stature from long bones of American Whites and Negroes. Am. J. Phys. Anthropol. 10, 463–514. https://doi.org/10.1002/ajpa.1330100407

Truszczyńska, A., Scherer, A., Drzał-Grabiec, J., 2016. The occurrence of overload at work and musculoskeletal pain in young physiotherapists. Work 54, 609–616. https://doi.org/10.3233/WOR-162343

Tsolakis, C., Kostaki, E., Vagenas, G., 2010. Anthropometric, Flexibility, Strength-Power, and Sport-Specific Correlates in Elite Fencing. Percept. Mot. Skills 110, 1015–1028. https://doi.org/10.2466/pms.110.C.1015-1028

Tsutaya, T., Yoneda, M., 2013. Quantitative Reconstruction of Weaning Ages in Archaeological Human Populations Using Bone Collagen Nitrogen Isotope Ratios and Approximate Bayesian Computation. PLoS One 8, e72327. https://doi.org/10.1371/journal.pone.0072327

Tucker, K., Berezina, N., Reinhold, S., Kalmykov, A., Belinskiy, A., Gresky, J., 2017. An accident at work? Traumatic lesions in the skeleton of a 4th millennium BCE “wagon driver” from Sharakhalsun, Russia. HOMO- J. Comp. Hum. Biol. 68. https://doi.org/10.1016/j.jchb.2017.05.004

Tumler, D., 2015. Paleopathological and musculoskeletal stress marker analysis of Early Medieval populations in Trentino-Alto Adige (Italy). Bournemouth University.

Tumler, D., Paladin, A., Zink, A., 2019. Perimortem sharp force trauma in an individual from the early medieval cemetery of Säben-Sabiona in South Tyrol, Italy. Int. J. Paleopathol. 27, 46–55. https://doi.org/10.1016/J.IJPP.2019.07.005

Tumler, D., Paladin, A., Zink, A.R., 2021. Trauma patterns and injury prevalence in early medieval Säben-Sabiona, Italy. Int. J. Osteoarchaeol. oa.2993. https://doi.org/10.1002/oa.2993

Turner, C.G., 1979. Dental anthropological indications of agriculture among the Jomon people of central Japan. X. Peopling of the Pacific. Am. J. Phys. Anthropol. 51, 619–635. https://doi.org/10.1002/ajpa.1330510413

Tyler, T.F., Fukunaga, T., Gellert, J., 2014. Rehabilitation of soft tissue injuries of the hip and pelvis. Int. J. Sports Phys. Ther. 9, 785.

Ubelaker, D.H., 2019. Recent advances in understanding hard tissue alterations related to trauma. Forensic Sci. Int. 299, 235–237. https://doi.org/10.1016/J.FORSCIINT.2018.08.035

Ubelaker, D.H., 1996. Pipe wear- dental impact of colonial American Culture. Anthropologie 34, 321–327.

Ubelaker, D.H., 1989. Human Skeletal Remains, excavation, analysis, interpretation, 2nd ed. Washington D.C.

Ubelaker, D.H., Pap, I., Alcantara-Russell, K., 2011. Skeletal evidence for morbidity and mortality in samples from Northeastern Hungary dating from the 10th century AD. Anthropologie 49, 171–183.

Ullathorne, O.S.B., 1856. A pilgrimage to the Proto-Monastery of Subiaco, and the Holy Grotto of St. Benedict. Rambl. 6, 334–345.

Uren, E., 2021. Health Disparities Between Women and Men in Medieval Europe: a Bioarchaeological Study of Gender Roles. Conspec. Boreal. 6, Article 6.

Üstündag, H., 2009. Schmorl's nodes in a post-medieval skeletal sample from Klostermarienberg, Austria. Int. J. Osteoarchaeol. 19, 695–710. https://doi.org/10.1002/oa.993

Valderrabano, V., Hintermann, B., Horisberger, M., Shing Fung, T., 2006. Ligamentouse posttraumatic ankle osteoarthritis. Am. J. Sports Med. 34, 612–620.

Van der Merwe, A.E., Maat, G.J.R., Watt, I., 2012. Diffuse idiopathic skeletal hyperostosis: Diagnosis in a palaeopathological context. HOMO- J. Comp. Hum. Biol. 63, 202–215. https://doi.org/10.1016/j.jchb.2012.03.005

Veselka, B., van der Merwe, A.E., Hoogland, M.L.P., Waters-Rist, A.L., 2018. Gender-related vitamin D deficiency in a Dutch 19th century farming community. Int. J. Paleopathol. 23, 69–75. https://doi.org/10.1016/J.IJPP.2017.11.001

Videman, T., Nurminen, M., Troup, J.D., 1990. Lumbar spinal pathology in cadaveric material in relation to history of back pain, occupation, and physical loading. Spine (Phila. Pa. 1976). 15, 728–740.

Villotte, S., 2006. Connaissances médicales actuelles, cotation des enthésopathies : nouvelle méthode. Bull. Mémoires la Société d'Anthropologie Paris 18, 1–2.

Villotte, S., Castex, D., Couallier, V., Dutour, O., Knüsel, C.J., Henry-Gambier, D., 2010a. Enthesopathies as occupational stress markers: Evidence from the upper limb. Am. J. Phys.

Anthropol. 142, 224–234. https://doi.org/10.1002/ajpa.21217

Villotte, S., Churchill, S.E., Dutour, O., Henry-Gambier, D., 2010b. Subsistence activities and the sexual division of labor in the European Upper Palaeolithic and Mesolithic: Evidence from upper limb enthesopathies. J. Hum. Evol. 59, 35–43.

Villotte, S., Knüsel, C.J., 2013. Understanding Entheseal Changes: Definition and Life Course Changes. Int. J. Osteoarchaeol. 23, 135–146. https://doi.org/10.1002/oa.2289

Vittore, S.B.D.S., Binotto, C.S., 2003. Via Claudia Augusta wo Kunst, Geschichte und Nature Zusammentreffen. Regione del Veneto, Vicenza.

Wagner, J.K., Yu, J.H., Ifekwunigwe, J.O., Harrell, T.M., Bamshad, M.J., Royal, C.D., 2017. Anthropologists' views on race, ancestry, and genetics. Am. J. Phys. Anthropol. https://doi.org/10.1002/ajpa.23120

Waldron, I., 1983. Sex differences in human mortality: The role of genetic factors. Soc. Sci. Med. 17, 321–333. https://doi.org/10.1016/0277-9536(83)90234-4

Waldron, T., 2009. Paleopathology. Cambridge University Press, Cambridge.

Waldron, T., 1995. Changes in the Distribution of Osteoarthritis over Historical Time. Int. J. Osteoarchaeol. 5, 385–389.

Waldron, T., 1993. The health of the adults, in: Molleson, T., Cox, M.J., Waldron, T., Whittaker, D.K. (Eds.), The Spitalfields Project. Volume 2: The Anthropology- The Middling Sort. Council for British Archaeology, York, pp. 67–89.

Walker-Bone, K., Palmer, K.T., 2002. Musculoskeletal disorders in farmers and farm workers. Occup. Med. (Chic. Ill). 52, 441–450.

Walker, P.L., 2008. Sexing skulls using discriminant function analysis of visually assessed traits. Am. J. Phys. Anthropol. 136, 39–50. https://doi.org/10.1002/ajpa.20776

Walker, P.L., Bathurst, R.R., Richman, R., Gjerdrum, T., Andrushko, V.A., 2009. The causes of porotic hyperostosis and cribra orbitalia: A reappraisal of the iron-deficiency-anemia hypothesis. Am. J. Phys. Anthropol. 139, 109–125. https://doi.org/10.1002/ajpa.21031

Wallace, I.J., Winchester, J.M., Su, A., Boyer, D.M., Konow, N., 2017. Physical activity alters limb bone structure but not entheseal morphology. J. Hum. Evol. 107. https://doi.org/10.1016/j.jhevol.2017.02.001

Waltenberger, L., Rebay-Salisbury, K., Mitteroecker, P., 2022. Are parturition scars truly signs of birth? The estimation of parity in a well-documented modern sample. Int. J. Osteoarchaeol. 32, 619–629. https://doi.org/10.1002/oa.3090

Walter, S., 2008. Das frühmittelalterliche Gräberfeld von Mengen (Kr. Breisgau-Hochschwarzwald). Ludwig Maximilians Universität.

Wang, T., Cessford, C., Dittmar, J.M., Inskip, S., Jones, P.M., Mitchell, P.D., 2022. Intestinal parasite infection in the Augustinian friars and general population of medieval Cambridge, UK. Int. J. Paleopathol. https://doi.org/10.1016/j.ijpp.2022.06.001

Wapler, U., Crubézy, E., Schultz, M., 2004. Is cribra orbitalia synonymous with anemia? Analysis and interpretation of cranial pathology in Sudan. Am. J. Phys. Anthropol. 123, 333–339. https://doi.org/10.1002/ajpa.10321

Watts, D., 2014. Christians and Pagans in Roman Britain (Routledge Revivals), Reprint. ed.

Routledge, New York.

Weisdorf, J., 2009. Why did the first farmers toil? Human metabolism and the origins of agriculture. Eur. Rev. Econ. Hist. 13, 157–172. https://doi.org/10.1017/S136149160900241X

Weiss, E., 2012. Calcaneal spurs: Examining etiology using prehistoric skeletal remains to understand present day heel pain. Foot 22, 125–129. https://doi.org/10.1016/j.foot.2012.04.003

Weiss, E., Jurmain, R., 2007. Osteoarthritis revisited: a contemporary review of aetiology. Int. J. Osteoarchaeol. 17, 437–450. https://doi.org/10.1002/oa.889

Weiss, K.M., Wobst, M., 1973. Demographic Models for Anthropology. Mem. Soc. Am. Archaeol. 27, 1–186.

Wellik, D.M., Capecchi, M.R., 2003. Hox10 and Hox11 Genes Are Required to Globally Pattern the Mammalian Skeleton. Science (80-.). 301, 363–367. https://doi.org/10.1126/science.1085672

Wells, C., 1964. Bones, bodies, and disease: evidence of disease and abnormality in early man. Thames and Hudson, London.

Wendling, D., Claudepierre, P., 2013. New bone formation in axial spondyloarthritis. Jt. Bone Spine 80, 454–458. https://doi.org/10.1016/j.jbspin.2013.02.004

Wescott, D.J., 2013. Biomechanics of Bone Trauma, in: Encyclopedia of Forensic Sciences. Elsevier, pp. 83–88. https://doi.org/10.1016/B978-0-12-382165-2.00015-5

Wheat, A., 2009. Assessing ancestry through nonmetric traits of the skull: A test of education and experience. Texas State University- San Marcos.

Wheatley, B., 2008. Perimortem or postmortem bone fractures? An experimental study of fracture patterns in deer femurs. J. Forensic Sci. 53, 69–72.

Wheeless, C., 2019. Wheeless’ Textbook of Orthopaedics [WWW Document]. Duke Orthop. URL http://www.wheelessonline.com/ortho/psoas (accessed 4.28.20).

White, T.D., Black, M.T., Folkens, P.A., 2012. Human Osteology, 3rd ed. Elsevier- Academic Press, Oxford.

White, T.E., 1953. A method of calculating the dietary percentage of various food animals utilized by aboriginal peoples. Am. Antiq. 18, 396–398.

WHO, 2005. The SuRF Report 2. Geneva.

WHO, W.H.O., 1999. Men ageing and health: Achieving health across the lifespan.

Wickes, I.G., 1953. A History of Infant Feeding: Part I. Primitive Peoples: Ancient Works: Renaissance Writers. Arch. Dis. Child. 28, 151–158. https://doi.org/10.1136/adc.28.138.151

Wilczak, C., Watkins, R., Null, C.C., Blakey, M.L., 2009. Skeletal Indicators of Work- Musculoskeletal, Arthritic, and Traumatic Effects, in: Blakey, M.L., Rankin-Hill, L.M. (Eds.), Skeltal Biology of the New York Burial Ground. Howard University Press, Washington D.C., pp. 199–223.

Wilding, A., Ingham, S.L., Lalloo, F., Clancy, T., Huson, S.M., Moran, A., Evans, D.G., 2012. Life expectancy in hereditary cancer predisposing diseases: an observational study. J. Med. Genet. 49, 264 LP – 269. https://doi.org/10.1136/jmedgenet-2011-100562

Wilks, D., Farrington, M., Rubenstein, D., 2003. The Infectious Diseases Manual, 2nd ed. Wiley, Oxford. https://doi.org/10.1002/9780470757253

Williams-Hatala, E.M., Hatala, K.G., Hiles, S., Rabey, K.N., 2016. Morphology of muscle attachment sites in the modern human hand does not reflect muscle architecture. Sci. Rep. https://doi.org/10.1038/srep28353

Williams, F.M.K., Manek, N.J., Sambrook, P.N., Spector, T.D., Macgregor, A.J., 2007. Schmorl's nodes: Common, highly heritable, and related to lumbar disc disease. Arthritis Rheum. 57, 855–860. https://doi.org/10.1002/art.22789

Williams, K.D., Meinzer, N.J., Larsen, C.S., 2019. History of Degenerative Joint Disease in People Across Europe- Bioarchaeological Inferences about Lifestyle and Activity from Osteoarthritis and Vertebral Osteophytosis, in: Steckel, R.H., Larsen, C.S., Roberts, C.A., Baten, J. (Eds.), The Backbone of Europe: Health, Diet, Work, and Violence over Two Millenia. Cambridge University Press, Cambridge, pp. 253–299.

Williams, L.R.T., Walmsley, A., 2000. Response Amendment in Fencing: Differences between Elite and Novice Subjects. Percept. Mot. Skills 91, 131–142. https://doi.org/10.2466/pms.2000.91.1.131

Winckler, K., 2012. Die Alpen in Frühmittelalter: Die Geschichte eines Raumes in den Jahren 500 bis 800. Böhlau, Wien.

Witt, K.A., Bush, E.A., 2005. College athletes with an elevated body mass index often have a high upper arm muscle area, but not elevated triceps and subscapular skinfolds. J. Am. Diet. Assoc. 105, 599–602. https://doi.org/10.1016/j.jada.2005.01.008

Wittwer-Backofen, U., Gampe, J., Vaupel, J.W., 2004. Tooth cementum annulation for age estimation: Results from a large known-age validation study. Am. J. Phys. Anthropol. 123, 119–129. https://doi.org/10.1002/ajpa.10303

Wolfram, H., 1995a. Grenzen und Räume. Geschichte Österreichs vor seiner Entstehung. Überreuter, Wien.

Wolfram, H., 1995b. Salzburg, Bayern, Österreich. Die Conversio Bagoariorum et Carantanorum und die Quellen ihrer Zeit. Oldenbourg (Mitteilungen des Instituts für Österreichische Geschichtsforschung Ergänzungsband 31), Wien.

Woo, E.J., Pak, S., 2013. Degenerative joint diseases and enthesopathies in a Joseon Dynasty population from Korea. HOMO- J. Comp. Hum. Biol. 64, 104–119. https://doi.org/10.1016/j.jchb.2013.02.001

Wood, J.W., Milner, G.R., Harpending, H.C., Weiss, K.M., Cohen, M.N., Eisenberg, L.E., Hutchinson, D.L., Jankauskas, R., Cesnys, G., Katzenberg, A.M., Lukacs, J.R., McGrath, J.W., Abella Roth, E., Ubelaker, D.H., Wilkinson, R.G., 1992. The osteological paradox: problems of inferring prehistoric health from skeletal samples. Curr. Anthropol. 33, 343–370.

Woolgar, C.M., Waldron, T., Serjeantson, D., 2006. Food in medieval England: Diet and Nutrition. Oxford University Press, Oxford.

Wright, J., 2015. Reconstructing Activity Patterns at Epidamnus, Albania: Impacts of Greek and Roman Colonizations. Univ. Nothern Color. Undergrad. Res. J. McNair Sch. Ed. 4, 139–152.

Yaussy, S.L., DeWitte, S.N., Redfern, R.C., 2016. Frailty and famine: Patterns of mortality and physiological stress among victims of famine in medieval London. Am. J. Phys. Anthropol. 160. https://doi.org/10.1002/ajpa.22954

Yorke-Edwards, V., 2019. Obesity in London 1700-1850. University College London.

Zagermann, M., 2014. Spätromische Kleidungs- und Ausrüstungsbestandteile entlang der via Claudia Augusta in Nordtirol, Südtirol und im Trentino. Frankfurt.

Zanier, W., 2017. Die frührömische Holz-Kies-Straße im Eschenloher Moos (Münchner Beiträge zur Vor- und Frühgeschichte 64). Beck, C.H., München.

Zarulli, V., Barthold Jones, J.A., Oksuzyan, A., Lindahl-Jacobsen, R., Christensen, K., Vaupel, J.W., 2018. Women live longer than men even during severe famines and epidemics. Proc. Natl. Acad. Sci. 115, E832–E840. https://doi.org/10.1073/pnas.1701535115

Zellweger, J.P., Lustenberger, J., Gygax, H., Van Melle, G., 1993. Ozone, respiratory function and bronchial reactivity. Study of a group of pre-Alpine agricultural workers. Schweiz. Med. Wochenschr. 123, 1013–1019.

Zhang, H., Merrett, D.C., Jing, Z., Tang, J., He, Y., Yue, H., Yue, Z., Yang, D.Y., 2017. Osteoarthritis, labour division, and occupational specialization of the Late Shang China - insights from Yinxu (ca. 1250 - 1046 B.C.). PLoS One 12, e0176329. https://doi.org/10.1371/journal.pone.0176329

Zincarelli, C., Iervolino, S., Di Minno, M.N.D., Miniero, E., Rengo, C., Di Gioia, L., Vitale, D., Nicolino, A., Furgi, G., Pappone, N., 2012. Diffuse idiopathic skeletal hyperostosis prevalence in subjects with severe atherosclerotic cardiovascular diseases. Arthritis Care Res. (Hoboken). 64, 1765–1769. https://doi.org/10.1002/acr.21742

Zumwalt, A., 2006. The effect of endurance exercise on the morphology of muscle attachment sites. J. Exp. Biol. 209, 444–454. https://doi.org/10.1242/jeb.02028

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11. Appendices

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