Hidden transitions. New insights into changing social dynamics between the Bronze and Iron Age in the cemetery of Destelbergen (Belgium)

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Abstract

Urnfields were the common type of cemetery in the Late Bronze Age (LBA) and Early Iron Age (EIA) in much of Northwest Europe. Rarely are there clear social or chronological differences between burials apart from changing pottery types. The cemetery of Destelbergen stands out because of the relatively high prevalence of monumental ditches surrounding a selection of graves, indicating a certain status difference between the deceased. Strontium concentrations ([Sr]) combined with radiocarbon (^{14}C) dates and spatial analysis bring to light clear differences between LBA and EIA traditions. The end of the LBA went hand in hand with the abandonment of the oldest part of the cemetery, which new ^{14}C dates demonstrate was strict. Additionally, [Sr] reveal changing diets in individuals buried centrally within monumental ditches. In the EIA these individuals present significantly lower [Sr] than the surrounding burials, potentially the result of a diet richer in animal protein at the expense of plant-based food, a distinction not seen in LBA burials. Even though continuity and equality are reflected in the uniform burial tradition seen within urnfields, this paper's analyses unlock subtle changes in social attitudes between the LBA and EIA and suggest increasing (dietary) social differentiation in the EIA.

Keywords

Metal Ages; LBA-EIA transition; Urnfields; Social Differentiation; Strontium; Radiocarbon Dating; Cremated bone

1. Introduction

Urnfields in Northwest Europe usually offer, due to a generalised lack of grave goods, very little to no evidence of status differences between the deceased (De Mulder and Bourgeois, 2015; Roymans, 1991; Schoenfelder, 1989). This does not necessarily mean that there is no social differentiation in these Late Bronze Age (LBA) – Early Iron Age (EIA) communities (Le Huray and Schutkowski, 2005; Lightfoot et al., 2015), but rather that such differences are not expressed or archaeologically visible in the burial ritual. It is likely that status differences were present throughout many practices in life, e.g. in festivities, daily customs such as diet or clothing, or sacrificial and other rituals (Fontijn, 2002). Indeed, large quantities of valuable (mostly Middle and LBA) metal finds have been dredged from rivers, the Scheldt river in particular, and recovered from wetland contexts rather than burials (De Mulder and Bourgeois, 2015; Verlaeckt, 1996). In the absence of status indicating grave goods, the atypical presence of monumental ditches surrounding a selection of burials in the site of Destelbergen suggesting a difference in regard towards these individuals (see below) (Lightfoot et al., 2015; Varalli et al., 2021), offers a unique opportunity to study differences in these individuals. It is the aim of this study to better understand how and when changes in social differentiation occur in the Metal Ages, for which several parameters like strontium signatures and spatial organisation are investigated. For this purpose, a refined chronological framework is needed. So far, 28 graves had been ^{14}C dated (De Mulder et al., 2009; De Mulder and Deweirdt, 2012; De Reu et al., 2012) and 14 additional graves were associated to typo-chronologically dated pottery (De Laet et al., 1986). This was, however, not sufficient to comprehend the chronological development and social dynamics in the cemetery between the LBA and EIA. As such, an additional 18 ^{14}C dates have been carried out in this study.

The Metal Ages urnfield of Destelbergen Eenbeekeinde, near Ghent, Belgium, (Figure 1), is situated on a modest ridge slope on the left bank of the Scheldt river. The first urns were discovered during sand extractions in 1927-1928 (De Laet et al., 1958), which led eventually to recurring excavation campaigns by Ghent University during the 1960s to 1980s, and later excavations until 2011 (De Laet et al., 1985; De Logi and Dalle, 2013). A total of 107 Metal Ages burials have been discovered. The oldest burial of the urnfield, burial 69, was dated between 1106 and 898 cal. BCE (2σ; KIA-37582, 2820±30 BP; De Mulder et al., 2009). Most burials belong to the LBA (1200-800 BCE) and EIA (800-450 BCE) (Figure 1), more or less corresponding with the 'Urnfield period'. From the Late Iron Age (LIA) (450-58 BCE) onwards the urnfield's use went in steep decline. Based on the medians of the calibrated ^{14}C dates, only six burials can be categorised in the LIA, of which three are mostly situated in the transition from EIA to LIA. A single chronological outlier (burial 4) extends as late as 343-49 cal. BCE (2σ, KIA-34909, 2120±30 BP; De Mulder et al., 2009).

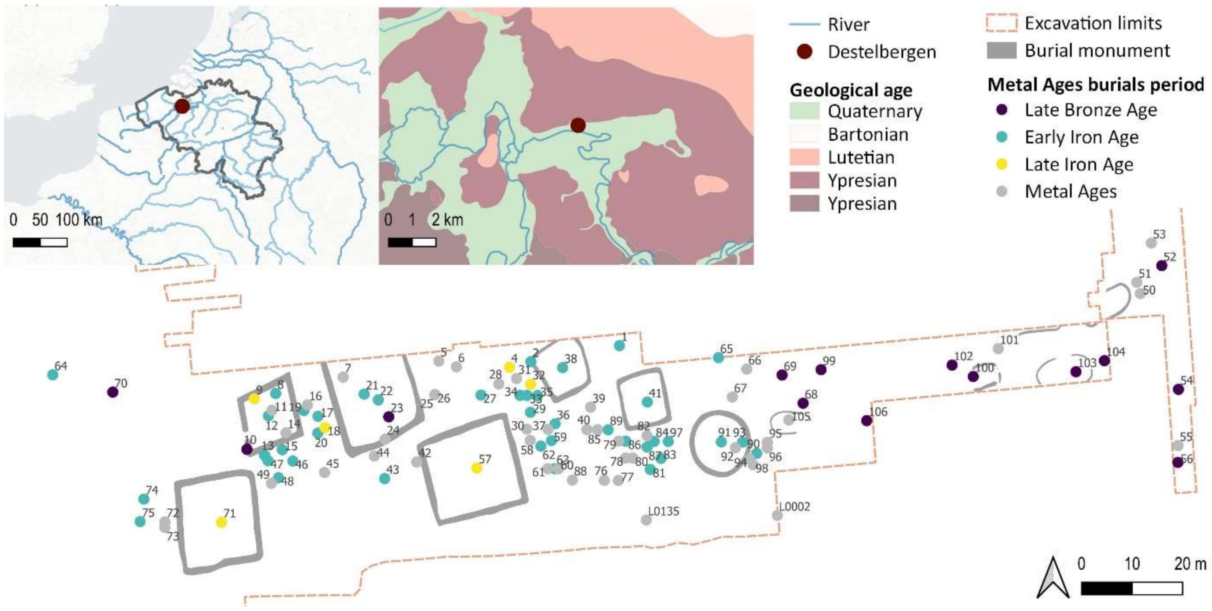

Figure 1 Site plan of the Metal Ages urnfield of Destelbergen with geographical and geological situation in the inset maps. Burials indicated as of Metal Ages date (grey) could not be dated more closely, while the other burials were dated based on either ¹⁴C dates or pottery typology.

<u>Burial monuments and status in Northwest European urnfields</u>

The Destelbergen cemetery distinguishes itself by the presence of monumental structures of different styles surrounding some of the graves (Figure 1). Four, possibly five, oval monumental ditches (so-called *langbedden*, or long barrows) are situated in the eastern part of the cemetery (**Fout! Verwijzingsbron niet gevonden.**). Oval monuments are not very common, but do occur in greatly varying dimensions and are a new introduction in the LBA (Roymans and Kortlang, 1999). Most were uncovered in the Campine area with a slight preference for the LBA, although representation in the EIA remains (Bourgeois et al., 2009; De Mulder, 2014). In Destelbergen, one circular ring ditch is also found and located centrally in the cemetery (Figure 1). Circular ring ditches and posthole circles are concentrated in the Campine region in the northeast of the country (associated with the so-called Northwest urnfields group or Maas-Demer-Schelde group) and rarely in the western Flemish group of which Destelbergen is part (De Mulder, 2014; Desittere, 1968). The habit of constructing burial mounds came to its first peak in usage in the Middle Bronze Age (1800-1200 BCE), and seems to slightly resurge in the EIA in the Scheldt basin where they are associated with high status burials (Capuzzo et al., 2023, 2020; De Mulder, 2014). Unique in Destelbergen, is the appearance of six square or rectangular ditches surrounding some graves as early as in the EIA. Elsewhere in Northwest Europe, this burial embellishment appears only in the beginning of the LIA, and remains in style well into the transition to the Roman period (De Mulder, 2014, 2011; Hessing and Kooi, 2005).

Although LBA-EIA urnfields in western Belgium are characterised by the absence of elaborate grave indicators, these structures appear sporadically, especially in such large numbers as in Destelbergen (De Mulder, 1994). Central and thus likely primary burials within the monuments can be assumed to be of higher status since there is a clear labour effort in creating these monumental earthworks for these individuals which was not spent for the majority of the population (Fernández-Götz, 2014; Lightfoot et al., 2015; Lohof, 1991; Peebles, 1971; Theunissen, 1999). This assumption can be presumed in sites where monument construction stands out from the standard ritual performed for most individuals and not where burial monuments seem to be standard procedure for the whole community. Here, the concept of ‘high status’ is approached in the widest fashion, varying from very small rank differences (e.g. family elders, local leaders or ritual and craft specialists) to the highest elites (such as regional leaders, kings or high nobility). Individuals of higher status belong to a select group of individuals receiving certain privileges as a result of the high(er) regard they hold in society.

To what extent we are, in Destelbergen, dealing with a stratified society with social inequality remains hard to asses as grave goods of the individuals buried centrally in the monuments do not substantially differ from the other burials (De Laet et al., 1986), suggesting minimal differences in living standards between higher and lower status individuals. These graves are by no means comparable to e.g. the rich EIA chieftain grave of Oss (Fokkens et al., 2012; Van der Vaart-Verschoof, 2017) or Court-Saint-Etienne (Mariën, 1958), which concern burial mounds with a substantial assortment of metal grave goods. High status burials with outstanding grave goods, usually weapon graves, only seldomly occur within urnfields in the region, e.g. in the particularly large urnfields of Hofstade Kasteelstraat (De Mulder, 2017; Hiddink et al., 2018) and Neerharen/Rekem Hangveld (De Mulder, 2017; Van Impe, 1979). In Hofstade, one burial contained a broken sword, while in Neerharen/Rekem three individuals in one burial were interred with three swords and spearheads and two chapes. The Destelbergen high status burials are also not comparable with the somewhat later burials with bronze containers and horse gear from Wijshagen 'De Rieten' (Van Impe and Creemers, 1991). The latter are associated with the phenomenon of the regional 'princely' elite dated to the end of the EIA and transition of EIA and LIA (600-400 BCE). These high status individuals are linked to elite hillfort sites such as Kemmelberg (Van Doorselaer et al., 1987) and Kesselberg (Van de Velde et al., 2013) in the agriculturally rich loam belt in Belgium. Status differences in a local community can indeed be more modest than these higher regional elites and can be expressed in subtle ways which are often hard to determine archaeologically (Turkon, 2004).

Table 1**Fout! Verwijzingsbron niet gevonden.** shows that three out of five LBA oval monuments in Destelbergen had central graves which underwent $^{87}Sr/^{86}Sr$ analyses (Dalle et al., 2022) of which two could be ^{14}C dated (De Mulder et al., 2009). No associated burials were found within this type of ditch structure. The single circular monument had a central grave and two associated burials, of which the central and one associated burial had sufficient bone material to be analysed ($^{87}Sr/^{86}Sr$, [Sr] and ^{14}C) (Dalle et al., 2022; De Mulder et al., 2009). The six rectangular monuments each had a surviving central burial of which all but one could be ^{14}C dated and all underwent $^{87}Sr/^{86}Sr$ and [Sr] analyses. Of the ten associated burials found within the enclosed area or within the ditch infill, two could be dated (De Mulder et al., 2009) and nine have published $^{87}Sr/^{86}Sr$ and [Sr]. Of the 85 simple pits surrounding the monuments, 17 were ^{14}C dated and 79 received $^{87}Sr/^{86}Sr$ and [Sr] results (Dalle et al., 2022).

*Table 1 Overview table of available data per monument type and burial category, with general chronology and location within the urnfield. Mind that simple pits persist throughout the entire timespan of the urnfield and are located over the entire spatial extent as well (** De Mulder et al., 2009*, *** Dalle et al., 2022)

Monument	Number of monuments	Burial location	Number of burials	Published data ^{14}C*	$^{87}Sr/^{86}Sr$ & [Sr]**	General chronology	Location in urnfield
Oval	5	**Central**	3	2	3	Late Bronze Age	east
		Associated	0	0	0		
Circular	1	**Central**	1	1	1	Iron Age	central
		Associated	2	1	1		
Rectangular	6	**Central**	6	5	6	Iron Age	west
		Associated	10	2	9		
Simple pit	-	**-**	85	17	79	Late Bronze – Iron Age	west, central, east

Strontium isotope and concentration analysis

Strontium concentrations ([Sr]) and ratios of its isotopes 87 and 86 ($^{87}Sr/^{86}Sr$) have been proven to not only be preserved in tooth enamel (Price et al., 2002), but also in cremated remains (Dalle et al., 2022;

Grupe and Hummel, 1991; Harbeck et al., 2011; Snoeck et al., 2015). The abundance of ^{87}Sr and of ^{86}Sr varies locally, depending on the age of the underlying bedrock and other factors. Plants growing on these soils take up this local Sr signature and accordingly reflect the characteristic isotope ratio, which then enters the local food chain (Bentley, 2006; Evans et al., 2010; Sillen et al., 1998). Comparing the $^{87}Sr/^{86}Sr$ of human bone with the locally occurring value recorded in modern plants, makes it possible to investigate mobility, in which the $^{87}Sr/^{86}Sr$ in the skeleton reflects the $^{87}Sr/^{86}Sr$ of the ingested food of the last decades or so in life, depending on the skeletal element and other factors (Montgomery, 2010; Price et al., 2002). Research on more precise bone turnover rates is still ongoing and demonstrates the complexity of the process (for a detailed discussion, see e.g. Parfitt, 2013). Conclusions about collagen turnover (e.g. Hedges et al., 2007) cannot be adopted without caution for cremated remains, where Sr is taken from the mineral bioapatite fraction of the bone. Alternatively to the majority of the skeleton, tooth enamel, which is usually destroyed in the burning process, and the otic capsule in the petrous bone, do not remodel during life and retain the Sr signature from early childhood (Harvig et al., 2014; Schmidt, 2015; Veselka et al., 2021b). In addition, [Sr] in the analysed human remains varies as a reflection of the bioavailable Sr signature. However, [Sr] in humans depend mostly on dietary preferences (Aufderheide, 1989; Montgomery, 2010; Underwood, 1977). On the one hand, the actual Sr intake, which varies in different food sources, is very influential. Because 99% of the bioavailable Sr is stored in the skeleton and only very little in the soft tissues, a meat-abundant diet will lead to low [Sr] in bone and teeth of the consumer (Bentley, 2006; Schroeder et al., 1972; Underwood, 1977). A plant-based diet instead is rich in Sr and will result in high [Sr] in the consumer. The trophic level of the deceased is thus generally reflected in their [Sr]. Additionally, there are dietary elements which actively alter the Sr metabolism in the body. Calcium (Ca), abundant in dairy-rich diets for instance, is an interchangeable element with Sr and is preferentially absorbed in the skeleton over Sr (Montgomery, 2010; Sillen and Kavanagh, 1982). Supplementation with Ca will, like high meat consumption, reduce the uptake of Sr and result in considerably lower [Sr] (Aufderheide, 1989; Montgomery, 2010; Schroeder et al., 1972). Opposed to this, a high salt intake stimulates Ca excretion which leaves more room for Sr to be taken up (Dalle et al., 2022; McParland et al., 1989; Teucher et al., 2008).

Previously, the differences in Sr signature between the two distinct Metal Ages (as a homogenous cultural entity) and Gallo-Roman groups in Destelbergen were investigated and led to an interesting development in the application of combined $^{87}Sr/^{86}Sr$ and [Sr] in cremated bone remains (Dalle et al., 2022). It was found that Gallo-Roman individuals in Destelbergen, but also in other Belgian sites such as Fize-le-Marsal and Blicquy, are characterised by significantly more marine-like $^{87}Sr/^{86}Sr$ and [Sr] which is likely caused by a substantial increase of salt in the Gallo-Roman consumption pattern. This Roman Sr pattern was not present in the Metal Ages individuals, who typically displayed $^{87}Sr/^{86}Sr$ more closely resembling the local baseline and also significantly lower [Sr]. The overall Metal Ages group in Destelbergen shows $^{87}Sr/^{86}Sr$ overlapping with the Roman group (0.7092-0.7098) but also extending into the range 0.7101-0.7105 of the Eocene formation. These values fit well with the bioavailable $^{87}Sr/^{86}Sr$ within a 3 km radius described below (Dalle et al., 2022). Because in Destelbergen there was an overlap in the local bioavailable $^{87}Sr/^{86}Sr$ and marine $^{87}Sr/^{86}Sr$ values, it was significant to find same shifts to marine $^{87}Sr/^{86}Sr$ in Roman individuals in other sites without local $^{87}Sr/^{86}Sr$ resembling the marine 0.7092. Contrary to the previous study, this current article refines the chronological (and spatial) differentiation seen in the urnfield (spatial organisation, Sr signatures and other burial characteristics such as bone weight in individuals of different status) within the long period of the Metal Ages (Late Bronze vs. Iron Age).

Archaeological and landscape context

To effectively interpret $^{87}Sr/^{86}Sr$ and [Sr] to study population dynamics and potential social differentiation, existing knowledge on the archaeological and landscape context should be considered.

In the urnfield period, people supposedly did not live adjacent to the cemetery, but in the surrounding area. The paradigm of the 'wandering farmsteads' during the LBA – EIA involves the use of a central cemetery over the generations by a scattered community living off the surrounding land (Gerritsen, 2003; Roymans and Fokkens, 1991; Schinkel, 1994). This system seems to be in use in agriculturally poorer regions in the Netherlands and possibly Flanders. Settlement features indeed were not found on site in Destelbergen, but 1.6 km north of the cemetery at Sint-Amandsberg "Kasteelwegel" at least two house plans and possibly three four-post granaries were excavated (Vanholme and Dalle, 2016). Only recently, at 2.5 km east, archaeologists excavated a small EIA farmstead with several four-post granaries (Hazen, 2020). They interpreted the configuration as longer-lived, over several generations, nuancing the concept of wandering farmsteads in this region (Hazen, 2020; Schinkel, 1994). The succession of house plans in the first case in Sint-Amandsberg also showed the location was exploited as a farmyard on a recurring basis during the Metal Ages. These types of modest farmsteads are expected to be associated to the urnfield of Destelbergen although it is not sure how far removed the users of the cemetery could live.

The immediate environment of the site is quite diverse with dry sandy ridges and extensive wetland near the river. Quaternary aeolian cover sands of varying thickness and Holocene fluvial deposits bordering the Scheldt river lay on top of the Eocene Gentbrugge formation (locally Ypresian unit; Figure 1). In Destelbergen, the bioavailable $^{87}Sr/^{86}Sr$ is between 0.7095-0.7104 (interquartile range (IQR) of 18 plant samples taken in six different locations) (Dalle et al., 2022). The nearby alluvion has an IQR of 0.7093-0.7098, the Eocene formation measured slightly higher (IQR 0.7101-0.7105). To calculate both separate ranges, six plant samples from two locations were integrated for each formation separately (Dalle et al., 2022). A third location for alluvion and Eocene formation each (respectively Dest_1 and Be_157) was excluded because these were sampled close by the border of both formations and due to imprecision in the geological map presented mixed results complying with both bordering formations.

It is assumed that the cover sands were not ideal for high yields of traditional grain-based harvests as is the more favourable loam area to the south (Flemish Ardennes region). These poorer sandy soils would yet provide enough production for small-sized subsistence farming and be suitable for rearing livestock (De Clercq, 2011; Groot et al., 2020; Roymans and Fokkens, 1991). In this social and geographical context and within a refined chronological framework, the analyses of published and new data from this Metal Ages group have to be reinterpreted.

2. Methods and materials

2.1. Sampling

To better understand the spatio-chronological development of the cemetery, 18 new ^{14}C dates were performed. Different and sometimes multiple reasons for selecting these graves for ^{14}C dating were formulated. Fourteen graves lacked other chronological indicators (urnless graves), 13 of the total were (sometimes additionally) situated in the extremities of the cemetery or in burial clusters which were previously not dated, and two of these 18 dated graves had an association with a rectangular monumental structure.

Sabaux et al. (2021) demonstrated that multiple individuals can be buried in the same grave in LBA-EIA Belgian urnfields and therefore it is best to perform both $^{87}Sr/^{86}Sr$, [Sr], and ^{14}C analyses on the same fragment to ensure the results refer to the same individual. For 11 burials, enough material from the same (diaphyseal) fragment remained after $^{87}Sr/^{86}Sr$ and [Sr] analyses for ^{14}C dating. For the seven others, unfortunately, a new fragment had to be selected from the bone remains. To ensure that all analyses could be related, these seven diaphysis fragments underwent ^{14}C, $^{87}Sr/^{86}Sr$ and [Sr] analyses, of which unfortunately one ^{14}C date failed. Consequently, seven burials delivered two Sr signatures on separate bone fragments. This article adds seven new $^{87}Sr/^{86}Sr$ and [Sr] results and a total of 18 new ^{14}C dates. Additionally, it incorporates the 89 published Sr signatures (Dalle et al., 2022) and 28 published ^{14}C dated burials (Dauchot-Dehon et al., 1984; De Laet et al., 1986; De Mulder et al., 2009; De Reu et al., 2012) of the 107 burials of the Destelbergen urnfield. An added 14 burials without ^{14}C dates could be dated typo-chronologically (De Laet et al., 1986). Unfortunately, the previously published ^{14}C dates obtained mostly in the years 2006-2009 can only be linked to the more recent $^{87}Sr/^{86}Sr$ and [Sr] results (2021-2022) with caution, due to the fact that there is a slight possibility that the separate fragments belonged to multiple cremated individuals buried together (Sabaux et al., 2021). All studied bone fragments being diaphyseal fragments, means that the Sr signatures in the bones are the accumulation of ingested Sr from more or less the last decade or so in life based on studies on collagen turnover (Hedges et al., 2007). Although collagen might give an indication of turnover of the mineral bioapatite which contains the studied Sr, it cannot be guaranteed that bone remodelling is the same in both fractions.

2.2. Strontium isotope and elemental analysis

The pretreatment, Sr extraction, and isotopic and elemental measurements of the cremated bone samples were done at the laboratories of the Analytical, Environmental and Geo-Chemistry (AMGC) research group at the Vrije Universiteit Brussel (VUB), Belgium.

The procedures described in Snoeck et al. (2015) were applied. The samples were first mechanically cleaned by drilling off the possibly contaminated outer layer. Next, chemical cleaning was done by three series of 10 minutes of ultrasonication in milliQ water, followed by one time of 3-10 minutes of ultrasonication in 1M acetic acid. Finally, another three times of ultrasonication in milliQ water finishes the cleaning process. The cleaned samples are then dried and powdered. The extraction process is described in Snoeck et al. (2015). Columns filled with Sr-specific resin (Eichrom Sr Spec) separated the Sr from the sample. The calculated Sr column recovery rate yields more than 95% of total Sr. As a reference for testing the accuracy of the subsequent analytical measurements, a sample of the standard 'bone ash SRM1400' underwent the same extraction process. The measurements were done on a Nu Plasma 3 (PD017 from Nu Instruments, Wrexham, UK). Each analysis consisted of 60 ratio measurements (3 blocks of 20 cycles), resulting in a data collection duration for each individual sample of 12– 13 min. All the Sr isotopes (84, 86, 87, 88) were measured, while the masses 85 (rubidium Rb) and 83 (krypton (Kr)) were simultaneously monitored, allowing for interference corrections on masses 84, 86 (Kr) and 87 (Rb). The Sr isotopic ratios were automatically normalized to $^{87}Sr/^{86}Sr = 0.1194$ using an exponential law. Repeated measurements of the NBS987 and SRM1400 standards yielded $^{87}Sr/^{86}Sr = 0.710250 \pm 35$ (2SD; n=26) and 0.713118 ± 28 (2SD; n = 28) respectively. This is sufficiently consistent with the mean value of 0.710252 ± 13 (2SD) obtained by Thermal Ionization Mass Spectrometry (TIMS; Weis et al., 2006). A standard bracketing method with the recommended value of $^{87}Sr/^{86}Sr = 0.710248$ was used to normalise all sample measurements. Procedural blanks were considered negligible (total Sr (V) of max 0.02 versus 7–10V for analyses, equivalent to ≈ 0.3%). The $^{87}Sr/^{86}Sr$ is reported with a 2SE error for each sample (absolute error of the individual sample analysis – internal error).

An aliquot of 0.5 ml of all dissolved samples was used to measure the Sr and Ca concentrations. Once diluted again with 0.42 M HNO_3, a Nu Instrument ATTOM ES ICP mass spectrometer at Vrije Universiteit

Brussel (VUB) was used to determine the Sr and Ca concentrations in low and medium resolution respectively using indium (In) as an internal standard and external calibration versus various certified reference materials (SRM1400, SRM1486, SRM1515). The actual strontium concentrations were then calculated by normalizing the calcium data to 40%. Accuracy was evaluated by the analysis of an internal bioapatite standards (CBA). Based on repeated digestion and measurement of these reference materials, the analytical precision of the procedure outlined above is estimated to be better than 5% (1SD, n = 10 for CBA).

2.3. Radiocarbon dating

The ^{14}C dating of the additional cremated bone samples took place at the Royal Institute for Cultural Heritage (KIK-IRPA) in Brussels, Belgium, following pretreatment procedures published in Wojcieszak *et al.*, 2020. Calibration of the ^{14}C dates was performed by means of the software OxCal 4.4 (Bronk Ramsey, 2009) and the IntCal20 calibration curve (Reimer et al., 2020). Kernel Density Estimate (KDE) analysis was carried out on the published and new ^{14}C dates using the tool *KDE_Plot()* in OxCal 4.4 (Bronk Ramsey, 2017) to determine the chronological distribution of the whole dataset. To calculate the time spans for the beginning and the abandonment of the site, boundary estimation modelling of the ^{14}C dates was carried out using the OxCal 4.4 *Boundary()* function and the tool *Difference()* was employed to determine the duration of the site use (Bronk Ramsey, 2009).

2.4. Geostatistical modelling

Empirical Bayesian Kriging (EBK) interpolation was performed in ArcGIS Pro 2.9.0 to study the internal development of the Destelbergen cemetery by space-time modelling the total of 46 georeferenced ^{14}C dated burials, thus updating the results obtained by De Reu et al., 2012 on 26 previously dated burials. Medians of calibrated ^{14}C dates were used as single estimates for the EBK interpolation (Capuzzo and Barceló, 2022; Mazzucco et al., 2018). The chosen EBK interpolation method can deal with some non-stationarity (i.e. data that are not equally and gradually varying throughout space), smaller datasets and moderately non-Gaussian data (Krivoruchko and Gribov, 2019). Beforehand, a power semivariogram was produced to evaluate the spatial autocorrelation in the ^{14}C data, i.e. if there is systematic spatial variation in the ^{14}C dates (Conolly, 2020). A cross-validation graph was obtained to compare the measured and the predicted chronological values for each dated burial and to detect whether the model over-generalises the existing pattern.

2.5. Osteological analysis

Ten burials underwent osteological analysis aimed at sexing and ageing the individuals who were buried centrally within monumental structures and deemed of higher status. All burials have been osteologically assessed in the past (De Laet et al., 1986; Janssens, n.d.; Smits, 2012), but a reassessment of a specific selection of graves under focus in this article was considered necessary since standards for sexing cremated remains have developed drastically since the initial analysis in the 1960-1970s.

2.6. Data processing

R Studio (running on R version 4.0.3 (2020-10-10)) was employed for the production of graphic plots and statistical tests. General mapping and automated Time Series maps using the Temporal Controller functionality were done with the help of QGIS (version 3.18.3-Zürich), while Empirical Bayesian Kriging interpolation was performed in ArcGIS Pro 2.9.0. The $^{87}Sr/^{86}Sr$ and [Sr] data will be openly available in the IsoArcH database (www.isoarch.eu) (Salesse et al., 2018).

3. Results

3.1. ^{14}C dates

Eighteen new ^{14}C dates (Table 2 and SI Table S1) refined the image of the cemetery's development. All burials in the eastern extent of the cemetery associated with oval monuments that had sufficient bone to be ^{14}C dated, delivered a 1σ calibrated date roughly before 800 BCE. The latest new date for this eastern zone is grave 56 with a calibrated ^{14}C date of 899-795 cal. BCE at 2σ (RICH-28606, 2669±25 BP), similar to the already dated grave 99 (KIA-36923, 2665±40 BP) (see SI Table S1). The new dating campaign also delivered two new oldest dates for the whole cemetery (burial 104: RICH-28601, 2825±23 BP and burial 106: RICH-28631, 2835±24 BP).

In the western part of the cemetery, burial 23 (RICH-28603, 2702±23 BP) delivered a 2σ calibrated date of 901-809 BCE and is one of the oldest dates in that zone. The dated burials in the central-west part of the cemetery are overwhelmingly dated in the Hallstatt plateau between ca. 800-400 BCE (De Mulder et al., 2009; De Reu et al., 2012; Reimer et al., 2020). This zone is also characterised by a much higher spatial density than the eastern part of the cemetery.

Table 2 New ^{14}C dates from the Destelbergen Metal Ages burials (also included in SI Table S1).

Sample ID	^{14}C Labcode	Grave number	Uncal. age BP ± σ	Cal. age BCE (2σ)	Cal. age BCE (1σ)	Location in urnfield
06136	RICH-28631	106	2834±24	1102 - 911 BCE	1015 - 931 BCE	East
06135	RICH-28601	104	2825±23	1048 - 911 BCE	1009 - 931 BCE	East
06127	RICH-28634	54	2783±24	1006 - 840 BCE	982 - 900 BCE	East
06126	RICH-28603	23	2702±23	901 - 809 BCE	897 - 811 BCE	West
06128	RICH-28606	56	2669±25	899 - 795 BCE	832 - 802 BCE	East
06132	RICH-28670	70	2639±24	831 - 781 BCE	812 - 795 BCE	West
06131	RICH-28599	64	2610±23	811 - 776 BCE	806 - 787 BCE	West
06130	RICH-28602	62	2609±23	810 - 776 BCE	806 - 786 BCE	West
06133	RICH-28604	81	2524±23	786 - 548 BCE	776 - 571 BCE	West
07140	RICH-30010	46	2519±26	787 - 544 BCE	774 - 570 BCE	West
06125	RICH-28605	21	2515±23	780 - 545 BCE	773 - 570 BCE	West
06134	RICH-28600	89	2501±23	774 - 544 BCE	765 - 564 BCE	West
07142	RICH-30022	97	2482±26	771 - 486 BCE	754 - 545 BCE	West
06129	RICH-28984	59	2473±24	767 - 480 BCE	753 - 542 BCE	West
07141	RICH-30009	48	2471±26	766 - 425 BCE	752 - 541 BCE	West
07139	RICH-30037	29	2463±21	756 - 421 BCE	750 - 517 BCE	West
07137	RICH-30008	17	2460±25	756 - 417 BCE	750 - 487 BCE	West
07138	RICH-30036	20	2457±28	755 - 416 BCE	749 - 481 BCE	West

3.2. Chronological and geostatistical modelling of the complete ^{14}C dataset

Chronological modelling

To synthesise the chronological and spatial development of the cemetery, several analyses have been done on 46 ^{14}C dates. The KDE plot (Figure 2A) visualises how the cemetery reaches its ultimate extent in the LBA-EIA, covering the period corresponding to the Hallstatt plateau (800-400 BCE) in the IntCal20 calibration curve. Boundary estimation of all dates in OxCal (Figure 2B-D) places the begin date (C) of the cemetery between 1047 and 942 cal. BCE, the end date (D) between 351 and 268 cal. BCE and the duration (B) at 610 to 750 years (all at 2σ).

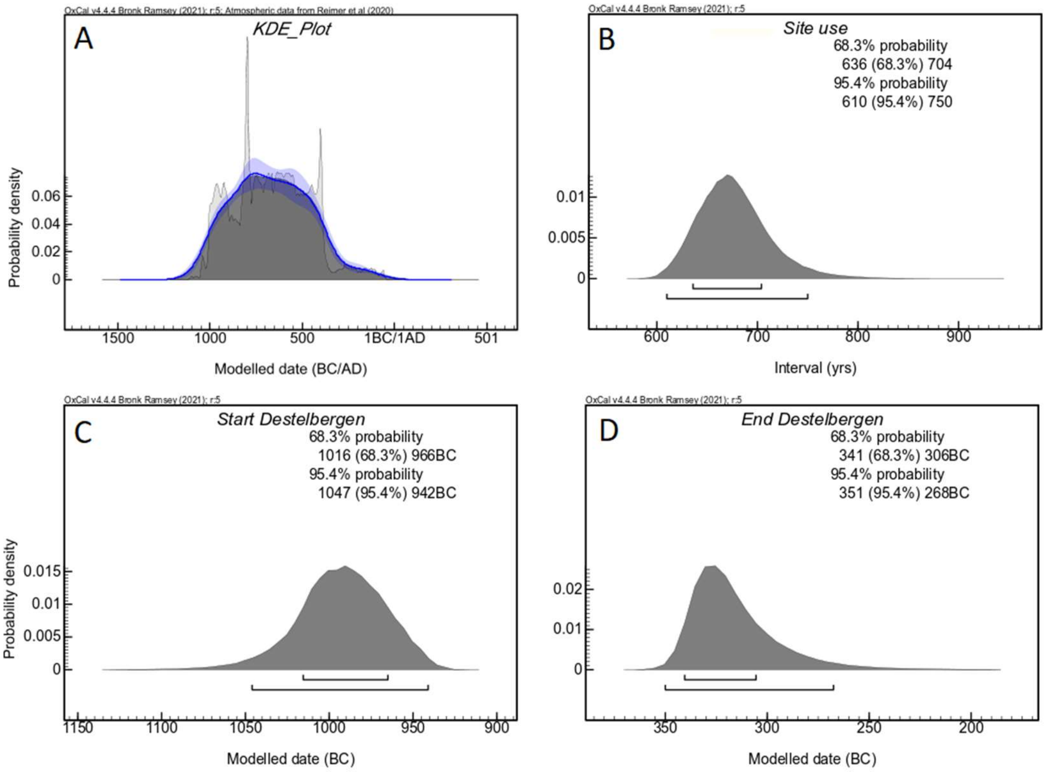

Figure 2 Kernel Density Estimate plot (A) and boundary estimations of respectively duration (B), start (C), and end (D) of the cemetery based on the published (De Mulder et al., 2009) *and new dates, calculated in OxCal.*

Geostatistical modelling

The empirical semivariances of the ^{14}C dataset are represented by blue crosses in the semivariogram in Figure 3. Except in two cases, these are all within the 25th and 75th percentiles (red dashed lines), calculated for the spectrum of semivariogram distributions (blue lines). This implies that similarity between the data points slowly diminishes over the distance between them, following Tobler's first law of geography which states that "near things are more related than distant things" (Tobler, 1970). The trend in the blue crosses shows a few dips, likely caused by the presence of some outlying dates within the western part of the site. Despite these dips, the main trend in the graph shows (imperfect) positive autocorrelation, meaning that closer burials are usually more alike in ^{14}C date than further burials. Even though the dataset might not be the most ideal case, it seems nevertheless appropriate to interpolate the data points into a model of expected dates.

The EBK interpolation (Figure 4) shows that the oldest nucleus of burials is located in the eastern part of the cemetery. From this area the deposition of new cremations progressively spread to the western part. However, the trend visible in the western half of the cemetery is not generalised, as the presence of both older and younger burials in the western part confirms. The lack of a clear trend in this part likely causes some of the measured and predicted chronological values in the cross-validation graph (Figure 3) to not match and to not follow the reference line ($r^2 = 0.35$). This result urges to be cautious when using the model. Despite this, the Root-Mean-Square Standardised Error calculated for the cross-validation, which is a measure of the goodness of fit, is 0.99, very close to 1, confirming that the predicted standard errors are satisfactory. Despite some minor deviations, the 14 typo-chronologically dated burials largely agree with the interpolation model (see triangles Figure 4). To be able to estimate the corresponding probabilities of the calibrated dates, the probability distributions of each sample have been divided into the same colour scheme as the model (see SI Figure S1).

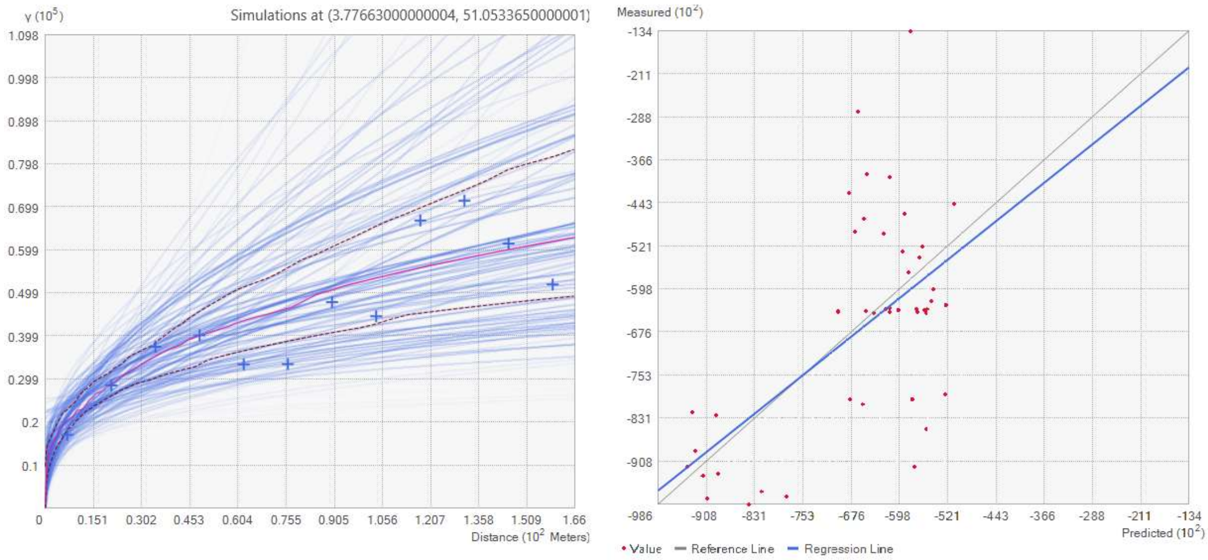

Figure 3 Semivariogram (left) and cross-validation graph (right) of the interpolation performed on the ^{14}C in Figure 4.

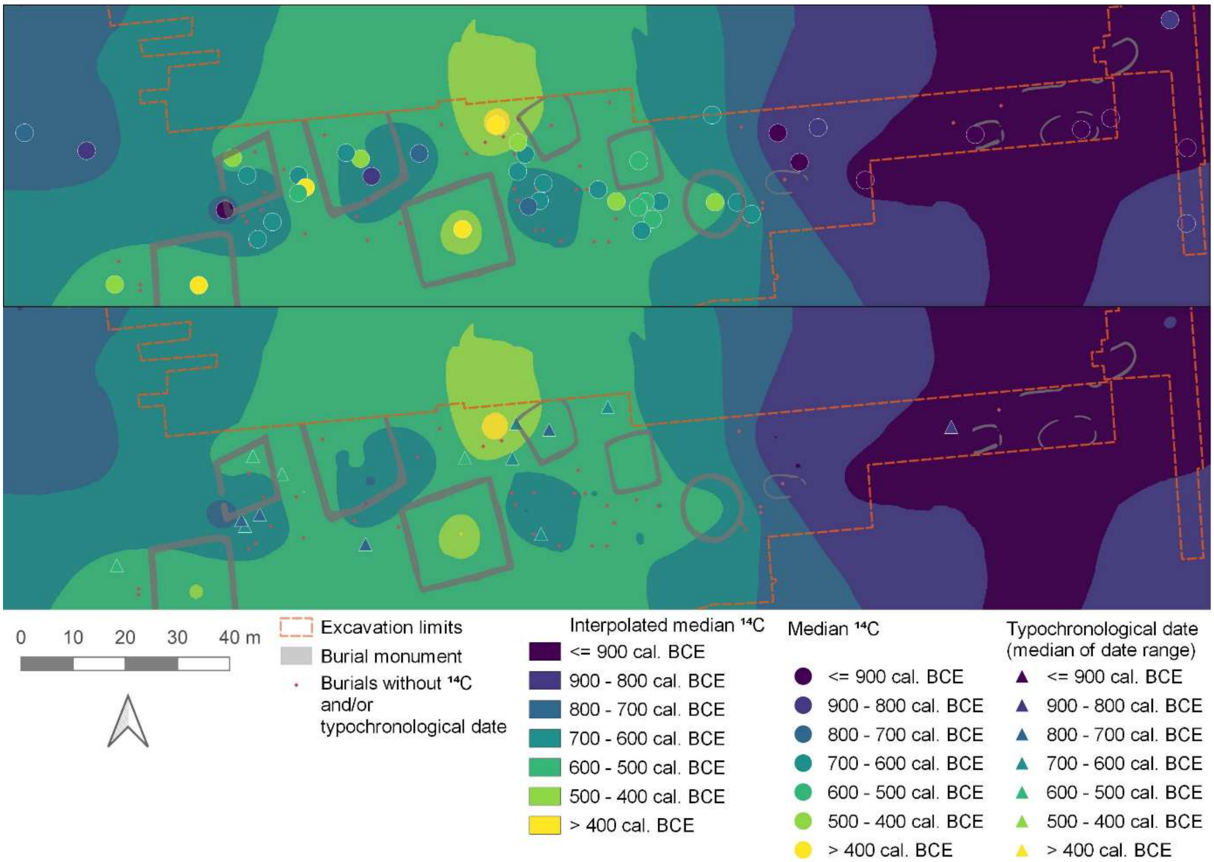

Figure 4 Empirical Bayesian Kriging interpolation of the ^{14}C dated burials with above the interpolated ^{14}C dated points and below the typochronologically dated burials to compare with the predictive model (De Mulder et al., 2009; De Reu et al., 2012).

3.3. $^{87}Sr/^{86}Sr$ and [Sr] data

Previous research showed that a single cremation grave can in some cases contain bone deposits of several individuals, even from different periods (Sabaux et al., 2021). In Destelbergen, however, comparing first and second analyses on bone fragments from the same grave provided very little variation (Table 3). A $^{87}Sr/^{86}Sr$ minimum difference of 0.000009 and maximum difference of still only 0.000153 between two different bones from the same grave can be considered minimal. Comparison between first and second measurements is found to be statistically significantly not distinguishable (Wilcoxon Signed Rank Test: V = 20, p = 0.375). The seven bone samples produced [Sr] varying between 124 and 166 ppm. The first and second analysed bone fragments differ on average with 10 ppm (min. 0 – max. 21 ppm difference) and both measurements are also statistically considered the same (Wilcoxon Signed Rank Test: V = 15, p = 0.4004). Interestingly, the largest difference in $^{87}Sr/^{86}Sr$ and in [Sr] was seen in the same sample pair (grave 20).

*Table 3 Second versus first published (indicated by *;* (Dalle et al., 2022)*) $^{87}Sr/^{86}Sr$ and [Sr] from the Destelbergen Metal Ages burials (** [Sr] normalised to 40 wt% Ca).*

Sample ID	Grave number	Sample type	$^{87}Sr/^{86}Sr$	$^{87}Sr/^{86}Sr$ 2SE	[Sr]** (ppm)	Difference $^{87}Sr/^{86}Sr$	Difference [Sr] (ppm)
07010*	17	Diaphysis	0.709715	0.000010	155	0.000058	7
07137	17	Diaphysis	0.709657	0.000009	148		

07013*	20	Diaphysis	0.709750	0.000015	137	0.000153	21
07138	20	Diaphysis	0.709597	0.000009	158		
07020*	29	Diaphysis	0.709674	0.000009	139	0.000062	1
07139	29	Diaphysis	0.709736	0.000009	138		
07035*	46	Diaphysis	0.709352	0.000014	135	0.000009	11
07140	46	Diaphysis	0.709361	0.000009	124		
07037*	48	Diaphysis	0.709351	0.000009	150	0.000036	18
07141	48	Diaphysis	0.709315	0.000009	132		
07073*	97	Diaphysis	0.709064	0.000009	149	0.000063	0
07142	97	Diaphysis	0.709001	0.000009	149		
07074*	98	Diaphysis	0.709810	0.000008	177	0.000020	11
07143	98	Diaphysis	0.709830	0.000008	166		

3.4. Osteological analysis

An osteological assessment (Table 4) was performed on the central burials within the monuments to see if sex would be associated with either higher status or $^{87}Sr/^{86}Sr$ and [Sr], contradicting some of the previous observations (Janssens, n.d.). The remains unfortunately contained only a minimal amount of fragments suitable for sexing the individuals. Sex determination of the three LBA central graves was entirely impossible due to the limited amount of deposited bone. Yet, a little more information came from the EIA graves. It could be concluded that the IA individuals of graves 12 and 41 were possible males, and graves 22 and 71 contained fragments determined as possible females. A mix of both male and female individuals can be assumed in the examined EIA graves. Eight out of ten centrally buried individuals were determined adult or probable adult, while the other two (LBA) bone assemblages did not reveal age indications.

Table 4 New osteological assessment of the Destelbergen Metal Ages individuals buried centrally within a monumental structure (bone weights published in De Laet et al. (1986)*).*

Grave number	Grave deposit	Monument type	Chronology	Bone weight (g)	Age	Sex
100	A	Oval	Late Bronze Age	16	Indeterminate	Indeterminate
103	A	Oval	Late Bronze Age	491	>22	Indeterminate
105	AA	Oval	Metal Ages	NA	Indeterminate	Indeterminate
91	A	Circular	Early Iron Age	794	>18	Indeterminate
12	A	Rectangular	Early Iron Age	1660	>18	Possible male
22		Rectangular	Early Iron Age	675		
	A				Indeterminate	Indeterminate
	B				35-63	Possible female
	C				Indeterminate	Indeterminate
38		Rectangular	Early Iron Age	1430		
	A				Indeterminate	Indeterminate
	B				>22	Indeterminate
41		Rectangular	Early Iron Age	1430		
	A				>22	Indeterminate
	B				>18	Possible male
	C				>18	Indeterminate
57	A	Rectangular	Late Iron Age	350	Indeterminate	Indeterminate
71		Rectangular	Late Iron Age	1066		
	A				>22	Possible female
	B				Indeterminate	Indeterminate

4. Discussion

4.1. Site chronology

The earlier dating campaigns noticed a gradual but not very pronounced east-to-west chronological trend in the cemetery (De Mulder and Deweirdt, 2012; De Reu et al., 2012). The urnfield was created at the earliest around 1050 BCE in the eastern section, associated with the smaller, oval monuments surrounding some of the graves (SI Figure S2). The earliest graves were, however, not ornamented with an oval ditch structure. Two of these monuments were associated with central burials dated to around 1000-850 BCE (De Mulder et al., 2009). Now that 10 out of 17 burials in the eastern part have been dated, it becomes more conclusive that this zone was strictly abandoned by 800 BCE. The burials extend westwards by the end of the Bronze Age, during the ninth century BCE. One exception to this is burial 10 (Figure 1) with a 2σ calibrated date between 1003-834 cal. BCE (KIA-34923, 2775±30 BP; De Mulder et al., 2009) which appeared in the infill of an EIA ditch in the western part of the cemetery (SI Figure S2), but the excavation synthesis describes that this burial was considered to be disturbed and probably not *in situ* (De Laet et al., 1986). The burial could originally – and most likely – come from nearby, but could just as well have been brought in with soil from a bit further. Apart from burial 10, also burial 23 (RICH-28603, 901-809 cal. BCE, 2σ) appears early in the western part of the cemetery.

During the EIA the western part of the Destelbergen cemetery becomes densely occupied. General demographic expansion in the urnfield period, but especially in the EIA has also been observed in the Meuse-Demer-Scheldt region to the northeast (Gerritsen, 2003; Roymans and Kortlang, 1999). In contrast, a recent Belgian ^{14}C study shows a peak in cremation burials rather in the LBA than in the EIA, whereas the settlement data shows a continuous higher prevalence in both LBA and EIA than in the earlier periods (Capuzzo et al., 2023, 2020). In the western section larger, rectangular (or square) monument types are common. The only circular monument belongs to the same period as the rectangular features (De Mulder and Deweirdt, 2012). The rectangular monuments in Destelbergen were a new style of monumentally delimiting burial space which are the earliest to be recognised so far (De Mulder, 2014, 1994). These monuments became more common from the sixth or fifth century BCE onwards and occurred in the Middle Rhine area in Germany, East Yorkshire (UK), the southern Netherlands and in Northern France and were originally associated with the Marne culture in France (Verlinde, 1985; Verwers, 1972). The earliest burial associated with a rectangular monument type is burial 38, typo-chronologically dated to Hallstatt C (800-600 BCE) (De Laet et al., 1986). The northern row of rectangular monuments is after this soon completed, demonstrated by the associated burials 12, 22 and 41 dated in the Hallstatt plateau between ca. 800-400 BCE (De Mulder et al., 2009; De Reu et al., 2012; Reimer et al., 2013).

A small southward expansion with two extra rectangular monuments forming a parallel southern row can be entirely attributed to the LIA (De Mulder et al., 2009) (see SI Figure S2). To the LIA monuments, no secondary graves were added and there were also fewer burials situated around. Only four more graves without monument were added during this period and two out of six burials in total are situated within rectangular monuments. This might mean that erecting monuments around graves became more standardised by the LIA in this cemetery, or that only a limited, higher status part of the LIA population is buried within the then probably outmoded, traditional urnfield cemetery.

In the transition from EIA to LIA, the habit of burying in urnfields clearly dies out and the KDE plot (Figure 2A) shows a steep decline around 400-350 BCE with an end date around 270 BCE at the latest. In the general burial narrative in Flanders it has been noticed that burials dating to (the first half of) the LIA are not as often encountered as burials in the urnfield period, for which the causes are not yet determined (e.g. changing burial ritual, selectiveness concerning who is buried, population decline, …).

Despite that the Destelbergen cemetery declines in the LIA, the very slight continuity of the practice with the addition of only a couple of individuals brings nuance to the generally accepted urnfield framework in which urnfields are primarily dated to the LBA-EIA (De Mulder et al., 2007). This slight continuity is also the case in e.g. Rekem Hangveld (Van Impe, 1980), Kontich Duffelsesteenweg (De Mulder and Bourgeois, 2014; Verelst and Baetsen, 2008), Wijnegem Blikstraat (De Mulder et al., 2017) and Brecht Ringlaan (Bracke et al., 2017). In Rekem, the excavators observed that the burials dating to the LIA might form a separate cemetery within this extensive site (De Boe, 1986). These cases show that the urnfields still acted as places of memory and ancestry, and continued use would stress kinship with these real or pretended ancestors and deepen the bond with the land (Fernández-Götz, 2014; Gerritsen, 2003).

4.2. Cemetery organisation and performance of the interpolation model

Overall, the westwards trend in the Destelbergen cemetery appears rather suddenly than gradually somewhere during the time period 900-800 BCE. SI Figure S2 shows best that the eastern part of the cemetery, despite low density of the (surviving) burials, became unfavourable for burials after 800 BCE. This same trend is demonstrated more vaguely by the updated space-time gradient of the site (Figure 4) (see previous version De Reu et al., 2012). The downside of these interpolation models applied to high-density ^{14}C dates is the supressing of burials of deviant date which can tell a particular story. Plotting the burials with their measured values in the same colour scheme on top of the model also helps highlighting deviant values, but the presence of these outlying values are not recognised by the model alone. Furthermore, the fact that these methods are preferably used with stationary spatial phenomena (i.e. data that are equally and gradually varying throughout space) prevents the model in this case to perform optimally (Krivoruchko and Gribov, 2019). This last characteristic leads to a seemingly gradual transition and temporal continuity in the model from east to west, although that analysis via time series with 100-year time slots (see SI Figure S2) reveals there is rather an abrupt duality in the urnfield with an eastern part that is deserted, during which the western part is taken into use in a fairly unorganised way over a longer period of time. This is important information that would not be unveiled by study of the predictive model alone. Although the interpolation model indeed has difficulty performing in the unorganised western part and tends to overgeneralise, it is nevertheless helpful in visualising the more general trends such as the clear difference between the western and eastern part. Additionally, as also De Reu et al. (2012) mentions, it is an impoverishment to have to express time ranges as single point measures (in this case medians). Destelbergen, for an important part covering the Hallstatt plateau, resulting in many burials with long and often overlapping calibrated time intervals of which the median is similar, reinforces this problem. Time intervals derived from calibration can inherently not be included in an EBK interpolation model devised to predict the most likely date of the burials. To resolve this issue, SI Figure S1 highlights those burials of which the time interval with highest probability overlaps with each time bracket of 100 years.

Careful study of SI Figure S2 (2σ calibrated dates) revealed the abandonment of the eastern area for the western area mostly between 900 and 800 BCE. This abandonment of the LBA graves could both be a sign of respectful distancing from ancestors, or of distancing from no longer accepted or fashionable past attitudes (Needham, 2007). This same divide between LBA and EIA burials was present in the extensive urnfield of Hofstade Kasteelstraat (Hiddink, 2019), although the site is not yet ^{14}C dated as intensely as Destelbergen and most dates are based on typo-chronological indicators. Here the directionality was northwest (LBA) to southeast (EIA) (Hiddink, 2019; Hiddink et al., 2018). The ^{14}C dated burials of Rekem Hangveld also display some clustering of MBA to LBA (southwest side), LBA (west) and EIA burials (east) in the cemetery (De Boe, 1986; Based on map of Temmerman, 2007). A minority of burials seems to be placed within clusters of different date, but most confirm the existence of clear LBA and EIA clusters in a defined area. All three mentioned large urnfields have a long chronology and were situated closely to a navigable river. Larger and longer persisting communities might have been better sustained in locations close to rivers.

4.3. Dietary catchment area and mobility

Neither the small $^{87}Sr/^{86}Sr$ differences between separate fragments of the same grave (Table 3), nor the osteological assessment (Table 4) deliver evidence that these burials contain more than a single individual. This, thus, increases the confidence with which the earlier, published dates can be related to the $^{87}Sr/^{86}Sr$ and [Sr] on a different bone fragment of the same grave. Forty-eight percent of the Destelbergen Metal Ages samples, also considering the published data (Dalle et al., 2022), is characterised by $^{87}Sr/^{86}Sr$ between 0.7093-0.7098, which reflects exploitation of the alluvion, while only a smaller part of the community seems to be predominantly consuming food sources harvested from the Eocene sands. This dominant exploitation of the alluvion is however rather surprising, because even today, most alluvia are considered too wet for raising crops and are primarily used as grazing lands. Some of the higher and dryer alluvial places might nevertheless be especially fertile and favourable to enable higher productivity in this area with poor cover sands. Due to the low [Sr] of river water – in the order of 0.006-0.8 ppm for river water and 0.001-0.4 ppm for rain water (Bentley, 2006; Capo et al., 1998) – the alluvial ground or river water used as drinking water should add rather little extra strontium. It seems that the individuals of the LBA riverine site of Herstal "Pré Wigier" were similarly more impacted by the alluvion with high $^{87}Sr/^{86}Sr$ than by the geological formation of the river terrace with lower $^{87}Sr/^{86}Sr$ (Dalle et al., 2022; Sabaux et al., 2021). Exploring Metal Ages land use near rivers on a larger scale could maybe better explain the dynamics expressed in the $^{87}Sr/^{86}Sr$.

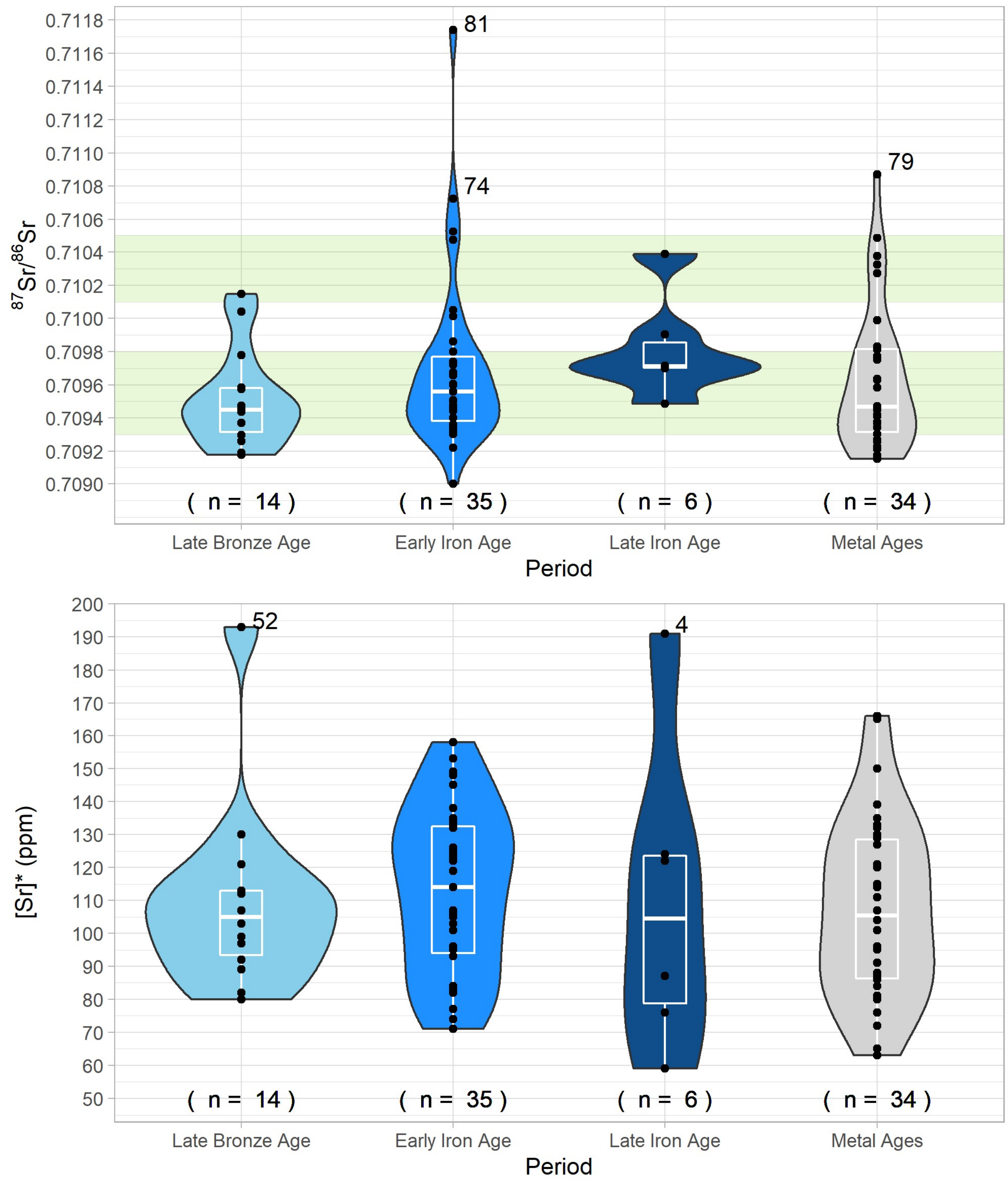

Figure 5 shows larger $^{87}Sr/^{86}Sr$ variability in the EIA and LIA than in the LBA. In the EIA, this seems to be the effect of a larger population likely exploiting more of the surrounding land simultaneously (Dalle et al., 2022). In this sense, the population was less restricted to the alluvion, but also extended in the surrounding Eocene sandy soils. Intensified agricultural activities in the EIA is also supported by the observations in the pollen record in the area (De Laet et al., 1986).

Signs of mobility are not easy to identify in this community. The material culture in Destelbergen (De Laet et al., 1986; De Mulder et al., 2009) predominantly reflect the characteristics of the local so-called Flemish Group (De Mulder, 2011; De Mulder et al., 2008), characterised by rather poor and scarce grave goods (Desittere, 1968), which is not ideal for tracking mobility. Although some urns (graves 52, 69, 100) show *Rhin-Suisse-France orientale* (RSFO) motives, which was more typical for continental central Europe, these seem rather local adaptations of the style than actual original imports (De Mulder, 2011). The individuals associated with these urns display $^{87}Sr/^{86}Sr$ perfectly in line with the rest of the group and the baseline of the immediate surroundings, supporting the previously supposed local origins of the pottery.

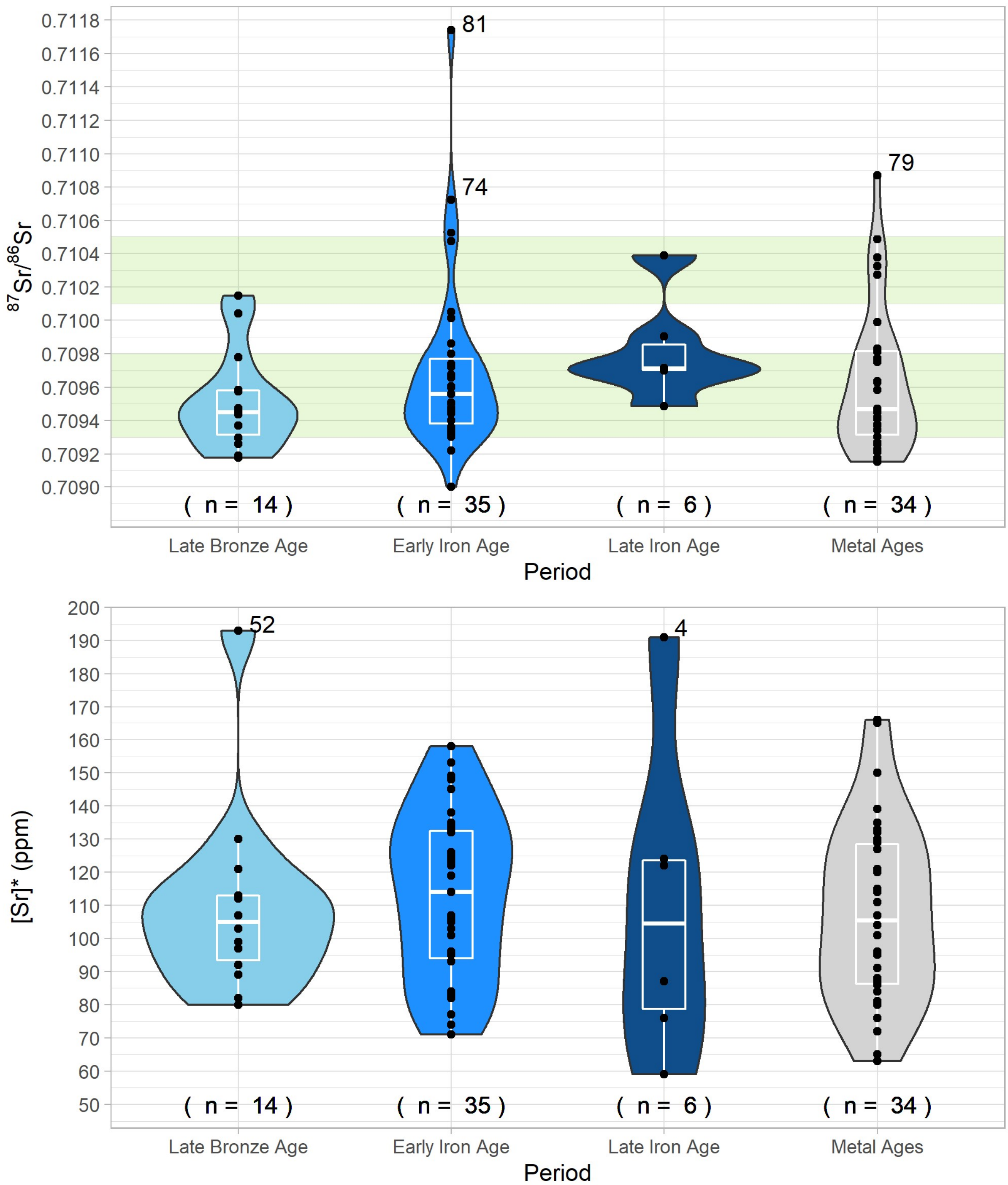

Figure 5 Chronological comparison of $^{87}Sr/^{86}Sr$ (above) and [Sr] (below) from the Metal Ages data published in (Dalle et al., 2022)*. The green bands in the upper graph describe the bioavailable $^{87}Sr/^{86}Sr$ per geological formation (Q1-Q3) present in the immediate surroundings (* [Sr] normalised to 40 wt% Ca).*

Nevertheless, a limited number of individuals might be incoming people, as was also observed in the Velzeke urnfields (De Mulder et al., 2021). Outliers 81, 74 and 79 (

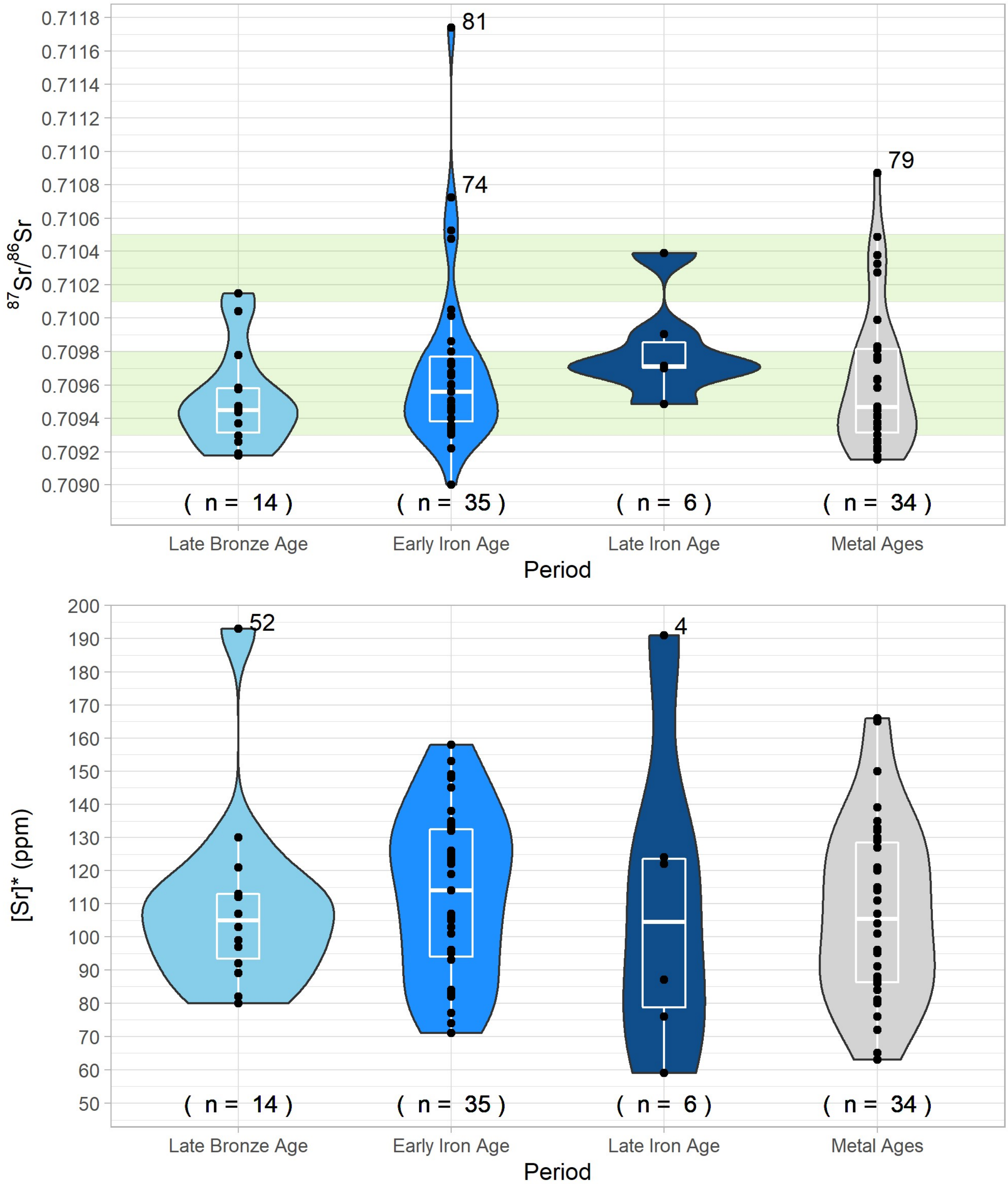

Figure 5) display $^{87}Sr/^{86}Sr$ above the local range of the Eocene deposits and thus consumed goods coming from a region with higher values in the last decade or so of their lives. Of these, the EIA individual from burial 81 (0.7117; Dalle et al., 2022) is the clearest and maybe most recent incoming person, who possibly had little time to incorporate the bioavailable $^{87}Sr/^{86}Sr$ around Destelbergen. These higher values have not yet been encountered in the western Scheldt-Lys area, and the predominant Eocene formation covering this region is not expected to deviate much. Higher $^{87}Sr/^{86}Sr$ did, however, occur in the different sites in the Meuse valley (Sabaux et al., 2021; Veselka et al., 2021a),

where older geological formations surface and could possibly also be expected in the eastern Scheldt and Campine area with its more variable underlying geology. At the other side of the spectrum, several burials from the LBA, EIA, and not more precisely dated group exhibit $^{87}Sr/^{86}Sr$ below the first quartile of the alluvion (0.7093), some extending below the minimum measured in the alluvial plants (0.7092). The upper flow of the Scheldt river for instance is characterised by lower $^{87}Sr/^{86}Sr$ around 0.7087 (Willmes et al., 2018) and can be a possible influence. Still, in general, there is some, although rather limited mobility visible in this group. A future bioavailable map of Belgium will provide a more detailed and complete characterisation of possible regions of origin of these outlying individuals.

4.4. Monumental graves and social status

In general, 92% of the individuals (n=89; see SI Table 1, including Dalle et al. (2022); in case of double analyses for the same grave, the new measurements replaced the older published measurement) show a [Sr] between 60-150 ppm (median 107 ppm). The minimum result of 59 ppm (burial 71) is not a statistical outlier in the entire Metal Ages, nor LIA group, but the maximum results of 193 ppm (burial 52) and 191 ppm (burial 4) clearly fall outside common [Sr] in this group (

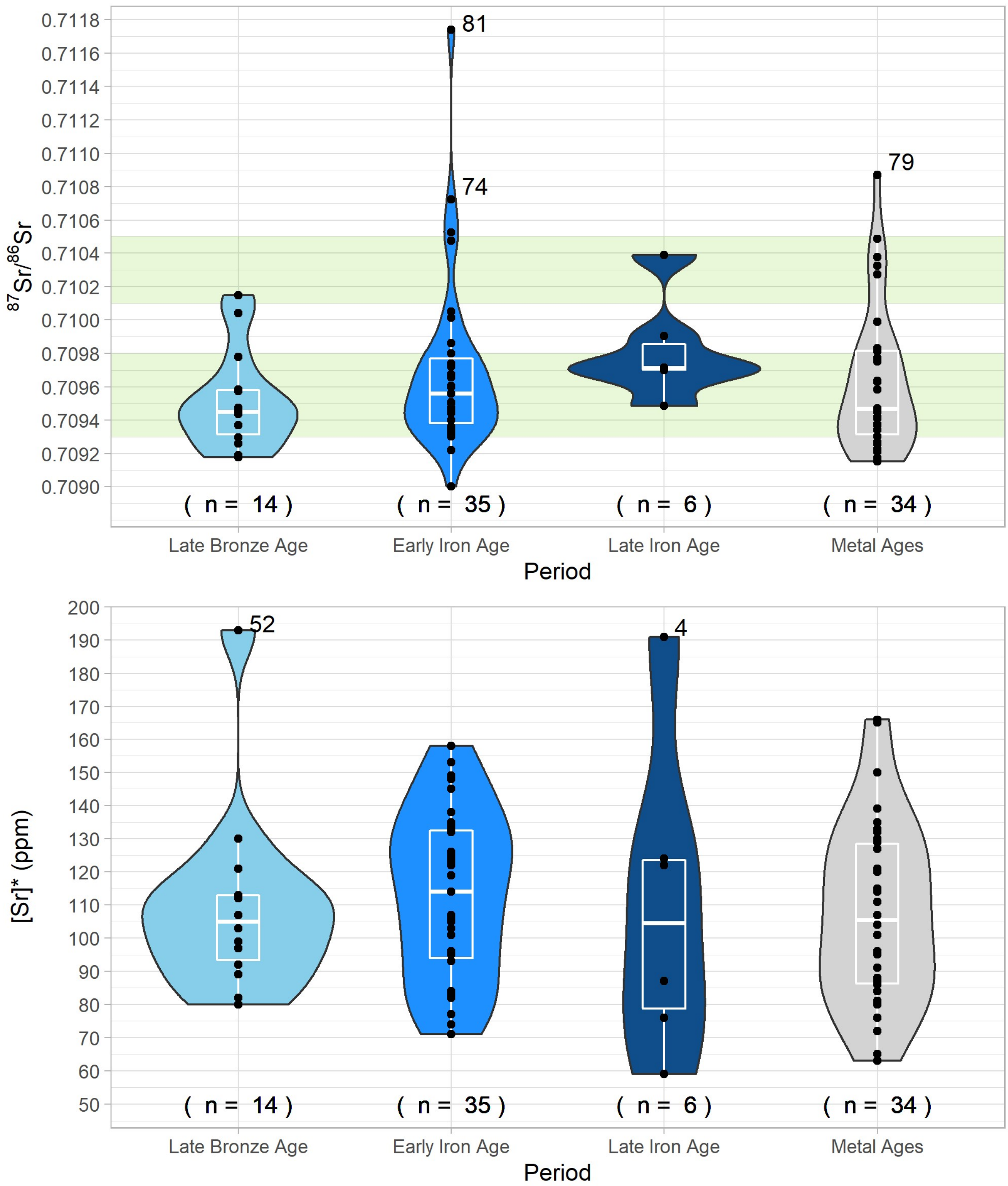

Figure 5). These high [Sr] are reminiscent of the values seen in Roman individuals with a suspected high salt diet, especially when in combination with a $^{87}Sr/^{86}Sr$ towards 0.7092. Despite these outliers, the general picture is in agreement with results from other Metal Ages sites in Belgium. For Herstal (Sabaux et al., 2021) with mostly LBA individuals for instance, [Sr] (n = 31) range between 63 and 147 ppm. Compared to the LBA, in the EIA more individuals display [Sr] above 120 ppm and the median has increased to 119 ppm. Despite the low number of individuals in the LIA, these six individuals display even more [Sr] variability.

Central graves (individuals deemed of higher status) within IA rectangular or circular monuments display generally lower [Sr] than those not buried centrally within a monumental structure (Figure 6).

Most centrally buried individuals fall below the median of 107 ppm of the entire group. This difference is specifically true for the IA burials in the rectangular monuments, but not for the LBA burials and is statistically significant (Mann-Whitney U test for IA group: $U = 113$, $p < 0.001$).

It is likely that the observed variations are related to differences in social status of the deceased. However, some authors warned to not overlook if the sex of the individuals does not cause these variations (Aufderheide, 1989; Sillen and Kavanagh, 1982). It is indeed possible that Ca depletion during pregnancy and lactation leads to an increased uptake of Sr in the female skeleton independent from dietary differences (Aufderheide, 1989; Sillen and Kavanagh, 1982). Unfortunately, it is very challenging to sex cremated individuals due to the fragmentation rate of the remains (Hlad et al., 2021). To get an idea of the effect of sex on the deceased's [Sr], 30 sexed individuals with associated [Sr] from the Early Medieval cemetery of Echt (NL) were compared (Veselka et al., 2021a) (SI Figure S3). The median [Sr] of (probable) female individuals is indeed 21.5 ppm higher than of (probable) male individuals, but the results show a lot of individual variation within each group and the IQR's of (probable) males (94-144 ppm) and (probable) females (99.5-133.5 ppm) largely overlap. Statistical testing could also not confirm a difference in [Sr] between both sexes (Mann-Whitney U test: $U = 37$, $p = 0.92$). This case shows there might possibly be a very slight effect of sex on [Sr], but other factors, such as dietary differences, likely cause more substantial variation still. To exclude that the lowered [Sr] effect seen in Destelbergen could be influenced by individuals of higher status being primarily male (opposed to lactating females), new osteological assessment on the centrally buried individuals was performed (Table 4). Even though the results did not lead to conclusive sexing of all examined individuals, it seems safe to conclude that these remains represented both males and females based on the presence of both typically male and typically female traits. The [Sr] of the two possible females in Destelbergen (59 and 96 ppm) was not systematically higher than the possible males (74 and 95 ppm).

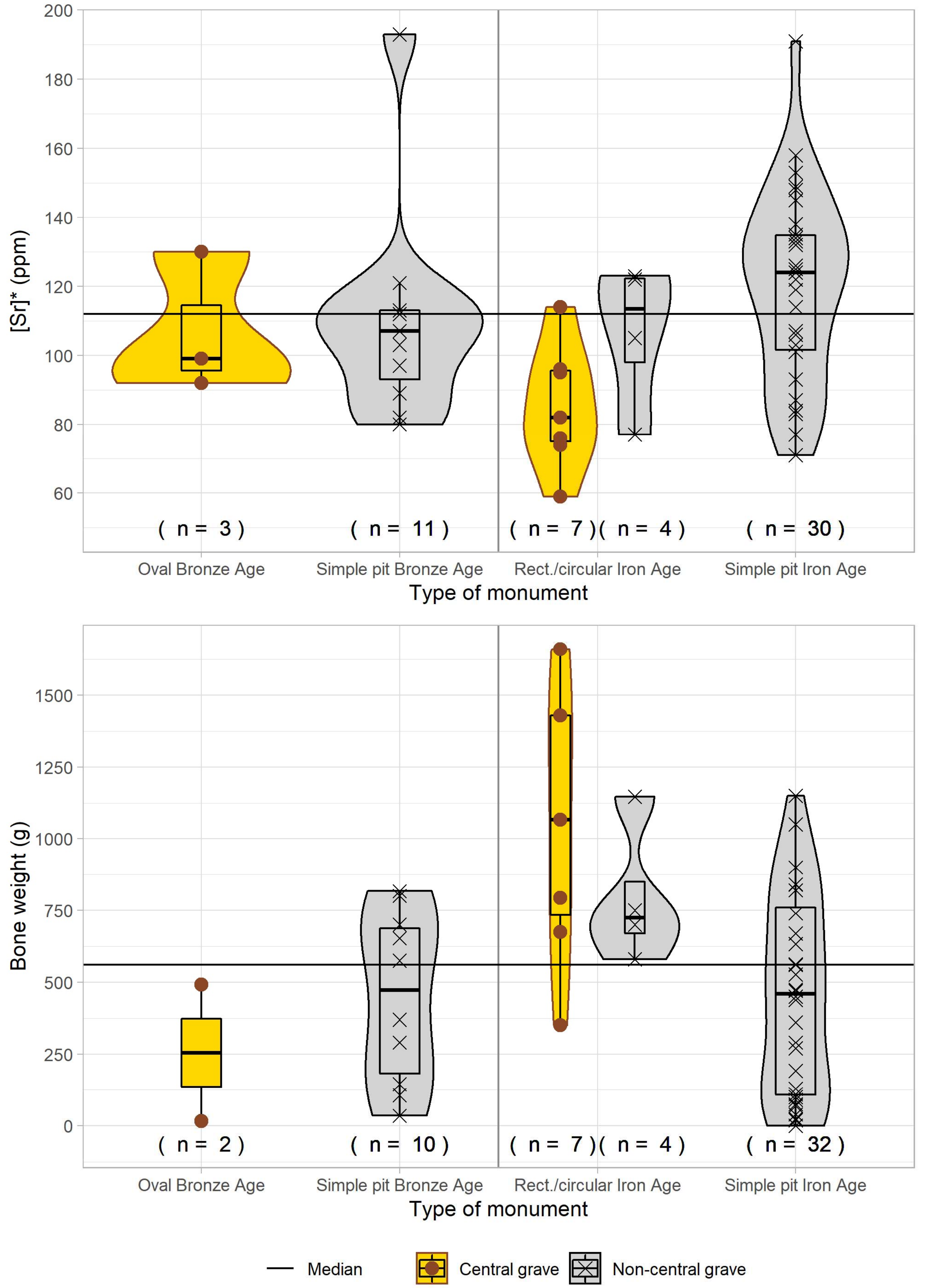

Figure 6 Comparing [Sr] (ppm) (above) and deposited bone weight (g) (below) between individuals buried centrally within a monument (assumed of higher status) and these not buried centrally ([Sr] normalised to 40 wt% Ca). Burials which could not be more closely dated than generally Metal Ages were excluded from this graph.*

Since sex of the individuals does not seem to play a role, the observation likely means there is a dietary difference in these IA individuals of different social status. A lower [Sr] could for instance be caused by a higher percentage of meat and milk products opposed to a dominance of grain and vegetables in the diet (Aufderheide, 1989; Montgomery, 2010; Schoeninger, 1979; Underwood, 1977). Individuals with greater wealth could indeed be able to spend more resources to providing animal products, possess larger herds, or get the first and best choice when food is served. A relationship between different diets for higher status individuals is not unseen in the Metal Ages in Europe. Although from another level of high status, nitrogen isotopic analysis ($\delta^{15}N$) of the Glauberg (DE) chieftain or 'prince' (fifth century BCE) also showed a clearly higher consumption of animal protein (Knipper et al., 2014), indicating that high meat consumption was indeed the privilege of those in higher regard. Similarly, osteological analysis of the EIA chieftain grave of Oss (NL) made the researchers conclude that the individual likely had a diet rich in animal protein (Fokkens et al., 2012; Van der Vaart-Verschoof, 2017). Individuals in IA sword graves, commonly identified as men of higher status, exhibited indicators of higher animal protein intake on numerous occasions in Europe (Knipper et al., 2014; Le Huray and Schutkowski, 2005; Moghaddam et al., 2016; Oelze et al., 2012; Varalli et al., 2021). Moreover, general rich graves in Greece showed a typical (although not rigid) trend of elevated $\delta^{15}N$ values, indicating high meat consumption (Panagiotopoulou et al., 2016). Yet, these high status indications are not always reflected in rich grave goods, but can just as well be linked with distinct grave structures (Lightfoot et al., 2015; Varalli et al., 2021). Varalli et al. (2021) see this dietary differentiation develop from the end of the BA onwards.

Higher meat consumption in individuals of higher status seems to be a relatively universal trend which crosses time and space (Hatch and Geidel, 1985; Knipper et al., 2015). In Germany, this pattern of high protein intake not only persisted in IA, but also in medieval elites (Knipper et al., 2015). Even worldwide, high meat consumption has been observed in high status individuals of the native American Cahokia dating to 1050-1150 CE (Ambrose et al., 2003) and is assumed in the Maya from Tikal (Haviland, 1967). Different eating patterns have been noted to be in some cases the only subtle, observable indicator of difference in social status, such as in the prehispanic Malpaso Valley in Mexico (Turkon, 2004).

The Destelbergen [Sr] results indicate that elevated meat consumption likely occurred in IA individuals assumed of modestly higher status (buried centrally within the monuments). The seemingly higher variability in the LIA (Figure 5) might indicate even more elevated differentiation in meat consumption in this period, although the number of studied individuals is very limited to draw strong conclusions. Additionally, the centrally buried IA individuals differ from the other IA burials in terms of a generally higher weight of the deposited bone (bone weights published in De Laet et al., 1986) (Mann-Whitney U test for only the IA group, centrally buried versus not-centrally buried: $U = 398$, $p = 0.012$). This difference was not seen between individuals of different status dating to the LBA. Differences in taphonomy, grave depth, or in grave type (e.g. urn grave, block of bones, …) do not adequately explain the lack of this difference in the LBA. Bone weights in LBA central graves being not elevated as in the IA is possibly related to a lacking difference in treatment between lower and higher status LBA burials, although the LBA sample size is relatively small to draw strong conclusions. One interpretation for elevated bone weights in the EIA might be that the bone was more carefully collected from the pyre. Another possible explanation is that the cremated remains of multiple individuals, e.g. ancestors or kin, were added together in the same burial pit. This practice has been attested in a central grave in Oud-Turnhout Hueve Akkers (Capuzzo et al., 2023) and in Neerharen/Rekem, where three individuals were buried in a weapon grave, which is considered a higher status grave (De Mulder, 2017; Van Impe, 1979). The fact that several of the central graves in Destelbergen indeed consisted of multiple bone deposits, which were in Herstal often found to belong to different individuals (Sabaux et al., 2021), might give more weight to this idea as a working hypothesis. Expressing kinship and closeness to an influential, high status forebear might have been more attractive than to common individuals (Theunissen, 1999). More analyses in line with the methods applied to the site of Herstal (Sabaux et al., 2021) could be useful to confirm if indeed central burials or higher status graves more often consist of multiple burials, since higher burial weights alone are not sufficient as evidence.

Multiple lines of evidence of different treatment are more convincing expressions of how pervasive status differences were than just one (Ames, 2008). In this case, sometimes subtle evidence of different treatment ([Sr], bone weight, monumental structure) makes it clear that there was stratification in this IA population to a higher degree than in the LBA, where we can only observe one difference (monumental structure). Additionally, the variability in [Sr] increased in the IA, suggesting more dietary variability and thus differentiation among the population. Indeed, population increases have been related to greater dietary differentiation between higher and lower status before (Hatch and Geidel, 1985). Rank differences in the LBA of course could have been expressed in ways not (yet) archaeologically visible (Ames, 2008). The fact that status differences in settlement sites in the area have not been identified, grave goods very rarely show differences, and the monumentality of the structures is not of the largest registered, makes the nature and extent of status differences and inequality in this community likely limited. It has to be acknowledged that there is also a relative amount of variability in [Sr] in the simple pits that are not recognised as of higher status (Figure 6 and SI Figure S4) and a minority of individuals also fit the pattern seen in high status individuals. In EIA Halos (Greece), the pattern of high meat consumption in rich graves was also found to be non-rigid (Panagiotopoulou et al., 2016). It is possible that some of the non-central graves contained individuals who also consumed a preferential diet but are today not archaeologically recognisable as of higher status (Lightfoot et al., 2015), due to e.g. no preference for or non-survival of specific burial markers. The significance of the findings lies in the fact that the central burials in the monuments primarily show a divergent pattern from most of the group, to a degree that the difference is statistically significant. Even within a society with limited inequality, there is still different treatment of individuals of higher status, not just (albeit rather limited) in death, but also in life.

Although many aspects of the LBA and EIA burial ritual (and settlement pattern) seem to suggest continuity and social equality, this study shows that there were also subtle things changing between both periods. This seems to happen in the context of the collapse of the Central, Western and Northern European bronze exchange networks and wide adoption of iron working (Roymans, 1991), although some social changes in Destelbergen likely already started in the ninth century BCE with the gradual abandonment of the eastern part of the cemetery and expansion to a new adjacent plot of funerary land. Changing technology and exchange networks did likely not uproot the entire society at once but certainly had impact on daily life and gradually affected social structures. Needham (2007) for instance, suspects that goods like salt and agricultural produce, and labour might have replaced the importance of bronze as an exchange product, while storage, redistribution, and feasting gained significance in social structures. A rise in social differentiation in the EIA as seen in Central-Europe, might be happening in current Belgium too, e.g. clearly observable at Court-Saint-Etienne (Mariën, 1958). Population increases can potentially be linked to greater disparity between higher and lower status diets (Hatch and Geidel, 1985). However, the degree to which segregation developed in the area of Destelbergen seems to have been mild and on a rather local level before the end of the EIA, when more regional chieftains appear somewhat more to the south, in the fertile Belgian loam areas. There, around 500 BCE, indeed, feasting and redistribution seem to have reached full maturity and leave clear archaeological evidence (e.g. Van Doorselaer et al., 1987). A rise in social differentiation was observed based on the appearance of rich graves in the lower Rhine basin too: "*… Ha[llstatt] C seems to be a formative phase in which elite groups start to assume other positions in the social system*" (Roymans, 1991). It is in this context that, although not much clear mobility was visible in the results, contacts and exchanges with nearby regions such as the Meuse or eastern Scheldt and potentially the upper Scheldt area occurred.

5. Conclusion

Although the same urnfield tradition lives on, several (cultural) changes seem to happen in the transition from LBA to EIA. This is not at all noticeable in the characteristics of the burial pits themselves, but is visible in the formal features of the monuments, and in well-hidden details, revealed amongst others by [Sr] analyses coupled with intense ^{14}C dating and spatial analysis. Social organisation was transforming. A new part of the cemetery was taken in use, while no new burials were added to the older LBA part of the cemetery, possibly indicating the adoption of general new attitudes. This same spatial trend in cemetery organisation is also visible in other large urnfields, but seems more diffuse in smaller urnfields in Belgium which rarely persist over both LBA and EIA. Another profound change seems to be a new relation towards higher status individuals, since the monuments are larger and shaped differently, the centrally buried individuals enjoyed a diet higher in animal protein and more cremated bone seems to be deposited in their graves. Around 400-350 BCE the cemetery is largely abandoned, apart from some exceptions probably still seeking connection and identification with these ancestors. The rare LIA additions to the urnfield often seem to follow the patterns of the EIA individuals of higher status. It could be wondered if in the LIA mainly higher status individuals were added to the then old cemetery.

This study shows that, when dealing with status differentiation in Europe or elsewhere, it is worthwhile to analyse [Sr]. Nevertheless, it is not advisable to interpret [Sr] based on this single proxy alone and preferably multiple lines of evidence, such as archaeological context information, can lead to an interpretation of low [Sr] as the result of higher meat consumption.

Author contributions

Sarah Dalle: conceptualization, data curation, formal analysis, software, visualization, writing – original draft, **Giacomo Capuzzo**: conceptualization, formal analysis, writing – review & editing, **Marta Hlad**: formal analysis, **Barbara Veselka**: writing – review & editing, **Rica Annaert**: writing – review & editing, **Mathieu Boudin**: formal analysis, funding acquisition, **Charlotte Sabaux**: writing – review & editing, **Kevin Salesse**: writing – review & editing, **Amanda Sengeløv**: writing – review & editing, **Elisavet Stamataki**: writing – review & editing, **Martine Vercauteren**: funding acquisition, **Eugène Warmenbol**: writing – review & editing, **Christophe Snoeck**: formal analysis, funding acquisition, methodology, supervision, writing – review & editing, **Guy De Mulder**: conceptualisation, funding acquisition, supervision, writing – review & editing

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