



Where are the Roman women of Ovilava? A spatio-temporal approach to interpret the female deficit at the eastern Roman cemetery (Gräberfeld Ost) of Ovilava, Austria

Dominik Hagmann^{1,2,3} , *Barbara Ankerl*¹, *Michaela Greisinger*⁴,
*Renate Miglbauer*⁴, *Sylvia Kirchengast*^{1,3} 

¹ Department of Evolutionary Anthropology, University of Vienna, Austria

² ARDIG – Archäologischer Dienst GesmbH, Austria

³ HEAS – Human Evolution and Archeological Science, University of Vienna, Austria

⁴ Stadtmuseum Wels Minoriten, OÖ, Austria

ABSTRACT: In historic and prehistoric populations, the sex ratio can often only be determined based on bioarchaeological analyses of cemeteries. In this context, a so-called female deficit has been described, which clearly contrasts the sex ratio typical of recent populations. The present study aims to analyze the sex ratio in the eastern cemetery ('Gräberfeld Ost') of the Roman town Ovilava. This site is located beneath today's city of Wels in Upper Austria (AUT), in the northwestern region of Noricum. Spatial as well as chronological aspects of the sex ratio were considered. A total of 111 individuals older than 15 years could be included in the analysis. Radiocarbon dating allowed a chronological classification of the burials. In addition, a spatial analysis of the cemetery was carried out using a geoinformation system. For the whole sample, a sex ratio of 200.0 and a marked female deficit were recorded. Considering the individual age classes and the periods separately, an apparent female surplus emerged among individuals younger than 20 years (sex ratio = 62.5). With increasing age class, the proportion of females reduced dramatically; among the over 40-year-olds, the sex ratio was 370.0. There was also an apparent female deficit in the Early Roman and Imperial Roman Periods but an almost balanced sex ratio in the early Middle Ages. Furthermore, the sex proportion varied between the cemetery areas. Consequently, a female deficit occurs mainly during Roman times and in specific areas of the burial ground.

KEY WORDS: female deficit, Roman burials, sex ratio, Noricum, bioarchaeology.



Original article

© by the author, licensee Polish Anthropological Association and University of Lodz, Poland

This article is an open access article distributed under the terms and conditions of the

Creative Commons Attribution license CC-BY-NC-ND 4.0

(<https://creativecommons.org/licenses/by-nc-nd/4.0/>)

Received: 04.06.2023; Revised: 28.06.2023; Accepted: 28.06.2023

Introduction

In 1662, the English businessman John Graunt (1620–1674) published the first detailed descriptive analysis of the numerical ratio of male to female newborns. His analysis of the sex ratio of baptized children in London revealed a significantly higher number of male newborns than female ones (Greuch 2020). This observation of a numerical preponderance of male infants was confirmed by both the English mathematician John Arbuthnott (1667–1735) and the German demographer Johann Süßmilch (1707–1767) (Greuch 2020). On the other hand, Charles Darwin (1809–1882) postulated a 1:1 ratio of male to female individuals in a natural population (Darwin 1871). This assumption was later adopted by Ronald Fisher (1890–1962), whose theory of a male-to-female ratio of 1:1 became known as Fisher's principle as an evolutionarily stable strategy (Greuch 2020). All these observations are related to the so-called secondary sex ratio, the numerical sex ratio at the time of birth or the neonatal period (Chao et al. 2019; DÁlfonso et al. 2023). In addition to the secondary sex ratio, the primary sex ratio is also defined as the numerical ratio of chromosomally female (XX constellation) to chromosomally male (XY constellation) zygotes at the time of conception. However, this primary sex ratio cannot be examined in demographic analyses (James 1987).

Currently, in populations without prenatal selection favoring one sex, a secondary sex ratio of 103–105 male newborns per 100 female newborns is observed (Hobbs 2004). However, a marked female deficit is observable in populations with prenatal selection against female offspring (Sharma et al.

2017). Following the neonatal period, which concludes on the 42nd day post-birth, the tertiary sex ratio becomes established. As individuals age, this ratio gradually shifts in favor of the biological female sex. Throughout adolescence and in the majority of human populations, males tend to exhibit higher mortality rates compared to females within the same age group. This discrepancy persists even after accounting for causes of death specific to females, such as child-birth-related fatalities. The higher mortality among males can be attributed to both natural factors, including heart attacks, strokes, and cancer (which account for the majority of deaths), as well as violent causes like homicide and warfare (Kruger and Nesse 2004). Consequently, females generally enjoy a longer life expectancy due to these factors. The low status of the female gender, however, increases female mortality rates and contributes in this way to an imbalance between the sexes and may lead to a female deficit, even today (Coale 1991). Consequently, the sex ratio (SR) varies considerably around the world, from a dramatic male surplus in states such as Qatar (SR=266), the United Arab Emirates (SR= 228.2) or Bahrain (SR = 163.8) to an apparent female surplus, as in the successor states of the former Soviet Union such as Georgia (SR= 88.7), Lithuania (SR=88.4), Russia (SR=86.7), Latvia (SR=86.7), Ukraine (86.2), Belarus (SR=85.5) and Armenia (SR=81.9) (UNO 2022). These differences can be biological-medical but also ecological, sociocultural, political-historical, or economic (Heshketh and Xing 2006).

A particular challenge is the reconstruction of the sex ratio of historical populations. On the one hand, written sources can be used; on the other hand,

if written sources are unavailable, bioarchaeological analyses of cemeteries are the only way to reconstruct the sex ratio among historical and prehistorical populations. In the case of bioarchaeological, i.e., osteological analyses, only the tertiary sex ratio of juvenile or adult individuals can be determined with macroscopic-morphological methods since sex-typical features on the skeleton only develop with the hormonal changes of puberty (Schaefer et al. 2009). Sometimes, however, a purely morphological sex diagnosis is impossible due to a poor state of preservation or an indifferent combination of features (White and Folkens 2005). Although there are limits to osteological analysis, bioarchaeological analyses often reveal an astonishing phenomenon that stands in marked contrast to observations of recent populations:

In numerous studies, a conspicuous surplus of male-classified adult individuals was reported (Schott 1964; Häussler 1969; Weiss 1972; Caselitz 1981; Wittwer-Backofen 1987; Volk and Büchner 1995), a finding that led to an assumption – rarely critically questioned – of a general female deficit in archaeological series (Kemkes-Grottenthaler 1997). This situation led to the point that if no female deficit was found, this finding was interpreted as a methodological artifact (Schott 1964; Kunter 1991). The female deficit in bioarchaeological series remained a mystery, although more than 25 years ago, Ariane Kemkes-Grottenthaler (1997) presented a critical analysis of possible explanations of this phenomenon. She discussed the importance of methodological problems in diagnosing sex on the skeleton, the focus on selected samples such as monastery cemeteries, poorhouses, or slave cemeteries (Weiss 1972; Caselitz 1981), but also sex-typ-

ically varying mortality patterns, or the theory of sex-differentiated parental investment according to Trivers and Willard (1973).

In recent years, however, descriptions of a general female deficit have been increasingly critically questioned, and various explanatory models have been postulated. Mostly, methodological problems in morphological sex estimation resulting in the benefit of male classifications are reported (Weiss 1972). White and Folkens (2005) discussed artifacts, such as misclassification by using only skull elements for sex determination and the problem of sex determination among juvenile individuals. Other studies yielded no significant differences in the preservation between male and female skeletons (Stojankowski et al. 2002; Walker et al. 1988). Cintas-Peña and Herrero-Corral (2020), who reported the apparent male surplus at 62 prehistoric sites on the Iberian Peninsula from the 8th to the 3rd millennium BC, discussed – but finally rejected the interpretation that a possibly poor state of preservation of female skeletal remains or the complete destruction of the smaller and more delicate female bones, might lead to the impossibility of a correct sex diagnosis.

However, a male surplus is not only described for prehistoric cemeteries; early and late medieval samples from Italy (Barbiera et al. 2017) and medieval England (Bardsley 2014) also suggest a clear male surplus. In contrast, a balanced sex ratio is described for Late Antique Italy (Barbiera et al. 2017). Again, this finding contrasts with an apparent male surplus or female deficit described for numerous Roman burial sites in Austria (Lebzelter 1935; Ehgartner 1947; Kloiber 1957, 1962; Pichlmayer 1972; Neugebauer 1987; Wiltschke and

Teschler-Nicola 1991; Berner 2014; Marschler 2013), Germany (Ziegelmayr 1979; Wahl 1988), and Switzerland (Brunner 1972), but also in the former Yugoslavia (Mikic 1984). A female surplus, on the other hand, is documented much more rarely (Pail 2009; Schweder and Winkler 2004). These very unbalanced gender relations of the Roman period skeletal series, however, are rarely subjected to a critical analysis. Therefore, the present study aimed to analyze and interpret the sex ratio of the Roman and early medieval inhumations at the eastern cemetery ('Gräberfeld Ost') of Ovilava, now known as Wels, in present-day Upper Austria (AUT). For the first time at this crucial urban Roman site, we applied a state-of-the-art archaeothanatological approach. This attempt integrates bioarchaeological, spatial archaeological, and social archaeological methods. Since the analysis of the sex ratio is based on the morphological analysis of the skeletal features, only the biological sex is considered in the present study.

For this purpose, the following hypotheses were tested:

1. The cemetery of Ovilava shows a female deficit.
2. The sex ratio of the cemetery of Ovilava varies depending on the burials' chronology and the burial areas' spatial patterns.

Material and methods

The site Ovilava – archaeological background

For around 500 years, between the ends of the 1st cent. BC and the 5th cent. AD, the southeastern Upper Danube River

Basin (sUDRB) (Fehér et al. 2015; Sommerwerk et al. 2022; Stagl and Hattermann 2015; Zoboli et al. 2015), comprising roughly the Roman provinces of Noricum and Pannonia, was under Roman rule and part of the *Imperium Romanum* (Hagmann 2019). Systematic civil settlement activities in Noricum emerged traceable from the 2nd half of the 1st cent. AD onwards, along the border zone next to the Danube river, known today as the UNESCO World Heritage site 'Danube Limes,' but called '*ripa Norica*' in ancient times (Hagmann 2019, 2022, 2023). The Roman town of *Ovilava/Ovilavis* (coordinates: 48.1575°, 14.026667° [EPSG:4326 WGS 84; <https://epsg.io/4326>]), which today can be found in the urban area of the city of Wels in Upper Austria (AUT), was located in the northwestern part of Roman *Noricum* (resp., in late antiquity, *Noricum ripense*), around 20 km south of the river Danube. Throughout hundreds of years of Roman settlement, Ovilava never served as a military camp near the Danube limes. Instead, it consistently functioned as a civilian and economic center in the hinterland of the frontier zone. Consequently, the inhabitants of Ovilava were mostly not active soldiers but mainly civil traders, craftsmen, and other kinds of workers, which likely originated from Noricum and adjacent regions. Nevertheless, some may also be migrated from other parts of the Roman Empire, such as North Africa, to this area near the Danube *limes* (Antonio et al. 2022) (Figure 1).

Currently, there is no archaeological evidence of any older, i.e., pre-Roman, settlement in this region. The first traces of a Roman settlement preceding the urban place can be assumed in the 2nd

half of the 1st cent. AD and can be possibly thought of as a rural *vicus* (roadside settlement). In the area of Ovilava, the east-west running trunk road that connected, e.g., in the 2nd cent. AD, the Roman town (*municipium*) and legionary fortress (*castra legionis*) *Lauriacum* (today Enns, AUT) and the town (*municipium*) of *Iuvavum* (today Salzburg, AUT), as well as the road that led from the supra-regional trading hub *Aquilea* in today's northern Italy over the Alps to the military camp (*castellum*) of *Boiodurum* (today Passau, GER), crossed each other. The favorable location at the intersection of two critical roads suggests that Roman Ovilava established itself as an important administrative, infrastructural, and economic node in the province

of *Noricum*. At the beginning of the 2nd cent. AD, when the whole region was at its height, Ovilava received Roman city rights during the reign of the Roman emperor Hadrian (76–138 AD) and became *municipium Aelium Ovilava*. During the second half of the 2nd cent. AD Ovilava seemingly remained untroubled by the Marcomannic wars. Ovilava was finally raised to *Colonia Aurelia Antoniniana* during the reign of Caracalla (211–217 AD), and town fortification walls were erected during the 3rd cent. AD. During the late-antique administrative reforms, e.g., by Diocletian (284–305 AD), Ovilava probably became the capital of the new province of *Noricum ripense*. (Miglbauer 2002, 2014, 2015)

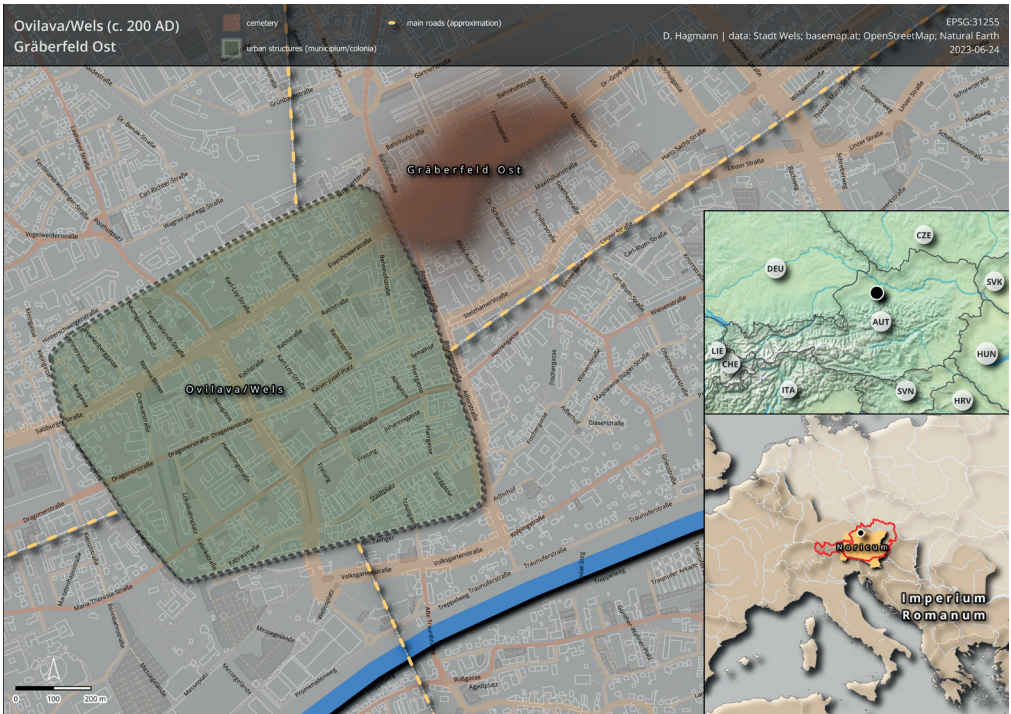


Fig. 1. Spatial location and extent of the Roman town of Ovilava and the eastern cemetery ('Gräberfeld Ost') in former northwestern Noricum, situated within the area of modern-day Wels in Upper Austria (AUT)

A long-lasting polycrisis, resulting from epidemics like the ‘Antonine plague’ in the late 2nd cent. AD or the ‘plague of Cyprian’ in the mid-3rd cent. AD, climatic changes with the end of the Roman Climate Optimum (RCO) and the beginning of the Late Antique Little Ice Age (LALIA) (Erdkamp 2021; Haldon et al. 2018b, 2018a, 2018c; Harper 2017; McCormick et al. 2012), various migration waves in the course of the great migration period (Meier 2019), as well as the regular massive internal political conflicts in the style of civil wars as also conflicts with external enemies (Börm 2022), triggered the relatively slow but somewhen ultimate decline of northern Noricum as an integral part of the Roman Empire (Hagmann 2019, 2022, 2023).

In 476 AD, the barbarian king Odoacer deposed Romulus August(ul)us, who is often considered the last emperor of the Western Roman Empire. Odoacer replaced him as the new king of the Italian peninsula’s lands, including Noricum. According to the *Vita sancti Severini* (44, 5), the life description of *Severinus* of Noricum (c. 410–482 AD), finished in 511 AD by the monk Eugippius and the most important written source for the ‘latest’ late-antique period of *Noricum ripense*, Odoacer’s brother Hunuwulf followed the king’s order to resettle the Roman people (officials as well as the ‘average’ population) from Noricum in 488 AD to the South (Winckler 2016). It cannot be verified that the entire population left the region because of that order and also not how the whole process took place (non-violent? forced?) but, e.g., the eastern cemetery of Ovilava (cf. *infra*) was only seldom used from the end of the 3rd cent. AD onwards. It was reoccupied again by early medieval populations, probably Bavarians, only in the early 7th cent AD. Therefore, Roman

settlement activities seemingly ended in the 5th cent. AD to a likely considerable extent, although it hardly came to a settlement hiatus (Hausmair 2022). It is thus not clear what really happened to the Roman population of this area.

The eastern burial ground of Ovilava – the ‘Gräberfeld Ost’

According to Roman custom, the civil inhabitants of Ovilava were buried in the necropoleis along the arterial roads outside the city gates (Retief and Cilliers 2010, 134). One of the town’s most significant cemeteries was located in the east along the road from *Lauriacum* to *Iuvavum* and is accordingly known as ‘eastern cemetery’ (‘Gräberfeld Ost’). Today the area of the Roman cemeteries is located in the densely built city of Wels. Therefore, excavations are only possible in the context of construction projects, mainly within the modern city – recorded archaeological finds are thus known since the 19th cent. Until today, it was not possible to uncover the entire burial ground, but only several unconnected areas have been excavated. (Jäger-Wersonig 1999a,b,c; Miglbauer 2007, 2009) For the study presented in this paper, 5 specific excavation areas from the Gräberfeld Ost are of utmost importance:

- Pendlerparkplatz (2004–2005) (Miglbauer 2006; Greisinger 2006; Greisinger et al. 2020);
- Kanalgrabung Dr.-Groß-Straße (2006) (Greisinger 2007; Greisinger et al. 2020);
- Alois-Auer-Straße (2007) (Miglbauer 2006; Greisinger et al. 2020);
- Dr.-Groß-/Dr.-Schauer-Straße (2002) (Miglbauer 2004; Greisinger et al. 2020);
- Fronius (2008–2010) (Greisinger 2010; Greisinger et al. 2020).

Taking into account the excavations from the 19th and 20th cent. a partial picture of the cemetery east along a *decumanus* (east-west street in the street grid) can be reconstructed in terms of its extent (Miglbauer and Waser 2020). The spatial locations of the excavated cemetery areas in the outskirts of the urban settlement as well as the cemetery itself, the (yet partially analyzed) grave goods, and (few) qualitative attributes of the tombs indicate that elite but also 'commoners' and 'poor' were buried at the burial ground of Ovilava. According to the archaeological finds, the burials dated mainly in the 2nd and 3rd cent. AD (Jäger-Wersonig 1999 20–22; Miglbauer 2007, 2009). Considering previous investigations, the cemetery seemed to be in use, although possibly very scarce in the end, up to Early Medieval times (Miglbauer 2001; Hausmair 2022). Few burials are attributed to Early Medieval Bavarians (Hausmair 2006).

Over 2/3 of the burials consisted of cremations; the remaining others were inhumations. The skeletal remains have been stored at the Archaeological Collection of the Stadtmuseum Wels-Minoritien. In 2019, the skeletons were temporarily transferred to the Department of Evolutionary Anthropology, University of Vienna, where the bioarchaeological analysis is currently in progress. The remaining cremations of the burial ground of Ovilava have not been analyzed up to now and are subject to a planned project which is scheduled to start in 2024.

Chronology

In order to be able to assess the chronological position of the individual cemetery areas better and to be able to reconstruct the settlement history based on archaeothanatological findings, we

decided to carry out radiocarbon dating of inhumations of the cemetery as much as possible (Pearce 2016). The radiocarbon dating of 97 individuals, with 83 individuals older than 15 years, has been carried out so far. Following a dedicated sampling strategy, clusters for pre-selection were spatially defined, and individuals from all cemetery areas were selected as a proportion of the total number of burials and dated using radiocarbon analysis. The samples determined in this way were further supplemented by individual samples of further individuals particularly suitable for dating. The radiocarbon datings were carried out at the VERA-lab of the Faculty of Physics at the University of Vienna (<https://isotopenphysik.univie.ac.at/en/vera/>).

A dedicated controlled vocabulary, explicitly tailored for Noricum, was used to periodize the data (Hagmann 2021): Based on the radiocarbon dating results, the inhumations were classified using the following time periods for Roman Antiquity (50 BC to 500 AD) in Noricum (resp. 50 AD to 500 AD in northern Noricum) as

- Early Period (50 AD to 117 AD);
- Imperial Period (117 to 284 AD);
- Late Antiquity (284 to 488 AD).

Early Middle Ages (for the Gräberfeld Ost, this period corresponds c. to the 7th and 8th cent. AD) were defined from 500 to 1100 AD following Eichert and Richards (2022).

21 individuals belonged to the Early Period, 58 to the Imperial Period, 2 to Late Antiquity, and 16 were classified as Early Medieval.

Sample

The excavated parts of the Ovilava burial ground include 328 cremation burials and 134 inhumations. A total of 153 in-

dividuals could be assigned to the inhumations. The spatial distribution of the burials is presented in Table 1.

All 153 individuals were osteologically analyzed using standard bioarchaeological protocols outlined by Buikstra and Ubelaker (1994) as well as Mitchell and Brickley (2017). Age at death and sex of the individuals were estimated by a combination of various standard techniques (White and Folkens 2005). Pathologies were determined according to Ortner (2003). Although the state of preservation of the individual skeletons differed, the preservation of the pelvis and/or the skull of 108 individuals older than 15 years allowed sex as well as age at death estimation.

Age at death determination

Age at death of non-adult individuals was estimated through dental development and eruption patterns, the degree of closure of the epiphyseal plates (Cardoso 2008; Coqueugniot and Weaver 2007; Schaefer et al. 2009), and metric documentation of diaphyseal lengths (AlQathani et al. 2010; Cunningham et al. 2016). If the specific skeletal elements were present, the age at death of adult individuals was estimated using the pubic symphysis scoring system according to Brooks and Suchey (1990), the auricular surface of the ilium according to Lovejoy et al. (1985), the sternal articular surfaces of the clavicle (Szilvássy 1978). Furthermore, the closure of cranial sutures (Meindl and Lovejoy 1985) and mandibular and maxillary attrition were analyzed according to Lovejoy (1985).

Sex/gender determination

For biological sex determination, pelvic bones were primarily used following the Phenice method (Phenice 1969) and the

classification scheme according to Walker (2005). In addition, skull morphology was used for sex determination, according to Walker in Buikstra and Ubelaker (1994). Furthermore, biological sex was determined using 28 selected characteristics of the skull and mandible, the pelvis, and the robustness of the humerus and the femur according to the catalog of characteristics by Acsádi and Nemeskéri (1970) and Ferembach et al. (1979). The degree of expression of these 28 characteristics was rated on a scale from -2 (hyperfeminine) to +2 (hypermasculine). In individuals under the age of 18, the sex was only determined if the sex-determining characteristics mentioned above were already clearly developed.

Besides biological sex, gender was estimated based on grave goods. Weapons and knives were associated with the male gender, while needles, specific jewelry, and mirrors were associated with a female identity. Since biological sex determination and archeological gender estimation differed only in one individual, in the present study, biological sex determination was used. This match of biological sex determination and gender-typical grave goods can be cautiously interpreted as evidence for a binary sex/gender system. Furthermore, among 10 adult individuals, an aDNA analysis was performed to verify the molecular sex of the individuals. The morphological sex determination and the molecular sex determination corresponded to 100%.

To quantify the ratio of male and female-determined individuals, the sex ratio was calculated. The sex ratio is commonly defined as the number of men to every 100 women (Hobbs 2004).

$$\text{sex ratio} = 100 * n \text{ men} / n \text{ women}$$

The sex ratio can be expressed in units (1.02) or hundreds (102) to demonstrate the number of men per 100 women. In the present study, we used units.

Statistical and spatial analysis

Statistical analyses were carried out using SPSS Version 24. After computing descriptive statistics, differences in the sex proportion between the burial areas, the age groups, and the chronological periods were calculated by means of Chi squares. A *p*-value below 0.05 was considered significant.

The entire dataset has spatial components. Therefore, a geographic information system (GIS) plays an essential role in the research design, as it can ideally accommodate our sites' complex relational and diachronically changing contexts. In addition to digital cartography, the GIS serves primarily as a central database and an analysis tool for all data, including open government data (OGD). Consequently, the study relies on the records of archaeological contexts, the recorded human remains, and their bioarchaeological analysis results for the digital and contextual archaeothantological analysis of (bio)archaeological data in a comprehensive geodatabase. For this purpose, an integrated digital approach was applied, using both proprietary and free and open source software (FOSS) for information management and spatial data analysis (Hagmann 2020). The GIS software was QGIS (latest 3.30 's-Hertogenbosch) installed on a Windows 11 Pro device (as SPSS). As a coordinate reference system, we used the Austrian National Survey Coordinate System for the central part of Austria, EPSG:31255 MGI / Austria GK Central (<https://epsg.io/31255>). In the first step, all digital and analog excavation plans were imported into the GIS or

(in the case of analog data) retro-digitized and then geo-referenced. The digital general archaeological map of the city of Wels provided the overall basis for spatial analysis (Greisinger et al. 2020). Then, in step 2, all burial pits were mapped in the GIS to obtain a complete dataset of all burials in Ovilava's eastern cemetery, also integrating data from the digital general map. In step 3, significant qualitative information was selectively extracted from the excavation documentation records and mapped onto the newly generated geospatial dataset utilizing standardized attributes. For this purpose, cultural data was collected in structured tables in Excel/Microsoft 365 (XLSX file format), and a sophisticated folder structure was used for sustainable data management. All data was securely stored in a cloud (Google Drive). Spatial vector data stored in ESRI shapefiles (SHP and auxiliary files) provided all quantitative technical information about the area of interest. In step 4, the qualitative archaeological dataset was merged with the systematic radiocarbon dating data and loaded into the FOSS GIS software as non-spatial tables in CSV file format. Further, the quantitative and qualitative bioarchaeological attributes were merged with those of the spatial cemetery dataset to obtain the final dataset. For this purpose, the cultural-qualitative tables were merged with the spatial-quantitative information, followed by validation activities regarding quality control. The results were used for map-based cartographic visualization and plotted in TIFF file format; by that, we applied a specific form of integrated 'deep-mapping'-approach for visualizing archaeological data, providing a richer, more nuanced, multilayered, and multidimensional understanding of the burial ground per each map (Hagmann 2020). (Hagmann 2020, 2021; Kirchengast and Hagmann 2022).

Results

Spatial analysis of the burial ground

The four defined burial areas differed highly significantly ($p < 0.003$) in temporal patterns. While most of the burials in the Kanalgrabung area dated to early medieval times (63.6%), the Alois-Auer-Straße

(100%) and Dr.-Groß-/Dr.-Schauer-Straße (50%) areas were predominantly used in Roman Imperial times. More than 70% of the Fronius area individuals dated in the Roman era, while the area of the Pendlerparkplatz was used also mostly used in Imperial Roman times (62.2%) but also the Early Roman (20%) and Early Medieval time (17.8%) (see Table 1 and Figure 3).

Table 1. Description of the individual burial areas at the Gräberfeld Ost

area	Period				Burial type	
	ER	IR	EM	cremations	inhumations	
					graves	individuals
n	n	n	n	n	n	
Pendlerparkplatz	9	28	8	116	61	77
Fronius	8	24	1	186	50	51
Kanalgrabung Dr.-Groß-Straße	1	3	7	20	15	17
Alois-Auer-Straße	0	2	0	0	5	5
Dr.-Groß-/Dr.-Schauer-Straße	1	1	0	6	3	3
total	19	58	16	328	134	153

Legend: ER = Early Roman, IR = Imperial Roman, EM =Early Medieval



Fig. 3. Spatio-temporal occupancy patterns of the defined excavation areas, segregated by male and female inhumation burials, in relation to Roman Antiquity and the Early Middle Ages

Age distribution

More than 30% of the individuals in the inhumation sample were subadults, with a particularly high percentage of regularly buried neonates (11.7%). 16.5% of the subadult individuals were classified as infans I or infans II, indicating an age at death between 2 months and 13 years. The majority of the individuals buried at the Gräberfeld Ost areal died between the ages of 20 and 40 years (42.6%). 22% died between 40 and 60 years, and only 2 % were older than 60 years (Figure 4).

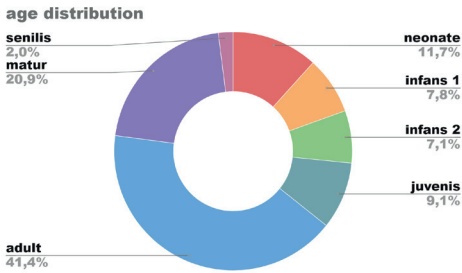


Fig. 4. Age distribution of the whole sample

Sex ratio

The biological sex distribution of the whole sample is presented in Figure 5. Considering the individuals classified as juvenile or adult only, the number of male-classified or likely male-classified individuals significantly surpassed the number of female-classified or likely female-classified ones (see Figure 5). The sex ratio of the whole sample is 200. This observation means that the proportion of men in this burial ground is twice as high as that of women.

However, when the individual cemetery areas, age groups, and chronology are considered separately, it becomes apparent that this marked female deficit varies temporally and spatially. As shown

in Table 2, the respective cemetery areas differ concerning the sex ratio. A female deficit can be observed for the Fronius, Pendlersparkplatz, Alois-Auer-Straße, and Dr.-Groß-/Dr.-Schauer-Straße areas. No female-classified skeleton was excavated in the Dr.-Groß-/Dr.-Schauer-Straße-area; however, this area yielded only 3 adult individuals. Considering the larger burial areas, the Fronius area showed the highest female deficit (sex ratio = 287.5).

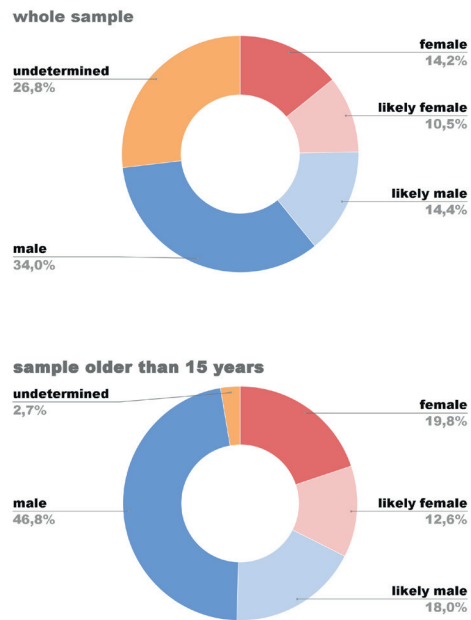


Fig. 5. Sex distribution of the whole sample (n=153) and of the individuals older than 15 years (n=110)

In the Pendlersparkplatz area, almost twice as many males are buried as females. Only the Kanalgrabung area revealed more female than male skeletons. When comparing the sex ratio across different age groups - juvenile (15 to 19 years), adult (20 to 40 years), and mature (>40 years) - a noticeable surplus of female-classified

skeletons is observed in the youngest age group. However, a female deficit emerges in the adult age group. In the highest age group, male-classified skeletons outnumber female ones by almost four to one (see Table 2).

In a further step, the time periods were compared. Here, the significantly highest surplus of men was observed in the Ear-

ly Roman Period (1st cent. AD). Furthermore, a significant female deficit could be observed in the Roman Imperial Period (2nd and 3rd cent. AD) – more than twice as many male-classified skeletons could be found. Only in the Early Middle Ages (7th and 8th cent. AD) the sex ratio was almost balanced, although a slight surplus of males could still be observed (see Table 2).

Table 2. Sex ratio (100*M/F) according to burial area, age group, and period

	F/F?		M/M?		UND		Total n	Sex ratio (men to every 100 women)
	n	%	n	%	n	%		
Areal								
Kanalgrabung	7	53.8%	6	46.2%	0	0.0%	13	85.7
Pendlerparkplatz	20	32.8%	38	62.3%	3	4.9%	61	190.0
Fronius	8	25.8%	23	74.2%	0	0.0%	31	287.5
Alois-Auer-Straße	1	33.3%	2	66.6%	0	0.0%	3	200.0
Dr.-Groß-/Dr.-Schauer-Straße	0	0.0%	3	100.0%	0	0.0%	3	.
Chi-square			12.2		p=0.429			
Total burial ground	36	32.4%	72	64.9%	3	2.7%	111	200.0
Age groups								
Juveniles 15 to 19 yrs	8	57.1%	5	35.7%	1	7.1%	14	62.5
Adults 20 to 40 yrs	18	37.5%	29	60.4%	1	2.1%	48	161.1
Mature > 40 yrs	10	20.4%	37	75.5%	1	4.1%	48	370.0
Chi-square			5.26		p=0.218			
total	36		71		3		110	
Period								
Early Roman	4	22.2%	14	77.8%	0	0.0%	18	375.0
Imperial Roman	15	30.0%	35	70.0%	0	0.0%	50	233.3
Early Middle Ages	7	46.7%	8	53.3%	0	0.0%	15	114.3
Chi-square			14.4		p=0.026			
total	26	31.3%	57	68.7%	0	0.0%	83	219.2

legend: F/F? = female and likely female, M/M? = male and likely male; UND =undetermined

In the last step, the sex ratio of the eastern Ovilava burial ground was compared to those of other Roman times samples from Austria, Germany, Hungary, Serbia, and North Macedonia. As presented in Table 3 and Figure 6, a female deficit occurred in many samples. Only the Austrian samples from Saladorf (Ro-

man rural *villa* population) and Petronell-Carnuntum (Roman urban population next to the legionary fortress), as well as the Hungarian sample from Pécs (Roman urban population of Sopianae), revealed a female surplus. All other samples showed a marked female deficit (see Table 3 and Figure 6).

Table 3. Sex ratio of Ovilava and Roman times samples (inhumations only) around the Danube River Basin (adapted from Schweder & Winkler 2004, 73 tab. 39 and supplemented by the authors)

Roman samples		F/F?	M/M?	Sex ratio (men to every 100 women)
Austria				
Saladorf ¹		12	9	75.0
Carnuntum ²		24	19	79.2
Carnuntum	Mühläcker ³	7	7	100.0
Lentia/Linz	Tiefer Graben ⁴	16	16	100.0
Mannersdorf a. Leithagebirge ¹		10	12	120.0
Halbturm ⁵		24	30	125.0
Brunn a. Gebirge ⁶		4	5	125.0
Vindobona/Vienna-Albertina	Albertina ⁷	20	26	130.0
Comagena/Tulln a. d. Donau ⁸		14	19	135.7
Arrianis (?)/Klosterneuburg ⁹		10	18	180.0
Lauriacum/Enns	Espelmayrfeld ¹⁰	34	65	191.2
Ovilava/Wels		36	72	200.0
Pottenbrunn ¹¹		15	36	240.0
Oggau a. Neusiedlersee ¹²		4	10	250.0
Lauriacum/Enns	Steinpaß ¹³	54	143	264.8
	Ziegelfeld ¹⁴	33	107	324.2
Germany				
Neuburg a. D.	Zone 1 ¹⁵	11	32	290.9
Neuburg a. D.	Zone 2 ¹⁵	9	27	300.0
Neuburg a. D.	Zone 3 ¹⁵	3	10	333.3
Stettfeld ¹⁶		4	18	450.0
Switzerland				
Bonaduz ¹⁷		190	269	141.6
Hungary				
Pécs ¹⁸		52	37	71.2
Tokod ¹⁹		50	56	112.0
North Macedonia				
Deboj-Ohrid ²⁰		21	45	214.3
Serbia				
Viminacium	Pećine ²⁰	65	144	221.5
Viminacium	Više Grobalja ²⁰	11	38	345.5

Legend: 1 Pail 2009; 2 Schweder & Winkler 2004; 3 Harrer 2014; 4 Wiltshcke & Teschler-Nicola 1991; 5 Berner 2014; 6 Szilvassy 1976; 7 Marschler 2013; 8 Lebzeltner et al. 1935; 9 Neugebauer et al. 1987; 10 Kloiber 1962; 11 Hölbling 2008; 12 Ehgartner 1947; 13 Pichelmayer 1972; 14 Kloiber 1957; 15 Ziegelmayer 1979; 16 Wahl 1988; 16 Knötzele 2018; 17 Brunner 1972; 18 Ery 1973, 19 Ery 1981, 20 Mikic 1984



Fig. 6. Geospatial location of Ovilava and Roman times samples (inhumations only) regarding sex ratio across the Danube River Basin

Discussion

In the present study, we analyzed the tertiary sex ratio of the inhumations of the eastern cemetery of Ovilava only. Before we start with a detailed discussion of the results, we must mention the limitations of the present study. First, it should be noted that the entire cemetery of Ovilava could not be excavated, as it is now located under the densely built-up urban area of the city of Wels in Upper Austria. It is, therefore, only possible to analyze individual areas uncovered randomly during rescue excavations. Therefore, the num-

ber of skeletons included in the analysis, 111, is relatively small. The analysis, however, included only inhumations, and the more than 328 cremations have yet to be analyzed. Although there is no hint from the literature that burial practices (inhumations versus cremations) varied significantly between men and women in the time periods considered in this study, the fact that cremations are not included in the analysis represents a major limitation of this study (*infra*).

Furthermore, regarding the general spatial location of the study area, it is unclear whether the road, which continued

eastward from the inner-city *decumanus*, was the main exit road or just another suburban feeder parallel to the principal axis. Therefore, it remains to be considered whether the present reconstructed picture corresponds at all to the full extension. It can also be assumed that the actual core areas of the cemetery are still archaeologically unrecorded and lay further southeast around the *decumanus maximus* (east-west main road) and a main drop-off road adjoining it, which so far could not be further identified archaeologically. Accordingly, it is also possible that the currently reconstructed area of the Gräberfeld Ost represents only a peripheral section of the outermost edge of a much larger cemetery. Further, it must be noted that radiocarbon dating has shown that inhumations occurred in the cemetery during the entire Roman Antiquity, even if during the Early Roman Period (seemingly in favor of cremations), the inhumations occurred only sporadically. Consequently, this result does not change the generally accepted assumption that inhumations only began to appear more frequently c. at the end of the 2nd cent. and largely replaced cremations, but it must be emphasized that inhumations should not be placed due to this premise in the later Roman periods from the outset (*infra*).

The tertiary sex ratio represents a crucial demographic parameter that quantifies a population's numerical ratio of male to female individuals. The analysis of the sex ratio of historical populations poses a particular challenge, as the numerical sex ratio can only be determined utilizing written records, such as gravestone inscriptions, or the bioarchaeological analysis of burial grounds. Since sex-typical features on the skeleton that allow sex diagnosis do not manifest until

puberty and adolescence, in most cases, osteological sex diagnosis can only be made from the juvenile phase onwards. Furthermore, poor preservation status reduces the possibility of a valid sex diagnosis.

The good state of preservation of the skeletons of the eastern Ovilava cemetery allowed a morphological sex estimation for the 108 older juvenile and adult individuals and, thus, hypothesis testing. Hypothesis 1 could be verified. Of the 108 individuals at least 15 years old, only 36 could be classified as likely female or female, while 72 skeletal individuals were determined to be likely male or male. Only for three skeletons, sex estimation was impossible due to the poor state of preservation. Therefore, a sex ratio of 200.0 among the inhumations could be determined for the sample older than 15 years, which means twice as many males as females among the inhumations at the Ovilava cemetery. This enormous male surplus corresponds to those of numerous other historical samples, especially from the Roman period:

As shown in Table 3, a sex ratio of 200.0, as in Ovilava, does not represent the most pronounced male surplus or female deficit. Except for the samples from Saladorf (Pail 2009) and Petronell-Carnuntum (Schweder and Winkler 2004), the majority of Roman samples from Austria (Lebzelter 1935; Ehgartner 1947; Kloiber 1957, 1962; Pichlmayer 1972; Neugebauer-Maresch and Neugebauer 1987; Berner 2014; Marschler 2013), Germany (Ziegelmayr 1979; Wahl 1988), and Switzerland (Brunner 1972), but also in the former Yugoslavia (Mikic 1984) had a sex ratio above 100.0 and thus a female deficit. Only for Lentia (Wiltshcke and Teschler-Nicola 1991) and Carnuntum Mühläcker (Har-

rer 2014), a sex ratio of 100, indicating as many females as males, was reported. Consequently, a female deficit seems a not unusual demographic pattern among inhumations in the Roman *limes* provinces.

In most older studies, the female deficit of historical populations was assumed to be an unquestioned fact; in new studies, methodological errors are often discussed as explanatory approaches (Cintas-Peña and Herrero-Corral 2020). Furthermore, a poor state of preservation of the female skeletons, which may lead to misidentifications, was postulated (White and Folkens 2005). Also, the possibility is discussed that gracile female skeletons would not have been preserved at all, and thus an unnatural sex proportion is justified. The present sample from Ovilava does not support this interpretation. The majority of the skeletons were in an excellent state of preservation, which allowed a morphological sex diagnosis. In addition, 10 aDNA analyses of skeletons from Ovilava are available to date, which had been analyzed as part of another study. All chromosomal sex diagnoses corresponded to the morphological sex estimations. Furthermore, the morphological sex estimation was compared with the grave goods. Here too, a correspondence between the biological sex and the gender associated with the material remains was found. Therefore, there is no indication of a methodological misdiagnosis.

Considering that only the inhumations, and not the cremations, have been included in the analysis, we must state that a complete demographic analysis would only be possible by including all burials, including both inhumations and cremations. Consequently, an obvious explanation for the female deficit

would be that Roman women in Ovilava were cremated more often than their male counterparts. However, no evidence from historical sources suggests that burial practices differed between sexes in a standardized manner nor that sex-specific, separate burial grounds were systematically used in the Roman Empire (Barber & Bowsher 2009; Gonçalves et al. 2010). Already in Ovilava, the well-known grave portraits of a married couple, dating back to the Roman Imperial Period (Antoninian/2nd cent. AD) and documented since the 16th cent., are prominently embedded in a house facade on the main square. They depict a married couple in the form of half-figures. In their original context, it is assumed that they were part of a more elaborate funerary monument, likely placed at a family burial site, indicating that individuals of all genders were interred there (<http://lupa.at/593>).

Moreover, in the case of the Pendlersparkplatz area, inhumation and cremation burials do not intermingle in the overall picture, except for very few possible exceptions (Figure 2). The burials, instead, tend to be distinctly separate from each other. For most cases, this observation can be understood as no mixing of cremated and physically buried individuals in the same plot. Instead, it seems that both males and females were either both cremated or physically buried. The general and precise situation regarding burial customs and rites in the Roman Empire over time remains generally unclear due to a lack of comprehensive data evaluation. Overall, one should always consider regional and zeitgeist-influenced specifics, as the explicit, 'typically Roman burial custom' in this particular form did not exist (Pearce 2011; Prowse 2014). While the 'Gräberfeld Ost' exhibits a bi-ritual

nature, it is currently difficult to foresee which patterns allow us to distinguish between cremation and inhumation burials regarding timing and funerary practices for each individual. The traditional division between early cremations until approximately the 2nd cent. AD and later body burials from approximately the 2nd cent. AD onwards (Darby Nock 1932; Toyne 1996) does not appear to be entirely applicable in Ovilava, as supported by radiocarbon dates (*supra*). This situation necessitates exploring other explanatory approaches (Pearce 2016).

Another interpretation of the female deficit may be the higher mortality rate of female newborns and children, which could have led to a deficit of adult females. Due to the low validity of morphological sex diagnoses on the subadult, especially prepubertal skeleton, this interpretation cannot be confirmed but also not refuted. Infant mortality was undoubtedly high in Roman times, but whether more girls died cannot be said. According to the male-disadvantage hypothesis, however, the male sex would be the more vulnerable and affected by a higher risk of morbidity and mortality (Naeye 1971; Kirchengast and Hartmann 2009; Pongou 2013). The male disadvantage hypothesis contrasted with an assumed lower social value of female children in the very patriarchal Roman society, which may have resulted in higher death rates of female children, whether by active infanticide or by deliberate neglect leading to higher mortality of girls (Boswell 1988; Harris 1982, 1994). Several other studies, however, found no evidence of increased female infanticide rates (Engels 1980; Haentjens 2000); the possibility of female infanticide, however, cannot be ruled out (Scheidt 2010). In the present

sample, higher mortality of females in the subadult age group was thus evident during adolescence. If increased mortality was evident at prepubertal age, too, this could lead to a shift in the sex ratio. On the other hand, skeletal evidence from Roman time cemeteries clearly showed that the majority of children, independent of their sex, suffered from severe stress phases caused by malnutrition or diseases resulting in visible skeletal stress markers such as Cribra orbitalia, enamel hypoplasias or even stunting (Pilkington 2013). However, high mortality rates among newborns and children can be assumed for both sexes. An indication of a female deficit at the marriageable age may be the marriage legislation under Augustus in the 1st cent. AD. Here, non-senatorial freeborn men are possibly encouraged to marry freed women, suggesting a shortage of women, at least among the Roman upper classes (McGinn 2004). However, this lack of women could also be due to the excess mortality of women of reproductive age. Pregnancy and childbirth represent dramatic mortality risks in the recent past and even today (Alkema et al. 2016; Hirshberg and Srinivas 2017).

Nonetheless, since the bioarchaeological evidence for deaths causally related to reproduction is extremely rare (Stone 2016), the interpretation here can only be indirect. The higher number of female skeletons in the juvenile age between 15 and 19 years could be interpreted concerning the increased mortality of females in relation to reproduction. Also, the female deficit is lower in the age class between 20 and 40 years, consequently in the reproductive phase than in the post-reproductive phase. This observation also proves the verification of the second hypothesis. In the present

study, it was shown that the sex ratio varies both as a function of age classes and between periods. Comparing the Early Period, i.e., the 1st cent. AD, with the Roman Imperial Period and the Early Middle Ages shows a reduction of the female deficit over time. The most prominent female deficit is found in the Early Period, which coincides with the land occupation and foundation of Ovilava. In this phase, men outnumber women by a factor of three. In the Imperial Period, the female deficit was reduced, and in the Early Middle Ages, the sex ratio was almost balanced, corresponding to other early medieval samples such as the Avar burial ground of Csokorgasse, Vienna (Grossschmidt 1990).

Although the proportion of early medieval skeletons in the cemetery of Ovilava is very low, a clear trend towards a balanced sex ratio can be recognized. This condition could be attributed to the increased societal value of the female sex on one hand, and to ecological changes on the other. After the RCO between 250 and 400 AD, temperatures dropped, and a more unstable climatic situation set in in the area of the Roman Empire. Studies of recent populations show that unstable climatic conditions lead to increased maternal stress and may lead to an increase in the sex ratio, as male fetuses are more vulnerable to stress, increasing miscarriages and stillbirths of male fetuses, while female fetuses prove to be more resistant to stress (Fukuda et al. 2014). The end of the RCO in the 3rd cent. AD would be possible as an explanatory model here, as a decline in average temperatures in southern and central Europe may have negatively affected the ratio of male to female neonates, thus reducing the female deficit. In the present study, there

is a reduction in the female deficit with increasing timing. In the other studies, which cite an apparent female deficit in Roman-period samples, this aspect cannot be verified since no dating of the individual individuals of the sample was carried out. However, mostly only a chronological classification was made based on material legacies. Stress factors such as plagues, economic changes, and increasing insecurity at the *limes* borders (McCormick et al. 2012; Pilkington 2013; Il and Joksimovic 2015; Wippert et al. 2017; Zuckermann and Crandall 2019) could also have increased the stress for expectant mothers and infants and thus led to a reduction of more vulnerable male fetuses and consequently a reduction of the female deficit.

Another explanatory model for the female deficit at sites of the *limes* region could be based on the legionary camps of the region, where females, despite their regular on-site presence, were a minority *per se*. However, such an explanation cannot be assumed for the present study since Ovilava did not represent a legionary camp but clearly a 'rural-civilian' town in the hinterland. For example, a similar picture can also be seen for Pottenbrunn (Hölbling 2008), which represents a distinct rural civilian settlement (probably a *vicus*), having an even lower sex ratio than Ovilava.

The present study tested another explanatory option as part of a spatio-temporal analysis. The second hypothesis predicted a variation in the sex ratio between the individual burial areas and could be verified. In a spatial-temporal analysis, the individual cemetery areas were compared, and it was shown that, on the one hand, the cemetery areas were mainly used at different times, so the Early Medieval skeletons were

mainly found in the area of canal excavation and, therefore a surplus of women in the Kanalgrabung area as well as a balanced sex ratio in the Early Middle Ages. Both of these findings are associated. The idea that males and females have been buried in different sections of the burial ground could be rejected because male and female individuals were found in all burial ground areas. Finally, such a model would have contradicted specifically the general evidence in most other places regarding Roman burial customs (Scholz 2022).

An extraordinary male surplus could be found for Alois-Auer-Straße and Dr.-Groß-/Dr.-Schauer-Straße, but each area contains only 3 individuals in total and is therefore of little significance. However, the area of Fronius, which is of particular interest and is located furthest from the town of Ovilava with a sex ratio of 0.35, exhibited a much higher male excess compared to the Pendlerparkplatz area, which had a sex ratio of 0.53. The Fronius area dates primarily to the Early and Roman Imperial Period and is characterized by a high proportion of skeletons with severe wear on the spine and joints (Kirchengast et al. 2023). Although these severe stress features are observable in male and female classified skeletons, this finding argues for a hard-working population composed predominantly of males. Indicators of increased somatic stress in the *limes* hinterland could also be demonstrated for skeletal series from Croatia. Here, too, men show particularly frequently load-induced pathological changes of the spine (Šlaus et al. 2003). The fact that men affected by particular physical stress were mainly buried in a specific decentralized area of the cemetery (Fronius area) allows the following cautious interpretation:

The urban center of Ovilava was an attraction point for migrant workers or labor migrants from nearer and farther regions (de Ligt and Tacoma 2016; Lo Cascio and Tacoma 2016). Nevertheless, a planned project with isotopic investigations and aDNA analyses should provide clarity here in the future. We interpret the results of the spatial analysis as indicating an organized funerary system, presumably in the form of private burial associations (*collegia funeraticia*) and possibly even municipal magistrates as proxies, to provide burial in distinct, remote, and therefore possibly favorable areas of the burial ground. They may have ensured that, after a fatal accident or a lonely death on the street, the human remains of workers, the poor, and even outcasts, as well as other accidental deaths without relatives, were recovered and given a dignified burial. This interpretation, also considering the hygienic aspects and the overriding social attitudes regarding death pollution, is further supported by the fact that we do not observe any of the much-quoted but hardly documented mass graves for the poor (*puticuli*) but discrete individual burials in the “potter’s fields” of Ovilava (Bodel 2000; Emmerson 2020; Graham 2006a, 2006b; Perry 2017; Sano 2012; Verboven and Laes 2016). The possible presence of a larger group of poor, predominantly male migrant workers or labor migrants, may have contributed to the observed female deficit or male surplus in the Ovilava inhumations (Le Guennec and Stevens 2020; Séguy 2019; van Driel-Murray 2008; Verhagen 2019) and may also be supported by contemporaneous observations: The most pronounced male surplus in the world is currently found in Qatar with a sex ratio of 287.0, which is compara-

ble to the findings of the Fronius area of Ovilava. This exorbitantly high male surplus in Qatar is explained by the high number of impoverished male migrant workers and labor migrants living in Qatar and not by a female deficit of Qatar's autochthonous population. Similar findings could be described for the Arab Emirates, Saudi Arabia, and Oman (UNO 2022).

Conclusion

Since only inhumations and no cremations have been included in the analysis, we must clearly state that this is a pilot study only. The analysis of the sex ratio of the civilian Roman city of Ovilava in the *limes* hinterland reveals an extremely unbalanced sex ratio in favor of the biological male sex. This situation was especially true of the Early Roman and Imperial Roman periods, but not for early medieval times. A female surplus was only found for the youngest age group aged between 15 and 19 years. Similar findings are reported for many other Roman times cemeteries in the *limes* hinterland. In the present sample, the spatial analysis of the sex ratio revealed an extremely high male surplus for the so-called Fronius part of the cemetery, an area that a physically hard-working population may have occupied. Therefore, the spatial analysis may allow a socioeconomic interpretation of the unbalanced sex ratio of the cemetery of Ovilava. Further studies, including aDNA and stable isotopes, are necessary to clarify the origin of the individuals buried at the Ovilava burial ground.

Funding

HEAS Seed Grant 2023.

Conflict of interest

The authors declare no competing interests.

Authors' contribution

D.H. designed the study, carried out the spatial analysis, and wrote the manuscript, B.A. did the osteological analysis, M.G. excavated the burial ground and provided information regarding material culture, R.M. excavated the burial ground and provided information regarding grave goods and history, S.K. designed the study, did the osteological analysis and wrote the manuscript

Corresponding author

Sylvia Kirchengast, University of Vienna, Department of Evolutionary Anthropology, Djerassiplatz 1, A-1030 Vienna/ Austria, e-mail: sylvia.kirchengast@univie.ac.at

References

- AlQathani SJ, Hector MP, Liversidge HM. 2010. Brief communication: the London Atlas of Human Tooth Development and Encryption. *Am J Phys Anthropol* 142:481–490. <https://doi.org/10.1002/ajpa.21258>
- Acsádi G, Nemeskéri J. 1970. History of Human life span and mortality. Akadémiai Kiadó.
- Alkema L, Chou D, Hogan D, Zhang S, Moller AB, Gemmill A, Fat DM, Boerma T, Temmerman M, Mathers C, Say L. United Nations Maternal Mortality Estimation Inter-Agency Group collaborators and technical advisory group. 2016. Global, regional, and national levels and trends in maternal mortality between 1990 and 2015, with scenario-based projections to

- 2030: a systematic analysis by the UN Maternal Mortality Estimation Inter-Agency Group. *Lancet*. 387:462–74. [https://doi.org/10.1016/S0140-6736\(15\)00838-7](https://doi.org/10.1016/S0140-6736(15)00838-7)
- Antonio ML, Weiß CL, Gao Z, Sawyer S, Oberreiter V, Moots HM, et al. 2022. Stable Population Structure in Europe Since the Iron Age, Despite High Mobility. *bioRxiv*, 2022.05.15.491973. <https://doi.org/10.1101/2022.05.15.491973>
- Barber B, Bowsher D. 2009. The Eastern Cemetery of Roman London: Excavations 1983–1990 (1.0.0) [Archaeological research data]. Archaeology Data Service. <https://doi.org/10.5284/1000001>
- Barbiera I, Castiglione M, Dalla Zuanna G. 2017. Missing women in the Italian middle ages? Data and interpretation. In: Huebner SR, Nathan G, editors. *Mediterranean families in antiquity: Households, extended families, and domestic space*. Wiley & Sons.
- Bardsley S. 2014. Missing women: sex ratios in England, 1000–1500. *J Brit Stud* 53:273–309. <https://doi.org/10.1017/jbr.2014.9>
- Berner M. 2014. Demographische und paläopathologische Untersuchungen der Skellette aus dem römerzeitlichen Gräberfeld Halbtürn. In: Doneus N, editor. *Das kaiserzeitliche Gräberfeld von Halbtürn, Burgenland*. Monographien des Römisch-Germanischen Zentralmuseums, Mainz 122/2:309–484.
- Bodel J. 2000. Dealing with the Dead: Undertakers, executioners and potter's fields in ancient Rome. In: Hope VM, Marshall E, editors. *Death and Disease in the Ancient City* (pp. 128–151). Routledge. <https://doi.org/10.4324/9780203452950>
- Boswell JE. 1988. *The kindness of strangers: the abandonment of children in Western Europe. from late antiquity to the Renaissance*. New York.
- Brooks S, Suchey JM. 1990. Skeletal age determination based on the Os pubis. A comparison of the Acsadi and Nemeskeri and Sucey Brooks methods. *Hum Evol* 5:227–238. <https://doi.org/10.1007/BF02437238>
- Brunner JA. 1972. Die frühmittelalterliche Bevölkerung von Bonaduz. Eine Anthropologische Untersuchung. *Schriftenreihe des Rätischen Museums Chur* 14:1–68.
- Börm H. 2022. The End of the Roman Empire: Civil Wars, the Imperial Monarchy, and the End of Antiquity. In: Gehler M, Rollinger R, Strobl P, editors. *The End of Empires* (pp. 191–212). Springer VS. https://doi.org/10.1007/978-3-658-36876-0_8
- Buckberry JL, Chamberlain AT. 2002. Age estimation from the auricular surface of the ilium: a revised method. *Am J Phys Anthropol* 119:231–239. <https://doi.org/10.1080/00665983.2014.984960>
- Buikstra JE, Ubelaker DH. 1994. Standards for data collection from human skeletal remains: proceedings of a seminar at the Field Museum of Natural History. Fayetteville: Arkansas Archeological Survey.
- Cardoso H. 2008. Epiphyseal union at the innominate and lower limb in modern Portuguese skeletal sample, and age estimation in adolescent and young adult male and female skeletons. *Am J Phys Anthropol* 135:161–170. <https://doi.org/10.1002/ajpa.20717>
- Caselitz P. 1981. Überlegungen zur Sexualrelation hoch- und spätmittelalterlicher Populationen am Beispiel der Bevölkerungsstichprobe aus dem Zisterzienserkloster zu Hude. *Archäol Mitt NWDeut* 4:75–90.
- Chao F, Gerland P, Cook AR, Alkema L. 2019. Systematic assessment of the sex ratio at birth for all countries and estimation of national imbalances and regional reference levels. *PNAS* 116:9303–9311. <https://doi.org/10.1073/pnas.1812593116>
- Lo Cascio E, Tacoma LE, editors. 2016. *The Impact of Mobility and Migration in*

- the Roman Empire: Proceedings of the Twelfth Workshop of the International Network Impact of Empire (Rome, June 17–19, 2015). Brill. <https://doi.org/10.1163/9789004334809>
- Cintas-Peña M, Herrero-Corral AM. 2020. Missing prehistoric women? Sex ratio as an indicator for analyzing the population of Iberia from the 8th to the 3rd millennia B.C. *Archaeol Anthropol Sci* 12:263 <https://doi.org/10.1007/s12520-020-01215-x>
- Coale AJ. 1991. Excess female mortality and the balance of the sexes in the population: An estimate of the number of “missing females”. *Popul Dev Review* 17:517–523.
- Coqueugniot H, Weaver T. 2007. Infracranial maturation in the skeleton collection from Coimbra, Portugal: new aging standards for epiphyseal union. *Am J Phys Anthropol* 134:424–437. <https://doi.org/10.1002/ajpa.20683>
- Cunningham C, Scheuer L, Black S. 2016. *Developmental Juvenile Osteology*. Second Edition ed. London: Academic Press.
- Darby Nock A. 1932. Cremation and Burial in the Roman Empire. *The Harvard Theological Review* 25(4):321–359.
- Darwin Ch. 1871. *The Descent of Man, and Selection in Relation to Sex*. London: John Murray.
- D’Alfonso A, Ludovisi M, Palermo P, Serava A, Polsinelli V, Bruno M, et al. 2023. Sex ratio at birth: causes of variation and narrative review of literature. *Minerva Obstet Gynecol* 75:189–200. <https://doi.org/10.23736/S2724-606X.22.05054-0>
- van Driel-Murray C. 2008. Those Who Wait at Home: The Effect of Recruitment on Women in the Lower Rhine Area. In: Brandl U, editor. *Frauen und Römisches Militär: Beiträge eines Runden Tisches in Xanten vom 7. Bis 9. Juli 2005: Beiträge eines Runden Tisches in Xanten vom 7. Bis 9. Juli 2005* pp. 82–91. Archaeopress. <https://doi.org/10.30861/9781407301983>
- Ehgartner W. 1947. Der spätrömische Friedhof von Oggau, Burgenland. *Mitt Anthropol Ges Wien* 73–77:2–32.
- Eichert S, Richards N. 2022. Early Medieval period in Austria as used in THANADOS from the end of the Late Roman period until the 11th Century [Controlled vocabulary]. *Period O. A Gazetteer of Periods for Linking and Visualizing Data*. Available at: <http://n2t.net/ark:/99152/p0cwwzn>
- Emmerson ALC. 2020. Re-examining Roman Death Pollution. *J Roman Stud*, 110:5–27. <https://doi.org/10.1017/S0075435820001227>
- Engels D. 1980. *The problem of female infanticide in the Greco-Roman world*. The Chicago: University of Chicago Press.
- Erdkamp P. 2021. Climate Change and the Productive Landscape in the Mediterranean Region in the Roman Period. In: Erdkamp P, Manning JG, Verboven K, editors. *Climate Change and Ancient Societies in Europe and the Near East* Springer International Publishing. (pp. 411–442). https://doi.org/10.1007/978-3-030-81103-7_14
- Ery KK. 1973. Anthropological data of the late Roman population at Pecs, Hungary. *Anthropologia Hungarica* 7:63–120.
- Ery KK. 1981. Anthropologische Analyse der Population von Tokod aus dem 5. Jahrhundert. In: Mocsy A, editor. *Die spätrömische Festung und das Gräberfeld von Tokod*. Budapest: Akademiai Kiado, pp. 223–263.
- Fehér J, Muerth M, Pistocchi A. 2015. Water models and scenarios inventory for the Danube region. Publications Office of the European Union. <https://doi.org/10.2788/412928>
- Ferembach D, Schwidetzky I, Stloukal M. 1979. Empfehlung für die Alters- und Geschlechtsdiagnose am Skelett. *Homo* 30:1–32.

- Fukuda M, Fukuda K, Shimizu T, Nobunaga M, Mamsen LS, Yding Andersen C. 2014. Climate change is associated with male:female ratios of fetal deaths and newborn infants in Japan. *Fertil Steril* 102(5):1364–1370.e2. <https://doi.org/10.1016/j.fertnstert.2014.07.1213>
- Gonçalves D, Duarte C, Costa C, Muralha J, Campanacho V, Costa AM, Angelucci DE. 2010. The Roman Cremation Burials of Encosta De Sant'Ana (Lisbon). *Revista Portuguesa de Arqueologia* 13:125–144.
- Greuch V. 2020. The sex ratio at birth – Historical aspects. *Early Hum Develop* 140:104857. <https://doi.org/10.1016/j.earlhumdev.2019.104857>
- Graham EJ. 2006a. Discarding the Destitute: Ancient and Modern Attitudes Towards Burial Practices and Memory Preservation Amongst the Lower Classes of Rome. In: Croxford B, Goodchild H, Lucas J, Ray N, editors. *TRAC 2005: Proceedings of the Fifteenth Annual Theoretical Roman Archaeology Conference, Birmingham 2005*. Oxbow Books No. 2005; pp. 57–72. https://doi.org/10.16995/TRAC2005_57_72
- Graham EJ. 2006b. The Burial of the Urban Poor in Italy in the Late Roman Republic and Early Empire. *Archeopress*.
- Greisinger M. 2006. Stadt Wels, KG Wels. *Fundberichte aus Österreich*. 44/2005:545–547.
- Greisinger M. 2007. Stadt Wels, KG Wels. *Fundberichte aus Österreich*. 45/2006:698–699.
- Greisinger M. 2010. Stadt Wels, KG Wels. *Fundberichte aus Österreich*. 48/2009:436–437.
- Greisinger M, Mayrhofer P, Miglbauer R, Waser M. 2020. Das römische Wels: Ein digitaler Stadtplan. Ein Projekt des Bundesdenkmalamtes, des Musealvereines Wels und des Stadtmuseums Wels 2019. *JBs Musealvereines Wels*, 39(2018/2019/2020):31–100.
- Grossschmidt K. 1990. Paläopathologische Untersuchungen an den menschlichen Skeletten des awarenzeitlichen Gräberfeldes Csokorgasse in Wien-Simmering: Schmelzhypoplasien, Cribrosierungen und Harris'sche Linien als Streßindikatoren. Unpublished PHD Thesis.
- Le Guennec MA. 2020. Women's Mobility and Migration in Roman Antiquity: A Fragmentary History. *Clio. Women, Gender, History* 51:35–54.
- Haentjens AME. 2000. Reflections on Female Infanticide in the Greco-Roman World. *L'Antiquité Classique* 69:261–264. Available at: <http://www.jstor.org/stable/41660053>
- Hagmann D. 2019. Roman Rural Landscapes in Noricum: Archäologische Untersuchungen zur römischen Besiedlung im Hinterland Nord-Noricums. In: Pieler F, Trebsche P, editors. *Beiträge zum Tag der Niederösterreichischen Landesarchäologie*, pp. 99–107.
- Wissenschaftliche Publikationen aus den Landessammlungen Niederösterreich. <https://doi.org/10.25365/phaidra.148>
- Hagmann D. 2020. Practicing Digital Archaeology at the Vienna Orme and Pesa Valley Project. In: Schörner G, editor. *The Vienna Orme and Pesa Valley Project: Proceedings of the International Workshop held at Vienna*. Vol. 1, pp. 221–234.
- Projektinitiative Roman Rural Landscapes am Institut für Klassische Archäologie der Universität Wien. https://doi.org/10.25365/phaidra.239_13
- Hagmann D. 2021. A Controlled Vocabulary for a Simple and Basic Chronology for the Roman Province of Noricum (2.0.0) [Controlled vocabulary; Online]. *Period O. A Gazetteer of Periods for Linking and Visualizing Data*. <https://doi.org/10.25365/PHAIDRA.390>
- Hagmann D. 2022. Ein „Roman Rural Landscape“ in Nordostnoricum: Ergebnisse der landschaftsarchäologischen Untersuchungen zur ländlichen Besiedlung der römischen Kaiserzeit in Niederös-

- terreich. In: Pieler F, Breibert W, editors. Beiträge zum Tag der Niederösterreichischen Landesarchäologie 2022 (S. 61–70). Wissenschaftliche Publikationen aus den Landessammlungen Niederösterreich Asparn/Zaya. <https://doi.org/10.5281/zenodo.6751583>
- Hagmann D. 2023. Die ländliche Besiedlung des nördlichen Noricum. Das Hinterland von Aelium Cetium/St. Pölten zwischen Erlauf- und Traisental. *Acta Carnuntina*, 13:18–27. <https://doi.org/10.5281/zenodo.7792969>
- Haldon J, Elton H, Huebner SR, Izdebski A, Mordechai L, Newfield TP. 2018a. Plagues, climate change, and the end of an empire: A response to Kyle Harper's *The Fate of Rome* (1): Climate. *History Compass*, 16(12):e12508. <https://doi.org/10.1111/hic3.12508>
- Haldon J, Elton H, Huebner SR, Izdebski A, Mordechai L, Newfield TP. 2018b. Plagues, climate change, and the end of an empire. A response to Kyle Harper's *The Fate of Rome* (2): Plagues and a crisis of empire. *History Compass*, 16(12):e12506. <https://doi.org/10.1111/hic3.12506>
- Haldon J, Elton H, Huebner SR, Izdebski A, Mordechai L, Newfield TP. 2018c. Plagues, climate change, and the end of an empire: A response to Kyle Harper's *The Fate of Rome* (3): Disease, agency, and collapse. *History Compass* 16(12):e12507. <https://doi.org/10.1111/hic3.12507>
- Harper K. 2017. *The Fate of Rome: Climate, Disease, and the End of an Empire*. Princeton University Press.
- Harrer B. 2014. *Demographie und Paläopathologie des spätantiken Gräberfeldes der Flur Mühlacker in Bad Deutsch-Altenburg (Carnuntum, Niederösterreich)*. unpublished MA thesis, University of Vienna.
- Harris W. 1982. The Theoretical Possibility of Extensive Infanticide in the Graeco-Roman World. *The Classical Quarterly* 32(1):114–116. <https://doi.org/10.1017/S0009838800022850>
- Harris W. 1994. Child-exposure in the Roman Empire. *J Roman Stud* 84:1–22.
- Häusler A. 1969. Archäologische Gesichtspunkte zur Erkennbarkeit und Auswirkung der Geschlechterdifferenzierung. *Wissenschaftliche Zeitschrift Humboldt Universität Berlin Math Nat R* 18:959–963.
- Hausmair, B. 2006. Die bajuwarischen Grabfunde aus Wels und Marchtrenk: Archäologische anthropologische und metallurgische Betrachtungen. *JB des Musealvereines Wels* 34(2004/2005):29–115.
- Hausmair B. 2022. Some Remarks on Society and Settlement Dynamics in the Early Medieval Alpine Foothills of Northwestern Noricum. *Beiträge Zur Mittelalterarchäologie in Österreich* 38:89–106.
- Hesketh T, Xing ZW. 2006. Abnormal sex ratios in human populations: causes and consequences. *PNAS* 103:13271–5. <https://doi.org/10.1073/pnas.0602203103>
- Hirshberg A, Srinivas SK. 2017. Epidemiology of maternal morbidity and mortality. *Sem Perinatol* 41:332–337. <https://doi.org/10.1053/j.semperi.2017.07.007>
- Hobbs F. 2004. Age and sex composition. In: Siegel JS, Swanson DA, editors. *The methods and materials of demography*, 2nd edition. California: Elsevier Academic Press, pp. 125–173.
- Hölbling E. 2008. *Das römische Gräberfeld von Pottenbrunn: Untersuchungen zur Bevölkerung des ländlichen Raumes um Aelium Cetium; die Grabungen des Bundesdenkmalamtes der Jahre 2000–2002*. Unpublished PHD Thesis University of Vienna.
- Il A, Joksimovic M. 2015. Women at the Verge: Roman and Byzantine women on the Danubian Limes. In: Tsetskhladze GR, Avram A, Hargrave J. *The Danubian lands between the Black, Aegean and Adriatic Seas*. *Proceedings of the 5th*

- International Congress on Black Sea antiquities. *Archaeopress Archeology*.
- James WH. 1987. The Human Sex Ratio. Part 2: A Hypothesis and a Program of Research. *Hum Biol* 59:873–900. Available at: <https://www.jstor.org/stable/41463954>
- Jäger-Wersonig S. 1999a. Das östliche Gräberfeld von Wels. *Forum Archaeologiae - Zeitschrift Für Klassische Archäologie*, 13/XII. Available at: <https://www.alpinehiking.eu/forum/forum1299/13wels.htm>
- Jäger-Wersonig S. 1999b. Das römische Gräberfeld-Ost von Wels: Die Grabung in der Dr.-Groß-Straße 1961 und in der Dr.-Schauer-Straße 1962. 1, Text [Diploma thesis, University of Vienna]. Available at: <https://ubdata.univie.ac.at/AC02520173>
- Jäger-Wersonig S. 1999c. Das römische Gräberfeld-Ost von Wels: Die Grabung in der Dr.-Groß-Straße 1961 und in der Dr.-Schauer-Straße 1962. 2, Katalog, Abbildungen und Tafeln [Diploma thesis, University of Vienna]. Available at: <https://ubdata.univie.ac.at/AC02520175>
- Kemkes-Grottenthaler A. 1997. Das Frauendefizit archäologischer Serien – ein paläodemographisches Paradoxon? *Anthrop Anz* 55:265–280.
- Kirchengast S, Hartmann B. 2009. The male disadvantage hypothesis reconsidered: Is there really a weaker sex? An analysis of gender differences in newborn somatometrics and vital parameters. *J life Sci* 1:63–71. <https://doi.org/10.1080/09751270.2009.11885136>
- Kirchengast S, Hagmann D. 2022. Spatial differences in childhood and adolescent obesity according to sex and migrant status in Vienna, Austria. *Hum Biol Public Health*, 1. <https://doi.org/10.52905/hbph2022.1.31>
- Kirchengast S, Hagmann D, Ankerl B, Greisinger M, Miglbauer R. 2023. The dead of Ovilava - paleopathological and spatio-temporal analysis of Roman and Early Medieval burials from the 'Gräberfeld Ost'. (In prep).
- Kloiber Ä. 1957. Die Gräberfelder von Lauriacum – das Ziegelfeld. *Forschungen in Lauriacum* 4/5.
- Kloiber Ä. 1962. Die Gräberfelder von Lauriacum – das Espelmayrfeld. *Forschungen in Lauriacum* 8.
- Knötzele P. 2018. Das römische Gräberfeld von Stettfeld II: Katalog der Gräber und übrigen Befunde. Dr. Ludwig Reichert. <https://doi.org/10.29091/9783954907021>
- Kruger DJ, Nesse RM. 2004. Sexual selection and the Male:Female mortality ratio. *Evolutionary Psychology*, 2:66–85. <https://doi.org/10.1177/147470490400200112>
- Kunter M. 1991. Variabilität der Sterblichkeit bei prähistorischen, historischen und rezenten Bevölkerungen. *Archäologische Informationen* 14:160–175.
- Lebzelter V, Thalmann G. 1935. Römerzeitliche Schädel aus Tulln. *Zeitschrift für Rassenkunde* 1:274–288.
- deLigt L, Tacoma LE, editors. 2016. *Migration and Mobility in the Early Roman Empire*. Brill. <https://doi.org/10.1163/9789004307377>
- Lovejoy CO. 1985. Dental wear in the Libben population. Its functional pattern and role in the determination of adult age at death. *Am J Phys Anthropol* 68:47–56. <https://doi.org/10.1002/ajpa.1330680105>
- Lovejoy CO, Meindl RS, Pryzbeck TR, Mensforth RP. 1985. Chronological metamorphosis of the auricular surface of the ilium. A new method of the determination of adult skeletal age at death. *Am J Phys Anthropol* 68:15–28. <https://doi.org/10.1002/ajpa.1330680103>
- McCormick M, Büntgen U, Cane MA, Cook ER, Harper K, Huybers P. et al. 2012. Climate Change during and after the Roman Empire: Reconstructing the Past from Scientific and Historical Evidence. *J Interdiscip History* 43(2):169–220. https://doi.org/10.1162/JINH_a_00379

- McGinn TAJ. 2004. Missing Females? Augustus' Encouragement of Marriage between Freeborn Males and Freedwomen. *Historia: Zeitschrift Für Alte Geschichte*, 53(2):200–208. Available at: <http://www.jstor.org/stable/4436723>
- Marschler M. 2013. Paläopathologie und Demographie des römerzeitlichen Gräberfeldes Albertina in Wien. Unpublished MA thesis, University of Vienna.
- Meier M. 2019. Geschichte der Völkerwanderung. C. H. Beck. <https://doi.org/10.17104/9783406739606>
- Meindl RS, Lovejoy CO. 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>
- Miglbauer R. 2001. Ovilava–Wels: Der Übergang von der Spätantike zum frühen Mittelalter. In: Felgenhauer-Schmiedt S, Eibner A, Knittler H, editors. Zwischen „Römersiedlung“ und mittelalterlicher Stadt. Archäologische Aspekte zur Kontinuitätsfrage, pp. 149–161.
- Miglbauer RM. 2002. Ovilavis. In: Šašel Kos M, Scherrer P, editors. The Autonomous Towns of Noricum and Pannonia // Die autonomen Städte in Noricum und Pannonien. Noricum Narodni Muzej Slovenije, pp. 245–256.
- Miglbauer R. 2004. Stadtmuseum und Stadtgalerie Wels (Jahresberichte 2000-2002). *JB Musealvereines Wels* 33(2001/2002/2003):483–506.
- Miglbauer R. 2007. Die letzte Reise: Ausgrabungen im östlichen Gräberfeld von Ovilava/Wels. Ausstellung im Stadtmuseum Wels – Minoriten. 4. Mai bis 14. Oktober 2007. Magistrat der Stadt Wels.
- Miglbauer R. 2009. Archäologie Aktuell: Archäologische Ausgrabungen in Wels der Jahre 2006 – 2008. Magistrat der Stadt Wels.
- Miglbauer RM. 2014. Das Wesen einer römischen Stadt am Beispiel von Ovilava/Wels. In: Aspernig W, Kalliauer G, Miglbauer RM, editors. Festschrift 60 Jahre Musealverein Wels 1953/1954–2013/2014. Jahrbuch des Musealvereines Wels, pp. 65–80.
- Miglbauer RM. 2015. Wels – Ovilava. In: Gassner V, Pülz A, editors. Der römische limes in Österreich (S. Wels-Ovilava Autonome Stadt). Verlag der Österreichischen Akademie der Wissenschaften. <https://doi.org/710.2307/j.ctt1vw0q15.23>
- Miglbauer RM, Waser M. 2020. Die Stadtbefestigung von Ovilava-Wels. In: Thüry GE, editor. Domi militiaeque. Militär- und andere Altertümer. Archaeopress Publishing Ltd, pp. 68–76. <https://doi.org/10.2307/j.ctv13nb7f5.15>
- Mikic Z. 1984. Beiträge zur Anthropologie spätrömischer bis spätmittelalterlicher Bevölkerungen Jugoslawiens. Godisnjak XXII. Sarajewo, Bosnei Herzegovina. Akademija nauka umjestnosti.
- Mitchell PD, Brickley M. 2017. Updated Guidelines to the Standards for Recording Human Remains. s.l. Chartered Institute for Archaeologists.
- Naeye RL, Burt LS, Wright DL, Blanc WA, Tatter D. 1971. Neonatal mortality, the male disadvantage. *Pediatrics* 48:902–6.
- Neugebauer-Maresch Chr, Neugebauer JW. 1986. Klosterneuburg in der Spätantike. der Friedhof der römischen Kaiserzeit in Klosterneuburg. *Amtsblatt der Stadtgemeinde Klosterneuburg* 5:1–8.
- Ortner DJ. 2003. Identification of Pathological Conditions in Human Skeletal Remains (2. Aufl.). Academic Press.
- Pail P. 2009. Demographie und Paläopathologie einer spätantiken Bevölkerung Pannoniens und Norikums am Beispiel der Gräberfelder Mannersdorf a. d. Leitha und Saladorf (Niederösterreich) unpublished MA thesis, University of Vienna.

- Pearce J. 2011. Representations and Realities: Cemeteries as Evidence for Women in Roman Britain. *Medicina nei Secoli* 23(1):227–254.
- Pearce J. 2016. Beyond the Grave. Excavating the Dead in the Late Roman Provinces. In: Lavan L, Mulryan M, editors. *Field Methods and Post-Excavation Techniques in Late Antique Archaeology*. BRILL, pp. 441–482. <https://doi.org/10.1163/9789004309777>
- Perry JS. 2017. *The Roman Collegia: The Modern Evolution of an Ancient Concept*. Brill. <https://doi.org/10.1163/9789047409373>
- Pfeiffer S, Doyle LE, Kurki HK, Harrington L, Ginter JK, Merritt CE. 2014. Discernment of mortality risk associated with childbirth in archaeologically derived forager skeletons. *Int J Paleopathol* 7:15–24. <https://doi.org/10.1016/j.ijpp.2014.05.005>
- Phenice TW. 1969. A newly developed visual method of sexing the Os pubis. *Am J Phys Anthropol* 30:297–301. <https://doi.org/10.1002/ajpa.1330300214>
- Pichelmayer OE. 1972. *Historisch-anthropologische Untersuchungen des römischen Gräberfeldes auf dem Steinpass zu Lauriacum*. PHD Thesis University of Graz.
- Pilkington N. 2013. Growing Up Roman: Infant Mortality and Reproductive Development. *J Interdiscip History* 44:1–35. Available at: <http://www.jstor.org/stable/43829415>
- Pongou R. 2013. 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* 50:421–444. <https://doi.org/10.1007/s13524-012-0161-5>
- Prowse T. 2014. Burial Practices and Tombs in the Roman World. In: Smith C, editor. *Encyclopedia of Global Archaeology*. Springer, pp. 1060–1069. https://doi.org/10.1007/978-1-4419-0465-2_950
- Retief FJ, Cilliers L. 2010. Burial Customs and the Pollution of Death in Ancient Rome: Procedures and Paradoxes. *Acta Theologica* 26(2):128–146. <https://doi.org/10.4314/actat.v26i2.52569>
- Sano M. 2012. Collegia Through Their Funeral Activities: New Light on Sociability in the Early Roman Empire. *Espacio Tiempo y Forma. Serie II, Historia Antigua*. Article 25. <https://doi.org/10.5944/etfii.25.2012.10298>
- Schaefer M, Black S, Scheuer L. 2009. *Juvenile Osteology*. Academic Press.
- Scheidel W. 2010. Greco-Roman sex ratios and femicide in comparative perspective. *Princeton Stanford Working papers in Classics*. 1–12.
- Scholz M. 2022. Grabbauten in den nördlichen Grenzprovinzen des Römischen Reiches zwischen Britannien und dem Schwarzen Meer, 1.-3. Jahrhundert n. Chr. (Vol. 1). *Propylaeum*. <https://doi.org/10.11588/PROPYLAEUM.1104>
- Schott L. 1964. Bevölkerungsgeschichtliche Aufschlüsse aus hochmittelalterlichem Skelettmaterial: ein Vergleich von Geschlechtsverhältniszahlen *Wiss. Zschrift der Humboldt Universität Berlin* 13:8–15.
- Schweder BI, Winkler EM. 2004. *Untersuchungen zu den Gräberfeldern in Carnuntum*. Verlag der Österreichischen Akademie der Wissenschaften.
- Séguy I. 2019. Current Trends in Roman Demography and Empirical Approaches to the Dynamics of the Limes Populations. In: Verhagen P, Joyce J, Groenhuijzen MR, editors. *Finding the Limits of the Limes: Modelling Demography, Economy and Transport on the Edge of the Roman Empire*, pp. 23–41. Springer International Publishing. https://doi.org/10.1007/978-3-030-04576-0_2
- Sharma S, Singh M, Sharma V, Pal R. 2017. Female deficit syndrome: trend, causes and challenges ahead. *Asian J Pharma Health Sci* 7:1747–1750.

- Šlaus M, Pećina-Šlaus N, Brkić H. 2004. Life Stress on the Roman Limes in Continental Croatia. *HOMO* 54(3):240–263. <https://doi.org/10.1078/0018-442X-00072>
- Sommerwerk N, Bloesch J, Baumgartner C, Bittl T, Čerba D, Csányi B, et al. 2022. Chapter 3 – The Danube River Basin. In: Tockner K, Zarfl C, Robinson CT, editors. *Rivers of Europe (Second Edition)*. Elsevier, pp. 81–180. <https://doi.org/10.1016/B978-0-08-102612-0.00003-1>
- Stagl J, Hattermann F. 2015. Impacts of Climate Change on the Hydrological Regime of the Danube River and Its Tributaries Using an Ensemble of Climate Scenarios. *Water* 7(11):6139–6172. <https://doi.org/10.3390/w7116139>
- Stone PK. 2016. Biocultural perspectives on maternal mortality and obstetrical death from the past to the present. *Am J Phys Anthropol* 159(Suppl 61):S150–71. <https://doi.org/10.1002/ajpa.22906>
- Toynbee JMC. 1996. *Death and Burial in the Roman World*. JHU Press.
- Trivers RL, Willard DE. 1972. Natural selection of parental ability to vary the sex ratio of offspring. *Science* 179:90–92.
- Stojanowski CM, Seidemann RM, Doran GH. 2002. Differential skeletal preservation at Windover Pond: causes and consequences. *Am J Phys Anthropol* 119:15–26. <https://doi.org/10.1002/ajpa.10101>
- Szilvassy J. 1976. Anthropologischer Befund des römerzeitlichen Gräberfeldes von Brunn am Gebirge. *Fundberichte Österreichs* 15:81–88.
- United Nations, Department of Economic and Social Affairs, Population Division 2022. *World Population Prospects 2022*. Online Edition. United Nations (2022). Available at: <https://population.un.org/wpp/Download/Standard/Population/>
- Verboven K, Laes C. 2016. Work, Labour, and Professions in the Roman World. In: Verboven K, Laes C, editors. *Work, Labour, and Professions in the Roman World*. Brill. <https://doi.org/10.1163/9789004331686>
- Verhagen P. 2019. Modelling the Dynamics of Demography in the Dutch Roman Limes Zone: A Revised Model. In: Verhagen P, Joyce J, Groenhuijzen MR, editors. *Finding the Limits of the Limes: Modelling Demography, Economy and Transport on the Edge of the Roman Empire*, pp. 43–59. Springer International Publishing. https://doi.org/10.1007/978-3-030-04576-0_3
- Volk P, Büchner S. 1995. Das “Frauendefizit” Vorgeschichte und antike Populationen als methodisches Problem der Archäologie. In: Saternur KS, Bonte W, editors. *Forensische Osteologie, Anthropologie, Biomechanik, Klinik, Archäologie*. Festschrift für Steffen Berg. Schmidt-Römhild. Lübeck, pp. 161–169.
- Wahl J, Kokabi M. 1988. *Das römische Gräberfeld von Stettfeld 1*. Forschungen und Berichte zur Vor- und Frühgeschichte in Baden-Württemberg. Kommissionsverlag, K. Theiss, Stuttgart.
- Walker PL, Johnson JR, Lambert PM. 1988. Age and sex biases in the preservation of human remains. *Am J Phys Anthropol* 76(2):183–188. <https://doi.org/10.1002/ajpa.1330760206>
- Weiss KM. 1972. On the systematic bias in skeletal sexing. *Am J Phys Anthropol* 37:239–250. <https://doi.org/10.1002/ajpa.1330370208>
- White TD, Folkens PA. 2005. *The Human Bone Manual*. Academic Press.
- Wiltschke-Schrotta K, Teschler-Nicola M. 1991. *Das Spätantike Gräberfeld von Lentia/linz*. Linzer archäologische Forschungen Band 19.
- Winckler K. 2016. „Wie aus dem Hause der Ägyptischen Knechtschaft“: Römer, Barbaren und Migration im Donauraum nach der Vita Severini. In: Geisler H, editor. *Wandel durch Migration?* 26. Internationales Symposium „Grundprobleme

- der frühgeschichtlichen Entwicklung im mittleren Donaauraum“. Straubing 2014. Dr. Faustus, pp. 28–38.
- Wippert PM, Rector M, Kuhn G, Wuertz-Kozak K. 2017. Stress and Alterations in Bones: An Interdisciplinary Perspective. *Frontiers Endocrinol* 8:96. <https://doi.org/10.3389/fendo.2017.00096>
- Wittwer-Backofen U. 1987. Siedlung und Friedhof. Eine methodische Studie zur Aussagekraft demographischer und paläodemographischer Parameter.- PHD Thesis, University of Mainz.
- Ziegelmayr G. 1979. Die anthropologische Befunde: In: Das spätrömische Gräberfeld von Neuburg an der Donau. Materialhefte zur bayrischen Vorgeschichte 40:71–133.
- Zoboli O, Viglione A, Rechberger H, Zessner M. 2015. Impact of reduced anthropogenic emissions and century flood on the phosphorus stock, concentrations and loads in the Upper Danube. *The Science of the total environment* 518-519C:117–129. <https://doi.org/10.1016/j.scitotenv.2015.02.087>
- Zuckerman MK, Crandall J. 2019. Reconsidering sex and gender in relation to health and disease in bioarchaeology. *J Anthropol Archaeol* 54:161–171. <https://doi.org/10.1016/j.jaa.2019.04.001>