

The presence of scurvy in Early Medieval (9th–10th centuries) Barcelona, Catalonia, Spain: Investigations at the necropolis of the Antics Jutjats Municipals (the former Municipal Courts)

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ABSTRACT

Objective: This study investigates patterns of nutritional stress in the context of the prolonged armed conflict between Muslim and Christian groups in Early Medieval Barcelona (9th–10th centuries CE).

Materials: A total of 115 individuals from the Antics Jutjats Municipals Early Medieval site in Barcelona were analysed, including 71 non-adults (0–20.99 years) and 44 adults (21–60 years).

Methods: Morphological characteristics classified as 'Diagnostic of', 'Highly consistent/Typical of', and 'Consistent with' scurvy were evaluated macroscopically using a hand magnifying glass.

Results: Evidence for possible scurvy was found in 12 of 87 observable individuals (13.8%): 9 non-adults and 3 adults (4 as "Diagnostic of"; 3 as "Highly consistent/typical" and 5 as "Consistent with").

Conclusions: The presence of scurvy in the analysed population reflects significant dietary stress associated with the prolonged armed conflict between Muslim and Christian groups during the 9th–10th centuries CE. The struggle for territorial control generated political instability in Barcelona, disrupting food production and distribution and contributing to nutritional deficiency.

Significance: This study contributes to a better understanding of scurvy epidemiology in the Iberian Peninsula and the Mediterranean region.

Limitations: Only 115 of the estimated 460 individuals have been excavated and analysed. Therefore, a comprehensive assessment of the remaining individuals would be necessary to obtain a more accurate estimate of the scurvy prevalence in this population.

Suggestions for further research: Increase the sample using this and other sites from the same period.

1. Introduction

During the Early Medieval period, Barcelona (Catalonia) occupied a frontier position between the Christian polities of Western Europe to the north and the Muslim territories of al-Andalus to the south (Banks, 1987; Tischler, 2019). At this time, Catalan society was undergoing a gradual transformation from earlier post-Roman social structures toward the socioeconomic systems that would later characterize the feudal world. Around 717 CE, the Arab-Berber conquest brought an end to Visigothic rule in this region of the Iberian Peninsula. Muslim authority remained established in much of Catalonia throughout the 8th century until the city of Barcelona was captured by Carolingian forces in 801. Following

this conquest, the region became integrated into the Carolingian frontier system and formed part of the Marca Hispánica (Spanish March), a defensive buffer zone established to contain the expansion of al-Andalus (Tischler, 2019).

As a frontier society, Barcelona was particularly exposed to political instability and military conflict. Throughout the 9th and 10th centuries, tensions between Frankish and Muslim powers, together with internal political struggles within the frontier territories, contributed to repeated episodes of warfare affecting the city and its surrounding territories. As a result, Barcelona was besieged on several occasions (Chandler, 2019; Tischler, 2019). Among the most significant episodes were three major sieges: (i) in 826–827, during a rebellion of local nobility of the Spanish

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March against Frankish authority; (ii) between 850–852, when Muslim forces temporarily occupied the city; and (iii) the most violent episode, in 985, when Barcelona was besieged and ultimately captured by the forces of al-Manşūr (Almanzor) (Ballestín, 2015, 2022; Chandler, 2019).

These repeated military confrontations likely had profound consequences for the local population (Chandler, 2019). Warfare, sieges, and the devastation of surrounding agricultural lands (Ballestín, 2015, 2022; Chandler, 2019) probably disrupted food production, trade networks, and access to essential resources. Such conditions may have resulted in periods of food scarcity and famine, potentially affecting the nutritional status and overall health of the population. It is recognised that war and sieges profoundly alter subsistence systems by isolating populations, limiting dietary diversity, and disrupting food distribution networks, resulting in famine, malnutrition, and epidemics (McCord, 1971; Mays, 2014; Prinzing and Westergaard, 1916). Civilian populations are particularly vulnerable to the indirect consequences of conflict, which include psychological stress, displacement, the loss of housing and livelihoods, reduced access to food and medical care, and the death of family members (Bendavid et al., 2021). Evidence from recent conflicts, including the Bosnian War, indicates that armed conflict adversely impacts human health and drives widespread undernutrition across all age groups (Cameron, 2023).

Despite the available documentary evidence regarding the history of Barcelona during the Early Medieval period, very little is known about the lived experiences of its population and even less from direct bioarchaeological data (Banks, 1987, 2003). Therefore, the individuals recovered from the Antics Jutjats Municipals site, who lived during the Early Medieval period in Barcelona, offer a unique opportunity to investigate these aspects through the study of their skeletal remains. There is a previous study (Merino and Rissech, 2025) on this Early Medieval population, which focused on the anthropometric characteristics and demographic information of the sample, as well as non-specific stress markers as evidence of physiological stress rather than a systematic study on nutritional deficiency. Consequently, it is largely unknown to what degree this military confrontation directly had on the nutrition of this population.

1.1. Nutritional deficiency in war context

Armed conflict environments create conditions that strongly predispose populations to both protein and micronutrient deficiencies (Grande and Perafa, 1941; Culebras, 2014). These deficiencies stem largely from reduced dietary diversity, with food consumption patterns dominated by carbohydrate-rich staples and limited access to nutrient-dense foods such as fruits, vegetables, and animal products. As a result, intake of key micronutrients, including iron, zinc, calcium, and vitamins A, B-complex, and C, often falls below adequate levels (Grande and Perafa, 1941; Culebras, 2014; Ramakrishnan, 2002; White and Broadley, 2009; Han et al., 2022). Medical studies on civilian populations during the siege of Madrid in the Spanish Civil War exemplify the severe impact of nutritional deficiencies, documenting cases of scurvy (vitamin C deficiency), rickets and osteomalacia (vitamin D deficiency), pellagra (vitamin B3 deficiency), deficiencies in the vitamin B-complex and hypovitaminosis A (vitamin A deficiency) among the affected population (Grande and Perafa, 1941; Culebras, 2014).

Only a restricted set of micronutrient deficiencies manifests in macroscopically observable skeletal alterations, notably scurvy, rickets and osteomalacia (vitamin D, calcium, or phosphate deficiency), hypovitaminosis A, pellagra, and deficiency-related anaemias involving iron, folate, and vitamin B12. Among these, scurvy is distinguished by robust and widely accepted diagnostic criteria within paleopathology (Ortner and Erickson, 1997; Ortner, 2003; Brickley and Ives, 2008; Crandall and Klaus, 2014; Snoddy et al., 2017; Brickley et al., 2020). Its clear association with inadequate nutrient intake makes it a particularly reliable indicator for examining the impact of micronutrient deficiencies in conflict settings. Consequently, this study employs scurvy as a proxy for

nutritional deficiency.

1.2. Pathophysiological perspective of skeletal scurvy

The identification of scurvy in skeletal human remains is largely based on the pathophysiology of the disease, from which the diagnostic criteria are derived. Initially developed by Ortner and Erickson (1997), this approach involves the interpretation of skeletal lesion patterning through knowledge of the anatomical expression of the disease. This framework is essential for ensuring methodological rigor in the diagnosis of disease (Mays, 2018). Scorbutic skeletal changes result from both direct and indirect effects of impaired collagen formation. Direct effects involve defective collagen synthesis within skeletal tissues, whereas indirect effects arise from compromised collagen in the vascular endothelium (Fain, 2005). This defective endothelium increases vessel susceptibility to haemorrhage during routine movements such as mastication, eye motion or adduction and abduction of the shoulder and hip joints respectively (Brickley et al., 2020). In regions where these vessels are closely associated with bone and underlying habitually used muscles, repeated muscle movement may result in recurrent vessel rupture and bleeding. This, in turn, triggers subperiosteal new bone (SPNB) formation as part of an inflammatory response (Brown and Ortner, 2011). Abnormal cortical porosity results from enhanced capillary formation triggered by repeated microtrauma to fragile blood vessels in connective tissues (Ortner and Erickson, 1997). Pathological porosity related to scurvy is commonly observed on the external surfaces of the greater wing of the sphenoid, temporal bone and the coronoid process generated by the use of the temporalis muscle during chewing food (Ortner and Erickson, 1997). Similarly, the movement of the masseter muscle can in pooling of blood leading to SPNB deposits and abnormal cortical porosity in the zygomatic bone that form in response to hematomas. Likewise, the supra and infraspinous fossae of the scapula, as well as the internal surface of the ilium, may also be affected by the movement of their respective muscles producing SPNB deposition and abnormal cortical porosity (Brown and Ortner, 2011). Scurvy subperiosteal haemorrhagic lesions and associated new bone response tend to be symmetrical and bilateral because the actions of these muscles occur bilaterally (Brickley and Morgan, 2023). However, scorbutic lesions can also occur unilaterally, especially in weight-bearing bones, likely reflecting haemorrhage induced by repetitive microtrauma during locomotion (Maat, 2004; Brickley et al., 2020; Simonit et al., 2023). However, unilateral lesions may be easily confused with other microtrauma associated with muscle strain. Presence of SPNB in scurvy suggests a partial reintroduction of C vitamin in the diet as it is essential for osteon formation, since small amounts of vitamin C may be sufficient to trigger new bone formation (Geber and Murphy, 2012; Klaus, 2017; Snoddy et al., 2017).

The scorbutic rosary (enlargement of the costochondral junctions of the ribs), resulting from subperiosteal haemorrhage, is a common clinical finding in infants (Jaffe, 1972: 453). The upper limb scorbutic changes seem to be less frequent than lower limb (Jaffe, 1972:450). Changes in the femur, tibia, fibula and lateral bulging of the legs are often observed in affected infants due to subperiosteal haemorrhaging (Jaffe, 1972:450). Metaphyseal flaring and Pelkan spurs may be present, accompanied by cortical thinning. In children, fractures, dislocations, and bone tenderness are common, reflecting disruption of osteoid formation. In growing individuals, porosity extending from the cortex on the metaphyseal area of the bone into the diaphysis represents a normal physiological process. This reflects osteoclastic resorption at this area, which facilitates continuous longitudinal bone growth (Ortner et al., 2001). In contrast, in children with scurvy, the extent of porosity exceeds that expected during normal growth. Currently, porosity extending beyond 10 mm from the cortex on the metaphyseal area of the bone is regarded as abnormal by Ortner et al. (2001).

This study aims to examine the nutritional impact of the prolonged armed conflict between Frankish and Muslim powers in Early Medieval

Barcelona, while evaluating the relative contribution of social, environmental, and biological factors to patterns of nutritional deficiency by assessing the skeletal evidence of scurvy. This analysis is based on bio-anthropological evidence derived from human remains recovered at the Antics Jutjats Municipals de Barcelona site, located at the present-day urban area of Barcelona city. The site dates from the 9th to 10th centuries, a period characterised for great political instability and the military conflict between Frankish and Muslim powers. These characteristics and the high representation of infants, children and adults in excellent state of preservation make this site particularly suitable to meet the objectives of the present study.

2. Material and methods

The analysed material derives from the Antic Jutjats Municipals de Barcelona site and comprises 115 individuals: 71 non-adults (68 indeterminate, 1 male and 2 females) aged between 0 and 20.99 years, and 44 adults (23 females, 19 males, and 2 indeterminate) aged between 21 and 60 years (Merino and Rissech, 2025) (see [Supplementary Material](#), Table 1).

2.1. Archaeological context

The Antics Jutjats Municipals de Barcelona site in Catalonia, Spain

(Fig. 1), has been dated to the 9th–10th centuries CE based on archaeological evidence and subsequent radiocarbon (^{14}C) analyses conducted by Beta Analytic (Merino and Rissech, 2025). The site was excavated between 2018 and 2019 by ABANS Serveis Culturals under the supervision of the lead anthropologist M.M. and represents an attritional cemetery from the Early Medieval period. An attritional cemetery is a burial population that accumulates through routine deaths in a community over an extended period, reflecting the normal demographic structure and mortality patterns of that population. At this time, this cemetery was located outside the Roman walls (the Medieval walls had not yet been constructed), in the suburbium (suburban area), close to the territorium (the surrounding countryside) (Fig. 1). Today it is located between Passeig Pujades, 3; Passeig Lluís Companys, 1–5; Passeig Picasso, 1; and Plaça de Vicenç Albert Ballester, in the Ciutat Vella district of Barcelona. A total of 123 primary and individual burials were located, of which 115 were completely excavated; the remaining 8 were not excavated as they lay outside the limits of the excavation (Merino and Rissech, 2025). It was estimated that the entire plot may contain more than 460 burials; however, the exact boundaries of the cemetery could not be determined (Merino and Rissech, 2025). The burials were strictly organized, oriented east–west, laid in a supine position, according to the Christian rites of the period, which were marked by simplicity and the absence of grave goods (Merino and Rissech, 2025).

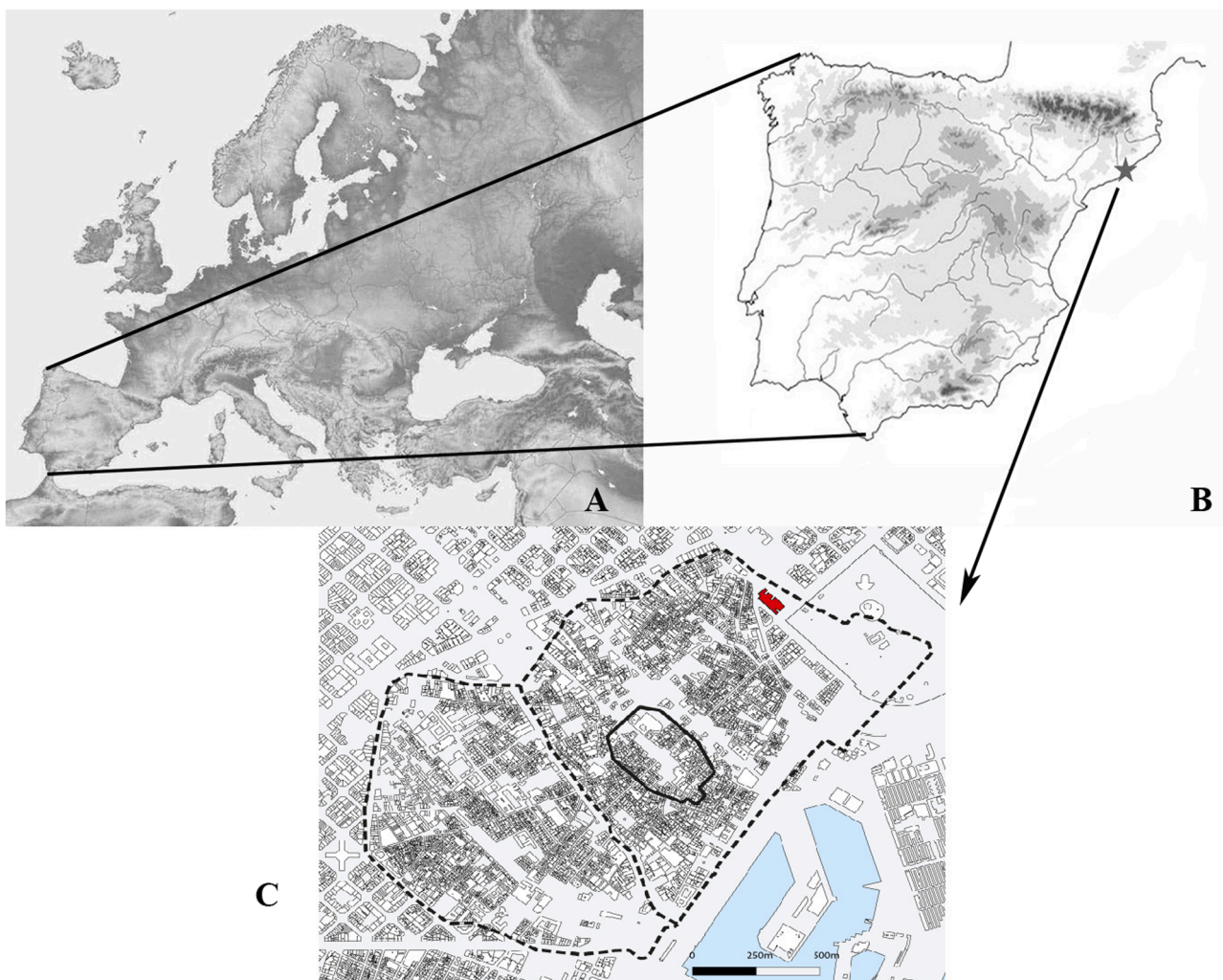


Fig. 1. The Iberian Peninsula in Europe (A). The star indicates the location of Barcelona within the Iberian Peninsula (B) and the Antic Jutjats Municipals de Barcelona site (in red) in relation to current Barcelona city (C). Continuous and discontinuous lines correspond to the Roman and Medieval walls, respectively. The Medieval wall was constructed in the 13th century.

To date, the archaeological site of the Antics Jutjats Municipals is unique in Catalonia. In addition to its organization and the number of burials and type of funerary ritual, it represents a large and significant Christian burial area in the region known as the Eastern Suburb of Barcelona (Beltrán-Heredia, 2010), which appears not to have been associated with any religious centre. This distinguishes the cemetery from other burial spaces from the 9th and 10th centuries (Ripoll and Molist, 2012). From the 6th century on, Christian burial practices were predominantly organized around urban religious buildings, basilicas or monasteries (Beltrán-Heredia, 2010). In contrast, the cemetery at the Antics Jutjats Municipals appears to have been a planned burial area, located a considerable distance from the Late Roman city wall of Barcelona (Merino and Rissech, 2025). As previously mentioned, the medieval wall of Barcelona had not yet been constructed at that time; it dates to the 13th century.

2.2. State of preservation

An assessment of the bones present was undertaken, as skeletal completeness is an important consideration in palaeopathological evaluation of scurvy. The state of completeness of the individuals was assessed using both the Preservation Index (IP₃) (Alesan, 1990; Rissech et al., 2023) and the bone presence scoring method of Buikstra and Ubelaker (1994: 7–8). The IP₃ calculates the percentage of present skeletal elements out of a total of 22 bones (12 long bones, 7 bones from both girdles, neurocranium, maxilla and mandible) from the human skeleton [IP₃ = (Number of present bones/22) × 100]. The presence of a part of a bone is considered as entire bone, and because of this it thus does not inform us about the physical state of the bone, but it is useful to inform us about the number of preserved bones. The bone presence scoring method of Buikstra and Ubelaker (1994:7–8) determines the presence of an element using the criteria outlined by these two authors. The criteria established by this latter method (ribs were scored as present when at least six heads and necks were preserved; long bones were scored as present when at least 25% of the diaphyseal shaft remained; and the cranium and mandible were scored as present when at least 25% of each element was preserved) represent minimum thresholds for recording bone presence, as many elements were substantially more complete. Skeletal surfaces erosion was analysed by the method of McKinley (2004).

2.3. Sex and age estimation

Estimation of sex was based on the standard criteria of the skull, mandible and hip bone (Ferembach et al., 1980; Rissech and Malgosa, 1991, 1997) in adults and non-adults above 15 years of age. Estimation of age was based on standard methods including pubic symphysis, auricular surface, acetabulum and sternal end of the ribs (Mitchell and Brickley, 2017; Rissech et al., 2006) in adults. For non-adult individuals, dental development, long bone length and fusion of skeletal elements (Ubelaker, 1989; Scheuer and Black, 2000) were considered.

2.4. Diagnostic protocol of scurvy

In accordance with the descriptions and suggestions for scurvy assessment put forward by Ortner and Ericksen (1997) and Brickley and Morgan (2023), cortex-penetrating pores (≤ 1 mm in diameter) and SPNB were macroscopically evaluated and documented, taking into account their location and their macroscopic status as active (A), healed (H) or absent (AB).

To ensure an accurate diagnosis, specific anatomical regions of the cranium, scapula, ilia and long bones were examined under strong illumination and with the aid of a hand magnifying glass. Particular attention was given to cranial areas characterized by a rich blood supply and limited mobility (Brickley and Morgan, 2023). These areas are the greater wing of the sphenoid, the medial area of the zygomatic bone, the

posterior maxilla, the coronoid process of the mandible, the medial surface of the mandibular ramus, the inferior surface of the palatine bone, the posterior alveolar regions of the maxilla and mandible, the orbital roof, the cranial vault, the infraorbital foramen, and the area surrounding the foramen rotundum. Limited emphasis was placed on the anterior alveolar region because other pathological processes, particularly infections, may influence the formation of SPNB in this area. In relation to the postcranial elements the supra- and infrapinnous fossae of the scapula, the ilia and the diaphyseal and metaphyseal regions of the tibiae and fibulae were also observed.

Bilateral lesions on the sphenoid greater wing are pathognomonic of scurvy (Brickley et al., 2016). The presence of bilateral lesions would ideally be used in all cases; however, the preservation of archaeological bone sometimes prevents this observation. To account for this limitation, slightly greater weight was assigned to unilateral lesions when postmortem damage precluded the assessment of bilateral involvement. Scurvy was considered likely when porosity (or SPNB) was observed on the greater wing of the sphenoid and at least one other skeletal site unaffected by dental pathology. As noted by Brown and Ortner (2011), scurvy could affect the skeleton without involving the greater wing of the sphenoid. Therefore, in the absence of lesions at this location, a diagnosis of scurvy was suggested when bilateral lesions were observed at two or more anatomical sites identified as diagnostic of scurvy in previous studies, including the posterior surface of the maxillae, the medial surface of the coronoid process, the medial surface of the zygomatic bone, supra and infrapinnous fossae of the scapula and the ilia (Brown and Ortner, 2011; Geber and Murphy, 2012; Brickley et al., 2016). In order to standardize the diagnostic terminology and achieve a more consistent degree of certainty in our diagnoses, we used the three categories from the modified Istanbul Protocol described by Brickley and Morgan (2023): *Diagnostic of Scurvy*, *Highly Consistent/Typical of Scurvy*, and *Consistent with Scurvy* (see Table 1).

A definitive classification of *Diagnostic of Scurvy* (Table 1) was made when skeletons of any level of completeness displayed macroscopic diagnostic lesions, specifically abnormal bilateral and symmetrical cortical porosities < 1 mm and/or SPNB formation on the greater sphenoid wing, together with at least one additional diagnostic region (e.g., temporal bones, zygomatic bones, maxilla, or mandible). Alternatively, a diagnosis was made when an individual exhibited porous lesions on the sphenoid wing in combination with other lesions not attributable to alternative diagnoses.

Table 1
Diagnostic Categories for Scurvy.

Diagnostic Category of Scurvy	Definition	Observed Lesions / Criteria
Diagnostic of	The pattern of lesions observed could not have been caused by any condition other than scurvy .	– A combination of unambiguous “Ortner” porosity great wings of Sphenoid. – Other clear lesion(s) that have few other possible causes. Great wings of Sphenoid lesions must be bilateral to contribute to assigning the diagnostic of category.
Highly consistent / typical	The lesions could have been caused by scurvy , though a limited number of other possible causes exist.	– Several highly consistent lesions observed macroscopically. – With the potential to also consider few other possible causes
Consistent with	The lesions may be consistent with scurvy , but are non-specific and may result from various other conditions.	– Porotic lesions and/or subperiosteal new bone formation (SPNB), potentially associated with scurvy – Reduced bone volume (often referred to as osteopenia).

The term *Highly Consistent/Typical of Scurvy* (Table 1) was applied to individuals with macroscopic lesions classified under the category of *diagnostic of scurvy*, but with a total or partial absence of the sphenoid bone that precluded its assessment. This mean that these individuals exhibit lesions frequently associated with scurvy, but for which alternative causes cannot be disregarded.

A diagnosis of *Consistent with Scurvy* (Table 1) was applied to individuals exhibiting lesions and SPNB formation, potentially associated with scurvy, but where a different cause cannot be ruled out, owing either to the appearance of the lesion, its location, or the lack of other corroborating evidence. All non-symmetrical lesions in key diagnostic bones of the skull were considered as suggestive. This third category corresponds to the lowest level of diagnostic confidence. It is important to consider this third category of diagnosis in the case of individuals showing limited evidence, in particular those cases where there is good contextual/skeletal evidence that the condition was present.

Due to various factors that can contribute to the presence of porosity in alveolar sockets such as dental eruption and oral diseases, porosity and SPNB at the alveolar sockets were not recorded in this study following Mays (2014) and Paladin et al., (2018).

3. Results

Both the adult and non-adult skeletons are characterized by a high degree of skeletal completeness, as illustrated in [Supplementary Material](#), Tables 1 and 2. More than 90% of the individuals are more than 75% complete, while over half are more than 90% complete ([Supplementary Material](#), Tables 1 and 2). In addition, the skeletal surfaces show very low levels of surface erosion (Grade 0–1 according to McKinley, 2004). Twenty-eight individuals did not preserve enough cranial and mandibular elements to allow evaluation for the presence of scurvy ([Supplementary Material](#), Table 2). From these 28 individuals, three non-adults (individuals UE 621, UE 265, and UE 568) and 7 adults (individuals UE 34, UE 144, UE 618, UE 394, UE 242 and UE 431), only

the lower portion of the skeleton was recovered because the cranial region lay within the profile of the foundation pillars or excavation trenches. The remaining 18 individuals had the lowest percentage of preserved skeletons affecting the cranium and mandible ([Supplementary Material](#), Table 2), making macroscopic observations of scurvy difficult. Consequently, these individuals could not be evaluated and the final observed individuals comprised 87 (87/115 75.7%).

Table 2 presents the results of applying the criteria of Ortner and Erickson (1997) and Brickley and Morgan (2023) to diagnose scurvy in the population of Antic Jutjats Municipals de Barcelona. Table 3 indicates the prevalence of scurvy in the analysed sample. A total of 4.6% (4/87) of the observable individuals in this study met the diagnostic criteria to be classified in the *Diagnostic of Scurvy* category and were observed with at least a bilateral symmetrical lesion of the sphenoid greater wing (pathognomonic) and at least one key diagnostic feature and at least one suggestive feature (Tables 2 and 3). The 3.5% (3/87) of

Table 3

Antics Jutjats Municipals de Barcelona adult and non-adult scurvy prevalence.

Age in years	Diagnostic of Affected/Observed (%)	Highly consistent Affected/Observed (%)	Consistent with Affected/Observed (%)
0–0.5	0/5 (0)	0/5 (0)	0/5 (0)
0.5–1	0/3 (0)	0/3 (0)	0/3 (0)
1–5	2/34 (5.8)	2/34 (5.8)	1/34 (3.1)
5–10	1/7 (14.3)	1/7 (14.3)	1/7 (14.3)
10–15	0/3 (0)	0/3 (0)	0/3 (0)
15–20	0/3 (0)	0/3 (0)	1/3 (50.0)
20–25	0/4 (0)	0/4 (0)	0/4 (0)
25–30	0/9 (0)	0/9 (0)	1/9 (12.5)
30–35	1/7 (14.3)	0/7 (0)	1/7 (25.0)
35–40	0/3 (0)	0/3 (0)	0/3 (0)
40–45	0/5 (0)	0/5 (0)	0/5 (0)
45–50	0/4 (0)	0/4 (0)	0/4 (0)
Total	4/87 (4.6)	3/87 (3.5)	5/87 (5.7)

Table 2

Distribution of macroscopic lesions in twelve individuals from the Antic Jutjats of Barcelona and their diagnostic category. Lesions are bilateral unless specified. X = bilateral pathology present; X(r) = Right pathology present; X(l) = Left pathology present; AB = Absence of lesion; “/” = element absent or too damaged to record. Subscript “A” means active lesion. Subscript “H” means remodelled (healed) lesion.

	Diagnostic of scurvy				Highly consistent/Typical				Consistent with scurvy			
Highly consistent/Typical Lesion location	UE613	UE438	UE219	UE509	UE195	UE598	UE647	UE347	UE445	UE361	UE514	UE554
	3–4 years	25–33 years	2–3 years	6–7 years	1.5–2 years	4–5 years	6–7 years	5–6 years	4–5 years	25–30 years	25–35 years	18–20 years
	-	female	-	-	-	-	-	-	-	female	male	female
Sphenoid greater wing, foramen rotundum	X _A	X _A	X _A	X _A	AB(l)/(r)	X _A (l)/(r)	X _A (r)	/	X _A (r)	X _A (r)/(l)	/	X _H (l)/(r)
Sphenoid lesser wing	AB	AB	AB	AB	AB	AB	AB	/	X _A	X _A	/	X _H (l)
Temporal bone	X _A	AB	X _H	X _A	X _A	X _A	X _A	/	X _A (r)/(l)	AB	/	X _A
Mandible coronoid process, medial surface	X _A	X _A	X _A	X _A	X _H	X _A	X _A	X _A (r)/(l)	X _A	AB	/	AB
Internal Zygomatic	X _A	X _A	X _H	/	X _A	X _H	X _A	X _A (r)	X _A	AB	X _H	X _A
Maxilla posterior Surface	X _A	X _A	X _A (r)	X _A	X _A	X _A	AB	X _A (r)/(l)	X _A	X _A (r)	X _H (l)/(r)	X _A
Palatine inferior Surface	AB	/	/	X _A	X _A	/	/	/	/	AB	/	AB
Orbital roof	X _A (r)	AB	X _A	X _A	AB	X _A	/	/	X _A	AB	AB	X _A
Cranial vault	AB	AB	AB	AB	X _A	X _A	AB	/	X _A (r)	AB	AB	AB
Infraorbital foramen	X _A	AB	AB	AB	AB	X _A	AB	/	X _A	X _H (l)	X _A	AB
Long bones	X _A (l)	X _A	X _A	X _A	X _A (r)	X _A (l)	X _A	X _A	X _A (r)/(l)	X _A	X _H	X _H
Scapulae, supra and infrapinnous fossae	X _H (l)	AB	X _H (r)	X _A	AB	X _A	X _A	AB	AB	AB	AB	AB
Iliac	AB	X _H	AB	X _A (r)	AB	AB	AB	AB	AB	X _H	X _H	X _H
Ribs	AB	AB	AB	AB	AB	AB	AB	AB	AB	X _A	AB	AB

fractures

Note: A bilateral lesion on the greater wing of the sphenoid is diagnostic of scurvy. Absence of the sphenoid or part of it, which allows us to observe a unilateral lesion, together with or two or more other diagnostic lesions, is *highly consistent with* a probable case. Two or more other diagnostic lesions in different states of active and healed or unilateral lesions is consistent with. Suggestive lesions that supplement diagnoses are provided in [Supplementary Material Table S1](#).

the observable individuals met the diagnostic criteria to be classified in the *Highly Consistent/Typical of Scurvy* category and were observed with at least two key diagnostic features and at least one suggestive feature (Tables 2 and 3). Five out of eighty-seven (5.7%) of the observable individuals met the diagnostic criteria to be classified in the *Consistent with Scurvy* category and did not have enough diagnostic features but had suggestive features (Tables 2 and 3). In total, they correspond to a total of 12 individuals (8 aged 1.5–7 years; 1 juvenile aged 18–20 years and 3 adults aged between 25 and 35 years) out of the 87 observed (13.8%). Considering the three categories of classification, the highest prevalence of scurvy is observed among individuals aged 1.5–7 years (Table 2), corresponding to the 1–5-year and 5–10-year age groups presented in Table 3, which together account for a total prevalence of 57.6% (Table 3). Adults are mostly classified in *Consistent with Scurvy* category. Most of these 12 individuals exhibited active lesions, particularly non-adults (Table 2). Only a non-adult individual under the age of two (individual UE 195) classified in the *Highly Consistent with Scurvy* category and two of the adult individuals (individuals UE 361, UE 514) and the juvenile individual (individual UE 554) who were classified in the *Consistent with Scurvy* category showed some areas of remodelled SPNB (Table 2). In addition, the female individual UE 361, classified in the *Consistent with Scurvy* category, exhibited an active lesion in the right sphenoid greater wing and in both sphenoid lesser wings together with a remodelled lesion in the left infraorbital foramen (Table 2) and evidence of SPNB formation across multiple skeletal elements, including the right twelfth rib and both ilia, the sacrum, the left radius, and both tibiae and fibulae, as well as 16 fractures at different stages of healing affecting the left zygomatic bone, nine ribs, both ulnae and radii, and the third and fifth metacarpals of the left.

The description of the lesions observed in each of the 12 individuals can be found in the [Supplementary material](#) Text S1. The most common bilateral diagnostic changes recoded in the study were sphenoid greater (13/24) and lesser (5/24) wings, squamous temporal bone (15/24), mandible medial surface (17/24), maxilla posterior surface (18/24), zygomatic medial surface (19/24), supra and infraspinous fossae of the scapula (8/24), internal surface of the ilia (9/24) and the diaphyses and metaphyses of the appendicular skeleton (20/24) (Figs. 2–8).

4. Discussion

The occurrence of scurvy in a Mediterranean context is not unexpected, given previous reports from other Mediterranean populations such as in Greece (Bourbou, 2010, 2014), Albania (Kyle et al., 2020), and Italy (Paladin et al., 2018) and others. Across all these populations, elevated scurvy prevalence is consistently linked to periods of subsistence transition, cultural change or significant political and socioeconomic instability. These types of studies provide valuable insights into the epidemiology of scurvy across the different historical populations.

4.1. Differential Diagnosis

Although the diagnosis of scurvy is challenging in clinical practice, it is even more difficult in a palaeopathological context (Bourbou, 2014). Besides skeletal completeness, which plays a crucial role in diagnosis, several pathological conditions can also give rise to porosity and SPNB formation (Crandall and Klaus, 2014; Srienć-Ściesiek et al., 2024). Furthermore, physiological porosity and new bone formation associated with skeletal growth, particularly in non-adults, may complicate diagnosis. Scurvy and other nutritional deficiency-related pathologies can produce similar skeletal manifestations and may co-occur. For instance, deficiencies of iron and vitamin D, which underlie anaemia and rickets, may present concurrently with other diseases (Ortner, et al., 2001; Schattmann, et al., 2016). Similarly, the site of bone remodelling influences the rate of healing; for instance, trabecular bone remodels more rapidly than cortical bone due to its greater vascularization (Brickley et al., 2020). Consequently, healing rates can vary both within a



Fig. 2. Left sphenoid greater wing of individual UE 598 showing SPNB formation.



Fig. 3. Medial view of the left mandibular ramus of individual UE 509, showing SPNB formation.



Fig. 4. Posterior view of the right maxilla of individual of UE 554, showing SPNB formation and porosities.



Fig. 5. Medial view of the right zygomatic bone of individual UE 347, showing SPNB formation and porosities.

single bone and among different bones (Brickley et al., 2020).

Magnified images of the bone elements from the individuals at the Antic Jutjats Municipals de Barcelona site reveal changes in colour, porosity, and growth, providing clear evidence of pathological alterations induced by inflammatory processes. Therefore, evaluating other processes with similar manifestations is crucial for a reliable diagnosis (Table 4). Caffey's disease, pellagra, nutritional rickets and osteomalacia, anaemia, hypophosphatemia and scurvy were included in the differential diagnosis (Table 4, Supplementary material Text S2). Scurvy was the most likely candidate.

Caffey's disease and hypophosphatemia were ruled out based on clinical data. Caffey's disease (infantile cortical hyperostosis) is a rare



Fig. 6. Infraspinous fossa of the right scapula of individual UE 219, showing SPNB formation and porosities.



Fig. 7. Left fibula of individual UE 647, showing active SPNB formation on the distal extreme of the bone.



Fig. 8. Interval view of the right innominate of individual UE 361, showing SPNB formation in the ischial spine.

genetic disorder of infancy affecting collagen development (Kamoun-Goldrat and Le Merrer, 2008). It is characterized by marked SPNB formation and cortical thickening throughout the skeleton, predominantly affecting the mandible, clavicles, and long bones (Kamoun-Goldrat and Le Merrer, 2008; Rodríguez et al., 2016). Given its self-limiting nature (Kamoun-Goldrat and Le Merrer, 2008; Rodríguez et al. 2016), Caffey’s disease was considered in the differential diagnosis only for infants within the assemblage. This disease does not cause discrete lesions as those seen in the infants from Antic Jutjats Municipals de Barcelona. Furthermore, in these infants the bone changes mirror lesions observed in older children and adults, whereas Caffey’s disease is exclusively restricted to infants. The more parsimonious explanation is that a single condition is responsible for these lesions in this population.

Hypophosphatemia is associated with a severe form of rickets, characterized by bending deformities and metaphyseal cupping and flaring (Linglart and Biosse-Duplan, 2016). While phosphate deficiency could be considered in the context of reduced protein intake at Antic Jutjats Municipals de Barcelona during the armed conflict, the predominance of discrete, symmetrical SPNB lesions is not consistent with this condition. Furthermore, discrete new bone formation and cortical

porosity are not typical manifestations of hypophosphatemia (Linglart and Biosse-Duplan, 2016).

Pellagra was also ruled out based on it does not result in haemorrhaging, SPNB formation at muscle sites points to haemorrhaging. Rickets and anaemia were also excluded. Rickets typically produces metaphyseal flaring and bowing of the long bones, neither of which was observed. Anaemia is commonly associated with cribra orbitalia and porotic hyperostosis resulting from marrow hyperplasia. Although porosity and SPNB formation were observed on the orbital roofs, their morphology was more consistent with haemorrhage and subsequent healing than with marrow expansion.

4.2. Causes of scurvy in Antic Jutjats Municipals de Barcelona

The results of the present study indicate that 13.8% of the observed individuals were potentially affected by scurvy (3 adults and 9 non-adults). When this prevalence of scurvy at Antics Jutjats Municipals de Barcelona is compared with the results of macroscopically analysis of other skeletal populations, it appears higher than those obtained by Brickley and Ives, which ranged from approximately 3–7% (see Brickley and Ives, 2008: Table A1). However, the sample analysed seem less affected by scurvy than those of Man Bac (>79% non-adults) (Vlok et al., 2023).

The adults were distributed across two diagnostic categories: *Diagnostic of Scurvy* and *Consistent with Scurvy*, with the latter including two of the three adults. The non-adults were distributed in the 3 diagnostic categories: *Diagnostic of Scurvy* with three individuals between 2 and 7 years of age; *Highly Consistent with Scurvy* with 3 individuals aged between 1.5 and 7 years and *Consistent with Scurvy* with 3 non-adults, two of which were aged between 4 and 6 years and the third between 18 and 20 years. The affected adults were young adults and predominantly female (2 out of 3), within the reproductive age range. The older non-adult, aged between 18 and 20 years, was also a female. Non-adults constituted the largest group. Apart from the young female aged between 18 and 20 years, all non-adults were aged seven years or younger; however, no individuals were under 1.5 years of age.

The good preservation and the excellent condition of bone surfaces at Antic Jutjats Municipals de Barcelona enabled a clear identification of the high number of cases, as active SPNB can be lost through a range of taphonomic factors (Roberts and Connell, 2004). It could be argued that the reported frequency of potential scurvy cases overrepresents individuals who actually have clinical scurvy. Nevertheless, all the individuals present more than three diagnostic lesions and those classified in the *Diagnostic of Scurvy* category have in addition the pathognomonic diagnostic lesions on the sphenoid greater wings. Probably, it is more plausible that scurvy cases are underestimated, as the incomplete

Table 4
Summary of pathologies considered in the differential diagnosis, including the criteria for their inclusion or exclusion.

Differential diagnosis	Disease background	Morphological characteristics of differential diagnosis	Reason for exclusion/inclusion	References
Caffey’s disease	Rare condition affecting collagen development.	SPNB on mandible, clavicle and long bones	Exclusion	Self-limiting disease found typically in infants Only.
Pellagra	Vitamin B3 deficiency, causes dermatitis and gastrointestinal problems.	Non-specific lesions, tooth loss, periostitis in lower extremities, costochondral joint fractures.	Exclusion	Does not result in hemorrhaging, NBF at muscle sites points to hemorrhaging.
Rickets	Vitamin D deficiency, causes weak and poor mineralized bones.	Flaring and cupping of costochondral junctions, curved/ bent long bone metaphyses.	Exclusion	Flaring and curving of the long bone shafts no observed.
Anemia	Hypertrophy of hematopoietic marrow in cranial vault.	Cribriform orbitalia	Exclusion	A combination of porosity and NBF observed in the orbital roofs with porosity suggesting hemorrhaging with phases of healing and not a hematoma
Scurvy	Vitamin C deficiency, causes weakness of blood vessels and hemorrhaging	Symmetrical porosity and SPNB, particularly in vascular regions	Inclusion	Lesions observed consistent with morphological characteristics of scurvy

preservation of key diagnostic skeletal elements may have prevented definitive classification and led to some individuals being assigned to the *Consistent with Scurvy* category.

The observed age pattern of scurvy in non-adults may be associated with breastfeeding and weaning practices, as well as increased susceptibility to mortality due to the progressive loss of passive immunity acquired in utero, which declines around three months of age (Lewis, 2018). Isotopic analyses by Toso et al. (2019) indicate that non-adults in the Medieval (7th–11th centuries CE) Iberian Peninsula were fully weaned no earlier than two years of age, and in some cases not until three years. This pattern aligns with other archaeological populations and with recommendations found in contemporary medical treatises (Baumgarten, 2004; Toso et al., 2025). Breastfeeding provides protection against malnutrition and infectious diseases, and after weaning, children become more vulnerable, increasing the risk of illness and mortality (O.N.U., 1984). Consequently, children under seven years of age were likely at higher risk of death from scurvy than older children.

Furthermore, the Antics Jutjats Municipals de Barcelona population had high levels of fertility (Merino and Rissech, 2025), which suggest shorter birth intervals, probably facilitated by the early introduction of weaning foods. The elevated frequency of scurvy cases observed between 1.5 and 7 years of age may be explained by the progressive loss of passive immunity acquired in utero, combined with dietary changes during weaning, and a heightened risk of vitamin C deficiency. On the other hand, as indicated by the results of this study, adults also exhibited scurvy, mostly females, although less frequently than non-adults. This may indicate that the mothers of the affected infants had low vitamin C levels, insufficient to support adequate infant nutrition and possibly their own nutritional requirements. Therefore, the elevated prevalence of scurvy among non-adults at the Antic Jutjats Municipals de Barcelona may be attributed to restricted dietary diversity affecting both children and their mothers, likely driven by environmental and wartime food shortages, which heightened infants' susceptibility to infectious disease and risk of death.

Palaeopathological research on scurvy has largely concentrated on non-adults, in whom lesions are generally more pronounced and readily identifiable (Ortner and Ericksen, 1997; Ortner et al., 1999; Ortner, 2003; Maat, 2004; Mays, 2008). In contrast, in adults such lesions are less frequent and more variable, complicating their identification (Mays, 2008). Moreover, as Geber and Murphy (2012) state, the individuals who do not manifest skeletal evidence of scurvy may paradoxically have been experiencing active vitamin C deficiency at the moment of death and therefore lack osseous signs of recovery. Given that scorbutic skeletal lesions manifest only after the reintroduction of vitamin C (Geber and Murphy, 2012), the evidence observed in individuals from Antics Jutjats Municipals de Barcelona suggests intermittent episodes of food deprivation. This is supported by the presence of both active and remodelled lesions in adults and non-adults, as well as within the same individual, regardless of age, including non-adults aged 7 years. The idea of these intermittent episodes is further supported by comparison with scorbutic frequencies at Antics Jutjats Municipals de Barcelona and populations undergoing agricultural transitions, such as Man Bac (Vlok et al., 2023), where scurvy appears to have been a chronic condition, given its high prevalence among non-adults (>79%).

Under normal conditions, scurvy is uncommon, but rather appears in situations involving human-made or natural disasters, or major changes in subsistence patterns (Bourbou, 2010, 2014). Particularly, war and sieges profoundly alter subsistence systems by isolating populations, limiting dietary diversity, and disrupting food distribution networks. All of this often results in famine, malnutrition, and epidemics. (McCord, 1971; Mays, 2014; Larsen, 2015; Prinzing and Westergaard, 1916).

As explained in the Introduction section, during the Early Medieval period, Barcelona experienced numerous incursions by both Carolingian and Al-Andalus forces (Rodríguez-Picavea-Matilla, 1999). These violent war episodes and sieges from both land and sea (Molina, 1981) disrupted supply chains and destroyed cultivated fields, resulting in food

shortages and famine (Benito-Monclús, 2022). The high percentage of cranial stab wounds (27%) in adults and non-adults of Antics Jutjats de Barcelona (Merino and Rissech, 2025) supports this documented violent period (Rodríguez-Picavea-Matilla, 1999; Benito-Monclús, 2022). On the other hand, the palaeopathological evidence of nutritional deficiencies among the population of Antics Jutjats de Barcelona, as indicated by the presence of scurvy, is in accordance with the described disruptions in supply chains and episodes of famines (Rodríguez-Picavea-Matilla, 1999; Benito-Monclús, 2022).

Antics Jutjats Municipals de Barcelona is an attritional cemetery located outside the city walls, at a considerable distance from the urban centre and without any apparent association with a religious building, an unusual feature for the period. These characteristics might initially suggest that the cemetery was established in response to the wars, for example, as a mass burial ground. However, the cemetery reflects the gradual accumulation of deaths rather than a catastrophic mortality event. This suggests that the mortality pattern at Antics Jutjats Municipals de Barcelona was not primarily driven by conflict-related deaths, but rather by nutritional deficiency diseases, probably as a consequence of prolonged political instability. A prolonged period of war and recurrent famine characterized these centuries (Ballestín, 2015; Benito-Monclús, 2022). In fact, during the Medieval period, Barcelona was involved in a very long (at least three centuries, from the 9th to 11th centuries) bloody war between Islamic and Christian forces (Banks, 1980; Tischler, 2019). This conflict led to violence, famines, sieges, and devastating sacks of Barcelona, during which males were killed and females and children were kidnapped and enslaved (Suñé, 2019). These circumstances severely compromised nutritional health (Cevallos and Rissech, 2026) and likely contributed to the development of scurvy.

Palaeopathological evidence of scurvy in environments capable of growing fresh produce is increasing. For example, scurvy is found in Middle Byzantine Greece (Bourbou, 2010, 2014), prehistoric and historic periods, including Medieval Albania (Kyle et al., 2020), Early Medieval Italy (Paladin et al., 2018), the Pacific Islands (Buckley and Tayles, 2003; Buckley et al., 2014), Southeast Asia (Halcrow et al., 2014; Vlok et al., 2023), and prehistoric Spain (Malgosa et al., 1996; Castilla et al., 2014). The presence of scurvy in Antic Jutjats Municipals de Barcelona suggests malnutrition suggests intermittent periods of intensified food scarcity, interspersed with phases of improved availability. The episodes of heightened scarcity may correspond to periods of siege. These observations are consistent with the results reported by Cevallos and Rissech (2026) in their diachronic study of past populations from the urban city of Barcelona, which suggested that living conditions were particularly challenging during the medieval period.

The Mediterranean diet, compared to that of northern Europe, typically included more vitamin C-rich foods, such as fresh fruits (figs, grapes, and, in later periods, citrus) and vegetables (leafy greens and onions). As a result, scurvy was generally less prevalent, though not absent. During periods of crop failure or economic or political instability, diets became increasingly cereal-based and low in fresh produce, thereby increasing the risk of deficiency. Hence, scurvy in Medieval Mediterranean contexts should be reconsidered as a potentially more common condition than previously thought, particularly during periods of sociopolitical unrest.

5. Conclusions

This study presents palaeopathological evidence of nutritional stress in Early Medieval Barcelona, interpreted in relation to the warfare that characterised this period in this north-eastern city of the Iberian Peninsula.

The evidence from the population recovered at the site of the Antics Jutjats Municipals de Barcelona provides valuable insights into how a community with an active role in regional exchange networks, could also be affected by nutritional deficiencies. Barcelona, in particular, was subjected to several sieges, including the well-documented episode of

985, during which the city remained under siege for several months. Such events, together with the prolonged period of armed conflict spanning nearly three centuries, may have severely disrupted food supplies and living conditions, thereby contributing to the development of scurvy (13.8% of the observable cases) among the affected population.

Further bioarchaeological, isotopic, and palaeopathological analyses may clarify patterns of diet, health, and resilience under sociopolitical and environmental stress. The health impact of Reconquista-related warfare, as in the case of Barcelona, should be examined at the site level, integrating evidence from non-specific stress markers and specific disease diagnoses to assess changes in population health. The partial excavation of the site offers only a limited perspective on the overall assemblage; 115 skeletons were recovered from an estimated total of approximately 460 inhumations. Future analyses of the complete sample will yield a more comprehensive understanding.

CRedit authorship contribution statement

Marta Merino: Writing – original draft, Investigation, Formal analysis, Conceptualization. **Carme Rissech:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization.

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Declaration of Competing Interest

The authors declare no conflicts of interest.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.ijpp.2026.09.001](https://doi.org/10.1016/j.ijpp.2026.09.001).

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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