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Using Content and Bibliometric Network Analysis to Understand the Development and Study of "Violence" in Bioarchaeology

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ABSTRACT Violence is an interdisciplinary concept subjected to the fluctuations of social and personal perceptions of morality, ethics, and justice. While its definition therefore proves to be elusive, it may serve as a way to research and reconstruct human behavior. This also applies to bioarchaeology, which is dedicated to the study of past societies through the analysis of human remains. The aim of this article is to analyze the general development, methodological key concepts, studied markers, and potential paradigm changes in the study of violence in bioarchaeology. This is done by applying bibliometric tools to selected scientific publications and building on previous research analyzing paleopathological literature. The results are then compared to qualitative reviews on violence in bioarchaeology to draw conclusions about significance and applicability of bibliometric network analysis in the light of the expanding scientific literature. Finally, a future trajectory of the concept of "violence" in bioarchaeology is presented.

Keywords: bibliometric analysis; field development; violence

Gewalt ist ein interdisziplinär konzeptualisiertes Phänomen, das soziokulturellen Schwankungen bezüglich zur Auffassung von Moral, Ethik und Gerechtigkeit stark unterworfen ist. Auch wenn sich eine präzise Definition daher als herausfordernd erweist, ist Gewalt zentraler Untersuchungsgegenstand für die Rekonstruktion menschlicher Verhaltensweisen. Dies gilt auch für die Bioarchäologie, die sich der systematischen Erforschung vergangener Gesellschaften anhand menschlicher Skelettüberreste widmet. Ziel dieses Beitrags ist es, die allgemeine Entwicklung, die methodologischen Schlüsselkonzepte sowie die potenziellen paradigmatischen Transformationen bei der Untersuchung von Gewaltphänomenen in der bioarchäologischen Forschungspraxis zu analysieren. Hierzu werden bibliometrische Analysen auf Basis ausgewählter wissenschaftlicher Publikationen angewandt, auch aufbauend auf früheren Untersuchungen zur Analyse paläopathologischer Literatur. Die hier erzielten Ergebnisse werden mit denen qualitativer Arbeiten über Gewalt in der Bioarchäologie verglichen, um Schlussfolgerungen über die Bedeutung und Anwendbarkeit der bibliometrischen Netzwerkanalyse im Hinblick auf die wachsende wissenschaftliche Literatur zu ziehen. Abschließend wird ein Ausblick auf die Entwicklung des Gewaltbegriffs in der Bioarchäologie gegeben.

Keywords: Gewalt; Trauma; Bioarchäologie; Netzwerkanalyse; Bibliometrie

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Bioarchaeology primarily focuses on human skeletal material and mortuary contexts, as well as other biological remains in archaeological contexts to address questions such as health, lifestyle, diet, and mortality of past populations (Buikstra 1977). Through classifications like age at death and sex estimation, conclusions can be drawn about the demography of a population (Berryman et al. 2013; Roberts 2019). Other information open for study and interpretation that can be derived from the skeletal record includes taphonomic influences, pathological conditions, and trauma. The term "trauma" may be considered too unspecific, and phrases like "traumatic injuries" are preferred in bioarchaeology or when referring to skeletal contexts. For the scope of this article, we deliberately use a broader term as we intend to cover a wider range of types of trauma. The study of trauma and violence is a major focus in bioarchaeology (Pérez-Flórez and Harrod 2021; Walker 2001). Through the nature of injury patterns observed on the bone, conclusions may be drawn about the causes of injuries related to weapons, and hypotheses regarding victimhood or perpetrator behavior may be tested. In contrast to the social sciences, violence in bioarchaeology is primarily understood as a physical force leaving traces on the human body itself (Redfern 2014), although it is accepted that interpersonal violence "does not occur in isolation from social and cultural forces" (Lee 2016:158). However, there are also understandings that focus on the body and its necropolitical agency. Bioarchaeology is able to explore the environment of the politically sensitive human body through time, interpreting changes and responses to it through cultural and political shifts (Geller and Suri 2014). Skeletal evidence, including burial contexts, provides clues for interpretation in terms of reconstructing behavior and possible motivations behind it. Particularly in violent contexts, this shows how the human body can be affected on a deeply personal and individual level (Harrod, Martin, et al. 2012). Many humanities and other scientific disciplines seek to understand and categorize violence, mainly due to its frequency in the human experience. Examples are the behavioral sciences, sociology, politics, psychology, philosophy, and archaeology, to name a few (Silverberg and Gray 1992; Wahl 2013; Whitehead 2007). Therefore, different and field-dependent definitions exist in varying detail (Mbembe and Corcoran 2019; Reemtsma 2010; Whitehead 2007). Philosophy is particularly well suited to the analysis of this topic, as it offers an objective approach to understanding and examining the overarching structures of society and objectively deals with analyzing and understanding societal encompassing structures. Thomas Hobbes (1588–1679), for example, approached violent behavior such as warfare as an integral part of human nature, present since prehistory, positioning him contrary to Jean-Jacques Rousseau (1712–1778), who attributed it to the emergence of sovereign states (Bachofen 2015). In the 1960s, the why and how behind what is perceived as violence and violent behavior gained new traction in the political postwar contexts, with scholars like Hannah Arendt (1906–1975) (Arendt 1970), and on postcoloniality by Frantz Fanon (1925–1961) (Fanon 2013). Today, philosophers like Jan Philipp Reemtsma (1952) even argue that violence is being overanalyzed and has become something that has to be understood, prevented, and fought rather than just being accepted by society as a part of human nature (Reemtsma 2010). While there seems to be no universal agreement on how or even if violence can be defined and analyzed, it is therefore a concept that is best studied using an interdisciplinary approach. The study of violence not only encompasses its physical aspects but also includes less tangible effects that may impact the human body, such as structural and epistemic violence (Galtung 1969). The disparities resulting in structural violence stem from medical, cultural, and economic factors, with capitalist structures often exacerbating social and political instabilities, leading to disadvantages for out-groups (Farmer 2004; Springer 2011; Whitehead 2007). This has led to "social bioarchaeology" considering archival and historical sources to explain and contextualize human remains, focusing on health markers (Agarwal and Glencross 2011; Klaus 2012). This does not imply the absence of structural violence in the bioarchaeological record; rather, it requires the consideration of multiple lines of evidence, introducing greater complexity into the analysis. As scholars creating knowledge, it is important to consider the epistemic implications of our research. When generally dealing with theoretical concepts of violence, we would therefore also like to briefly consider epistemic violence. It arises from the creation and interpretation of knowledge, granting power to those who assert the primacy and universality of their knowledge over the knowledge systems of marginalized Others. Prevalent in scientific culture, epistemic violence dismisses but also silences alternative perspectives through assumptions and exclusions (Spivak 1988; Teo 2010). It ultimately culminates in the control and interpretation of knowledge, reflecting a nontangible power dynamic in the realm of information. Teo (2010) illustrates this by showing how a randomly chosen anatomical characteristic, such as ear size, can lead to a claim of population superiority.

The scientific literature is growing exponentially, with a doubling of literature currently set at every

15 years (Fortunato et al. 2018). This development has created a new field of study that analyzes the information of this output. Bibliometrics refers to the data scientific publications create through their metadata, such as citation scores, (co)authorships, affiliation data, and abstract keywords (Donthu et al. 2021). These huge data sets can then be analyzed using network analysis to relate these metrics to each other and to get a deeper understanding of the past, current, and potential future developments of the respective field. This can include the detection of the currently most cited documents, coauthorship networks, as well as research subfields. Bibliometric network analysis can therefore help not only to identify key concepts and research trends in science in general, but has especially shown what research incentives influence interdisciplinary fields in detail (Donthu et al. 2021; González-Alcaide et al. 2015; Leng and Leng 2021). This offers the chance to quantitatively and qualitatively explore the development of the study of violence in bioarchaeology using large amounts of selected publications.

This article analyzes how violence is studied with and through human remains from archaeological contexts to understand the current and past research approaches to violence in the bioarchaeological field using content and quantitative bibliographical analysis of relevant scientific publications. The documents are analyzed using their bibliographical data to map the development of study regarding methods, quantitative output, and key concepts. This is followed by a focus on their content and a manual analysis of previously identified key concepts.

Based on previous research and review, it is hypothesized that the bioarchaeological interest in violence will continue to grow, sparking research around terms such as interpersonal, systemic, and epistemic violence (Agarwal and Glencross 2011; Walker 2001). It is also hypothesized that there has been a shift toward a more interdisciplinary approach of contextualizing human remains within the framework of "violence," resulting from a general increased influx of theoretical concepts and approaches from the social sciences and humanities into biological anthropology (Accomazzo 2012). Previous bibliometric analysis on paleopathological literature has found a quantitative dominance of the publication of case studies as publication type (Boutin et al. 2022). This study picks up from there to apply a similar methodology to a body of literature concerned with the study of violence in the osteological record. Because there is no previous research and data on this type of study, it is for now hypothesized that case studies are also the focus of research regarding violence, in contrast to population analyses. In the end, the results from the quantitative review were compared to those of qualitative reviews that have been conducted in the past, to draw conclusions on their results and similarity. This is done to gain a better understanding of the possibilities offered by bibliometric approaches to reviews in bioarchaeology, especially for junior scholars and outsiders who are new to the field. This novel approach is also necessary in light of the exponential growth of scientific literature (Donthu et al. 2021; Fortunato et al. 2018).

Material and Methods

This study did not involve the analysis of human remains; instead, it focused on examining publications containing bioarchaeological content related to violence. The initial research phase involved acquiring scientific articles (Fig. 1). The aim was to use citation analysis to identify key documents in the field of bioarchaeology and the skeletal markers studied here. In addition, bibliographic coupling and co-occurrence analysis of keywords were applied to identify potential subfields of research. This will help reconstruct the development of the field on a quantitative and qualitative basis.

Data collection and search strategies

The data used in this study were extracted from Scopus (https://www.elsevier.com/solutions/scopus) on March 11, 2024. Scopus is a large citation database containing 93 million records from more than 25,000 scientific outlets and publishers.[1] The first step of data retrieval was to identify relevant scientific outlets that would cover the study of human bones in an archaeological context. These were identified based on keywords in their source title (Table 1). This means that no bias was created in the selection of publication outlets, but also that popular scientific outlets not specializing in archaeological sciences and with broader scopes, such as journals like *Nature*, *Science*, and *PLoS ONE*, were not included in the search. Then, documents were selected based on the occurrence of "violence" in the document's title, abstract, and keywords and the concluding search results saved as lists in Scopus. Lastly, the document lists were manually cleaned by scanning their content to exclude research on other *Homo* species, exclusively recent medicolegal contexts and material culture including weapons and fortifications. An exception for this was the "forensic" list containing information

1 https://www.elsevier.com/products/scopus/content, accessed November 27, 2023.

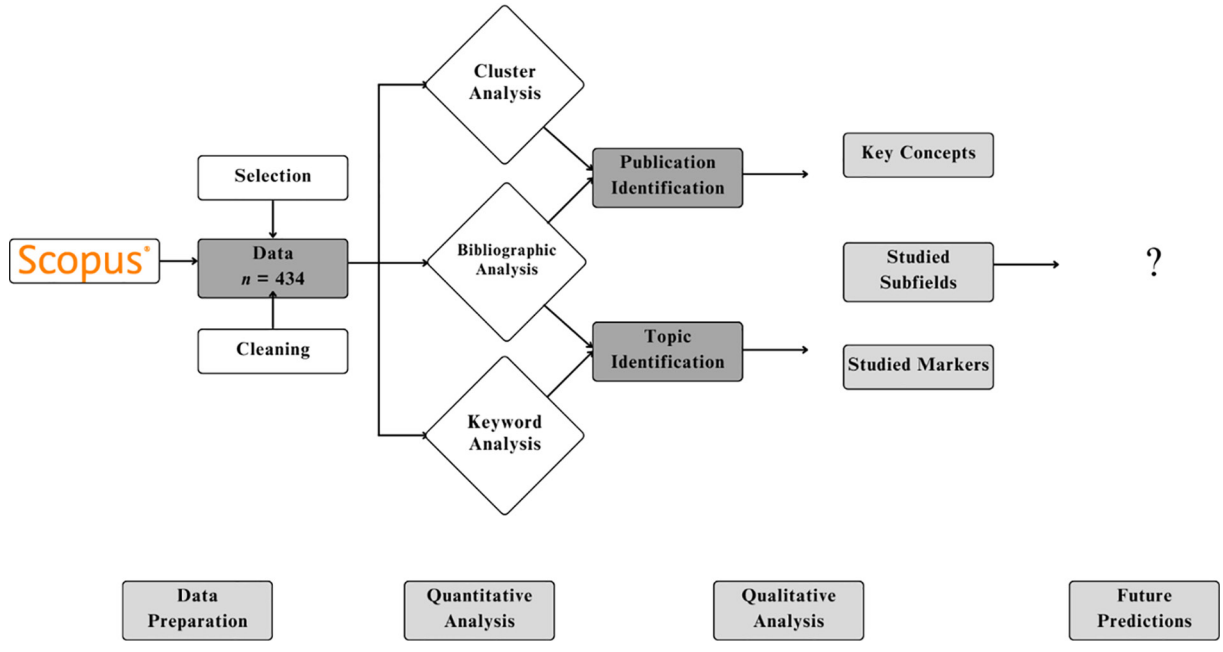

Figure 1. Workflow for the data selection process and network analysis conducted in this research.

Table 1. Steps in retrieving relevant literature for this study using the Scopus Database. The data query consisted of requesting source titles through relevant bioarchaeological keywords and then identifying relevant documents by searching for "violence" in document title, abstract, and keywords.

Source title: Word	Document Title, Abstract, Keywords: Word	Amount of Retrieved Publications	Amount of Retrieved Publications after Manual Content Cleaning	Total Amount of Retrieved Publications, with Duplicates	Total Amount of Retrieved Publications, without Duplicates
"Anthropology"	AND "violence"	1,149	84	$n = 473$	$n = 434$
"Anthropological"		342	37		
"Archaeology"		280	92		
"Archaeological"		90	52		
"Bioarchaeology"		75	70		
"Bioarchaeological"		5	4		
"Forensic"		2,760	14		
"Osteoarchaeology"		84	82		
"Osteoarchaeological"		0	0		
"Paleopathology"		36	33		
"Paleopathological"		3	0		
"Pathology"		232	3		
"Pathological"		3	2		

from publication outlets with "forensic" in their title. Here, the number of selected documents was not only higher compared to the other outlets but was also mostly focusing on present crime or accident cases. Therefore, only documents also containing "archaeology" and "archaeological" were automatically selected from this list and then manually cleaned using the same procedure as explained above.

Retrieved bibliographic information per publication for this study included author(s), title, abstract, keywords, and additional geographic and affiliatory data. This way, a total of 434 documents relevant for the analysis could be exported as a .csv file from Scopus for further data analysis after merging all lists from manual content cleaning.

Classification of publications

All publications included in this database were also classified according to their publication type. Here,

the categorization approach presented by Boutin et al. (2022) in their quantitative analysis of paleopathological literature was followed. They examined the relevancy of case studies in the paleopathological literature by coding publications into types and consequently analyzing their citation frequency. Because Scopus does return numerous scientific types of publications, including whole books, errata, and conference posters, categories for "Book" and "Other" were added to the analysis. The categories were as follows:

- *Case Studies*: The analysis was conducted, and results and discussion were presented on an individual level, with multiple case studies being possible within one publication.
- *Population Analysis*: The focus of this analysis was the quantitative analysis of a whole population, including sex or ethnic affiliation.
- *Methods*: The development of diagnostic and innovative approaches was in focus.
- *Review/Comments*: The general development of the field and/or its parts was reviewed, discussed, and put in context to other concepts.
- *Book*: The entry was referring to a whole book or volume with multiple chapters.
- *Other*: No other category applied.

Conclusions will be drawn based on the proposed hypothesis that different types of violence are studied either on a population level or through an individual case report. All publications were classified independently by two bioarchaeological scholars to achieve greater consistency in data collection.

Network analysis

All network analyses herein have been conducted using VOSViewer (Version 1.6.19) with standard algorithm settings for analysis, if not stated otherwise. VOSViewer is a software application used to study bibliometric data sets, providing visual representations of bibliometric data as networks (Van Eck and Waltman 2010). Generally speaking, network analysis connects items in a data set through links created by different types of analyses. These links can represent bibliographic coupling links between publications, coauthorship links between researchers, and co-occurrence links between keywords. Each link is characterized by a strength, denoted by a positive numerical value, indicating the intensity of its connection. This can signify, for example, the number of shared references between two publications, the number of coauthored publications by two researchers, or the frequency of co-occurrence of two keywords. These networks can then be visualized as a map, where items are organized within clusters. Items can only appear in one cluster but can also be unclustered or excluded in the visualization process for an improved visualization. Items can also have two numerical attributes: weight and score. Weight is a nonnegative value and indicates the "importance" of an item; higher weight implies greater importance, resulting in a more prominent visualization within the map. Scores can represent various numerical properties of an item, for example, publication year. In VOS Viewer, clusters are sequentially visualized through a distinctive color (red, green, blue, yellow, purple, light blue, orange, brown). Relevant types of analysis for this study are as follows (Van Eck and Waltman 2018):

- *Citation analysis*: Citation analysis is a way to understand if and how often documents in a data set cite each other. A relationship analysis like this can also be done based not only on citation but also on the number of occurrences of a selected item within a document, for example, a keyword.
- *Coauthorship analysis*: Here, we analyzed which authors tend to publish together by clustering previous publications together by authorship. It can help identify collaboration dynamics in the field.
- *Co-occurrence analysis*: This analysis counts how often items like keywords appear together in one document. It can help identify important "mini-concepts" and research interests within the documents analyzed.
- *Bibliographic coupling analysis*: Here we analyzed how similar documents are based on the references cited in their bibliographic body, placing similar research topics and approaches together.

At first, a general citation analysis of the documents of this data set was created to identify current key concepts and the general consensus among bioarcheologists who research violence in the past, as well as to see which documents are cited the most. Based on the similarity of the cited literature in the bibliography of the publications, the publications were visualized in a network. This means that publications presenting similar research approaches or themes are clustering together more closely. Ideally, these clusters appear without a lot of overlapping of items to allow for the detection of distinct research fields. Regarding the potential paradigm shifts in the study of violence, the documents were evaluated using co-occurrence analysis of keywords. When a change

could be observed in the distribution of keywords over time, instead of a continuous occurrence, it was assumed that a shift in research trends had occurred in the study of violence within bioarchaeology. A quantitative analysis of author keywords also revealed the current most prevalent research approaches. A demographic analysis of authors and institutions was performed to highlight the most productive scholars and their affiliations. For all network analyses, including names and keywords, appropriate thesauri were applied to account for name duplicates, and minimum thresholds for keyword occurrences were set for their later display in the network maps. Finally, the results from the quantitative bibliometric analysis were also compared with those from the previously categorized qualitative, mostly cited reviews from within the analyzed data set. This is done to see where the strengths, weaknesses, and limitations of this quantitative analysis lie.

Results

The purpose of this article is to identify, analyze, and report the concepts and methodologies used to investigate the patterns of violence that have been and are being studied through human remains in archaeological contexts. As Table 1 shows, a total of $n = 434$ documents containing the term "violence" in their document title, abstract, or keywords published in peer-reviewed, English-speaking journals from the fields of anthropology, archaeology, bioarchaeology, palaeopathology, and forensic journals were identified. The first publication was published in 1987; the last ones were published in 2024 (Fig. 2). The maximum number of publications occurred in 2012, with a publication of $n = 42$ documents. A total of $n = 94$ publication outlets were identified; the one cited the most was the *International Journal of Osteoarchaeology* ($n = 82$).

Before a demographic author and coauthor analysis, a thesaurus—a text file grouping synonyms together—was applied to account for duplicates, abbreviations, and differences in spellings in country and author names, resulting in a total of $n = 897$ authors with affiliations from $n = 57$ countries (Table 2). Coauthorship analysis was able to connect $n = 235$ of these authors together in 22 clusters, reflecting their collaboration dynamics (Fig. 3).

Between the first 10 authors, the most cited document in the data set is from an author who did not publish the most documents. This deviation in the number of documents and citations is also the case for other authors. There is a clear dominance of scientific output from U.S.-based affiliations, followed by affiliations from Canada and Europe and only a little from Australia or South America, where there is a dominance from Chile.

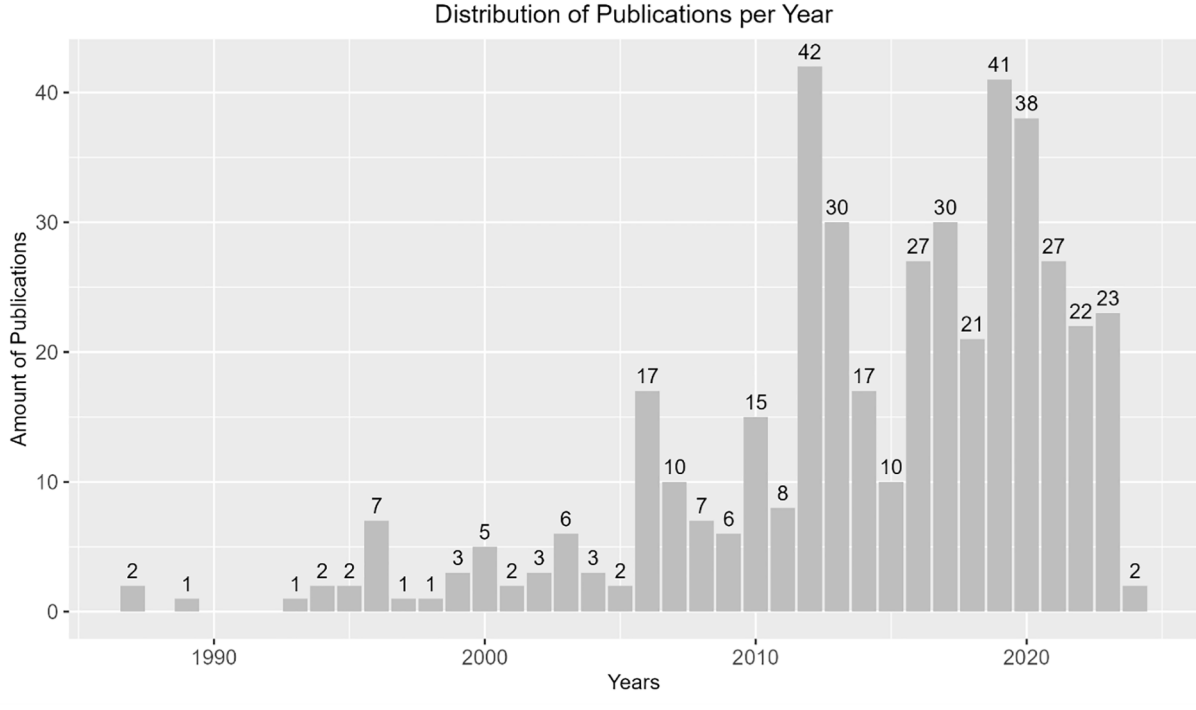

Figure 2. Distribution of publication years for documents relevant for this study. The maximum number of $n = 42$ retrieved documents occurred in 2012. The first publications for this data set occurred in 1987. Status: March 11, 2024.

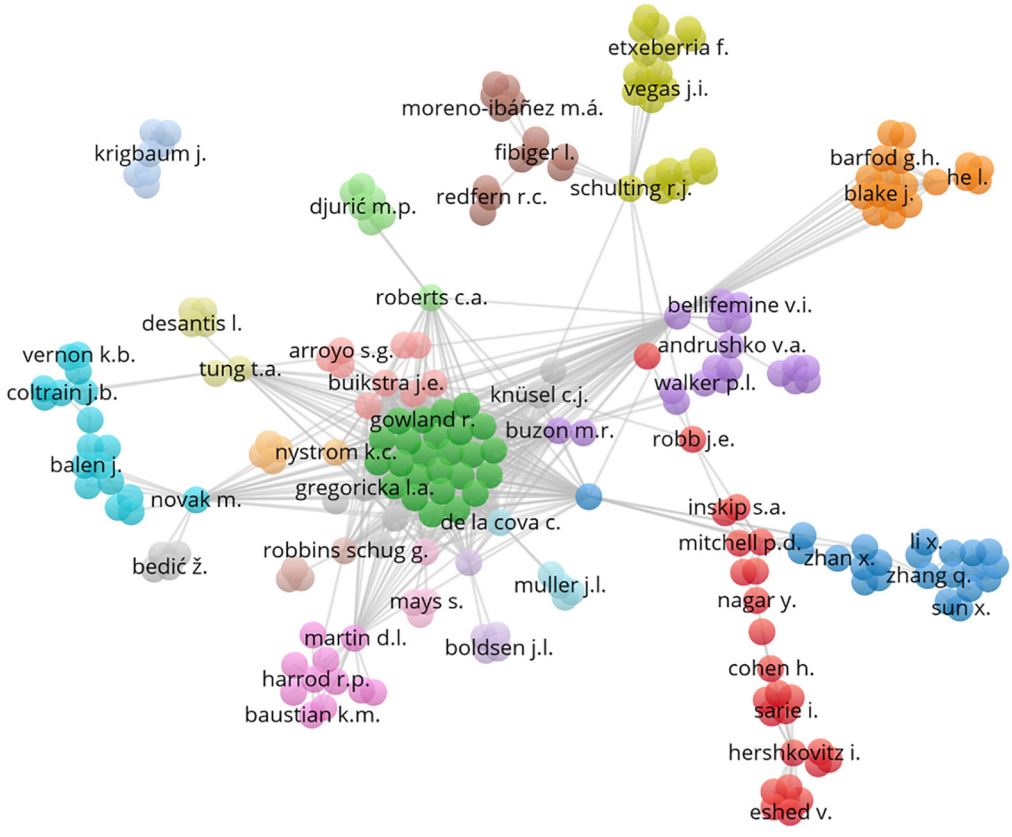

Figure 3. Coauthorship analysis clustering $n = 235$ out of $n = 897$ authors together in 22 clusters, visualizing who collaborated and published together on the topic of "violence" in the data set.

Table 2. Listing the 10 most prevalent authors in the data set studying violence in bioarchaeology through the number of documents and the total number of their citations within the data set. Listed are also the top 10 countries mentioned in the affiliations. Total number of authors $n = 897$, of countries $n = 57$.

Author	Documents	Citations	Country	Affiliations Mentioned
Tung T. A.	13	596	United States	202
Harrod R. P.	12	348	United Kingdom	76
Martin D. L.	11	334	Spain	29
Redfern R. C.	9	127	Canada	26
Knüsel C. J.	8	103	Germany/ Italy	18
Schulting R. J.	7	127	France	15
Novak M.	6	116	Chile	13
Fibiger L.	6	107	Australia	10
Walker P. L.	5	792	Russia	10
Pérez V. R.	5	147	Portugal	9

Classification of publication

The documents were classified according to their publication type (Fig. 4). Because Scopus does also include references for nonclassical entries such as errata and conference abstracts, some entries could not be classified into classical means of publications ("Other").

The most prevalent type of publication was population studies ($n = 234$). Second in frequency were reviews and comments ($n = 93$), followed by case studies ($n = 62$). A focus of the discussion is on the reviews and their impact on the field (Table 3). The seven documents listed as "Other" were errata and introductory chapters to books and journal special issues, which did not contain any research information.

Citation analysis: Author interactions and studied subfields

To identify key documents in the data set, a citation analysis was conducted. The citation analysis connected and clustered $n = 347$ of 434 documents together. This is because not all documents are linked to each other through citations. The threshold of a minimum number of citations of a document was set to 0 before the analysis to ensure the best coverage. The cluster presents which of the retrieved documents are currently most cited within the data set in 2024 (Fig. 5). Proximity and clustering are influenced by citation frequencies within the data set. The color

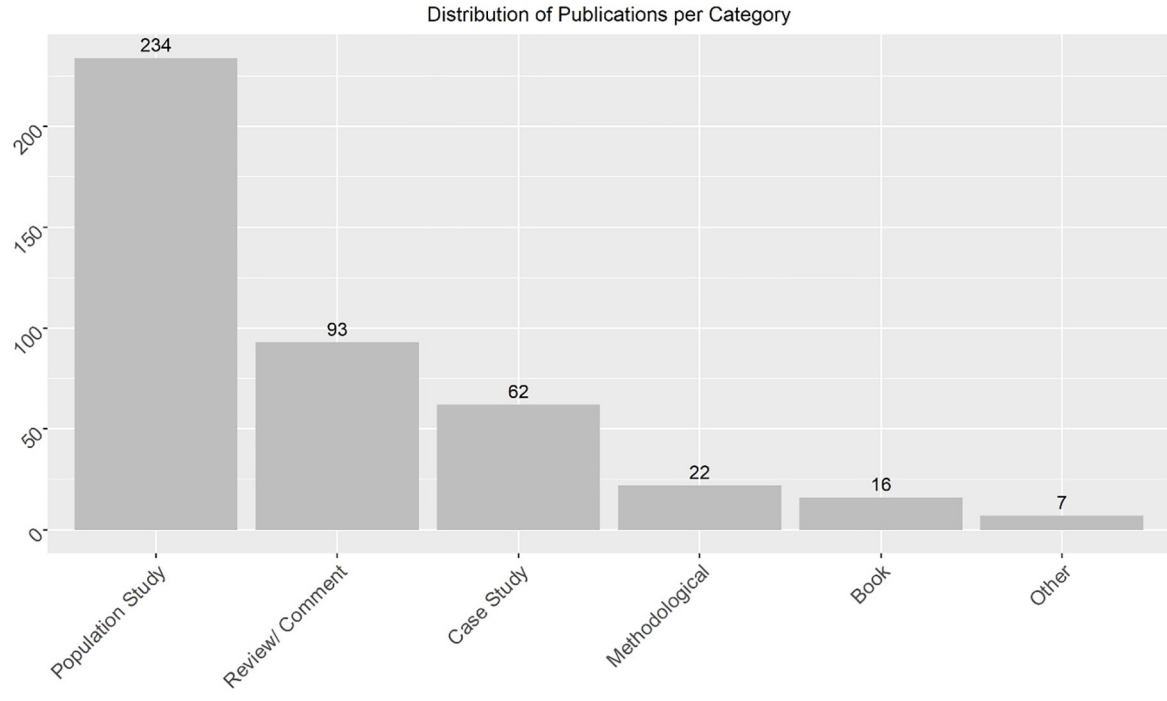

Figure 4. Distribution of publications included in this bibliometric study according to their classification into study type. A total of $n = 434$ publications was manually classified, following a two-eye approach.

Table 3. Ten most cited articles with review and comment characteristics identified and their number of citations within this data set. Note that multiple citations of one reference are possible within a document.

Author(s)/Editor(s)	Year of Publication	Title	Number of Citations
Lovell, N. C.	1997	Trauma Analysis in Paleopathology	474
Walker, P. L.	2001	A Bioarchaeological Perspective on the History of Violence	415
Lambert, P. M.	2002	The Archaeology of War: A North American Perspective	155
Larsen, C. S.	2002	Bioarchaeology: The Lives and Lifestyles of Past People	132
Martin, D. L., Harrod, R. P.	2015	Bioarchaeological Contributions to the Study of Violence	121
Larsen, C. S.	1994	In the Wake of Columbus: Native Population Biology in the Postcontact Americas	70
Gat, A.	2015	Proving Communal Warfare among Hunter-Gatherers: The Quasi-Rousseauan Error	59
Rodríguez-Martín, C.	2006	Identification and Differential Diagnosis of Traumatic Lesions of the Skeleton	49
Kissel, M., Kim, N. C.	2019	The Emergence of Human Warfare: Current Perspectives	41
Muller, J. L., Pearlstein, K. E., de la Cova, C.	2017	Dissection and Documented Skeletal Collections: Embodiments of Legalized Inequality	30
Stone, P. K.	2012	Binding Women: Ethnology, Skeletal Deformations, and Violence against Women	

gradient indicates the publication year of the document, from oldest (purple) to latest (yellow).

Bibliographic analysis: Identifying research fields

Using bibliographic coupling analysis, the documents were then analyzed based on similarities in their cited references in their bibliographic body (Fig. 6). This refers to citing the same or similar documents. To account for the development of the field of violence research in bioarchaeology through time, the analysis was conducted in 10-year research brackets based on the year of publication, starting with the first publication in 1987 (Supplemental Figs. S1–S4). In the first two decades, because of the small amount of research present at the time, all

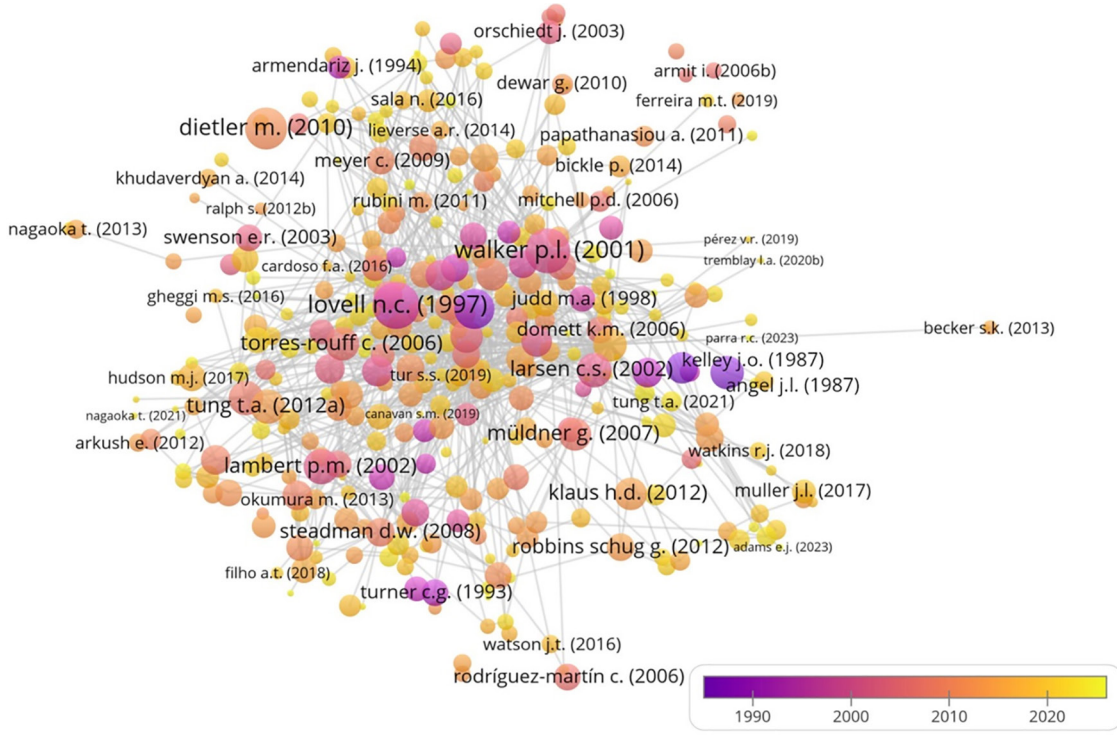

Figure 5. Visualizing an almost four-decade-long network of publications associated with bioarchaeology and violence and their authors citing each other in the data set (n = 347), spanning from the first publication in 1987 to the latest in 2024. Proximity of and clustering of nodes are influenced by citation frequencies within the data set, while the color gradient denotes the publication year of each document from oldest (purple) to latest (yellow).

documents were included in cluster visualization, even if they did not cite each other and thus did not produce any links. For all decades, the threshold of a minimum number of citations of a document was set to zero before the analysis to ensure the best coverage. Mapping was visualized using a cluster-sensitive color gradient indicating the belonging to a cluster as well as representing the citation quantity of a document by size. Note that the cluster color is always newly calculated based on the additional references and does not continuously represent the same clusters throughout the temporal analysis.

Co-occurrence analysis: Framing and labeling through keywords

In addition to the keywords used to retrieve relevant documents for this study, keywords within the data were also analyzed (Fig. 7). All author keywords appearing at least three times in the data set were included in the co-occurrence analysis. Before the analysis, a thesaurus was applied to account for duplicates. Keywords referring to plurals were counted as singulars (e.g., "humans" as "human"), and other semantic peculiarities and spellings were standardized (e.g., "anthropology, physical" was counted as "physical anthropology," "archeology" as "archaeology"). Additionally, countries were excluded because the region of study was not of interest here but rather how violence is studied. For a summary of geographic author affiliations, see Table 2 instead. Keywords hinting at different ethnicities and regions were, however, kept in the analysis (e.g., "Kerma," "Black"). This resulted in clustering n = 85 of 980 author keywords together when a keyword appeared at least three times in the data set (Table 4). The map is presented using an overlay network with a time-sensitive color gradient indicating the average publication year. In addition, a network density visualization was conducted to account for quantity and thus the topical density of these keywords in the field on a scale from blue to yellow.

Discussion

The bibliometric analysis of the topic of violence in bioarcheology on the basis of author and keyword analyses yields noteworthy results, which will be discussed below.

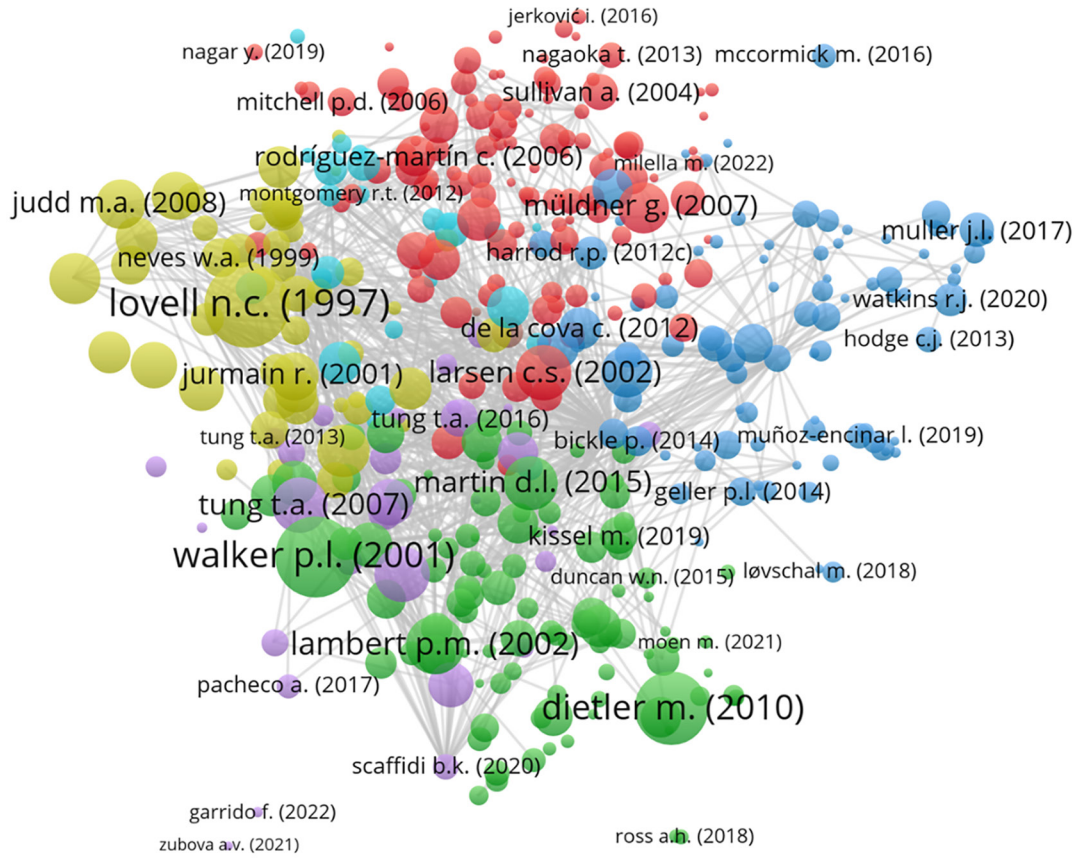

Figure 6. Cumulative visualization of documents in the bibliographic coupling analysis. Here, the documents are placed based on the similarity of references cited in their bibliography bodies. Clusters are indicated by color.

Structuring the field–key concepts and subfields

There is a clear dominance of documents affiliated with institutions in the United States, with nearly three times as many affiliations as in the second-highest, the United Kingdom. Author analysis has shown that the quantity of published documents in the data set studied does not necessarily correspond to the authors of the relevant key concepts identified in the field (see discussion below). The most cited authors did not write the most documents in this data set.

Citation analysis: Highly relevant documents. Today's representation of violence in bioarchaeology has revealed several important key documents (Fig. 5) that continue to be relevant since their publication. Central to this map are the works of Lovell, Walker, and Dietler (Dietler 2010; Lovell 1997; Walker 2001). Lovell and Walker represent standards in the development of methods and are also reviewing the interpretation of violence in the bioarchaeological record. No less quantitatively relevant, however, are also other publications generating clusters around them (Lambert 2002; Larsen 2002; Martin and Harrod 2015; Müldner and Richards 2007; Torres-Rouff 2008; Tung 2012).

Bibliographic coupling: Subfields of research. When the documents were clustered based on the similarities in their references, documents similar to the citation analysis were centralized. A total of eight clusters, connecting n = 411 of 434 items to each other, suggest the development of eight large and small subfields that are partly overlapping and interacting with each other (Fig. 6). In the beginning decade of the selected documents between 1987 and 1996, very little exchange between research documented in these publications happened (Supplemental Fig. S1).

Only between 1997 and 2006 did the first real cluster emerge (Supplemental Fig. S2), showcasing once again in its biggest accumulation mainly case studies but also reference works that have impacted the field until today (e.g., Lambert 2002; Larsen 2002; Lovell 1997; Walker 2001). The other documents are mostly grouped together based on type of trauma and circumstances (e.g., head trauma in the Pacific region

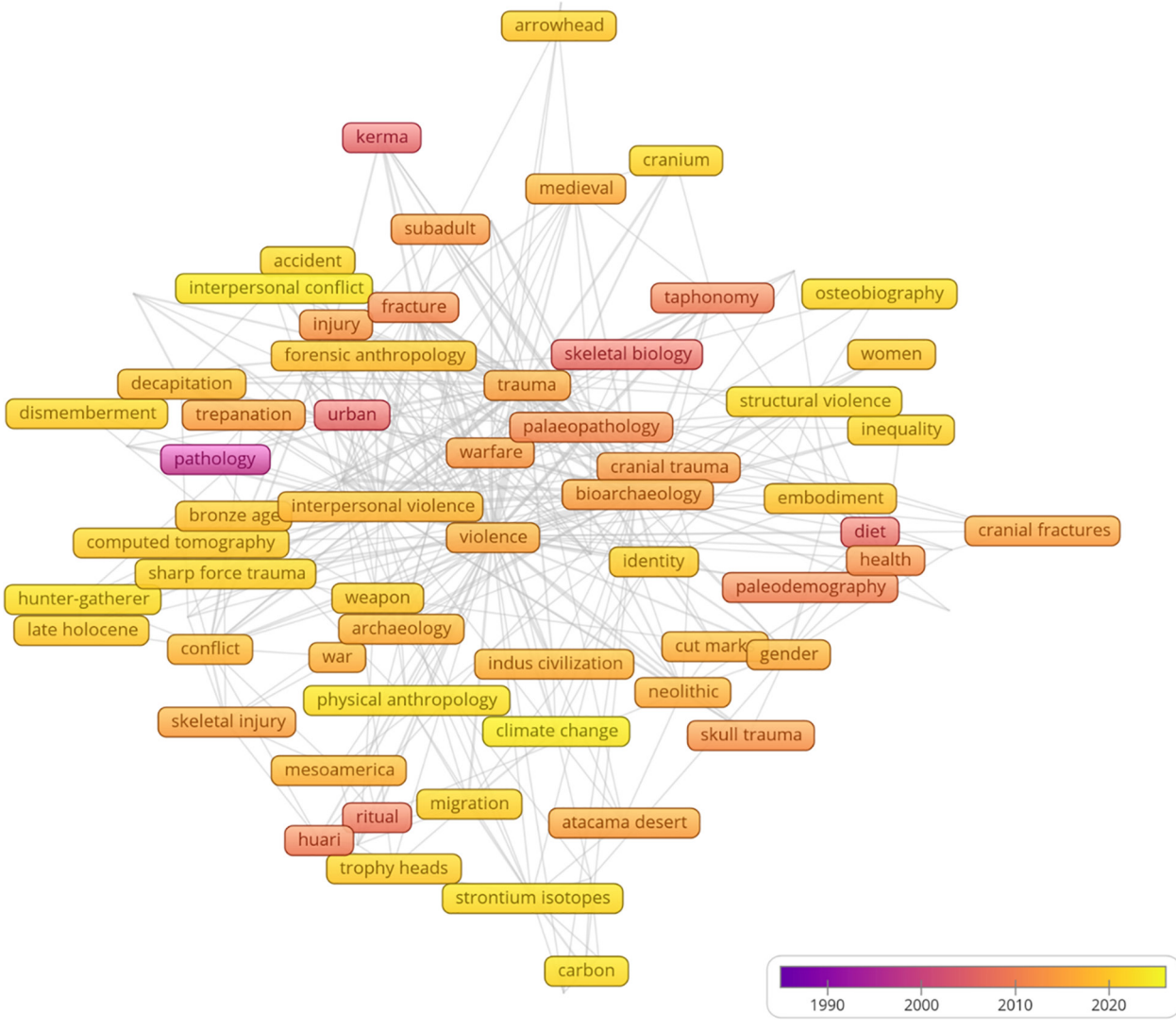

Figure 7. Keyword analysis results of $n = 85$ author keywords used in publications between 1987 and 2024, showcasing the average publication year of the respective keyword on a scale from oldest (purple) to latest (yellow). To see how frequently the most common 30 keywords occur, please refer to Table 4.

possibly associated with cannibalism, trauma in Neolithic Europe; Degusta 1999; Orschiedt et al. 2003), but also already slowly hinting at studying structural violence associated with shifts in societal structures and climate change in the next decades (Gronenborn 2006c; Hutchinson 1996; Lessa and Mendonça De Souza 2004). Additionally, collaborative projects and student–mentor relationships might have influenced how papers were cited.

This development of slowly establishing numerous bioarchaeological subfields studying violence continued between 2007 and 2016, where the field differentiated into seven clusters (depicted as seven different colors in Supplemental Fig. S3) that are content-wise already closely related to the clusters presented in the last evaluated decade. Several centered key concepts identified in the citation analysis, such as Tung and Dietler, are also emerging as relevant for the field for the first time (Dietler 2010; Tung 2012), while others are cementing their status as key concepts in this continuous representation through time, as already indicated by the citation analysis (Lambert 2002; Lovell 1997; Tung 2012; Walker 2001). However, this is not always the case, as one of the first documents studying structural violence in general, and the first one in this data set, was not clustered and thus represented in both the third and fourth final cluster visualization at all (Angel et al. 1987). Instead, it disappears during the development of the field, suggesting a differentiating establishment of new, different methods studying structural violence from the late eighties until today.

Table 4. Keyword analysis results, listing the quantitative representation of $n = 980$ keywords in the documents that appeared at least three times.

Place	Keyword	Appearances	Place	Keyword	Appearances
1	Violence	79	**16**	Medieval	9
2	Trauma	57	**17**	Sharp Force Trauma	9
3	Bioarchaeology	53	**18**	Cranial Trauma	9
4	Interpersonal Violence	45	**19**	Decapitation	8
5	Fracture	25	**20**	Gender	7
6	Paleopathology	24	**21**	Blunt Force Trauma	7
7	Warfare	22	**22**	Identity	7
8	Structural Violence	20	**23**	Health	6
9	Perimortem Trauma	15	**24**	Strontium Isotopes	6
10	Injury	14	**25**	Weapon	6
11	Conflict	12	**26**	Prehistory	6
12	Neolithic	11	**27**	Bronze Age	6
13	Taphonomy	10	**28**	Migration	5
14	Skeletal Trauma	10	**29**	Scalping	5
15	Forensic Anthropology	9	**30**	Embodiment	5

In the most recent decade (Fig. 6), the first appearing and three largest clusters evolve around topics on how to study violence. Within the first red cluster, the document with the highest link strength is Larsen (2002). Generally, the documents in this cluster focus on context-specific studies of violence, meaning the "classical" research on how and where violence is observed (e.g., Jordana et al. 2009; Kanz and Grossschmidt 2006; Müldner and Richards 2007). This is followed by the green cluster grouping around Walker (2001), which also incorporates social theory (e.g., Dietler 2010; Gat 2015) and studies within these theoretical frameworks (e.g., Andrushko and Verano 2008; Hurlbut 2000). A seemingly exclusive focus on structural violence is the third blue cluster grouping around Klaus (2012), surrounded by research about social inequality and gender differences (e.g., Cheung et al. 2017; Harrod, Thompson, et al. 2012; Muñoz-Encinar 2019). The fourth and yellow cluster around Lovell (1997) shows similar documents grouped together as in the red cluster, but an influx of paleopathological analysis is visible (e.g., Judd 2002; Jurmain 2001; Van der Merwe et al. 2010). Looking at the content of the following clusters, they are then grouped together based on their geographical research focus and are located throughout the other clusters, suggesting a high topical overlap with them. This is not surprising, as a local research focus requires a contextualization within the local archaeological record, which would also be reflected in the reference body.

Keyword co-occurrence: Markers and fields. The content analysis through author keywords revealed four methodological subfields that support the study of violence in the archaeological record. These are "bioarchaeology," "palaeopathology," "forensic anthropology," and analysis through "taphonomy" (Fig. 7). There are no time period constrictions, although most research was linked to the "Neolithic" and "medieval" times (Table 4). The average publication years are more oriented toward the 2010s, hinting at a continuous use of these keywords since they are calculated as an average. An exception is the pre-2000 keywords "fracture," "urban," and the oldest clustered keyword "pathology," which not only denotes its own research field but also represents one of the oldest subfields in bioarchaeology (Aufderheide and Rodriguez-Martin 1998). Most importantly, however, the analysis revealed that bioarchaeology, since its beginning, seems to focus on the study of two types of violence: interpersonal and structural violence. Closely associated with structural violence are "women," "institutionalization," "inequality," and "osteobiography," whereas interpersonal violence unsurprisingly heavily associates with the field of forensic anthropology, "interpersonal violence," "trauma," and "male".

Bioarchaeology's lens on traumatic and stressful contexts

Trauma. Physical violence leaving evidence on the skeleton may be the most obvious because of its

inherent bodily and visible nature. The keyword analysis showed that the most often researched marker was "trauma," mostly studied through "fracture" and "injury," just a few ranks below them in terms of frequency. Other words that may refer to this include (traumatic) lesions, wounds, and injuries. As explained before, however, trauma does not necessarily have to manifest itself physically. The more direct and detailed keywords studying interpersonal violence (e.g., "decapitating," "scalping") are becoming gradually more abstract when trying to cover the topics of structural violence. Here, the surroundings and circumstances of potential contexts of structural violence are the focus (e.g., "migration," "health") and studied through context-dependent proxies rather than fractures ("strontium isotopes," "gender"). What markers exactly are being used to study structural violence does not become ultimately clear through keyword analysis. Rather, an idea is given of what concepts are being included in the study (e.g., "migration," "health," but also "gender" and "identity"), but no ultimate bioarchaeological markers stand out in the analysis. Past research on a seemingly clear bioarchaeological term like "bone remodeling" has already highlighted the subjective differences in the reception and meaning of scientific terms in bioarchaeology and paleopathology (Wei and Cooper 2023).

Stress. As indicated in the temporal and topical implications of the co-citation and co-occurrence analysis, bioarchaeology focuses on the study of interpersonal and structural violence. Notably, within this data set, structural violence is even the study focus of the first two publications (Fig. 5; Angel et al. 1987; Kelley and Angel 1987). Because of the clear focus on interpersonal violence in this data set and a lack of data on the markers of structural violence, it was zoomed in to the cluster from the citation analysis, focusing on Angel et al. (1987) and subjected to further manual content analysis. In it, the health, lifestyle, and occupation of a nineteenth-century Free Black community in Philadelphia, United States, are analyzed. Black people, enslaved people, and contextualization around hospitals continue to be the research focus in this cluster (Atwell 2022; de la Cova 2012; Halling and Seidemann 2017), but it is also studied how other marginalized groups like women (Stone 2012) and migrants (Harrod, Thompson, et al. 2012) were affected by structural violence in the past. Documents in this cluster offering general background and methodology in what markers can be studied (Klaus 2012), as well as a more generalized conceptual approach (Zuckerman and Crandall 2019), were published way later than the works by Angel et al. in 1987, suggesting a development without referencing these works. Zuckerman and Crandall, in particular, offer a thorough background review of the influences social theory has had on bioarchaeology and consequently stress the implementation of additional models and theories in what has previously been labeled "social bioarchaeology" (Agarwal and Glencross 2011; Zuckerman and Crandall 2019). Their analysis greatly reflects which skeletal markers are associated with health, disease, and trauma, but also sex and gender can be studied, as well as the social impact(s) they themselves may have had on past populations.

The manual cluster content analysis could show that structural violence is mostly studied through what can best be described as stressors, acting as "proxies for resource inequity" (Blevins et al. 2023). These are inevitably more complicated than studying the mere absence or presence of healed and unhealed trauma, and have therefore been represented diversely, mainly by lesions associated with certain diseases. More common markers researched were inflammation, porotic hyperostosis, dental caries, and dental enamel defects (Klaus 2012; Zoëga and Murphy 2015). However, these markers are nonspecific, appearing as osseous or dental manifestations in different conditions. This includes, for example, metabolic diseases like vitamin C deficiency and tuberculosis (Atwell 2022; Blevins et al. 2023). The presence of syphilis—more diagnostic—was investigated through a combination of bioarchaeological and historical analysis (Atwell 2022). The keyword analysis already suggested that the use of osteobiographies, a (detailed) life history reconstruction based on various individual aspects, as reflected mainly by bone morphology, but also molecular analyses, synthesizes these interdisciplinary data at least on an individual level.

Structural violence in bioarchaeology is, therefore, as the keyword occurrence had already indicated, also considering "social injustices" (Galtung 1969) in its approaches when studying human remains. These structural disadvantages can result from medical, cultural, and economic perspectives, where capitalist structures and practices are currently the most prevalent, promoting political as well as societal instabilities (Farmer 2004; Springer 2011; Whitehead 2007). Stressors or markers of stress take time (months to years) to manifest in the skeleton. Physical trauma is an indicator of personally experienced violence, and stress markers are represented throughout the continuously present societal marginalization caused by structural violence. These markers do not have to be necessarily indicative of one specific disease but can be general symptoms, as is the case for inflammatory reactions. In the herein reviewed documents, some diseases and their markers stood out (e.g., syphilis in

women), in their implications on both health and society. Additionally, compared to the study of interpersonal violence, there was an even higher degree of interdisciplinarity visible through the implementation of ideas and concepts, especially from social theory and intersectional feminist studies (Atwell 2022; Zuckerman and Crandall 2019). This reveals the prevalence of a three-sided approach to study structural violence affecting past populations, happening through bioarchaeological analysis, provenance research approaches, and historical contextualization of the researched human remains.

Prevalent study type of violence in bioarchaeology

The most prevalent study type in violence is population studies, meaning a focus on quantitative distribution of fracture patterns—or other indicators of violence—in the osteological record. This is in strong contrast to paleopathology, a neighboring field of bioarchaeology that studies pathological changes in bones, teeth, and, in special cases, soft tissues and hair when dealing with mummies or bog bodies. Here, a review of publication types of documents published in one journal yielded the prevalent type as case studies, highlighting the diagnostic nature of paleopathology over its demographic analysis (Boutin et al. 2022). For this study, it was hypothesized that this must be the same case in the study of "violence" markers, such as fracture patterns or stressors, and that the diagnostic distinguishment of perimortem versus postmortem fractures might have yielded similar scholarly discourse in the past. Instead, the results present an alternative perspective. This might be because fracture and injury patterns, the most studied markers concerning violence, as revealed in this study, can be interpreted with fewer contextual data than compared to paleopathological cases. Here, the observed pathological markers are mostly disease unspecific and gain their diagnostic meaning through contextualization with factors such as the presence of other pathological markers, malnutrition, or sex. Therefore, especially data-driven case studies with a focus on paleopathological method development and the identification of diagnostic markers have a significant impact on academic research (Boutin et al. 2022).

Comparison of aspects of qualitative versus quantitative literature reviews

The advantage of conducting a network analysis of scientific literature lies in its quantitative approach, replicability, and comparatively faster speed compared to qualitative literature. It is easily conducted after setting the search parameters, and the development of a field can be repeatedly studied through different periods of time, taking various formal aspects into account, including relevant keywords, authorship, and demographic author information. This can be best described as research metadata, which give information about the anchors and geographical placements of the field itself. Quantitative research is, therefore, especially useful to track interdisciplinary fields that draw from different subfields, subsequently developing its methodology. Research patterns and clusters can be detected and analyzed quantitatively, without bias, and are thus reproducible. Although this is lacking in the qualitative approach, this can be bypassed by subjecting identified key concepts to a manual analysis to answer more specific research questions, as done for this study. However, the bibliometric analysis does not indicate whether a document was cited frequently due to agreement, disagreement or other controversies surrounding its theme. This interpretation needs to be done by contextualizing it into the past and present scientific discussion.

Selecting keywords for document retrieval introduces bias, especially toward scientific outlets. Non-subject-specific documents and potentially revealing innovative data patterns were thus potentially excluded—however, "violence," studied across disciplines, yielded n = 250,247 entries in Scopus in March 2024 when globally searched for in the "document title, abstract, keywords" field. Our criteria also excluded so-called high-impact journals such as *Nature*, *Science*, and *PLoS ONE*. However, previous research (Boutin et al., 2022) employed a comparable approach, focusing solely on one specialized paleopathological journal. We also wanted to target a range of archaeological journals to gain a deeper understanding of violence in bioarchaeology. Additionally, while the authors' presumed awareness was based on the keyword's presence, it cannot be ruled out that relevant documents were not included because the corresponding indexing is missing. This is also the case even if all search criteria apply, but it may still yield documents that ultimately are studying violence "more" compared to other topics. Even though Michael Dietler's (2010) volume, *Consumption, Entanglement, and Violence in Ancient Mediterranean France*, hit all criteria for search and inclusion, it must be considered that its content mainly deviates from the scope of this study as it focuses on materialistic rather than osteological studies. And while it shows up with high citation scores in the analysis, its position in the clusters also indicates a small relatedness to the other documents within the data set.

Two major reviews identified in the bibliometric analysis were conducted by Nancy Lovell (1997) and Philip Walker (2001), cited a total of $n = 474$ and $n = 415$ times, respectively, as multiple citations of one reference are counted within a document. These are qualitative reviews by skilled and senior scholars revisiting the study of violence on human remains. Lovell (1997) reviews the methodological concepts necessary to diagnose skeletal fractures for each bone in detail. The fracture types, as well as proximate and ultimate causes of injury, she argues, help in the paleopathological analysis and interpretation of trauma–connected paleopathology with violence. Lovell also focuses on bone development, mechanical properties, and the cause and effect of forces that could potentially cause fractures. The presentation of this information for each skeletal element is what makes Lovell's review so impactful, demonstrated through its central placement in all bibliometric analyses conducted herein. In total, she cited 108 documents stemming from as early as 1910. Four years later, Walker (2001) provided an extensive review of not only the history but also the development of how human remains are studied in the context of violence. Directly asking what bioarchaeology has contributed to the understanding of violent behavior in the past, he illuminates the potential of bioarchaeological research, also drawing on the influences and methodologies from other fields like history and the social sciences. By proposing ways to connect bioarchaeological methodology and highlighting caveats for research, his review gains its main strength. In total, Walker references 110 further documents in his bibliography, providing insights into scientific literature published between 1906 and 2001, the year he published his review, although his first reference for an osteological reference was Angel's comparative work on fractures from the Neolithic to modern times from 1974 (Angel 1974). Patricia Lambert's review, cited $n = 155$ times, and Clark Spencer Larsen's work ($n = 132$ times) address similar opportunities and challenges in the study of violence compared to Walker's, although Lambert puts her scope on North America only (Lambert 2002; Larsen 2002).

One major point of critique for qualitative reviews is that they might be biased through the authors' preferences for picking their own case references (e.g., Walker 2001). One advance, however, is their focus on the contents. Both Walker and Lovell provide suggestions for markers to study violence, while the author keyword co-occurrence in this study only provided directional hints. Additionally, offering a huge citation database, the indexed contents on Scopus are not complete, as the outlets need to fulfill certain criteria to be indexed.[2] This can also lead to the presence of duplicates. In the data set evaluated, three documents appear through eight entries. In the first case, two documents with the same digital object identifiers (DOIs) appear as a journal article as well as a book chapter (Frazer 2007a, 2007b). This is similar to the second case, where three entries of the same publication, indexed through different DOIs, appear in different outlets (Gronenborn 2006a, 2006b, 2006c). In the third case, an introductory book chapter was indexed three times in Scopus because of similar reasons (Armit et al. 2006a, 2006b, 2006c). Because all entries appeared independently and already showed different numbers of citations, it was decided to consider all of these publications as independent of each other. It is not likely to be a mistake by the authors but rather an indexing mistake by Scopus wrongly classifying the entries multiple times under different publication types. That Scopus is not a complete database also becomes apparent, for at least three documents could be identified that, while following the requirement for data selection, are not indexed in Scopus (e.g., Buckley 2000; Smith 1996; Williamson et al. 2003). Additionally, Martin and Frayer's volume *Troubled Times* from 1997 did not hit any search criteria and was therefore not included in the data set, although it is a common reference (Martin and Frayer 1997). These are all consistent challenges in bibliometric network analysis, which are not exclusive to bioarchaeology. Otherwise, it could be shown that the quantitative literature review approach through bibliometric analysis is at least equal to the qualitative approach in terms of speed, reproducibility, and range of topics covered, and it even offers advantages. This includes providing visually appealing networks of quantitative data through a clear visualization of complex bibliometric data, including more documents than the qualitative reviews observed here. This allows for a clear understanding of the influences of different fields and neighboring disciplines in interdisciplinary fields such as violence in bioarchaeology, especially through the analysis of cluster contents. By referencing databases like Scopus, future researchers can reproduce the analysis, thereby eliminating the possibility of reviewer bias, such as familiarity with the already known literature and specific approaches and methods. Last but not least, bibliometric analysis tools make scientific fields more accessible to outsiders and young scientists, helping them understand current and past concepts and providing more experienced scholars with an overview of their development, including potential input from previously unknown literature. To avoid the pitfalls mentioned above in the

2 https://www.elsevier.com/products/scopus/content#3-selection-standards, accessed November 7, 2024.

retrieval of literature, it is recommended to define the search criteria precisely but with a certain openness. Initially, a selection of publication outlets and types should be made. Subsequently, a search for keywords may be conducted, with a certain degree of flexibility in terms of precision advised to aim for potentially previously unknown topics. The results can then be reflected upon with the help of a qualitative addition of further publications, such as previous reviews, as done here. This is the optimal way to provide a multifaceted picture of the current state of debate in scientific fields.

Violence in Bioarchaeology—Changes and Challenges

The historical analysis of violence, briefly mentioned in the introduction, has shown that what is considered violence is constantly changing and evolving, depending on societal, cultural, and personal influences. Contemporary attitudes therefore also affect how violence is studied. In this data set, we found a high prevalence of author affiliations to the United States, suggesting not only a research focus from North American universities but also a dominance in the methodological development of the field. The number of publications studying violence has increased in the past decade, with a focus on analysis at the population level (Fig. 2; Fig. 4). While the fundamental cornerstones for studying structural violence have been set since at least the 1980s, and the first two publications in this data set even directly refer to studying structural violence (Angel et al. 1987; Kelley and Angel 1987), the keyword analysis suggests an increase in this subfield only in the 2010s. This is also supported by the bibliographic analysis, which indicates that no cluster specific to the study of structural violence has been identified in the past decade. After a differentiation between interpersonal violence in bioarchaeology and structural violence in the social sciences (Accomazzo 2012), the question also remains if and how epistemic violence, a violence inherent in knowledge and power and proposed by postcolonial researchers such as Spivak (1988), will become a future bioarchaeological research subfield. Even more abstract than structural violence, it acts through the creation and transport of violence through knowledge (e.g., racial categorization promoted by science and followed by social discrimination). It is expected that in the future, with the rising self-awareness of bioarchaeology and especially its contribution to racist ideologies and the treatment of minorities (Buikstra et al. 2022; Roberts 2019), it will also look more closely at what bioarchaeology contributed to the creation and establishment of epistemic oppression. The collection practices and often colonial contexts involved in the provenance of human remains collections (Pollock 2023), the centerpiece of many bioarchaeological works, can already be interpreted and labeled as epistemic violence. Analyzing how epistemic violence is investigated in the bioarchaeological context was only indirectly possible in this analysis. It can, however, be thematically situated closely to clusters and keywords that deal with or link to structural violence. For the future, a continuation of the increase in publications regarding the general study of violence in the skeletal record is predicted. The current global geopolitical tensions are perpetuating, especially the less tangible types of structural and likely also epistemic violence.

Conclusion

This work has analyzed how violence has been studied in bioarchaeology using content and quantitative bibliometric network analysis. For one, it accounted for how the increasingly growing and fast-paced body of scientific literature can be used to quantitatively study an interdisciplinary field in a fast and easy way. It also showed how bibliometric metadata can be used to understand scholarly collaboration and publication dynamics. The analyses presented here also, not surprisingly, showed that studies of violence have become interdisciplinary in bioarchaeology. Only a broad treatment of this topic can lead to an account that is capable of depicting the highly contextualized physical, social, and cultural factors and consequences of violence in the bioarchaeological record. In the past, this happened through consistent bioarchaeological methods and without many changes in its paradigms. Therefore, the most unforeseen aspect to be considered when studying violence in the future is the necessity to take the present societal and scientific challenges and changes into account while adapting them into the bioarchaeological research repertoire. A change of perspective on how and what we perceive as violence in our everyday lives could thus lead to research on how epistemic violence has affected human remains. This is particularly necessary when considering the origins of many osteological collections of human remains.

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Supplemental Information

Supplemental Figures S1–S4 can be found online.

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