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RESEARCH ARTICLE

The role of status, diets, and mobility in understanding the impacts of urbanization in early medieval Bergen, Norway (St. Mary's Church): Insights from stable isotope analyses

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Abstract

This research examines the diets and mobility of higher status individuals buried in the St. Mary's (Mariakirken) churchyard (1140 and 1248 AD), located in Bergen, Norway. Stable isotope data are used to explore the role that diets (preferential access, choice of foods) may have played in mitigating the negative impacts of rapid urbanization. Dietary reconstruction involved analysis of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope ratios from paired bone and tooth samples from St. Mary's individuals ($N = 25$). Oxygen isotope ratios ($\delta^{18}O$) were derived from analyses of tooth enamel carbonate to comment on individuals' origins and mobility ($N = 26$). Individual $\delta^{13}C$ and $\delta^{15}N$ collagen values indicate that St. Mary's individuals consumed variable diets, with some relying on marine animal protein almost exclusively, while others primarily consumed C_3 plants or animals that consumed C_3 plants as the main source of their dietary protein. $\delta^{18}O$ ratios showed that some individuals originated outside of Bergen. Thus, the stable isotope evidence ($\delta^{13}C$ and $\delta^{15}N$) indicates that diets of St. Mary's individuals were more varied, and in some cases, relied primarily on imported trade goods such as grain/grain fed animals, and marine resources. This reinforces the view that St. Mary's represented an affluent segment of the growing Bergen population, and that its members were heavily involved in trade. Oxygen isotopes show that some individuals spent time living outside of Bergen during childhood. These data suggest that diets were more variable within the St. Mary's sample than at contemporary Norwegian sites, and that the process of urbanization did not impact the people of Bergen in a unified way.

KEYWORDS
diet, Mariakirken, medieval Norway, mobility, stable isotopes, urbanization

1 | INTRODUCTION

In the 12th and 13th centuries, Bergen, Norway, underwent a process of rapid urbanization, growing from a village with hundreds of inhabitants to the largest town in Scandinavia (>10,000 people) in under 200 years (Helle, 1982; Herteig, 1985). Early in the transition from small village site to bustling town, the church of St. Mary's (Mariakirken) served an emerging, relatively affluent segment of the population who were involved in trade, and ultimately in ecclesiastic life, and governance (Øye, 2009). While the processes of urbanization are complex and variable, studies of contemporary and past contexts have identified several of their negative impacts on human populations, particularly where change occurs at a rapid pace with significant increases in population density (Boldsen, 1996; Kjellström et al., 2005; Manchester, 1992; Roberts, 2007). The resulting poor sanitation, crowding, food insecurity, and pollution have been linked to the spread of infectious disease, nutritional deficiencies, heavy metals and toxins exposures, and limited social support networks of seasonal workers/travelers (Betsinger & DeWitte, 2021). Diets and mobility have a synergistic relationship with infectious disease loads of urbanizing populations (Scrimshaw, 2003; Wolowczuk et al., 2008), with impacts being experienced variably by individuals depending upon their socioeconomic status and/or degree of marginalization (Betsinger & DeWitte, 2020).

This research explores the possible differential impacts of urbanization in Bergen, focusing on the relatively affluent individuals buried at the St. Mary's cemetery between 1140 and 1248 AD. We examine whether the previously hypothesized negative impacts of urbanization during the emergence of Bergen as a town (Helle, 1982) were indeed felt by the upper class, and what role diets (preferential access, choice of foods) may have played in mitigating them. Stable isotope analyses (carbon and nitrogen) of paired bones and teeth from St. Mary's individuals were used to reconstruct not only what people ate, but the diversity of dietary choices among this relatively privileged portion of the growing population. In addition, oxygen isotope analyses of tooth enamel were used to explore the origins and mobility of St. Mary's individuals to assess whether higher status individuals were indeed representatives of the permanent, local population (Helle, 2006), or perhaps included community members from further afield.

1.1 | Bergen and the Bryggen wharf area: Emergence of a town

Although the definition and processes of urbanization vary across contexts (Betsinger & DeWitte, 2021), the medieval town of Bergen displayed many of the classic characteristics of a growing urban center, including permanent settlement, increased population density, centralization of administrative and religious institutions, occupational diversity, and mobility of people and goods within Norway and throughout the North Atlantic (Hansen, 2005). For Bergen, the earliest settlement sites were located in the "Bryggen" (dock/wharf) area of Bergen, Norway by the late 8th/early 9th centuries (Hansen, 2005), with the town itself taking root in the 11th century and growing quickly to become the largest town of medieval Scandinavia by 1300 AD (Herteig, 1985). Thus, the population of Bergen grew from several hundred to ∼13,000 people (Øye, 2009) in about 200 years. As a result of this growing population, the Bryggen area within Bergen witnessed increased population density within a fairly limited geographical area, and growth of a mixed population of permanently-based locals, immigrants, and a large proportion of seasonal workers and traders (Helle, 2006; Lorvik, 2009). Bergen became a center for the royal court, administration, religious institutions, and commerce (Hansen, 2005), with the main impetus for this growth coming from the town's strategic trade location.

Its central location for seagoing transport between Lofoten and Vesterålen on the northern coast of Norway, continental northern European harbors, and communities throughout the North Atlantic (Iceland, Greenland, the Faroe Islands, Shetland, the Orkneys, and the British Isles), meant that, at the heart of the emergence of Bergen as a town, was the significant role of trade and mobility moving both goods and people in and out of the region. The Bryggen wharf area was the assembly point for products from fishing, hunting, and animal husbandry along the coast of Norway, which were in turn exchanged for foreign grain, flour, and malt (Herteig, 1985). By the 11th and 12th centuries, long-distance trade within Norway, and internationally, expanded as growing towns throughout the North Atlantic and Northern Europe demanded more preserved food that could be eaten in the late winter and spring. Large quantities of cod, known as stockfish, contributed heavily to Norwegian exports as early as the 1100s (Sawyer & Sawyer, 1993). This trade brought a diverse group of travelers to the permanent local community in Bergen, as documented by Danish and Norwegian crusaders setting out from Bergen in 1191 AD: "A very great number of people live in the town, which is rich, and abounding in wares. There is dried fish (known as *skrei*) beyond telling. Ships and men arrive from every land; there are Icelanders, Greenlanders, Englishmen, Germans, Danes, Swedes, Gotlanders, and other nations too numerous to mention. Every nation can be there if one only takes the trouble to look. There are also quantities of wine, honey, wheat, fine cloths, silver, and other commodities and a busy trade in all of them" (Helle, 1972, p. 12).

From its inception, the rapid growth in population size and density of Bergen, and the Bryggen area within it, was driven by the mobility of traders and travelers, some of whom would likely have decided to stay and become a part of the local community of landowners, tradespeople, specialist craft producers, and laborers. While many visitors would have been only seasonally-based in Bergen (Helle, 1982) or would have arrived as young people and left for home after some time in the town (Lorvik, 2009), the question of how newcomers were integrated into the higher status portion of the local community is not well-understood.

1.2 | Excavations and osteological analyses of the St. Mary's (Mariakirken) collection

In 1955 a large fire destroyed the oldest (11th and 12th c.) portion of the double-row tenement buildings that characterize the "Bryggen" (dock/wharf) area of Bergen. The fire resulted in the loss of structures that had, up to that point, survived from the earliest days of the town (Herteig, 1959). Prior to being painstakingly rebuilt, a 13-year archeological excavation of the site (1955–1968) provided an opportunity to undertake the first, and only, large scale urban archeological assessment of the earliest years of the town's emergence. The area affected by the fire, and subject to excavation, included a portion of the St. Mary's (Mariakirken) churchyard, which is located on a moraine plateau just north of the Bryggen tenements (Øye, 2009). Built in the 1140s, St. Mary's was one of six main churches in town by the 12th century. Choice of cemetery was determined by social status, group membership, and geographical origin (Lorvik, 2009). Given the size and location of St. Mary's, directly behind the Bryggen wharf area and in the heart of medieval Bergen, it likely served those permanent community members who were involved with trade, administration and religious activities, and overall high-status activities (Helle, 1982; Lorvik, 2009). St. Mary's Guildhall, built on the church grounds after the fire of 1248, was one of the most privileged guilds in Bergen, further connecting St. Mary's churchyard with members of the town's upper social stratum (Helle, 1982). With their likely involvement in the development of trade in Bergen, and their higher status, members of the St. Mary's cemetery would have shared greater access to goods relative to lower status community members. As such, variation in consumption of foodstuffs for this higher status sample may reflect matters of preference in addition to access.

Previous work by Lorvik (2009) identified 76 individuals from the southwest corner of the churchyard (Figure 1), that were deemed suitable (relatively complete, not commingled) for in-depth osteobiographical analyses (following methods outlined in Buikstra & Ubelaker, 1994, and Brickley & McKinley, 2004). Lorvik investigated the impacts of urbanization on the demographic profile, activity and health of this portion of the St. Mary's population. Despite assumptions regarding the greater involvement of males in trade, administration, and high-status positions at Bryggen, Lorvik found that 61% of the 76 individuals could be identified as female. The age distributions for males and females were similar to one another, however, the most common age-at-death (40–59, 12% living to over 60 years of age) was higher than for other comparable medieval Scandinavian towns. Sub-adults (up to age 19) make up only 20% of the sample, and there were no children under the age of 7 identified. These findings may reflect practices determining the spatial organization of the cemetery, although the provincial law of western Norway (Gulathing), which came into effect in the 12th century, did not require spatial organization by sex or social status, as was the case in eastern Norway. Small children were not absent from Bryggen during the 12th and 13th centuries, given the recovery of many children's shoes and toys from the archeological record (Mygland, 2007), but simply buried elsewhere in the cemetery. Given the rapid increase in population density centered on the Bryggen area, and the expected impacts urbanization would have had on the health of those living there, Lorvik evaluated the presence of pathology among the 76 individuals' remains. Sub-adults showed little evidence of metabolic or infectious disease, but some did bear the signs of cribra orbitalia, enamel defects, and periosteal new bone formation, although the prevalence is low when compared to similar sites in Scandinavia (Lorvik, 2009). For adults, however, the prevalence of cribra orbitalia was higher than expected, with no sex differences evident. They also had relatively few caries, suggesting a diet low in the sugars and carbohydrates that are cariogenic, and again, there were no differences in dental disease by sex. The most common form of pathology among adults was degenerative joint disease, particularly of the vertebrae, for both males and females. Osteoarthritis of the hands and feet was not common in this sample, while spondylolysis of the vertebrae was, suggesting that the prevalence of

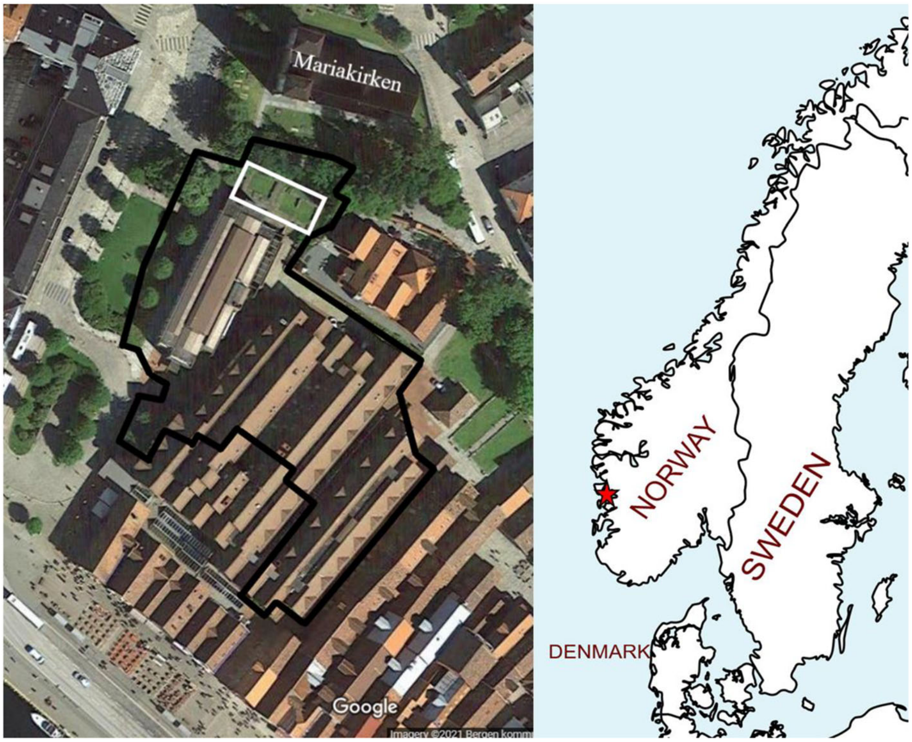

FIGURE 1 Location of Bergen on the western coast of Norway (right, indicated by star) and map of Bryggen excavation site (left, black outline), location of human remains (white outline), and of St. Mary's (Mariakirken) church. [Colour figure can be viewed at wileyonlinelibrary.com]

joint disease for these individuals was less a matter of activity-related stress and more a consequence of advanced age (Lorvik, 2009). Ultimately, the results of Lorvik's work suggest that the rapid urbanization of Bergen may not have affected more affluent members of the community as negatively as might be expected for the population of locals and visitors overall.

2 | STABLE ISOTOPIC RECONSTRUCTIONS OF DIETS, ORIGINS, AND MOBILITY

2.1 | Reconstructing diets

The stable isotope compositions of human bones and teeth (among other tissues) can be used to reconstruct broad categories of foods consumed during the formation of those tissues. The isotope ratios for both carbon (^{13}C and ^{12}C) and nitrogen (^{15}N and ^{14}N), measured from collagen in bones and dentine are reported, relative to a known standard, in parts per mil (‰) with the delta values δ^{13}C and δ^{15}N. Carbon isotope ratios vary in relation to the types of plants in the food web and their distinct photosynthetic pathways (O'Leary, 1981; Smith & Epstein, 1971), with C$_4$ plants producing δ^{13}C values between −9‰ and −14‰, and C$_3$ plants generating values between −20‰ and −35‰ (Ambrose & Norr, 1993; DeNiro & Epstein, 1978). A diet-tissue offset occurs between plants and consumer of approximately 5.4‰ (Jim et al., 2004), with a tissue-to-tissue spacing of 0‰ to 2‰ existing between herbivores and carnivores (Bocherens & Drucker, 2003). Based upon stable isotopic studies of human and faunal remains from archeological sites in the North Atlantic (Barrett et al., 2008; Naumann, Price & Richards 2014; van der Sluis et al., 2016), individuals with a 100% terrestrial diet approach a δ^{13}C value of −24‰, while someone with a 100% marine diet would approach −12‰ for δ^{13}C (Naumann et al., 2019).

Nitrogen isotope ratios reflect the trophic level of the consumer, or their position on the food chain (Minagawa & Wada, 1984; Schoeninger & DeNiro, 1984). δ^{15}N values of bone collagen serve to discriminate between animal and plant sources of protein, as well as between marine and terrestrial protein sources (Chisholm et al., 1982; Tauber, 1981). Omnivores and carnivores are enriched in nitrogen-15 as there is a tissue-spacing of ∼3‰ between diet and tissue when moving up by trophic level (Schoeninger & DeNiro, 1984). Additionally, terrestrial environments tend to have three trophic levels (primary producers, herbivores, and carnivores). Human terrestrial consumption therefore typically comes from the 1st and 2nd trophic levels. This is not true for marine and aquatic environments where we typically see at least 5 trophic levels. The vast majority of marine animals that would be consumed by humans are from the 3rd, 4th, and 5th trophic levels. This means that δ^{15}N values from human remains are useful for helping to discriminate between terrestrial and marine/aquatic dietary foods. Finally, when examining δ^{15}N data, it is important to consider the possible variable impacts of illness, pregnancy, aridity, and use of fertilizers when drawing conclusions about diets (Bogaard et al., 2007; Fuller et al., 2005).

2.2 | Reconstructing origins and mobility

Stable oxygen isotope ratios (^{18}O:^{16}O; or δ^{18}O) in the structural carbonate of bone and dental enamel reflect the isotopic composition of imbibed water, which varies from region to region (Longinelli, 1984). δ^{18}O ratios are determined by the influences of altitude, humidity, temperature, and distance from the sea (Bowen & Wilkinson, 2002; Lightfoot & O'Connell, 2016) such that, when water is consumed by an individual, any tissues forming at that time will bear the oxygen isotope values characteristic of that region. An individual's geographic origins and/or movements in life can be reconstructed with comparison of δ^{18}O ratios in tissues from early life to those from later in life (Dupras & Schwarcz, 2001, Prowse et al., 2007; White et al., 1998). This works only when δ^{18}O ratios from the early- and late-developing tissues are sufficiently temporally distinct from one another, and indicative of isotopically distinct regions. Mobility. Price et al. point out that, while modern oxygen isotope ratios vary considerably at northern latitudes (2015:126), their evaluation of published mean δ^{18}O values from archeological human remains from the North Atlantic (Denmark [−4.3‰], Norway [−4.4‰], Faroe Islands [−3.4‰], Iceland [−4.7‰], Greenland [−7.7‰], Dublin [−7.2‰]) demonstrate "surprisingly little variation … with the exception of Greenland and Dublin having distinctly higher values" than the others (2015:130). They point out that variation within populations is greater within these samples than it is between regions and caution against using modern rainfall measures to interpret the δ^{18}O ratios of past North Atlantic populations. Thus, δ^{18}O ratios are best used to identify possible non-local individuals rather locals.

3 | ISOTOPIC EVIDENCE FOR DIET AND MOBILITY IN NORWAY

Human remains from several Norwegian archeological sites, spanning the Merovingian to the Post-Reformation periods have provided stable isotope data regarding the diets and mobility of their inhabitants. Figure 2 provides a map locating all Norwegian archeological sites with published isotopic data provided in this text. Table 1 provides a summary of stable carbon, nitrogen, and oxygen isotope ratios from human bones and teeth retrieved from the Norwegian archeological sites discussed.

3.1 | Dietary evidence from Norwegian archeological sites

The first examination of Norwegian paleodiets (Johansen et al., 1986) using carbon isotopes found both regional and temporal variation between samples. For example, inland values from a medieval context (Heidal, Oppland) ranged between −21.1‰ and −19.9‰ for δ^{13}C, suggesting a diet of primarily terrestrial foods, while early medieval values from the island of Sanda (off the coast of northern Norway) fell between −19.0‰ and −15.7‰, indicating a diet of mixed seafood

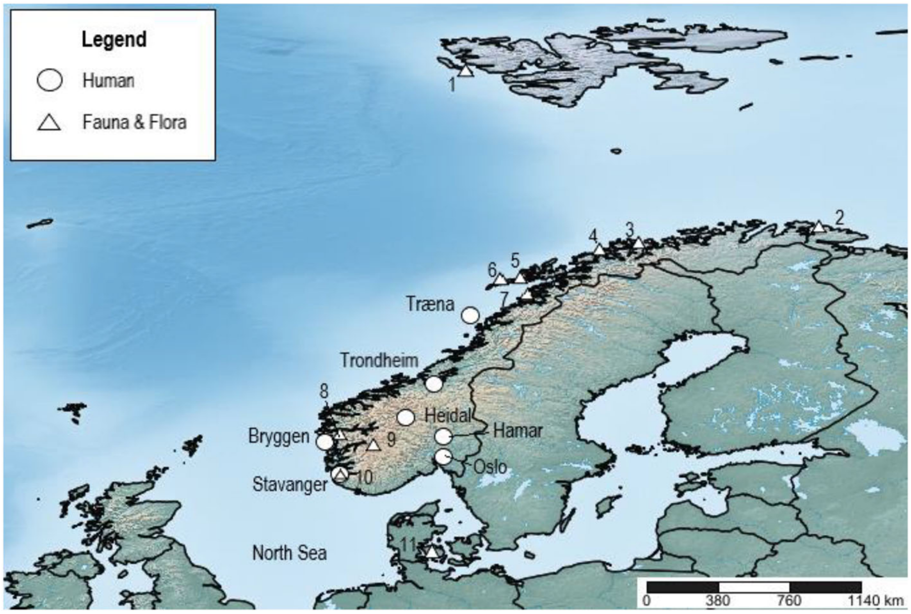

FIGURE 2 Locations of Norwegian archeological sites mentioned in the text. 1. Svalbard, 2. Skongsvika & Kongshaven, 3. Helgøygården, 4. Hillesøy, 5. Storvågan, 6. Flakstad, 7. Rønvik, 8. Skipshelleren, 9. Hardangervidda, 10. Stavanger, 11. Sarup, Skaghorn & Damsbo. [Colour figure can be viewed at wileyonlinelibrary.com]

and imported cereals. Greater variation was found among individual isotopic values from Sanda, with the authors suggesting that this could have been the result of inequalities affecting the distribution of trade goods coming into the community (Johansen et al., 1986).

Naumann, Price and Richards (2014) examined the stable carbon isotope signatures of 22 Merovingian, 9 Viking Age, and 2 Late Iron Age individuals from burials scattered along the northern coast of Norway, identifying a range of values between −20.5‰ and −14.4‰, with a mean of 18.2‰. δ^{15}N values from these same samples ranged from 11.0‰ to 18.1‰, with a mean of 14.2‰, indicating a reliance on freshwater fish and/or marine predators, particularly during the Viking Age and at locations further north. However, no distinct dietary patterns emerged with the δ^{13}C or δ^{15}N, there was no difference between values for males and females, and, although diets did shift for many individuals from child- to adulthood, the direction and degree of that shift was variable.

In 2015, Price and Naumann (2015) published stable isotope data (C, Sr, O) for several Norwegian locations. Human enamel samples from Hamar produced a δ^{13}C mean of −13.5‰ (range −16.9‰ to −11.3‰), while Trondheim individuals provided a δ^{13}C mean of −15.5‰ (range −16.1‰ to 14.5‰), and a Bryggen (Bergen) mean of −14.7‰ (range of −16.9‰ to −11.3‰). No δ^{15}N ratios were published for the three sites. Six of the Bryggen individuals sampled by Price et al. (2015) have also been analyzed for this present study, albeit utilizing different tooth types with different periods of development. The overlap in analysis of these six individuals will serve to improve the ability to explore any shifts in diet or location of these people.

van der Sluis et al. (2016) reconstructed the diets of 18 individuals living in the Stavanger area of Norway from the Viking Age to the Post-Reformation period. Mean δ^{13}C ratios from bone collagen were −20.7‰ (Viking Age), −18.7‰ (Early Medieval), and −19.4‰ (Post-Reformation), while δ^{15}N ratios were 10.8‰ (Viking Age), 13.7‰ (Early Medieval), and 12.9‰ (Post-Reformation). While sample sizes were small (e.g., $n = 2$ for Viking Age; $n = 7$ for Early Medieval), van der Sluis and colleagues indicate a shift from a terrestrial-based diet during the Viking Age to one more focused on consumption of marine products as indicated by an elevation of both δ^{13}C and δ^{15}N ratios. Following Barrett et al., 2011, the authors suggest that this shift may have resulted from "a combination of Christian dietary practices and the demand for food in expanding urban centers" (van der Sluis et al., 2016: p. 130).

Located at the end of a long fjord on semi-inland terrain, Oslo also grew to be a major Norwegian town beginning in the 11th and 12th centuries. Analyses of tooth and bone collagen from 20 individuals who lived during this time found a mean δ^{13}C value of −19.9‰, with a range of −21.82‰ to −17.67‰, and a δ^{15}N mean of 12.82‰ with a range from 10.33‰ to 15.57‰ (Naumann et al., 2019). These values revealed mixed diets of both terrestrial and marine foods, with considerable variation occurring from individual to individual, and minimal dietary change across individuals' lifespans, unlike what has been documented previously for the Viking Age (Naumann, Krzewińska et al., 2014).

3.2 | Evidence of origins and mobility from Norwegian archeological sites

Price and Naumann (2015) provide enamel δ^{18}O ratios for three archeological populations in Norway, including Hamar (mean = −6.3‰; range = −7.7 to −4.9‰), Trondheim (mean = −6.0‰; range = −7.6 to −4.5‰), and Bergen (mean = −4.3‰; range = −5.3 to −3.2‰). The authors caution that each of these samples includes both locals and non-locals Price and Naumann (2015: p. 91), so the data are of limited value when attempting to characterize local δ^{18}O signatures. When considering the oxygen ratios for their Bergen

TABLE 1 $\delta^{13}C$, $\delta^{15}N$, and $\delta^{18}O$ isotope values for human remains from Norwegian archeological sites.

Site	Date	*n*	$\delta^{13}C$ (‰) range	$\delta^{13}C$ (‰) mean	$\delta^{15}N$ (‰) range	$\delta^{15}N$ (‰) mean	$\delta^{18}O$ (‰) range	$\delta^{18}O$ (‰) mean	Reference
Heidal	Medieval Period	10	−21.1 to −19.9	N/A	N/A	N/A	N/A	N/A	Johansen et al. (1986)
Traena	Early Medieval Period	11	−19.0 to −15.7	N/A	N/A	N/A	N/A	N/A	Johansen et al. (1986)
Northern coast of Norway	Merovingian, Viking Age, Late Iron Age	33	−20.5 to −14.4	−18.2	11.0 to 18.1	14.2	N/A	N/A	Naumann, Price and Richards (2014)
Hamar	Medieval Period	17	−16.9 to −11.3	−13.5	N/A	N/A	−7.7 to −4.9	−6.3	Price and Naumann (2015)
Trondheim	Medieval Period	9	−16.1 to −14.5	−15.5	N/A	N/A	−7.6 to −4.5	−6.0	Price and Naumann (2015)
Bryggen	Medieval Period	15	−16.9 to −11.3	−14.7	N/A	N/A	−5.3 to −3.2	−4.3	Price and Naumann (2015)
Stavanger	Viking Age	18	N/A	−20.7	N/A	10.8	N/A	N/A	van der Sluis et al. (2016)
	Early Medieval Period		N/A	−18.7	N/A	13.7	N/A	N/A	
	Post-Reformation Period		N/A	−19.4	N/A	12.9	N/A	N/A	
Oslo	11th and 12th centuries (Medieval Period)	20	−21.82 to −17.67	−19.9	10.33 to 15.57	12.82	N/A	N/A	Naumann et al. (2019)

sample, which come from three different medieval sites (Nykirken, Lille Ovregt, and Bryggen), individuals' values are not provided by Price and Naumann; however, the authors state that “no particular pattern or unusual value was noted” Price and Naumann (2015: p. 93).

4 | MATERIALS AND METHODS

Bone and permanent tooth samples from 26 of the available 76 St. Mary's individuals, dated to between 1170 and 1248 AD, were prepared such that analyses of dental histology, trace elements, stable isotopes, and diagenesis were conducted. Only 26 individuals from the original sample could contribute both a bone sample and at least one intact tooth (no significant wear, pathology, and discolouration) for isotopic analyses. This paper will address only the stable carbon, nitrogen, and oxygen isotope, as well as diagenetic, data derived from this work. Bone samples were taken from rib and cranial fragments that showed no signs of pathology. One permanent tooth per individual (canine, premolar, or molar) was chosen for analysis. Details regarding osteological analyses of the remains are available in Lorvik (2009).

4.1 | Bone samples

For each of the individuals included in this study, powdered bone samples (30–35 mg) were prepared for extraction of bone collagen using a modified Longin (1971) method, which is outlined in more detail by Szpak et al. (2014). Isotopic compositions were determined using a Thermo Scientific Delta V Plus continuous flow, isotope-ratio mass spectrometer coupled to a Costech Elemental Analyzer at the Laboratory for Stable Isotope Science (LSIS) at Western University, London, Ontario, Canada. Blanks, as well as internal and international standards, were checked throughout the analysis. The resulting $\delta^{13}C$ and $\delta^{15}N$ stable isotope values were used to explore aspects of individuals' diets during their last few years of life.

4.2 | Tooth samples

Each tooth was prepared to accommodate multiple distinct analytical goals. Teeth were embedded in epoxy resin and cut longitudinally to produce two thick and one thin section, providing samples suitable for multiple analytical applications (see Dolphin et al., 2016, for details). One section (∼250 μm thick) per tooth was sampled using a Leica GZ6 Merchantek micromill, allowing for the precision removal of powdered enamel samples (∼2 mg).

Isotopic analyses of the carbonate component of the tooth enamel were conducted using a VG Optima dual-inlet isotope ratio mass spectrometer coupled to a Micromass MultiPrep autosampler, with calibrations of $\delta^{13}C$ to VPDB and of $\delta^{18}O$ to VSMOW, also at the LSIS lab. Duplicate samples were milled from four teeth to test reproducibility and found to be ±0.7‰ for carbon and ±0.3‰ for oxygen. Accuracy was determined using an internal calcite standard (WS-1). For carbon, the average difference from expected values was ±0.1‰ and ±0.2‰ for oxygen. For δ^{18}O, the average observed value for WS-1 was þ26.4 ± 0.2‰ (1σ) and þ0.8 ± 0.1‰ (1σ) for carbon. These observed values closely correspond with the expected values of þ26.2‰ and þ0.8‰ for oxygen and carbon, respectively.

4.3 | Diagenesis

For each tooth, an additional powdered sample (∼2 mg) was milled, from another thick longitudinal section, in order to assess the degree of diagenetic alteration using Fourier transform infrared spectroscopy (FTIR) analysis. FTIR analysis and crystallinity indices (CI) were determined using a Bruker Vector 22 Spectrometer and in accordance with standards protocols developed at the LSIS lab (see Webb et al., 2014).

5 | RESULTS

5.1 | Carbon and nitrogen

Bone collagen for all samples was well preserved, with C:N ratios between 3.25 and 3.37 (recommended range 2.9–3.6 as per DeNiro, 1985). The δ^{13}C mean for all individuals was −18.4‰ with a range of −16.2 to −21.4 and a standard deviation of 1.3‰. The δ^{15}N mean for all individuals was 13.5‰ with a range of 10.1 to 16.6 and a standard deviation of 1.9‰. Tooth enamel carbonate δ^{13}C values produced a mean for all individuals of −14.7‰ with a range of −16.7 to −12.4 and a standard deviation of 1.0‰.

Data for the human remains from St. Mary's are provided in Table 2, while comparative faunal data are available in Table 3.

For those buried at St. Mary's it was found that δ^{13}C and δ^{15}N bone collagen values were highly positively correlated, $r(23) = 0.95$, $p = 2.7E{-}13$ (Figure 3). The high correlation between δ^{13}C and δ^{15}N bone collagen values for the Bergen individuals indicates that, although there is high variability in individual diet, there seems to be

TABLE 2 Sample characteristics and results for δ^{13}C, δ^{15}N, and δ^{18}O of 26 human individuals from St. Mary's (Mariakirken) churchyard in the Bryggen wharf area of Bergen, Norway.

Sample	Tooth	Bone	Sex	Age	Date	$\delta^{13}C_{carb‰}$	$\delta^{18}O_{carb‰}$	$\delta^{13}C_{co‰}$	$\delta^{15}N_{co‰}$	C/N
BRM 75002	M3	Rib	F	40–59	1170–98	−15.7	−6.4	−20.4	10.1	3.32
BRM 75005	PM	Rib	M?	Adu	1170–98	−13.9	−6.0	-	-	-
BRM 75009	C	Cranial	F	20–39	1179–98	−16.7	−4.6	−19.9*	11.7	3.37
BRM 75013	C	Rib	-	13–19	b.1198	−15.5	−5.4	−17.4	14.5	3.33
BRM 75014	C	Rib	-	13–19	1170–98	−12.9	−5.5	−18.8	13.3	3.35
BRM 75016	M3	Rib	F	40–59	a.1198	−15.3	−5.6	−19.1	12.1	3.33
BRM 75019	M2	Rib	M	20–39	b.1170	−12.8	−5.6	−17.1	15.4	3.30
BRM 75021	C	Rib	?	20–39	1170–98	−13.9	−5.3	−17.9	15.4	3.30
BRM 75023	C	Rib	-	Inf II	a.1198	−14.2	−4.0	−16.2	16.2	3.35
BRM 75030	M3	Rib	F?	40–59	b.1248	−15.7	−5.5	−20.5	10.2	3.25
BRM 75032	M1	Rib	-	Inf II	1170–98	−14.6	−5.7	−18.0	14.6	3.27
BRM 75038	M3	Rib	F	20–39	1170–98	−15.0	−6.1	−18.2	14.0	3.31
BRM 75039	M2	Rib	M	20–39	1170–98	−13.6	−5.2	−17.2*	14.6	3.32
BRM 75045	M3	Rib	F?	20–39	1170–98	−15.7	−6.2	−21.4	10.4	3.35
BRM 75049	PM	Rib	-	13–19	1170–98	−14.9	−5.3	−16.9	15.9	3.37
BRM 75050	PM	Rib	-	13–19	a.1198	−14.6	−5.6	−18.1	15.4	3.30
BRM 75058	M3	Rib	F	20–39	a.1198	−14.9	−5.5	−18.1	14.4	3.32
BRM 76322	PM	Cranial	M?	20–39	b.1248	−12.4	−7.1	−18.2	13.1	3.30
BRM 76323	M3	Rib	-	13–19	b.1248	−14.7	−5.6	−18.6	13.2	3.28
BRM 76325	M2	Cranial	F?	20–39	b.1248	−15.2	−5.6	−18.3	14.4	3.33
BRM 76335	M3	Rib	F	20–39	b.1170	−14.0	−7.1	−18.8	13.6	3.32
BRM 76337	C	Rib	M	20–39	1170–1248	−15.6	−5.3	−20.9*	10.5	3.29
BRM 76340	PM	Cranial	-	13–19	b.1248	−14.6	−5.0	−19.6	12.5	3.28
BRM 76346	M3	Rib	F?	40–59	b.1248	−14.9	−6.5	−19.4	12.7	3.27
BRM 76350	M1	Rib	-	13–19	b.1248	−15.7	−5.7	−16.9	16.6	3.31
BRM 76351	M3	Cranial	-	Mat	b. 1170	−14.8	−6.8	−17.9	13.8	3.32

TABLE 3 Local reference values for $\delta^{13}C$ and $\delta^{15}N$ from various fauna and flora species. "TEF" is the corrected trophic enrichment factor. Animal bone collagen was corrected by +1.0‰ and +4.0‰ for $\delta^{13}C$ and $\delta^{15}N$, respectively (Bocherens & Drucker, 2003). Whole edible plant was corrected by +5.4‰ and 4.0‰ for $\delta^{13}C$ and $\delta^{15}N$, respectively (Bocherens & Drucker, 2003; Jim et al., 2004). TEF was corrected for to make reference values comparable to consumer bone collagen values (humans). Numbers in parenthesis indicates analyses done multiple times on the same faunal sample.

Site/area	Time period	Species	n	$\delta^{13}C_{VPDB}$	$\delta^{13}C_{VPDB}$ standard deviation	$\delta^{15}N_{air}$	$\delta^{15}N_{air}$ standard deviation	*TEF corrected* $\delta^{13}C_{VPDB}$	*TEF corrected* $\delta^{15}N_{air}$	Reference
Flakstad, Arctic Norway	800–1030 AD	Bovine	1 (2)	−22.4	0.0	5.1	0.4	−21.4	9.1	Naumann, Krzewińska et al., 2014
Stavanger, SW Norway	Pre 1272 AD	Bovine	1	−22.2	-	2.7	-	−21.2	6.7	van der Sluis et al., 2016
Svalbard, Arctic Norway	Modern	Cod	12	−16.6	0.6	13.9	0.6	−15.6	17.9	Barrett et al., 2008
North, North Sea	1000–1100 AD; 1400–1500 AD	Cod	16	−13.1	0.5	14.3	0.5	−12.1	18.3	Harland, 2006; Kilroy, 2006
South/Central North Sea	900–1400 AD	Cod	14	−13.2	0.6	15.6	0.6	−12.2	19.6	Barrett, 2005; Jones, 1991; Locker, 1997; Pieters et al., 2005
Skonsvika, Arctic Norway	1240–1390 AD	Cod	4	−14.2	0.5	14.5	0.9	−13.2	18.5	Olsen et al., 2011
Kongshaven, Arctic Norway	1300–1400 AD	Cod	6	−15.5	0.9	13.9	0.5	−14.5	17.9	Olsen et al., 2011
Helgøygården, Arctic Norway	1300–1400 AD	Cod	9	−14.7	1.5	14.3	0.6	−13.7	18.3	Holm-Olsen, 1981
Storvågean, Arctic Norway	1100–1400 AD	Cod	6	−15.1	1.2	14.7	0.8	−14.1	18.7	Bertelsen et al., 1987
Flakstad, Arctic Norway	800–1030 AD	Horse	1 (2)	−22.5	0.4	4.9	0.1	−21.5	8.9	Naumann, Krzewińska et al., 2014
Stavanger, SW Norway	Pre 1272 AD	Ling	2	−12.9	0.4	14.8	0.6	−11.9	18.8	van der Sluis et al., 2016
Hillesøy, Norland	800–1030 AD	Pig	1	−22.1	-	3.8	-	−21.1	7.8	Naumann, Price & Richards et al., 2014
Skipshelleren, W. Norway	5500 BC to 200 AD	Pig	22	−21.9	0.7	3.9	1.0	−20.9	7.9	Rosvold et al., 2010
Skipshelleren, W. Norway	5500 BC to 200 AD	Red Deer	13	−21.6	0.5	3.8	0.5	−20.6	7.8	Rosvold et al., 2010
Hardangervidda, Norway	11th century	Reindeer	18	−19.0	1.0	2.4	0.6	−18.0	6.4	Beijersbergen et al., 2021
Hardangervidda, Norway	13th century	Reindeer	142	−18.1	1.0	2.6	0.4	−17.1	6.6	Beijersbergen et al., 2021
Stavanger, SW Norway	Pre 1272 AD	Seal	1(4)	−13.7	0.1	16.2	0.1	−12.7	20.2	van der Sluis et al., 2016
Rønvik, Bodø, Norway	800–1030 AD	Sheep	1	−22.2	-	3.6	-	−21.2	7.6	Naumann, Price & Richards et al., 2014
Flakstad, Arctic Norway	800–1030 AD	Sheep/goat	2	−21.9	0.4	3.7	0.1	−20.9	7.7	Naumann, Krzewińska et al., 2014
Sarup, Denmark	3400–2900 BC	Emmer wheat	13	−24.6	0.4	2.5	0.9	−19.2	6.5	Bogaard et al 2007
Skaghorn, Denmark	3400–2900 BC	Emmer wheat	1	−23.0	-	6.1	-	−17.6	10.1	Bogaard et al 2007
Damsbo, Denmark	2800–2400 BC	Emmer wheat	1	−24.2	-	5.1	-	−18.8	9.1	Bogaard et al 2007
Skaghorn, Denmark	3400–2900 BC	Naked barley	1	−25.9	-	4.1	-	−20.5	8.1	Bogaard et al 2007

Note: Medieval $\delta^{13}C$ and $\delta^{15}N$ isotope values from Norway.

only two isotopically distinct dietary protein sources. The humans at Bergen ate varying amounts of C_3 derived and marine protein. Given the δ^{13}C and δ^{15}N values from the baseline reference material (Figure 3), it is likely that the C_3 derived protein part of the Bergen diet was not from the plants themselves, but from animals that fed on those plants. If intense fertilization was being used at this time, then the δ^{13}C and δ^{15}N values of local or imported grains, such as naked barley, could reach values whereby they contributed toward the proteinous portion of the human diet of this population. Due to the protein poor nature of these plants when compared to consumer animals, this still seems unlikely. Regardless, the people at Bergen were not confined to eating from either C_3 derived protein sources or from marine protein sources, but each individual analyzed had varying amounts from those proteinous sources and some agency in the foods that they ate. Although it could be argued that the variation could be the result of differential access to goods, given the similar status of all individuals analyzed, it is more likely that there was agency and personal choice involved in the varying levels of C_3 and marine derived proteins.

Adult individuals for whom sex estimation was possible provided a male $\delta^{13}C_{collagen}$ mean of −18.4 ‰ (range = −20.9 to −17.1; standard deviation = 1.8), while the female $\delta^{13}C_{collagen}$ mean was similar at −19.4 ‰ (range = −21.36 to −18.11; standard deviation = 1.10) (Figure 4). Although the sample size for males is low ($n = 4$), and they are underrepresented in the sample overall (vs. 10 females), three of the four male individuals bore the highest carbon and nitrogen ratios of the entire sexed-adult sample. These data suggest that males in this sample consumed diets heavily reliant on marine resources, perhaps because of their involvement in the trade of such resources throughout the North Atlantic. However, due to the skewed age-at-death and sex distribution of individuals in the examined portion of the St. Mary's cemetery, any such interpretations are tentative.

A consideration of δ^{13}C and δ^{15}N in relation to age-at-death indicates that no distinct differences between age groups were apparent.

Bryggen bone collagen isotope data span the lowest and the highest δ^{13}C and δ^{15}N values identified for medieval Norwegians. The broad range of δ^{13}C and δ^{15}N isotope ratios for Bryggen, with standard deviations higher than those published for other medieval Norwegian communities (Table 1), indicates dietary profiles of the early inhabitants of this town were varied. Six individuals produced δ^{13}C values greater than −17.5‰ and δ^{15}N values greater than 14.0‰, indicating considerable reliance on the consumption of marine foods. Despite being buried in a circumscribed area of the St. Mary's churchyard, and within a time frame spanning no more than three

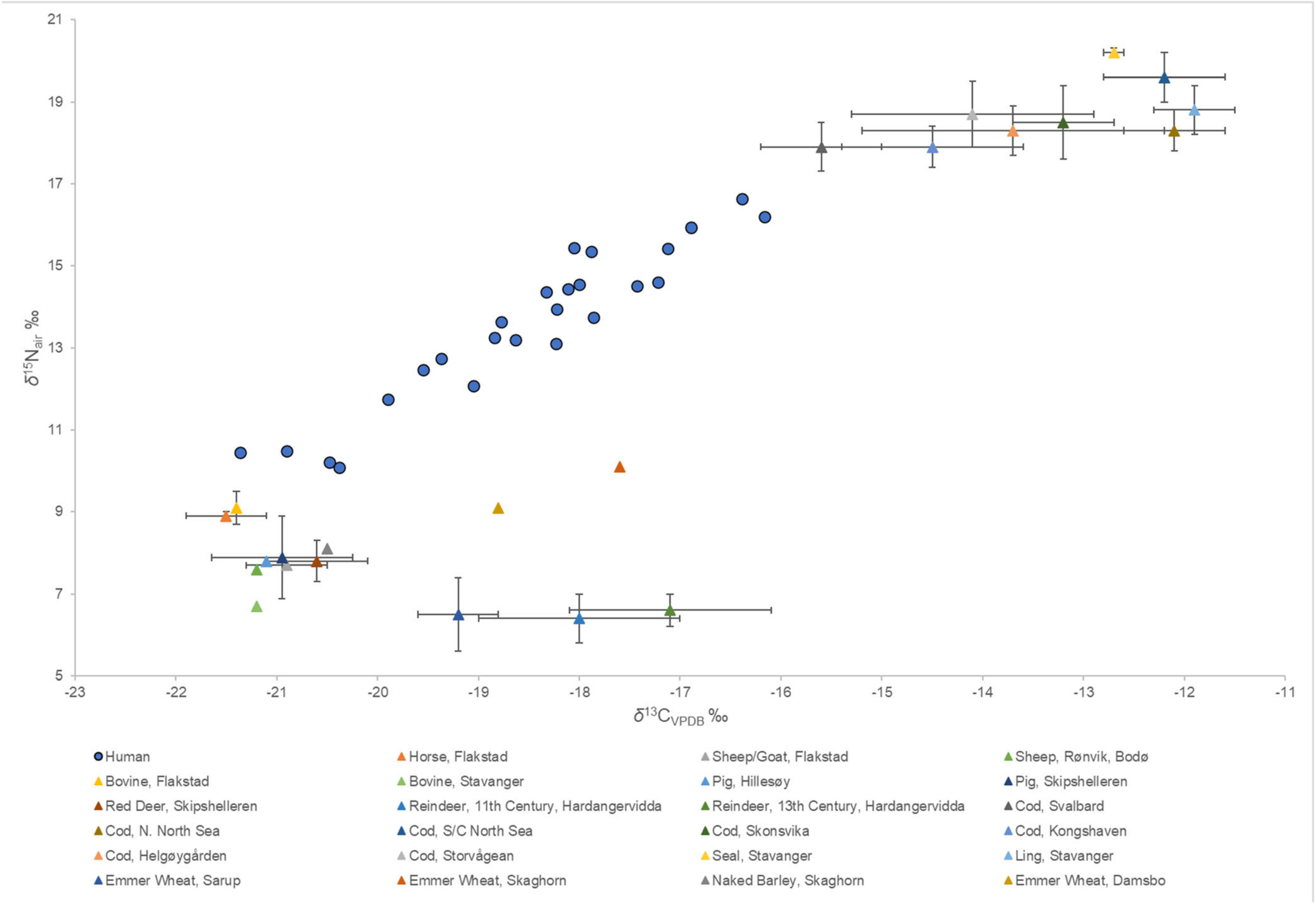

FIGURE 3 Plotted distribution of all 25 human δ^{13}C and δ^{15}N values with local baseline reference fauna and flora stable carbon and nitrogen isotope values. Bars represent one standard deviation. [Colour figure can be viewed at wileyonlinelibrary.com]

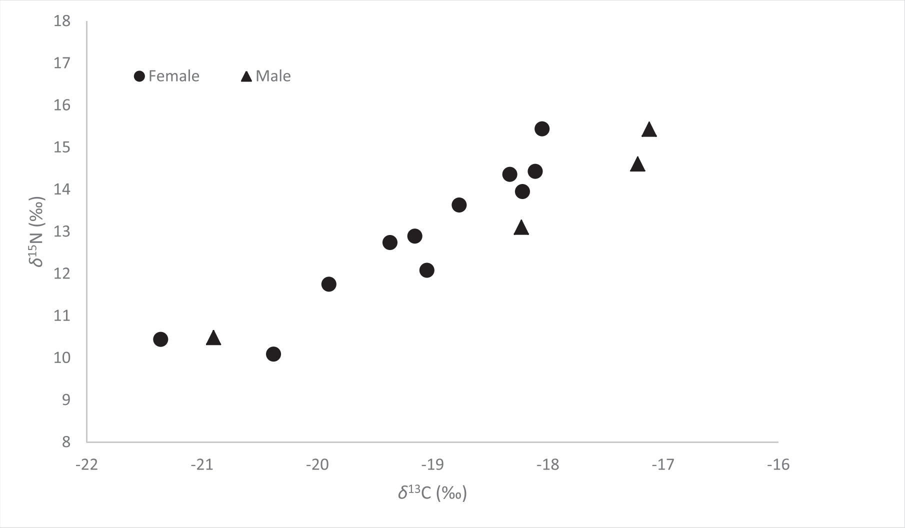

FIGURE 4 Dietary variation in δ^{13}C and δ^{15}N values from bone collagen samples of 15 adult female and male St. Mary's Church (Mariakirken) individuals.

TABLE 4 Comparison of δ^{13}C ratios from Price et al., 2015 and the present study.

	Price et al., 2015			Present study			
Individual	Tooth type	Formation[a] time	δ^{13}C	Tooth type	Formation time	δ^{13}C	δ^{13}C (‰) difference
75,009	M1	Birth to 3 years 1 month	−16.9	C	8 month to 7 years	−15.74	+1.16
75,013	M1	Birth to 3 years 1 month	−15.2	C	8 month to 7 years	−15.50	−0.30
75,019	P4	2 to 8 years	−11.3	M2	2 years 6 months to 8 years	−12.78	−1.48
75,032	P4	2 to 8 years	−14.4	M1	Birth to 3 years 1 month	−14.59	−0.19
75,038	P4	2 to 8 years	−15.3	M3	8 to 11 years	−14.97	+0.33
76,335	M1	Birth to 3 years 1 month	−14.4	M3	8 to 11 years	−13.97	+0.43

[a]Approximate tooth formation times derived Reid and Dean (2006) and Reid et al. (2008).

generations, the δ^{13}C and δ^{15}N isotope data clearly demonstrate that individuals had access to a variety of plants, terrestrial animals, and marine resources, and that the proportions of these dietary components varied considerably from person to person.

Tooth enamel carbonate from six of the individuals included in this present study was previously independently analyzed for δ^{13}C by Price et al. (2015). In all cases, both studies sampled different tooth types from the same person, providing δ^{13}C data from differing periods of subadult development. Sample details and δ^{13}C ratios for both studies are presented in Table 4. Only very small, and likely negligible, shifts in δ^{13}C values were identified (0.3‰ to 1.48‰) and there was no discernable pattern of increase or decrease with age of enamel formation, even in cases where the teeth provided data from distinct periods (e.g., M1 vs. M3).

5.2 | Oxygen in enamel carbonate

Oxygen isotope ratios were measured from the dental enamel of each Bryggen individual ($N = 26$). The mean δ^{18}O value was −5.7‰ ± 0.7, with a range of −7.12‰ to −4.04‰. A histogram of the oxygen ratios (Figure 5) indicates an approximately normal distribution, with most values falling between −5.0‰ and −6.5‰. Comparable oxygen isotope means from archeological sites within Norway are −6.3‰, −6.0‰, and −4.3‰ for Hamar, Trondheim, and Bryggen (three sites), respectively (Price et al., 2015: p. 91). Two individuals have higher values between −4.9‰ and −4.0 ‰, which align with published mean δ^{18}O values from several archeological sites in Sweden and Denmark (Price et al., 2015: p. 131), while the two lower δ^{18}O values (both −7.1‰) from Bryggen teeth analyzed here are more similar to published values for Dublin (−7.2‰) than they are for other locations in Norway, Denmark, the Faroe Islands, or Iceland (Price et al., 2015: p. 131).

There were no notable differences between females and males (−5.9‰ and −5.8‰, respectively), nor by age-at-death grouping (Inf II = −5.12; Juv = −5.39; Adu = −5.81; Mat = −5.81), with respect to mean δ^{18}O values.

It is possible to compare δ^{18}O values from tooth enamel carbonate analyses performed here with those published for the same six individuals in Price et al., 2015. Given that both studies sampled different tooth classes, thus capturing distinct periods of development for each individual, it is possible to examine whether enamel oxygen isotope ratios changed over time and, as a result, indicate some degree of mobility occurring during childhood. The δ^{18}O ratios for both studies are presented in Table 5. On average δ^{18}O values from both studies differed by 1.4‰ (std. dev = 0.7, range = 0.3‰ to

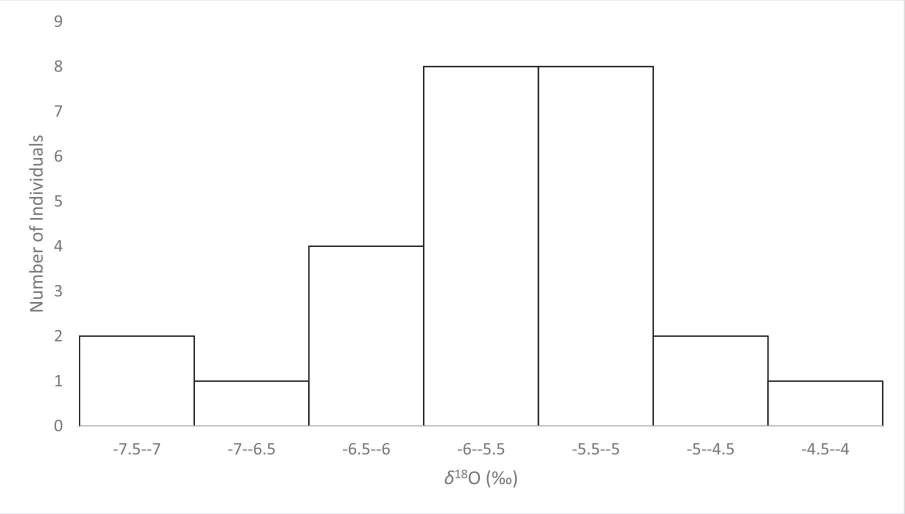

FIGURE 5 Histogram of enamel $\delta^{18}O$ (‰) ratios for 26 individuals from St. Mary's Church (Mariakirken).

TABLE 5 Comparison of $\delta^{18}O$ ratios from Price et al., 2015 and the present study.

	Price et al., 2015			Present study			
Individual	Tooth type	Formation[a] time	$\delta^{18}O$	Tooth type	Formation time	$\delta^{18}O$	$\delta^{18}O$ (‰) difference
75,009	M1	Birth to 3 years 1 month	−3.2	C	8 month to 7 years	−4.6	1.4
75,013	M1	Birth to 3 years 1 month	−3.6	C	8 month to 7 years	−5.4	1.8
75,019	P4	2 to 8 years	−5.3	M2	2 years 6 month to 8 years	−5.6	0.3
75,032	P4	2 to 8 years	−3.8	M1	Birth to 3 years 1 m	−5.7	1.9
75,038	P4	2 to 8 years	−5.1	M3	8 to 11 years	−6.1	1
76,335	M1	Birth to 3 years 1 month	−4.9	M3	8 to 11 years	−7.1	2.2

[a] Approximate tooth formation times derived from Reid and Dean (2006).

2.2‰). Teeth from 75,019 sampled concurrently-formed enamel, resulting in only a small difference between $\delta^{18}O$ ratios (0.3‰), while 75,032 indicated an increase of 1.9‰ with age. Four individuals demonstrated small decreases of 1‰–2‰ with age; however, the interpretation of these increases is clouded by the fact that some of the enamel from both teeth from each individual would have developed concurrently. Individual 76,335 transitioned from a $\delta^{18}O$ ratio of −4.9‰ to −7.1‰ between birth (M1) and approximately 11 years of age (M3). Based upon aggregate regional $\delta^{18}O$ values published by Price et al., 2015, it could be possible that 76,335 was born in Norway, Denmark, or Iceland, prior to spending their later childhood years in the Faroe Islands, before moving on to Bergen, where they ultimately were interred.

6 | DISCUSSION

Several bioarcheological works have explored the impacts of rapid urban growth on health, diets, and mobility, given what are commonly assumed to be significant differences in the disease load, subsistence, and composition of urban versus rural populations. As Betsinger and DeWitte remind us, however, "urbanisation produces a mix of effects that do not impact all individuals within the population uniformly" (2021:3). The St. Mary's individuals examined here were likely more affluent members of their rapidly growing town, given their location within a privileged burial ground and the results of osteological analyses (Lorvik, 2009) indicating the relatively long lifespan of many individuals, as well as few signs of infectious disease or activity-related trauma. As such, the current examination of diet and mobility among this group of early *Bergensa* may not be representative of all members of the Bryggen community between 1170 and 1248 AD. However, stable isotope analyses can allow for some comment on whether this particular group of people consumed distinct diets, and whether or not they were composed of individuals who traveled to Bergen and became integrated into the more privileged social class there.

When considering the diets of individuals from the St. Mary's cemetery (Bryggen/Bergen) in relation to those of other medieval Norwegians for whom both stable carbon and nitrogen isotopes ratios are available, it is clear that St. Mary's individuals were an especially diverse group. Mean $\delta^{13}C$ ratios from Bryggen/Bergen, Oslo (Naumann et al., 2019), and Stavanger (van der Sluis et al., 2016) are all similar, while $\delta^{15}N$ values for Bryggen/Bergen, Oslo, and Stavanger, vary only somewhat, with Stavanger bearing the highest average value, indicating a significant input of marine animals, and perhaps pigs enriched in nitrogen-15 (van der Sluis et al., 2016). However, examination of standard deviations for δ^{13}C and δ^{15}N at the three sites indicates that, despite being buried together within a small portion of the cemetery during a relatively short period of time (1170–1248 AD), the protein portions of the diets of St. Mary's individuals were highly variable. Several individuals consumed relatively low amounts of marine protein, with significant C_3 components, potentially reflecting their consumption of the chief import to Bergen—grain/or terrestrial animals—while others bore relatively high carbon and nitrogen isotope values indicative of a significant reliance on marine food products. Interestingly, $\delta^{13}C_{carbonate}$ ratios from the tooth enamel of these individuals, which provides insights on the isotopic composition of the whole diet during childhood (Ambrose & Norr, 1993), are not notably different from those documented for teeth from other medieval Norwegian towns such as Hamar and Trondheim (Price & Naumann, 2015), nor from contemporary sites located in Sweden and Denmark (Price, 2013; Price et al., 2011, 2012). The standard deviations in $\delta^{13}C_{carbonate}$ values are also similar between these sites, perhaps due to the common practice of heavy cereals consumption among children at this time in Scandinavia (Sawyer & Sawyer, 1993). When comparing $\delta^{13}C_{carbonate}$ results from the present study with those from Price et al., 2015 this small subsample indicates that, while children, those buried at St. Mary's consumed primarily terrestrial plant-based diets (as has similarly been found at other contemporary Scandinavian sites) and that these diets did not shift significantly until sometime after the formation of the third molars, or ~8–11 years of age.

Given the rapid population growth of the early medieval town of Bergen researchers have suggested that the town would have received both seasonal and permanent migrants in search of new opportunities (Lorvik, 2009). Historical documents demonstrate that visitors from across the North Atlantic, and from the rural inland of Norway, made their way to Bergen and other Scandinavian towns; however, Bergen was the dominant hub for trade within the region by the 13th century. δ^{18}O analyses of teeth from St. Mary's indicated a mean value (−5.7‰) that falls in line with those documented for other growing contemporary towns in Norway, such as Hamar and Trondheim (Price et al., 2015). When examining individual values, two people buried at St. Mary's may have traveled from Sweden or Denmark, and one may have come from Ireland, thus representing only a small proportion of the overall sample. This could suggest that the population of Bergen residents buried at the relatively affluent St. Mary's churchyard was composed more of locals than of migrants. However, several problems with this assessment need to be acknowledged. Oxygen isotope variation in the North Atlantic region only indicates the possibility that an individual originated in a particular region, and this possibility is complicated by several factors. Oxygen isotope ratios vary only across very broad regions within the North Atlantic, such that the resolution for pinpointing origins is low compared to other isotopes like strontium (Price et al., 2015). For example, when considering the standard deviations of the St. Mary's mean δ^{18}O ratio (−5.7‰ ± 0.7) in relation to the standard deviations published for several other North Atlantic locations (see Price et al., 2015), there is a considerable overlap of values, thus making fine interpretations regarding anything other than the most extreme values within a population difficult.

Another interpretive complication comes from the fact that means and standard deviations published for δ^{18}O from archeological sites in the North Atlantic, and Norway in particular, generally do not control for the almost certain presence of non-locals. Aggregate δ^{18}O data are often provided to characterize entire towns or countries knowing that movement of people between locations within the North Atlantic would not have been uncommon during the time that the St. Mary's individuals lived. The presentation of oxygen data for Norway also do not tend to explore variation within communities, which may be tied to any number of contextual factors. When considering Price et al.'s (2015) δ^{18}O values for Bryggen (−4.3‰ ± 0.7), and their difference from those presented with this study (−5.7‰ ± 0.7), they clearly differ, but it is important to note that the Price et al. values come from 3 different burial locations within the broader Bryggen area. The St. Mary's values are different from those representing a more general view of the population of Bergen at the time, and perhaps indicate the influence of burgeoning differences in socioeconomic status and origins within the rapidly growing town, however, further comparative research between all three contemporary burial sites (Nykirken, Lille Ovregt, Bryggen) is needed.

Regardless of the details of where the St. Mary's individuals originated, the stable oxygen isotope data presented here suggest that long-range mobility of children, potentially within Norway itself, or the North Atlantic region more broadly, was occurring during this time period (1170–1248 AD). The ability to compare δ^{18}O values across tooth types for six St. Mary's individuals has revealed that St. Mary's individuals may have moved directly to Bergen, or via other North Atlantic locations, during childhood. These findings contradict assertions by other researchers who have suggested that migrants to Bergen would have been adult males involved directly in trade (Lorvik, etc.). These data suggest that children and their families were also settling in Bergen.

Limitations of this study include the matter of sample representativeness. The St. Mary's remains analyzed were from a limited location within the churchyard affected by the fire of 1955. No children under the age of 7 were retrieved from this portion of the cemetery, so this sample is clearly limited in terms of its capacity to represent the experience of infants and children living in Bergen between 1140 and 1248 AD. With respect to paleodietary reconstruction, it is possible that a mixture of different food items may lead to the same isotopic values (e.g., underdetermination, where the estimated relative contributions are incompletely identifiable). For the isotopic mobility data, as mentioned in Section 2.2, there is notably little variation in oxygen isotope values from the North Atlantic, thus limiting the specificity of attempts to pinpoint the origins of individuals buried at St. Mary's.

7 | CONCLUSION

In summary, individuals buried at the St. Mary's cemetery in the Bryggen area of Bergen, between 1170 and 1248 AD, consumed childhood diets akin to those of their peers at other growing town sites in the early medieval period. While they had incorporated mean bone collagen δ^{13}C and δ^{15}N values similar to those published for other contemporary Norwegian sites, those buried at this relatively privileged churchyard in the center of Scandinavia's most powerful trade center of that time, demonstrated varied diets where some individuals had significant and sustained access to C$_3$ protein sources brought into the town via trade while others relied on marine protein sources. It appears that many of these relatively affluent individuals may have been local to Bergen, but δ^{18}O values indicate that some members of this group may have migrated to the town during childhood, or during their later years of life. δ^{18}O ratios from St. Mary's differ from those published for other contemporary cemeteries in Bergen, reminding us that, as stated by Betsinger and DeWitte (2021), the processes and impacts of urbanization may be unevenly distributed within an emerging town such as Bergen, and as such the contextual analysis of stable isotope data from medieval Norwegian samples is in need of further investigation.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data supporting the findings of this study are available from the corresponding author upon request.

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