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5 Violence-related skeletal trauma in the Epi-Jomon period: A case study from the Koboro cave site in

6 Hokkaido, Japan

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23 Running Title:

24 Violence-related trauma in Epi-Jomon Hokkaido

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30 Abstract

31 This study presents two newly identified cases of violent trauma on skeletal remains unearthed at the
32 Koboro cave site in southwestern Hokkaido, Japan. Clear evidence of perimortem trauma was found on
33 cranial (Koboro 1) and postcranial (Koboro 8) bones belonging to an adult male or males aged between
34 25–39 years old. Koboro 1 exhibits two injuries (one blunt force and one semi-sharp force) on its
35 cranium, while two stone projectile points were found embedded in the right ilium and left eighth rib of
36 Koboro 8. With no signs of healing in either case, the Koboro remains show evidence of violent death. In
37 addition to macroscopic observations, computed tomography (CT) and 3D scanning were conducted on
38 the postcranial injuries to estimate the directions of penetration of the stone projectile points in the bones.
39 The position of the projectile lodged in the rib suggests that Koboro 8 was shot in the chest from
40 diagonally right anteriorly, the arrowhead likely puncturing both lungs (or liver and left lung) and
41 possibly piercing the heart. It is unclear whether or not the Koboro 1 and Koboro 8 remains belong to the
42 same individual. These new trauma cases provide further insights into the types of injuries and violence
43 present in Epi-Jomon society (ca. 400 BC – AD 700), and also highlight the importance of re-examining
44 old skeletal collections where evidence of violence may have been overlooked in the past.

45
46 Key words

47 Perimortem injuries, blunt force trauma, projectile trauma, Epi-Jomon culture, Japanese prehistory

57 1. Introduction

58 On the island of Hokkaido in northern Japan, archaeological evidence of lethal conflict has been found
59 on human remains from various periods (e.g., Yamaguchi, 1967; Dodo, 1973; Terazawa, 2006; Braddick,
60 2022; Schulting et al., 2022; Aono et al., 2023). Yet, despite a considerable number of excavated
61 skeletons (Dodo & Kawakubo, 2002), few cases of violent trauma have been reported from the
62 prehistoric Epi-Jomon period. The Epi-Jomon (or Zoku-Jomon in Japanese) was a continuation of the
63 hunter-gatherer Jomon cultural tradition in the northern Tohoku and Hokkaido regions (Mizoguchi,
64 2013). It was roughly contemporaneous with the agricultural Yayoi and Kofun periods elsewhere in
65 Japan. The Epi-Jomon people of Hokkaido maintained a foraging subsistence base, relying mostly on
66 hunting, gathering, and especially fishing (Takase, 2014, 2019). While continuing to make stone tools and
67 bone implements, they also used iron tools imported from the main island of Honshu (Hudson, 1999;
68 Takase, 2014, 2019). Here, we describe two new cases of violence-related perimortem trauma that were
69 identified on Epi-Jomon remains from the Koboro cave site during re-examination of the skeletal
70 collection at Hokkaido University School of Medicine.

71

72 2. Materials and Methods

73 Located on the northern coast of Funka Bay (or Uchiura Bay) near Toyoura in southwestern Hokkaido
74 (Figure 1), Koboro cave was carved out of tuffaceous sedimentary rock by wave erosion. With an area of
75 roughly 240m², the irregular rectangular-shaped cave faces south-eastwards towards the Pacific Ocean
76 (Oba et al., 1963). The site was discovered in August 1950 by members of the Hokkaido Date High
77 School local history research club. Led by the club, a one-day trial investigation was conducted in
78 September 1952. This was followed by a more systematic, full-scale excavation in August-September
79 1961 by a team of archaeologists and physical anthropologists from Hokkaido University School of
80 Medicine and Sapporo Medical University (Oba et al., 1963). The excavations uncovered the remains of
81 at least seven incomplete skeletons from inside the cave near its western wall (Point B of the 1961
82 excavation), along with Esan-type pottery (representing the early phase of Epi-Jomon culture in southern
83 Hokkaido), stone tools, bone implements, and terrestrial and marine animal bones (Oba et al., 1963;
84 Nishimoto, 1984).

85 The state of bone preservation and completeness of the Koboro human remains varied. With the
86 exception of Koboro 4 (the only complete skeleton found), the burial conditions and context are unclear

87 as the scattered remains were excavated from sedimentary layers that had been disturbed during later
88 periods (Oba et al., 1963). Radiocarbon dating of the skeletons, however, indicates that most date to the
89 Epi-Jomon (Takigawa et al., 2011; Kubo et al., 2023). In addition to pottery finds from the Final Jomon,
90 Epi-Jomon, and Satsumon periods, the skeletal remains reveal that Koboro cave was utilised for over a
91 thousand years, including for the entirety of the Epi-Jomon (Oba et al., 1963; Kubo et al., 2023).

92 All available human remains unearthed at the Koboro cave site and dated to the Epi-Jomon period
93 were examined at Hokkaido University School of Medicine. Clear evidence of trauma was identified on
94 the cranium of Koboro 1 and on the right ilium and left eighth rib of Koboro 8 through macroscopic
95 observation, recorded in detail, and photographed. The rib and pelvic injuries of Koboro 8 were also
96 analysed using computed tomography (CT, NAOMi-CT 3D-M, RF Co. Ltd., Nagano, Japan) and a 3D
97 surface scanner (EinScan Pro SHINING 3D Tech Co. Ltd., Hangzhou, China) at Sapporo Medical
98 University, in order to estimate the trajectories of the stone projectile points into the bones. The
99 orientation of these bones (when in an upright posture) was determined by superimposing their
100 reconstructed mesh models on an educational model of an articulated skeleton using Rapidform XOS3
101 software (INUS Technology, Inc., Seoul, Korea). Analyze 11.0 software (Mayo clinic, Rochester, MN,
102 USA) was used to observe the CT data, and to reconstruct the mesh models based on the CT data.

103 The remains of Koboro 1 consisted of generally well-preserved but incomplete cranial and facial
104 bones, maxillary and mandibular dentition, and atlas and axis vertebrae. It was one of three skulls found
105 during the 1952 survey (along with stone tools and bone arrowheads). The excavation context of the
106 Koboro 8 remains—a number of well-preserved but fragmentary trunk and limb bones, including a rib,
107 left os coxa, sacrum, right ilium, and a femur—is somewhat ambiguous; they were discovered in a
108 collection of intermingled human and animal bones. A rough sketch of the trial investigation depicting
109 what appears to be a femur beside one of the three skulls (with a mandible present nearby in apparent
110 association), and a handwritten memo from a member of the research club describing the sketched scene
111 imply that these remains were also excavated during the 1952 survey (Kubo et al., 2023). Osteological
112 analysis of the surviving bones and teeth indicated that both Koboro 1 and Koboro 8 were probable male
113 adults, aged between 25–39 years old (Kubo et al., 2023).

114 While labelled separately, similarities in the age, sex, and preservation conditions of the bones, as well
115 as the survival of different skeletal elements seem to support the distinct possibility that the remains of
116 Koboro 1 and Koboro 8 belong to the same individual. Although the uncalibrated radiocarbon dates (2600

117 ± 30 BP for Koboro 1, Takigawa et al., 2011; 2720 ± 26 BP for Koboro 8, Kubo et al., 2023) are
118 sufficiently different to suggest that the remains belong to separate individuals, their interpretation is
119 complicated by the impact of the marine reservoir effect, which increases the uncertainty of the
120 measurements as they may vary even between different elements of the same individual (cf. Schulting et
121 al., submitted). Thus, the possibility that the remains might belong to the same individual cannot be
122 excluded entirely. Moreover, given the ambiguous burial conditions, displaced bones, and post-burial
123 disturbances to the site, it is difficult to ascertain whether Koboro 1 and Koboro 8 were the same
124 individual without conducting DNA analysis of the bones to verify their identity.

125

126 3. Results and Discussion

127 Koboro 1 exhibited two perimortem injuries on its cranium (Figure 2). A partial curvilinear fracture
128 arc is visible on the incomplete frontal bone above the lateral half of the right orbit (Figure 2A). The
129 fracture margin is sharp, and a radiating fracture extends through the orbit socket and across the glabella
130 (Figure 2B, Figure 2C). Internal bevelling is present on the surviving curve with clear patination (Figure
131 2C). This injury is also evident in Figure 2 of Takigawa et al. (2011). It is characteristic of blunt force
132 trauma, such as might be caused by a wooden club. The second injury, an oblong-shaped depressed
133 fracture, was identified on the upper middle occipital bone, slanting diagonally right towards the
134 lambdoid suture (Figure 2D). The force of the blow perforated the inner table, and sent multiple oblique
135 fracture lines radiating across the occipital bone (Figure 2D, Figure 2E). There is clear internal bevelling
136 and patination (Figure 2F). The more angular fracture margins suggest that this semi-sharp force injury
137 was caused by a percussive implement such as a stone axe (Schulting & Bradley, 2013). In addition to
138 these markers of perimortem trauma (Berryman & Haun, 1996; Boylston, 2000; Fleming-Farrell et al.,
139 2013; Kimmerle, 2014; Martin & Anderson, 2014; Kranioti, 2015; Ubelaker, 2015), the lack of healing or
140 infectious response at the trauma sites further indicates that the injuries occurred at or around the time of
141 death. Based on the injury locations and characteristics, this individual appears to have been attacked
142 from both the front and rear by one or more assailants. No metal tools were unearthed from the Epi-
143 Jomon layers at Koboro cave. Further analysis is required to determine whether numerous defects found
144 on the posterior parietal and occipital bones are perimortem chop marks (sharp force trauma) or
145 postmortem excavation damage (e.g., examination under a scanning electron microscope should
146 distinguish between a stone and metal tool).

147 The precise tool-weapon that inflicted two projectile injuries on the postcranium of Koboro 8 is more
148 apparent, as small fragments of translucent dark stone (most likely obsidian) arrowheads were found
149 embedded in bone (Figure 3). One is located in the left eighth rib, near the angle and costal groove on the
150 vertebral end, which penetrated to the posterolateral side leaving an overhanging bone fragment (Figure
151 3A-D). The direction and angle of entry of the arrow into the body is difficult to determine accurately, as
152 the apex of the projectile point was lost, and most bones of the thorax that may have been struck were not
153 preserved. The position and shape of the injury, however, suggests that the victim was shot in the chest
154 from diagonally right anteriorly, the arrow likely puncturing both lungs (or liver and left lung) and
155 possibly piercing the heart. The other arrowhead pierced approximately 8mm into the lateral right ilium,
156 but did not penetrate to the medial side (Figure 3E-G). The base of the projectile broke off, leaving
157 2.5mm protruding from the outer surface of the bone. The orientation of this embedded arrowhead (with
158 its apex still intact) suggests that it entered from the right side, tearing the gluteus maximus and/or medius
159 as it stuck in the ilium. The absence of healing indicates that these injuries also occurred perimortem, and
160 are associated with the cause of death. Additionally, there is a circular perforation to the middle of the left
161 ilium that is assumed to be postmortem damage, though the thinness of the bone here makes it difficult to
162 identify any potential perimortem injury.

163 As mentioned above, whether the bones of Koboro 1 and Koboro 8 belong to the same individual is
164 unclear. If so, then this individual sustained at least four lethal injuries, indicative of excessive violence.
165 Cases of overkill are extremely rare from the Jomon period. Perhaps the best known example is that of an
166 elderly male (skeleton 7) from the Final Jomon Hobi shell midden site in Aichi Prefecture. He suffered
167 seven or eight predominantly blunt force perimortem injuries to his cranium from a brutal attack by
168 several assailants (Suzuki, 1975; Braddick, 2022). If not, then these new, separate trauma cases provide
169 further insights into the types of injuries and violence present in Epi-Jomon society (ca. 400 BC – AD
170 700). Considering their location and characteristics, the perimortem injuries to Koboro 1 and Koboro 8
171 were caused intentionally. Similar skeletal evidence of violence has been discovered at the neighbouring
172 Epi-Jomon sites of Usu-Moshiri (formerly Usu-10) and Minami-Usu 6 (see Figure 1 for their locations).
173 At the former, an obsidian arrowhead point was found embedded in the right femoral head of an adult
174 male (Matsumura, 1989), while at the latter an adult female cranium exhibited a perimortem blunt force
175 injury (Dodo, 1983). The motives for these prehistoric violent incidents are unknowable, but may have

176 revolved around intergroup disputes over hunting/fishing territories, or interpersonal reasons such as theft
177 of property, jealousy, or revenge for real or perceived slights.

179 4. Conclusions

180 In sum, regardless of the potential association between Koboro 1 and Koboro 8, this case study
181 provides two additional, previously unreported cases of violence-related skeletal trauma from Epi-Jomon
182 sites in Hokkaido. It also highlights the importance of re-examining the skeletal collections of museums
183 and academic institutions for evidence of violence which may have been overlooked in the past.

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263 Japanese).
- 264

265 Figure Legend:

266 Figure 1. Geographic locations of the Epi-Jomon sites in Hokkaido discussed in this paper.

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268 Figure 2. Blunt force and semi-sharp force perimortem injuries on the Koboro 1 cranium. A. Partial
269 curvilinear fracture arc (long diameter 24.8mm) on the frontal bone above the right orbit (indicated by the
270 arrow). B. Close up of A. (radiating fracture indicated by the arrow). C. Internal surface of B. showing
271 bevelling (indicated by the arrows), patination, and the radiating fracture through the orbit socket
272 (indicated by the bracket). D. Penetrating fracture (20.8mm x 8.4mm) on the upper middle occipital bone
273 (radiating fracture lines indicated by the arrows). E. Endocranial surface of D. F. Close up of E. showing
274 internal bevelling (indicated by the arrows) and patination. Photographs taken by D. Kubo and R.J.
275 Schulting.

276

277 Figure 3. Two projectile perimortem injuries on the postcranial remains of Koboro 8. A. Arrowhead
278 embedded in the left eighth rib near the angle, anteromedial aspect (entry hole 6.5mm x 2.2mm, arrow
279 points to the projectile). B. Superoposterolateral aspect of A. (exit hole ca. 8mm x 4.5mm). C. Closeup of
280 A. D. Closeup of B. E. Arrowhead (total length 10.5mm) embedded in the lateral right ilium (7.4mm x
281 3.2mm). F. 3D scan of the Koboro 8 remains superimposed on an articulated skeletal model to show their
282 anatomical position, posterior aspect (arrows point to the projectiles). G. CT scan of E. showing the
283 embedded arrowhead point (transverse plane, right side is lateral, left side is medial). Photographs taken
284 by D. Kubo and R.J. Schulting.