Interdisciplinary studies tackling the Jomon social structure

Newly discovered banjo-shuseki-bo (square-shaped bone-pile burial) human bones from the Final Jomon Period Hobi shell-mound site, Aichi Prefecture, Japan

Soichiro Mizushima1*, Osamu Kondo2, Nobuo Shigehara3, Yasuhiro Yamada4

1Department of Anatomy, St. Marianna University School of Medicine, 2-16-1 Sugao, Miyamae-ku, Kawasaki-shi, Kanagawa 216-8511, Japan
2Department of Biological Sciences (Anthropology), Graduate School of Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
3Center for Archaeological Operations, Nara National Research Institute for Cultural Properties, 2-9-1 Nijo-cho, Nara-shi, Nara 630-8577, Japan
4Department of Philosophy, History and Cultural Studies, Graduate School of Humanities, Tokyo Metropolitan University, 1-1 Minami-Osawa, Hachioji-ku, Tokyo 192-0397, Japan

Received 27 September 2021; accepted 31 January 2022

Abstract Banjo-shuseki-bo, unique accumulations of human bones among Jomon collective secondary burials, have been found intensively in the Final Jomon Period Mikawa region of Aichi Prefecture. At the Hobi shell-mound site in Tahara City (c. 3000–2400 BP), two cases of banjo-shuseki-bo have been so far documented, referred to as Ichi-go-shuseki (Accumulation No. 1) and B-shuseki (Accumulation B). During the 2010–2013 excavations at the Hobi site, we discovered a new case of banjo-shuseki-bo (named Accumulation 2010) and retrieved all the bones (1331 samples). Here we report anthropological data from this unpublished sample and confirm the differences between the three accumulations (2010, No. 1, and B) and individual skeletons of primary burial origin from the same archaeological site. The Accumulation 2010 bones contained 13 individuals in total: eight adult males; one subadult (late adolescent) male; three adult females; and a 1.5-year-old child of undetermined sex, thus indicating a male-dominated group. It was also found that the body-part composition of Accumulation 2010 exhibited a site-specific bias, specifically skewed toward the lower limb bones such as the femur and tibia, almost equivalent to those of Accumulations No. 1 and B. In comparisons of the femur between the banjo-shuseki-bo human bones and individual skeletons, no systematic size differences were found in either sex; however, the male femora from the three (2010, No. 1, and B) accumulations showed a significantly/near-significantly greater pilasteric index than those of the individual skeletons. One possible explanation for why the femur pilasteric structure was so developed in the Hobi banjo-shuseki-bo males is that people who worked in physically demanding labor during their lives or a specific kinship group may have been chosen as the subjects of the banjo-shuseki-bo burials.

Key words: Jomon, Hobi shell-mound, banjo-shuseki-bo, pilasteric femur, bone cut mark and trauma

Introduction

The Jomon, prehistoric hunter-gatherers in Japan, are known to have frequently reburied multiple human remains in one spot during the Late to Final Jomon Periods (c. 4400–2400 BP), creating a bone accumulation known as ta-itai-
saiso-bo, or collective secondary burial (Habu, 2004). The Tagara shell-mound site (Miyagi), the Sanganji shell-mound site (Fukushima), and the Kosaku shell-mound site (Chiba) are all well-known large-scale examples of this type of burial, as is the Nakatsuma shell-mound site (Ibaraki), which is an extreme case with remains of approximately 100 individuals deposited in a single pit (Nishimoto, 1995; Shitara, 2001; Harunari, 2002; Yamada, 2008). Over the past two decades, archaeologists have variably interpreted such Jomon reburial behavior in terms of its social significance. Yamada (2008), for example, proposed that when several small tribe-groups formed a large-scale settlement, each group may have transported their ancestors’ bones and reburied them together in one spot to reduce social tensions...
that arose there. In a case study of the Gongenbara shell-mound site (Chiba), Watanabe (2001) investigated the settlement structure and tooth morphology of the unearthed collective human bones, and inferred that the bone assemblage may have played a purpose in integrating two previously exclusive tribes.

The *banjo-shuseki-bo*, or square-shaped bone-pile burial (Habu, 2004), is a unique type of collective secondary burial and has been found intensively in the Final Jomon Period Mikawa region of Aichi Prefecture (Harunari, 2002; Masuko, 2019). The shape of a *banjo-shuseki-bo* is not always uniform, but shared features include a polygonal assembly of limb bones as an outer frame, partial skulls arranged in each corner, and fragmentary bones deposited within the frame. The first two cases were discovered in 1922 by the anthropologist Kenji Kiyono at the Yoshigo shell-mound site in Tahara City. He named them *jinkotsu-no-banjo-shuseki*, literally translated as a ‘board’-shaped accumulation of human bones, because the limb bones were arranged in a square pattern similar to a Japanese *shogi* (go) game board (Kiyono, 1925). Subsequently, one more case was discovered at the Yoshigo shell-mound site, two at the Hobi shell-mound site, and two at the Ikawazu shell-mound site in Tahara City; one at the Miyahigashi Ichigo shell-mound site and one at the Motokariya shell-mound site in Kariya City; and one at the Karekinomiya shell-mound site in Nishio City (Nakayama, 1952; Kato, 1968; Ehara et al., 1972, 1988; Hisanaga and Saito, 1975; Ogata et al., 1981). Thus, the total number of *banjo-shuseki-bo* specimens unearthed in Aichi Prefecture is ten, spread over six archaeological sites (Kamishikiryō, 1987).

*Banjo-shuseki-bo* is a reburial of human remains, as initially pointed out by Kiyono (1925); the placement of the bones in an anatomically disordered and disjointed manner undoubtedly substantiates this interpretation. However, archaeologists disagree about whether the bones handled by the Jomon were discovered by chance or deliberately excavated for reburial (Kiyono, 1925; Nakayama, 1952; Hisanaga and Saito, 1975; Hayashi, 1977; Ishikawa, 1981; Ogata et al., 1981; Kamishikiryō, 1987; Harunari, 2002). Regarding the reason why the Jomon people created the *banjo-shuseki-bo* graves, some speculate that it could be a burial custom for a specific social group, such as intermarried people from out of the settlement (Harunari, 2002), or it could relate to a particular cause of death (Kamishikiryō, 1987). However, we have yet to reach a clear consensus on this issue. Furthermore, few researchers have provided anthropological information on the people buried in these accumulations, such as the number of individuals, sex and age compositions, and their physiques.

Previously, two types of human bone accumulation were reported at the Final Jomon Period Hobi shell-mound site (c. 3000–2400 BP): *A-shuseki*, here referred to as Accumulation A, consisting of bones from approximately 20 individuals deposited in an irregular and disorganized manner; and *Ichi-go-shuseki* and *B-shuseki*, referred to as Accumulation No. 1 and Accumulation B, respectively, which were both smaller in size than Accumulation A but possessed the typical *banjo-shuseki-bo* features (Hisanaga and Saito, 1975; Endo and Endo, 1979). Mizushima, one of the authors of the present study, conducted an anthropological survey of the latter two (No. 1 and B) human bone accumulations and reported some data, such as the minimum number of individuals, bone identification, age and sex compositions, and morphological characteristics of the femur (Mizushima et al., 2004). Their study demonstrated that the male femora of Accumulations No. 1 and B have a significantly developed linea aspera, forming a pilasteric structure far exceeding that of the femora of primary burial origin excavated from the same Hobi site. Recent excavations at the Hobi shell-mound site conducted by the archaeologist Yasuhiro Yamada and colleagues from 2010 to 2013 discovered a new case of *banjo-shuseki-bo* and collected the human bones (referred to as Accumulation 2010).

In this study, we present anthropological data from this unpublished *banjo-shuseki-bo* human bone sample and confirm the difference between the three accumulations (2010, No. 1, and B). Furthermore, we explain the characteristics of the subjects involved in the *banjo-shuseki-bo* graves and explore an aspect of reburial behavior in the Final Jomon Period by comparing them to bones of primary burial origin from the same archaeological site.

**Materials and Methods**

The Hobi shell-mound site is located on the Atsumi Peninsula, Aichi Prefecture, central Honshu, on a plateau west of the Memeda River (Figure 1). Previous surveys revealed that the archaeological site consists of three shell-mounds, distributed in a circular pattern, currently called Shell-mounds A, B, and C (Masuyama, 2017). During the excavation in 2010, we discovered a new *banjo-shuseki-bo* human bone accumulation at lat 34.62547°N and long 137.09524°E (JGD 2011) within the Shell-mound B area. The burial pit was oval in shape, with a surface area of approximately 3.3 m × 2.3 m and a height of 0.4 m, which is larger than the ten previously reported *banjo-shuseki-bo* examples. The accumulation of human bones was described as follows: limb bones assembled into multiple rectangular and parallelogram shapes to form an outer frame; partial skulls placed around each corner; and numerous fragmentary bones, such as clavicles, scapulae, ribs, vertebrae, and coxal bones, contained inside the frame (Figure 2).

Each bone was systematically numbered for registration throughout the collection process, and a total of 1331 specimens were retrieved. In the restoration, we searched for possible conjoint specimens, and determined the bone identification and right/left side. Individual interpretations were carried out only on well-preserved bones; fragmented bones, which caused disagreements among researchers, were avoided. We analyzed 79 skulls, 10 clavicles, 17 scapulae, 15 humeri, 11 radii, 16 ulnae, 19 coxal bones, 25 femora, 23 tibiae, and 18 fibulae, based on the human bone collection reorganized according to the above procedure. All recovered human bones are now temporarily under the care of Tokyo Metropolitan University for research purposes (September 2021).

The comparative sample consisted of bones from Accumulations No. 1 and B, both of which were discovered and collected in 1965 by Haruo Hisanaga and Hisashi Suzuki.
NEWLY DISCOVERED BANJO-SHUSEKI-BO HUMAN BONES

Hisanaga and Saito (1975). Mizushima et al. (2004) published anthropological data for these accumulations, including the minimum number of individuals, bone identification, age and sex compositions, and morphological characteristics of the femur; these data were used for comparison. Another comparative sample was adult Jomon individual skeletons of primary burial origin excavated from the Hobi shell-mound site in 1922–1965, consisting of 14 males and 17 females. For this sample, we chose only specimens with all the epiphyses entirely fused and determined their sex using pelvic morphology. All of the comparative samples are currently under the care of The University Museum, The University of Tokyo, and their details are available in the museum catalogs (Endo and Endo, 1979; Suwa et al., 2003, see Appendix.

Figure 1. Location map of the Hobi shell-mound site: (a) small scale, (b) medium scale, and (c) large scale. In each map, the top corresponds to the north and the bottom to the south. These maps were created by processing vector data from the Geospatial Information Authority of Japan.

Figure 2. Excavation photographs of the banjo-shuseki-bo human bones discovered at the Hobi shell-mound site. (a) The example discovered by Yasuhiro Yamada and colleagues in 2010 (this study). (b) An example, known as Ichi-go-shuseki (Accumulation No. 1), collected by Haruo Hisanaga and Hisashi Suzuki in 1965. Hisanaga and Saito (1975) reported that at the time of excavation, the limb bones were assembled in a hexagonal shape as an outer frame, with the skulls and other bones contained within. (c) An example also collected by Hisanaga and Suzuki in 1965, known as B-shuseki (Accumulation B). The limb bones were arranged in a square pattern, and the skulls were placed in each corner. Note that one corner has been cut off by digging. Photographs: (a) taken by Yasuhiro Yamada; (b) courtesy of Tahara Municipal Museum; and (c) courtesy of The University Museum, The University of Tokyo.
Table uploaded online).

We estimated the minimum number of individuals and the adult/non-adult breakdown based on ten bones (skull, clavicle, scapula, humerus, radius, ulna, coxal bone, femur, tibia, and fibula). Bones with unfused epiphyses, apparent small size, and those with insufficiently developed bone substance were identified as non-adult. We also computed the body-part composition based on the minimum number of individuals from the following five categories: skull; upper major long bones (humerus, radius, and ulna); lower major long bones (femur, tibia, and fibula); coxal bone; and other bones (clavicle and scapula).

For sex determination, Accumulation 2010 lacked adequate amounts of the essential parts of the skull and coxal bone. Instead, we used the femur as a sex-discriminating object, because this bone was more abundant and better preserved than other parts. Because the sizes of Jomon limb bones varied considerably between geographical regions or site locations (Takigawa, 2006), we developed a sex-discrimination criterion based on the adult femora unearthed from the same Hobi site. We chose the adult individual skeletons mentioned above as reference material because their sex could be determined with high reliability using the pelvis. Nakahashi and Nagai (1986) performed sex discrimination on Jomon bones using only the parts most likely to be preserved, and demonstrated practical determination surpassing 80% accuracy with a single measurement item or a combination of multiple ones. Of these, the circumference of the middle femoral diaphysis was shown as one of the items with a consistent and high discrimination rate, strongly supporting the utility of femoral shaft size for sex determination. Thus, we established a sex discriminant-function equation (Pons, 1955) based on the anteroposterior and mediolateral midshaft diameters of the femora of the individual skeletons and then applied it to the Accumulation 2010 samples to determine their sex. As a sex discriminant function, the following equation was obtained: \( y = 0.500 \times \text{anteroposterior midshaft diameter} + 0.211 \times \text{mediolateral midshaft diameter} - 19.383 \) (Wilks’s \( \lambda \): 0.335; approximate \( F \)-value: 27.753; \( P < 0.001 \); and discrimination rate: 100%). Note that a positive value of \( y \) indicates a male, whereas a negative value denotes a female. For individuals for whom the discriminant function equation could not be applicable, we alternatively used the size of the femoral head (mediolateral head diameter) to determine their sex.

We obtained eight linear measurements as femur size indicators and the pilasteric index (100 × anteroposterior midshaft diameter ÷ mediolateral midshaft diameter) as the shape of the middle section of the diaphysis, using the Martin technique (Baba, 1991). A two-sample \( t \)-test with no assumption of the equality of variance (the so-called Welch method) was adapted to evaluate group differences. All statistics were run on the SYSTAT 13 software (SYSTAT Software, Inc.), and were considered statistically significant when \( P < 0.05 \).

Results

The minimum number of individuals (MNI) for each bone site for the \textit{banjo-shuseki-bo} human bones is listed in Table 1. The greatest MNI of Accumulation 2010 was for skulls, with at least 13 individuals identified, 12 of which were adult equivalents and the remaining one a non-adult. The femur and tibia were the second and third most abundant bones, with 12 individuals each. In the femur, ten of the 12 individuals were classified as adult equivalents, one as a late adolescent subadult, and one as an infant, estimated to be 1.5 years old based on a maximum diaphyseal length of 156 mm (Scheuer and Black, 2000). From this information, the Accumulation 2010 human bones are considered to be a mix of at least 13 individuals, including two non-adults. Accumulations No. 1 and B, in contrast, did not contain many skulls but exhibited the greatest MNI values for femurs, with 14 individuals for Accumulation No. 1 (including three non-adults) and six individuals for Accumulation B (including one non-adult). The body-part composition for the \textit{banjo-shuseki-bo} human bones based on the minimum number of individuals is illustrated in Figure 3. In Accumulation 2010, the lower major long bones were the most abundant type (36%), whereas the upper major long bones were less abundant (24%). This tendency for lower limb bone predominance was also common, to varying degrees, in Accumulations No. 1 and B. Therefore, the bones interred in the three \textit{banjo-shuseki-bo} graves at the Hobi shell-mound site were likely to have a site-specific bias that was particularly skewed toward lower limb bones.

| Bone site     | Accumulation 2010 | Accumulation No. 1* | Accumulation B* |
|---------------|-------------------|---------------------|-----------------|
|               | MNI Adult Non-adult | MNI Adult Non-adult | MNI Adult Non-adult |
| Skull         | 13 12 1            | 4 4 0               | 3 3 0           |
| Humerus       | 7 6 1              | 6 5 1               | 2 2 0           |
| Radius        | 7 7 0              | 5 5 0               | 3 3 0           |
| Ulna          | 8 7 1              | 3 3 0               | 1 1 0           |
| Coxal bone    | 8 7 1              | 3 3 0               | 2 2 0           |
| Femur         | 12 10 2            | 14 11 3             | 6 5 1           |
| Tibia         | 12 11 1            | 7 6 1               | 5 4 1           |
| Fibula        | 10 9 1             | 6 6 0               | 3 3 0           |
| Clavicle      | 8 8 0              | 2 2 0               | 1 1 0           |
| Scapula       | 8 8 0              | 2 2 0               | 1 1 0           |

* Adapted from Mizushima et al. (2004).
The eight linear measurements, the pilasteric index, and the results of sex determination on the Accumulation 2010 femora are provided in Table 2. The sex discriminant-function equation could be applied to the femora of nine adult individuals, resulting in seven males and two females being identified. The two femora to which the discriminant function equation could not be applied (B475 subadult and B841 adult) were regarded as males because their femoral head size was well within the variation of males (see also Figure 4). Thus, the Accumulation 2010 femora can be estimated to have come from eight adult males, one subadult (late adolescent) male, two adult females, and a 1.5-year-old infant of unknown sex, indicating a male-dominated population. It is noteworthy that visual observation of the coxal bone specimens confirmed three adult females within. In summary, the Accumulation 2010 bone pile was composed of eight adult males, three adult females, one subadult male, and one infant of undetermined sex, a total of 13 individuals.

The basic statistics of the linear measurements and the significance probability of the sex differences for the femora are shown in Table 2. Underlining indicates estimated values. Measurements are in millimeters, except for the pilasteric index, which is given as a percentage.
from the banjo-shuseki-bo human bones and individual skeletons are provided in Table 3. A box plot of the six representative morphological indicators of the femur is provided in Figure 4. In comparisons between the banjo-shuseki-bo human bones and individual skeletons, no systematic size differences were found in both sexes. However, it is noteworthy that the femora from both the 2010 and 1965 accumulation males exhibited a significantly/near-significantly greater pilasteric index than those of the individual skeleton males (Accumulation 2010, $P = 0.085$; Accumulations No. 1 and B, $P < 0.01$; Accumulations 2010 and No. 1 and B, $P < 0.01$). This finding suggests that in the male banjo-shuseki-bo femora, the anteroposterior midshaft diameter became more elongated than the mediolateral midshaft diameter, implying a more significant development of the linea aspera region on the posterior surface of the diaphysis.

**Discussion**

The banjo-shuseki-bo human bones discovered in 2010 contained at least 13 individuals (eight adult males, three adult females, one male in his late teens, and one child of...
Table 3. Basic statistics and sex differences for the femora from the banjo-shuseki-bo human bones and individual skeletons

| Measurement item with Martin No. | Individual skeletons | Accumulation 2010 | Accumulations No. 1 and B (integrated) |
|----------------------------------|----------------------|-------------------|----------------------------------------|
|                                  | Male     | Female | Sex difference | Male     | Female | Sex difference | Male     | Female | Sex difference |
| 1. Maximum length                | 7        | 10     | 3 — — — —       | 422.0    | —      | — — — — —       |
|                                  | Mean     | 415.0  | 390.0 P < 0.01  | 422.0    | —      | — — — — —       |
|                                  | SD       | 10.4   | 15.1 — — — — — — | 15.6      | —      | — — — — — — — — — |
| 3a. Trochanteric length          | 10       | 9      | 1 — — 2 1       | 387.0    | —      | — — — — — — — — — |
|                                  | Mean     | 396.6  | 373.2 P < 0.01  | 387.0    | —      | — — — — — — — — — |
|                                  | SD       | 10.8   | 15.8 — — — — — — | 10.8      | —      | — — — — — — — — — |
| 6. Anteroposterior midshaft diameter | 14      | 17     | 7 2 7 7         | 31.6     | 23.9  P = 0.162 | 34.5  26.4 P < 0.001 |
|                                  | Mean     | 30.3   | 25.8 P < 0.001  | 30.3     | 25.8  P = 0.162 | 34.5  26.4 P < 0.001 |
|                                  | SD       | 1.9    | 1.6 — — — — — — | 1.9      | 1.6   | — — — — — — — — — |
| 7. Mediolateral midshaft diameter | 14      | 17     | 7 2 7 7         | 27.1     | 24.8  P < 0.001  | 27.1  24.8 P < 0.001  |
|                                  | Mean     | 27.1   | 24.8 P < 0.001  | 27.1     | 24.8  P < 0.001  | 27.1  24.8 P < 0.001  |
|                                  | SD       | 1.6    | 1.3 — — — — — — | 1.6      | 1.3   | — — — — — — — — — |
| 10. Anteroposterior diameter of proximal shaft | 12      | 15     | 6 — — — —       | 25.4     | 22.2  P < 0.001  | 25.4  22.2 P < 0.001  |
|                                  | Mean     | 25.4   | 22.2 P < 0.001  | 25.4     | 22.2  P < 0.001  | 25.4  22.2 P < 0.001  |
|                                  | SD       | 1.6    | 1.1 — — — — — — | 1.6      | 1.1   | — — — — — — — — — |
| 18. Mediolateral head diameter   | 12       | 15     | 6 — — — —       | 45.9     | 40.7  P < 0.001  | 45.9  40.7 P < 0.001  |
|                                  | Mean     | 45.9   | 40.7 P < 0.001  | 45.9     | 40.7  P < 0.001  | 45.9  40.7 P < 0.001  |
|                                  | SD       | 2.0    | 1.3 — — — — — — | 2.0      | 1.3   | — — — — — — — — — |
| 19. Bicondylar width             | 4        | 5      | 2 — 2 2 —       | 75.5     | 69.8  P < 0.01   | 75.5  69.8 P < 0.01   |
|                                  | Mean     | 75.5   | 69.8 P < 0.01   | 75.5     | 69.8  P < 0.01   | 75.5  69.8 P < 0.01   |
|                                  | SD       | 1.4    | 2.3 — — — — — — | 1.4      | 2.3   | — — — — — — — — — |
| 22. Anteroposterior diameter of lateral condyle | 7       | 11     | 3 — — — — — — — | 59.5     | 54.7  P < 0.01   | 59.5  54.7 P < 0.01   |
|                                  | Mean     | 59.5   | 54.7 P < 0.01   | 59.5     | 54.7  P < 0.01   | 59.5  54.7 P < 0.01   |
|                                  | SD       | 2.5    | 2.4 — — — — — — | 2.5      | 2.4   | — — — — — — — — — |
| Pilasteric index                 | 14       | 17     | 7 2 7 7         | 112.0    | 104.2 P < 0.01  | 121.5 96.1 P < 0.05  |
|                                  | Mean     | 112.0  | 104.2 P < 0.01  | 112.0    | 104.2 P < 0.01  | 112.0 96.1 P < 0.05  |
|                                  | SD       | 8.1    | 7.2 — — — — — — | 8.1      | 7.2   | — — — — — — — — — |

Measurements are in millimeters, except for the pilasteric index, which is given as a percentage. Adapted from Mizushima et al. (2004).

Figure 5. Cut marks and an incised object in the proximal femora. (a) Cut marks on the proximal shaft of the right femur (No. B1056) and on the neck of the right femur (No. B619). (b) An incised object (separated into two parts) in the head of the right femur (No. B1026). The trauma extends approximately 18.6 mm long and 6.7 mm deep, on the basis of computed tomography (CT) measurement. The CT image was captured using the microfocal X-ray CT system (TXS225-ACTIS, Tesco Corp., Tokyo, Japan) at The University Museum, The University of Tokyo.
approximately 1.5 years of age); thus, the age composition is highly skewed toward adult males. However, the prevalence of adult males is not observed in the other cases from the same archaeological site. Accumulation No. 1 (14 individuals overall) contains four adult males, six adult females, one adult of undetermined sex, and three non-adults, indicating a preponderance of adult females. Moreover, Accumulation B (six individuals overall) consists of three adult males, two adult females, and one non-adult, and has a sex ratio of almost 50:50 (Mizushima et al., 2004).

The sex and age compositions estimated in the present study further indicate that the people selected for the banjo-shuseki-bo reburial were not of a specific sex or age. Except for the Hobi shell-mound site, information on sex and age for the banjo-shuseki-bo human bones was limited, sporadically reporting the inclusion of males or a single child (Nakayama, 1952; Ehara et al., 1972, 1988; Ogata et al., 1981; Harunari, 2002), but not mentioning any presence of adult females or a mix of adults and non-adults. Thus, further research is strongly encouraged to reveal the characteristics of the banjo-shuseki-bo human bone samples.

Scholars initially assumed that the banjo-shuseki-bo graves resulted from the Jomon’s accidental discovery of human bones and their reburial (Kiyono, 1925; Nakayama, 1952). However, this ‘coincidence’ theory is unsupported because this type of burial has been confirmed exclusively in Aichi Prefecture during the first half of the Final Jomon Period; in addition, as demonstrated by our research, a large number of human bones were included in a single reburial. Given that well-preserved lower limb bones were selectively used to create the outer frame for the banjo-shuseki-bo grave, Jomon people most likely prioritized lower limb bones when collecting human bones and making the accumulation. Taking into consideration the estimated scale of the reburials and the emphasis on lower limb bones, it is more plausible that the banjo-shuseki-bo graves resulted from deliberate excavation and reburial behavior by the Jomon people (Hisanaga and Saito, 1975; Ishikawa, 1981).

Cut marks on two pieces of the right femur (Nos. B619 and B1056) are worth mentioning for their relevance to the reburial behavior of Accumulation 2010 (Figure 5a). These artificial cuts are thought to be proof that the creators of the banjo-shuseki-bo grave purposefully severed ligaments and connective tissues around the hip joint, implying that bones with soft tissue may have been reburied as well. In other words, this evidence might indicate that the Jomon people purposefully exhumed some bodies relatively soon after their primary burials and extracted their bones for use in the banjo-shuseki-bo creation. Another noteworthy observation is an unidentifiable object deeply incised along the head-neck border of one right femur (No. B1026, Figure 5b). The shape of this object, revealed by a preliminary computed tomography scan, is long and flaky, but we could not determine it to be a stone tool fragment from its appearance, nor could we deny the possibility of it being bone or shell material. The trauma on the femur corresponds to the inside of the hip joint in vivo, and it shows no obvious healing indications on the surface or in the internal image. Therefore, this trauma is classified as a postmortem injury. We assume that this incised object is related to the creation process of the banjo-shuseki-bo grave, and we intend to study this fragment further in the future.

In this study, a comparison of femora between the banjo-shuseki-bo human bones and individual skeletons revealed no systematic size differences in either sex. However, we also discovered a more developed pilaster (cross-sectional shape more elongated in the anteroposterior direction) in the banjo-shuseki-bo males. Even when comparing the femur pilasteric index with the range of Jomon male averages (112.6–117.2 from Takigawa, 2006), that of the banjo-shuseki-bo males in the present study is more prominent. This pilasteric feature of the Jomon femur is believed to have resulted from their hunter-gatherer lifestyle, the intense muscle activity involved in this lifestyle, and the resulting significant bending stress on the femur in the anteroposterior direction (Kimura and Takahashi, 1982; Yamaguchi, 1982). In addition, experimental studies in myostatin-deficient (excessively muscular hypertrophied) mice have demonstrated that bone accretion occurs in the enthesis (connection between tendon, ligament, and bone), which is not directly related to mechanical loading on the long bone diaphysis (Hamrick et al., 2000). Thus, the femoral pilasteric structure may be created and also enhanced in populations with genetically elevated muscle mass, by mechanisms other than so-called ‘bone functional adaptation’ (Pearson and Lieberman, 2004; Ruff et al., 2006). Alternative explanations for why the femoral pilaster was so developed in the Hobi banjo-shuseki-bo males are as follows. (1) This apparent development simply results from sampling error and the male femora with well-developed pilasteric structures merely happened to be gathered in one spot. (2) Because reburial behavior targets human remains from the past, the influence of a generational difference may have resulted in differences seen in the pilasteric structure. (3) Alternatively, and this is purely speculation, it may be possible that the Jomon people wished to select thick and robust ‘material’ for the outer frame of the banjo-shuseki-bo grave, and chose femora with the developed pilasteric structure as good candidates. In this connection, it may be possible to assume an inherent link between the Jomon reburial practices and the pilasteric femur. For example, people who worked in physically demanding labor during their lives might have been chosen, resulting in the collection of bones from those with common bodily characteristics such as robust body shape (pilasteric femur). Alternatively, the bones of people from outside the settlement, as proposed by Harunari (2002), or those of a single kin group, might have been selected; in these cases, the pilasteric femur was a shared feature of these groups. The validity of these hypotheses could be tested to some extent in the future by examining banjo-shuseki-bo and ta-itai-saiso-bo examples from other Jomon archaeological sites.

Acknowledgments

For their photographic materials, we are grateful to Professor Yosuke Kaifu of The University Museum, The University of Tokyo, and Curator Toshiteru Shimizu of Tahara Municipal Museum. We would also like to thank Tadayuki Masuyama, Director of Tahara Municipal Museum, for his insightful comments on the manuscript. The Japan Society
NEWLY DISCOVERED **BANJO-SHUSEKI-BO** HUMAN BONES

Masuko Y. (2019) Banjo shuseki so no sai kento. Jomon Jidai, 30: 147–161 (in Japanese).

Masuyama T. (2017) Hobi kaizuka chosa no rekishi to gaiyo. In: Tahara-shi Kyokuin linkai (ed.), Hobi Kaizuka, Tahara-shi Maizo Bunkai-cho Chosa Hokokusho, 11. Tahara-shi Kyokuin linkai, Aichi, pp. 7–75 (in Japanese).

Mizushima S., Sakaue K., and Suwa G. (2004) Human bones of the Latest Jomon Period Hobi shell mound ‘banjo-shuseki’ burials: a study of bone compositions and morphological characteristics. Anthropological Science (Japanese Series), 112: 113–125 (in Japanese with English summary).

Nakahashi T. and Nagai M. (1986) Sex assessment of fragmentary skeletal remains. Journal of the Anthropological Society of Nippon, 94: 289–305.

Nakayama E. (1952) Jinkotsu. In: Bunkazai Hogi linkai (ed.), Yoshiko Kaizuka, Maizo Bunkazai Hakutsutsu Chosa Hokoku, 1. Bunkazai Hobi linkai, Tokyo, pp. 125–144 (in Japanese).

Nishimoto T. (1995) A doko shitsudo jinkotsu. In: Nakatsuma Kaizuka Hakkotsu Chosadan (ed.), Ibaraki-ken Toride-shi Nakatsuma Kaizuka Hakkotsu Chosa Hokokusho. Toride-shi Kyokuin linkai, Ibaraki, pp. 122–129 (in Japanese).

Ogata T., Morimoto I., Ogata T., Morisawa S., Ikinari M., and Hattori M. (1981) Jinkotsu. In: Nishio-shi Kyokuin linkai (ed.), Karekinomiya Kaizuka, 1: Shizen Ibutsu, Jinkotsu. Nishio-shi Kyokuin linkai, Aichi, pp. 50–78 (in Japanese).

Pearson O.M. and Lieberman D.E. (2004) The aging of Wolff’s ‘law’: ontogeny and responses to mechanical loading in cortical bone. Yearbook of Physical Anthropology, 47: 63–99.

Pons J. (1955) The sexual diagnosis of isolated bones of the skeleton. Human Biology, 27: 12–21.

Ruff C., Holt B., and Trinkaus E. (2006) Who’s afraid of the big bad Wolff? ‘Wolff’s law’ and bone functional adaptation. American Journal of Physical Anthropology, 129: 484–498.

Scheuer L. and Black S. (2000) Developmental Juvenile Osteology. Academic Press, San Diego.

Shitara H. (2001) Taninzu shukotsu so no kento. In: Nihon Kokogaku Kyoky. Gakuseisha, Tokyo, pp. 50–64 (in Japanese).

Symposium Jomon Jin to Kaizuka: Kanto ni Okeru Haniwa no Seisan to Kyokyu. Gakuseisha, Tokyo, pp. 50–64 (in Japanese).

Suwa G., Mizushima S., and Sakaue K. (2003) Database of Jomon Period Skeletal Remains, 1: Hobi, Material Reports No. 52. The University Museum, The University of Tokyo, Tokyo (in Japanese).

Takigawa W. (2006) Inter-regional variation of metric traits of limb bones in Jomon and modern Japanese. Anthropological Science (Japanese Series), 114: 101–129 (in Japanese with English summary).

Watanabe A. (2001) Gongenbara kaizuka no jinkotsu shuseki kara shuraku no jinko kozo wo kangaeru. In: Nihon Kokogaku Kyoky. and Ibaraki-ken Kokogaku Kyokyoka (eds.), Symposium Jomon Jin to Kaizuka: Kanto ni Okeru Haniwa no Seisan to Kyokyok. Gakuseisha, Tokyo, pp. 65–80 (in Japanese).

Yamada Y. (2008) Jinkotsu Shitsudo Rei ni Miru Jomon no Bosei to Shuketsu. Doseisha, Tokyo (in Japanese).

Yamaguchi B. (1982) A review of the osteological characteristics of the Jomon population in prehistoric Japan. Journal of the Anthropological Society of Nippon, 90 (Supplement): 77–90.