Fertility and Survivorship in the Jomon and Yayoi Periods Estimated from Human Bones

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ABSTRACT

Fertility and survivorship among the Jomon and Yayoi peoples were reconstructed by examining human skeletal remains from Jomon and Yayoi sites to acquire basic data for considering the influence of gender in prehistoric societies. Fertility and survivorship were estimated, respectively, based on data from pregnancy parturition scars (PPS) on the ilium and age from the auricular surface. The results indicated that both fertility and mortality were different from one population to another: they were high among Hokkaido Jomon women and low among Kyushu and Yamaguchi Yayoi women. To determine whether these differences were caused by differences in the area (climate or subsistence system) or era (Jomon and Yayoi, that is, by genes or means of subsistence), fertility and survivorship in southern Jomon and central and northern Yayoi populations need to be examined. Analysis not only of paleogeographic data relating to such factors as fertility and survivorship but also anthropological data and archaeological data concerning such factors as subsistence activity, maternal nutrition, and cooperative childcare will bring deeper understanding of prehistoric societies including the role of gender in prehistoric societies.

KEYWORDS: fertility, survivorship, pregnancy parturition scars on the pelvis, Jomon, Yayoi

Paleodemographic analysis is one of the useful methods for understanding prehistoric societies. Several studies have been conducted on population structure in the Jomon and Yayoi periods. Koyama (1984) estimated the population of each sub-period of Jomon from the number of archaeological sites. Nakahashi and Iizuka (1998) estimated the number of immigrants during the Yayoi period through simulations based on analysis of skulls of Yayoi individuals. Watanabe *et al.* (2019) estimated changes in population from the Jomon through the Yayoi period based on the results of genome analysis of modern humans.

As for the study of survivorship in the Jomon period, Kobayashi (1967) was a pioneer study. He examined Jomon skeletal remains and estimated that the average life expectancy at 15 years old was around 16 years old and that no one survived above 65 years old, although many scholars including Kobayashi himself insisted that this estimated age was too low. Nagaoka *et al.* (2008) estimated the age at death in the Jomon population on the basis of examination of Jomon skeletal remains and concluded that the average age was older than that estimated by Kobayashi (1967), positing an average life expectancy at 15 of

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32 years old.

In this paper, I estimate the survivorship and fertility patterns of Jomon and Yayoi populations by conducting a morphological analysis of human skeletal remains. To construct the correct survivorship of prehistoric populations, the skeletal age at death must be correctly estimated; in other words, accuracy is essential. Among the macroscopic methods of calculating age that have been developed, the method using the auricular surface of the ilium is useful because of the robustness of the ilium as found in archaeological sites. Among methods of determining age using the auricular surface of the ilium, the methods adopted by Lovejoy *et al.* (1985) and Buckberry and Chamberlain (2002) were widely used. However, with the method used by Lovejoy *et al.* (1985), it is often difficult to classify each auricular surface into one specific age category, and with the method used by Buckberry and Chamberlain (2002), it is rather difficult to estimate the area that the target feature occupies on the auricular surface. After observing these results, Igarashi *et al.* (2005) established a new method for estimation of adult skeletal age at death from the morphology of the auricular surface of the ilium. This method was based on data from modern Japanese skeletal samples with confirmed data on age. The process of age estimation is as follows. The auricular surface is classified according to the presence or absence of nine surface features and four features of hypertrophy of the structure around the surface of the bone, for a total of 13 variables. The variables are tabulated for each specimen; the estimated age will be automatically calculated by the formula [and a formula was developed for automatically calculating estimated age]. By this method, the process of calculating age is easy because the observers merely need to check for the presence or absence of each target feature, and don't need to estimate the area occupied by the target features as in the method used by Buckberry and Chamberlain (2002) or Lovejoy *et al.* (1985). For this reason, in the present study, I estimated the skeletal age at death from the morphology of the auricular surface by the method developed in Igarashi *et al.* (2005).

In previous studies, the rates of demographic growth in prehistoric populations were estimated by simulation (Nakahashi and Iizuka 1998) or genome analysis (Watanabe *et al.* 2019). If fertility could be estimated from skeletal materials, we could estimate demographic movements from skeletal remains. Indentations in the bone of the preauricular area of female pelvises (Figure 1) have been regarded as the sign of pregnancy and/or parturition, and many scholars have discussed whether the degree of development of such preauricular grooves is associated with the number of pregnancies and/or parturitions or not, and the results differ from one study to another (Igarashi *et al.* 2020). Recently, Igarashi *et al.* (2020) showed that certain types of preauricular grooves could be regarded to be pregnancy parturition scars (PPS) and that the degree of development of the scars could indicate the relative number of pregnancies and parturitions. Igarashi *et al.* (2020) derived their results by developing new identification criteria for the preauricular groove, thereby improving the reliability of fertility

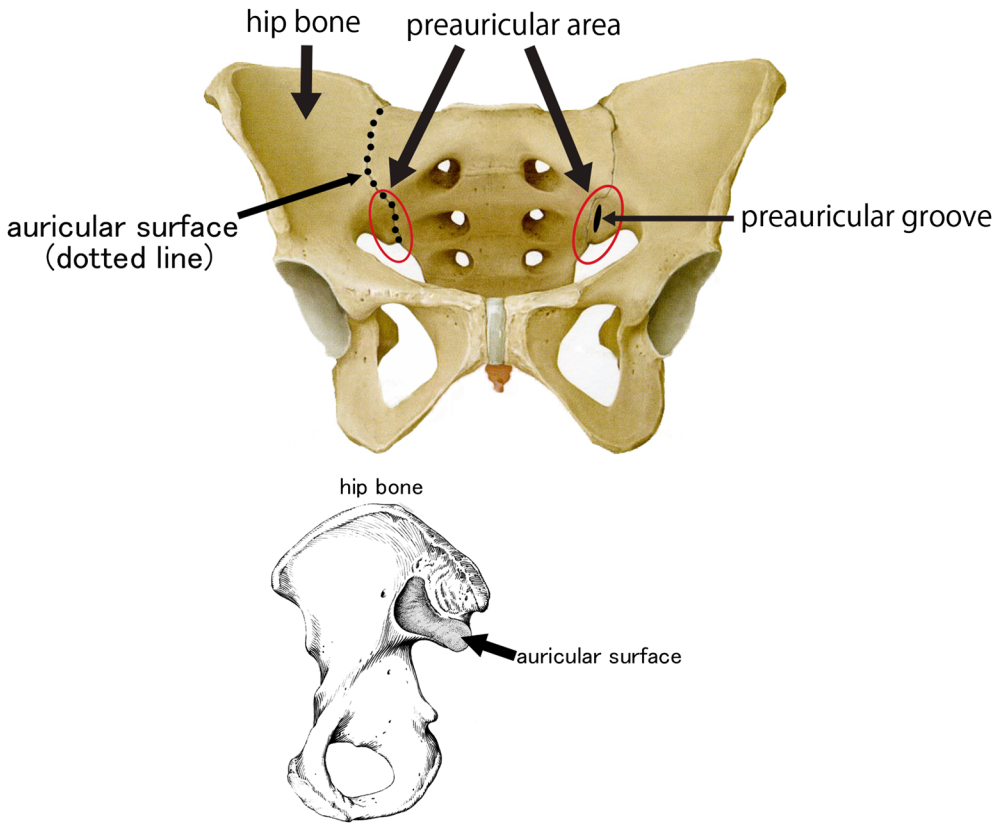

Figure 1. Preauricular area, preauricular groove, and auricular surface

data, and by adopting new statistical methods. It is easy to judge macroscopically the degree of development of PPS by the Igarashi *et al.* (2020) method, which makes it possible for anthropologists and archaeologists to estimate the fertility of prehistoric populations through examination of human skeletal remains. This is the method used in this study of the fertility of the population.

Since fertility can be an indicator of the state of gender in pregnancy, parturition, and childcare, this paper provides basic data for future discussions of the state of gender.

Materials and methods

1. Materials

I used prehistoric human skeletal remains from the archaeological sites. The remains are of adult individuals over 15, namely, whose iliac bone, pubic bone, and ischiac bone

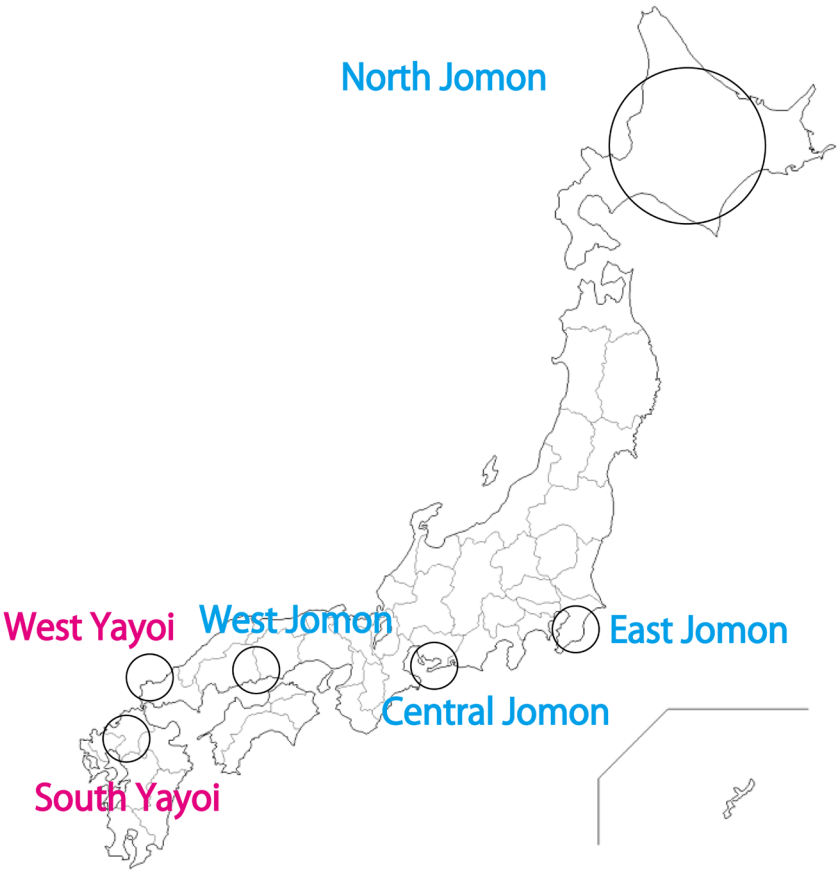

Figure 2. Groups and archaeological sites where samples were excavated

are united, and whose gender was confirmed. The samples were grouped by era and district: North Jomon, East Jomon, Central Jomon, West Jomon, West Yayoi, and South Yayoi (Figure 2). The number of the samples are shown in Table 1. The prefecture and archaeological sites of each group are also shown in Table 1.

2. Methods for estimating fertility

Fertility was determined by observing the preauricular groove on the pelvis of each female in the population. A preliminary survey of the bones of modern humans (Igarashi *et al.* 2020) categorizes the specimens according to the following five preauricular groove types: Type 1 no scars, Type 2 scars that are palpable but not visible, Type 3 perceptible grooves or pits found in both males and females; Types 4 and 5 have perceptible grooves or pits that are specific to females. Since Types 4 and 5 were identified in females only,

Table 1. The number of examined samples, groups, archaeological sites where samples were excavated

Era	Group	Male	Female	Total
Jomon	North	12	16	28
	East	31	32	63
	Central	42	54	96
	West	26	44	70
Yayoi	West	29	35	64
	South	43	42	85
Total		183	223	406

Group	Prefecture	Sites
North Jomon	Hokkaido	Yakumo Kotan Onsen
		Irie Kaizuka
		Kitakogane Kamisaka Kaizuka
		Abashiri Midori Machi
		Takasago Kaizuka
		Kushiro Tenneru Kaizuka
		Kushiro Midorigaoka
		Kushiro Higashikushiro Kaizuka
East Jomon	Chiba	Rokutsuu Kaizuka
		Ubayama Kaizuka
		Kasori Kaizuka
		Arayashiki
		Sonnou Midorimachi syougakkou
		Iitomi
		Ichihara
		Kounodai
		Yoyama
		Soya
		Yahagi
Central Jomon	Aichi	Yoshigo
West Jomon	Okayama	Tsukumo
West Yayoi	Yamaguchi	Doigahama
		Nakanohama
South Yayoi	Fukuoka	Kuma Nishioda
		Nagaoka
		Dobayama
		Kanenokuma
		Aoki
		Hara

the grooves were tentatively determined to be pregnancy parturition scars (PPS). Type 4 indicates that the grooves or pits are weak and its contours are singular, and Type 5 indicates that the grooves or pits are well developed and its contours are double. In accordance with these shapes, Type 4 was regarded as indicating a smaller number of pregnancies and parturitions and Type 5 a larger number. Type 1–3 grooves were found in both females and males and were therefore regarded as caused by factors, such as ligamentous attachment, other than pregnancy and parturition. To examine the relationship between the development of PPS and the total number of pregnancies and parturitions, score 0 was assigned to Types 1–3. A score of 1 was assigned to Type 4, which was assumed to indicate a smaller number of pregnancies and parturitions. A score of 2 was assigned to Type 5, which was thought to indicate a larger number of pregnancies and parturitions. The preauricular areas were observed and the types and scores for the preauricular grooves were assessed in the left and right ilium of females, and then the sum of the left and right scores were taken as that individual's total score (from 0 to 4). Further, total scores of 0 (TS0) were set aside, total scores of 1 and 2 were collectively set as low scores (TSL), and total scores of 3 and 4 were collectively set as high scores (TSH). The relationship between the development of PPS, which is indicated by the individual's total PPS score (TS0, TSL, TSH), and the total number of pregnancies and parturitions was then examined. The results indicated that females with TS0 experienced no pregnancies or parturitions, those with TSL experienced a smaller number of pregnancies and parturitions, and those with TSH experienced a larger number of pregnancies and parturitions. It was also found that the exact number of pregnancies and parturitions could not be estimated from PPS. The details of PPS have been described by Igarashi *et al.* (2020) (https://doi.org/10.1002/ajpa.23961). Based on the above analyses, I decided to use the ratio of TS0, TSL and TSH in each group as an index of the fertility of that group.

3. Estimation of survivorship

Age was estimated for all individuals in each population by observing the auricular surface (Igarashi *et al.* 2005), and a survivorship curve was drawn based on the results.

Results

1. Fertility

The fertility of each group is shown in Figure 3. It was found that the proportion of scores for PPS differed among the populations. For the North Jomon people, no TS0 was observed, and the percentage of TSH was the highest. For the East Jomon people, no TS0 was observed, and the percentage of TSH was the second highest. On the other hand, for the South Yayoi people, no TSH were observed, and the ratio of TS0 was the second

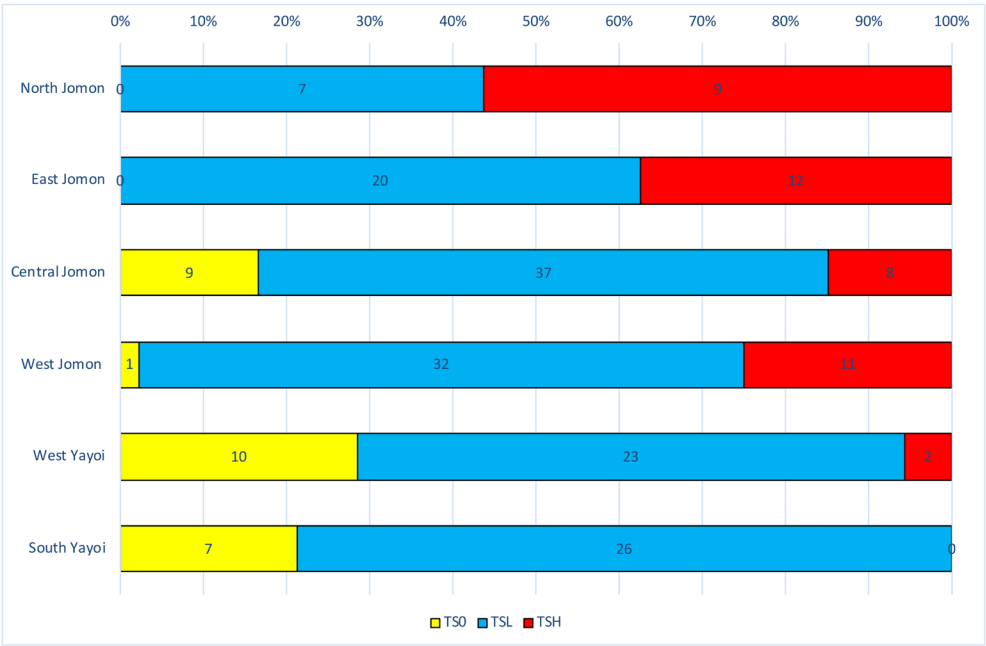

Figure 3. Percentages of the types of pregnancy parturition scars for all groups. Numbers in bar graphs show size of the samples.

highest. For the West Yayoi people, the percentage of TSH was the lowest, and the ratio of TS0 was the highest. The Central Jomon and West Jomon showed an intermediate tendency. Based on Figure 3, it can be estimated that fertility was the highest in the North Jomon population and second highest in East Jomon population; the fertility of South Yayoi and West Yayoi people was lower than for any other populations and was intermediate for the Central Jomon and West Jomon populations.

2. Survivorship

The survivorship curves for each population are shown in Figures 4 and 5. In the case of females (Figure 4), the values for the South Yayoi and West Yayoi people were higher than others after 45 years and were intermediate before 45 years. The values for the North Jomon people were lowest before 45 years and after 65 years, which means that South Yayoi and West Yayoi people tended to have a higher survival rate, that is, longer lives, compared with the other populations studied, and that the North Jomon people tended to have a lower survival rate, that is, shorter lives compared with the other populations. On the other hand, in the case of males (Figure 5), even though North Jomon tended to have the lower survival rate after 25 years old, no clear differences were observed.

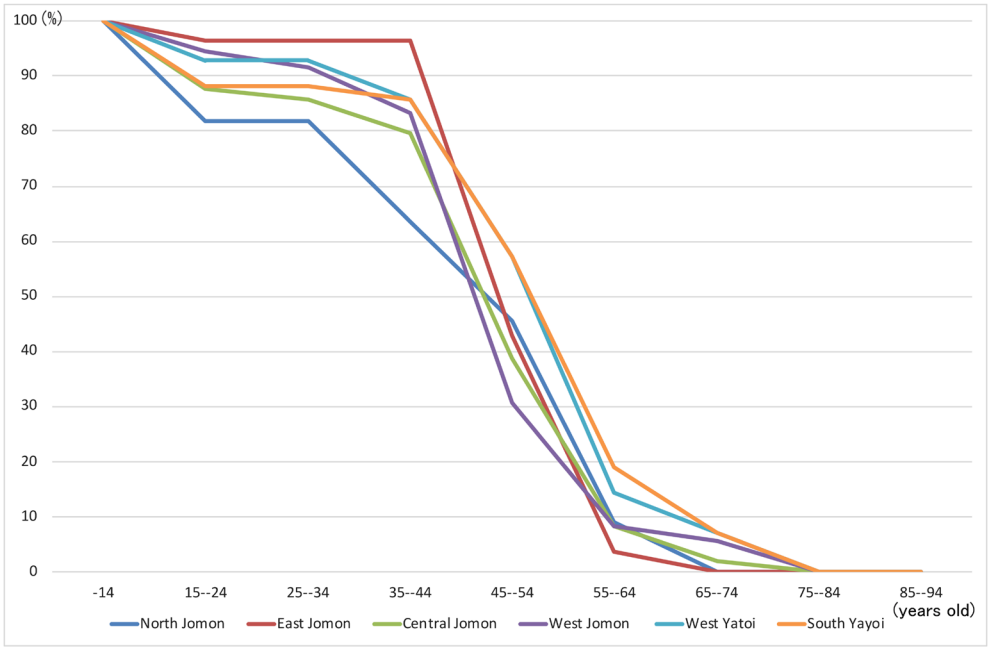

Figure 4. Survivorship of females for all groups. The horizontal axis shows range of age; the vertical axis shows the percentage.

3. Differences in fertility and survivorship patterns

These findings suggest that fertility and survivorship in females differs from one population to another (Figures 3 and 4). The study revealed a pattern in North Jomon females of "high fertility and high mortality," whereas in South Yayoi and West Yayoi females, the pattern was one of "low fertility and low mortality."

Discussion

1. Estimation of skeletal age at death

Kobayashi (1967) showed that for the Jomon people, average life expectancy at 15 years was around 16 years and no one survived above 65 years. Nagaoka *et al.* (2008) estimated the age at death of the people of Jomon by the method of Buckberry and Chamberlain (2002) and concluded that the estimated age distributed older than that by Kobayashi (1967) and that average life expectancy at 15 years old was 32 years.

In the present study, the results of age estimation showed that the patterns of survivorship were different from one population to another, and that in West and Central Jomon females and South and West Yayoi females, some persons survived beyond 65

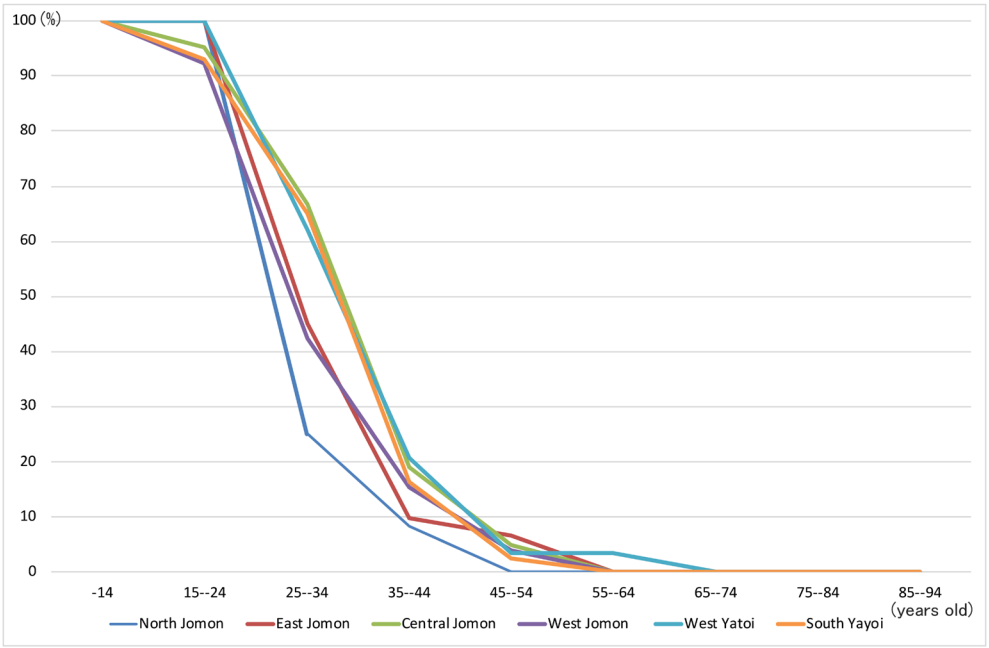

Figure 5. Survivorship of males for all groups. The horizontal axis shows range of age; the vertical axis shows the percentage.

years. Therefore, the results of the present study also showed that the estimated age for some Jomon populations was older than that reported by Kobayashi (1967). Igarashi (2004) suggested that the reason Kobayashi (1967) underestimated skeletal age at death might have been because his method of age estimation relied on cranial suture closure and the development of osteophytes.

2. Fertility and survivorship patterns

The results of the present study indicated that fertility was high in North Jomon females and low in South Yayoi and West Yayoi females, and suggested that mortality was high in North Jomon females and low in South Yayoi and West Yayoi females; in other words, fertility and survivorship patterns differed from one population to another. However, I cannot currently determine whether these differences were caused by geographical differences (latitude), such as climate or system of subsistence, or by temporal differences (Jomon and Yayoi), such as genes or diet. To identify more clearly the cause of differences in fertility and survivorship, fertility and survivorship among the southern Jomon and central and northern Yayoi populations must be conducted in the future.

That the fertility and survivorship patterns differed among the Jomon and Yayoi

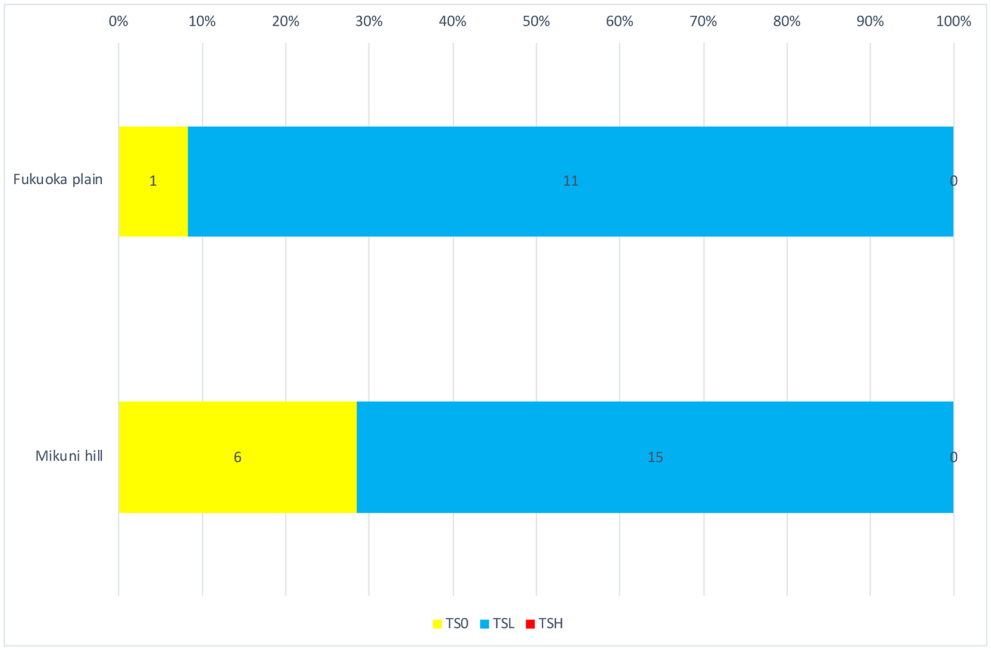

Figure 6. Percentages of types of pregnancy parturition scars in the South Yayoi population. Numbers in bar graphs show size of the samples.

populations requires that the fertility and survivorship patterns be as much as possible estimated separately for each population. This is only natural because, as shown by various archaeological studies, the lives of Jomon and Yayoi people were quite different from one region to another.

As an example of an ongoing study, I discuss a comparison of the fertility and survivorship patterns between two Yayoi subgroups in the South Yayoi population. The South Yayoi population can be divided into two subgroups according by district: the Fukuoka plain (Kanenokuma, Aoiki, and Hara sites) and the Mikuni hills (Kumanishioda, Nagaoka, Dobayama sites), both subgroups in Fukuoka prefecture. Figure 6 shows the fertility for the Fukuoka plain group and the Mikuni hill group. Fertility was higher for the Fukuoka plain group than for the Mikuni hill group. Figures 7 and 8 show survivorship for the Fukuoka plain and Mikuni hill groups. In females (Figure 7), survivorship tended to be higher in the Fukuoka plain than in the Mikuni hills. In males (Figure 8), no clear tendency was observed. Judging from these results, we could hypothesize that fertility was higher and female longevity longer in the Fukuoka plain than in the Mikuni hills. Archaeological studies showed that in the Fukuoka plain, there were wide plains suitable for rice farming and settlements continued from Jomon to Yayoi times (Yonemoto 2016).

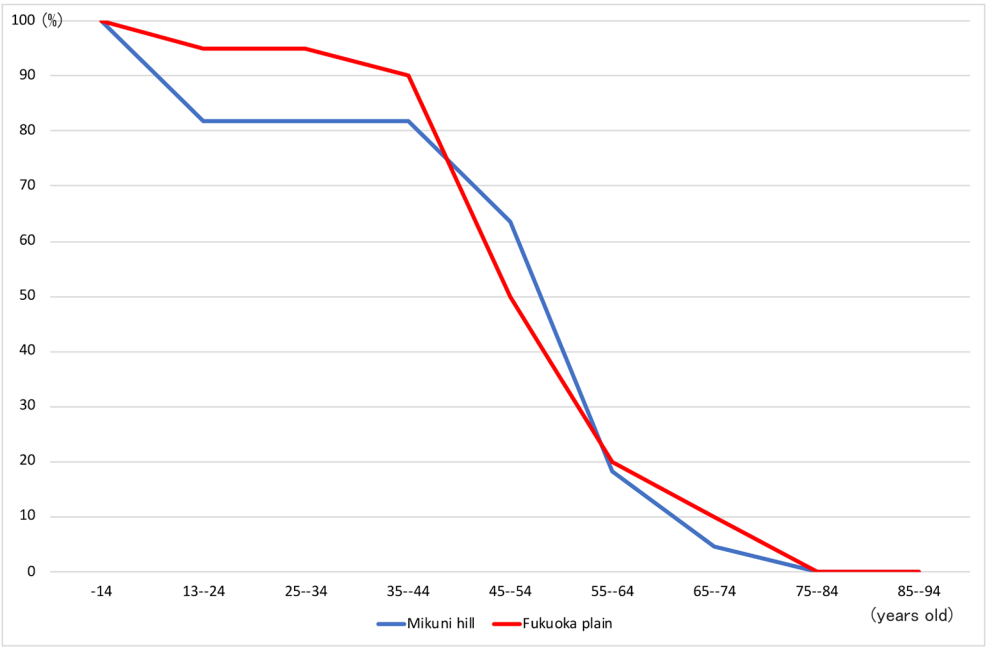

Figure 7. Survivorship of females in the South Yayoi population. The horizontal axis shows range of age; the vertical axis shows the percentage.

In the Mikuni hills, people moved into that area in the Yayoi era and started to farm with small rice paddies built on the scarce land available (Yonemoto 2016). The different environment may have influenced the fertility and survivorship patterns in the Fukuoka plain and Mikuni hills. Although these results are based on data drawn from a sample of relatively small size, once fuller data are accumulated, we would obtain more precise information about the lives of the people in these areas. This might offer a good example of how cooperation between paleodemographical and archaeological research could usher in greater understanding of prehistoric societies.

3. Factors that determine fertility

The data for fertility not only make possible conjecture about population movements but also support discussion of gender in prehistoric societies.

Hrdy (2005) suggests the following factors as determining fertility in the data of cultural anthropology.

1) Lifestyle: nomadic or sedentary. People who move their domicile frequently are less likely to have a large number of children, who may be less independently mobile. Fertility tends to be higher in populations that remain settled in one place.

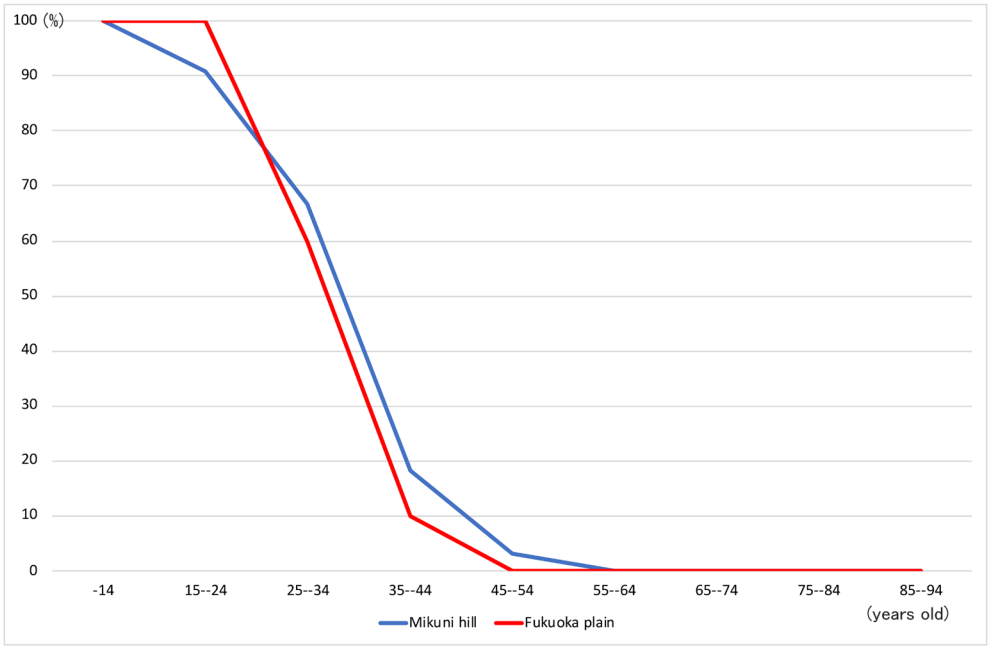

Figure 8. Survivorship of males in the South Yayoi population. The horizontal axis shows range of age; the vertical axis shows the percentage.

2) Subsistence activity: hunters-gatherers or farming. The diet of hunter-gatherer subsistence systems features ingredients less suited to soft foods for babies. Agrarian-based subsistence systems provides ingredients suitable to transition to a solid diet, which leads to shorter weaning periods. When a child is weaned, maternal ovulation, which is suppressed during lactation, resumes. By this logic, it may be inferred that among agricultural populations, the weaning period and birth interval is shorter, leading to higher fertility.
3) Maternal nutrition: In populations where women can obtain more protein and fat, their birth interval is shorter and fertility is higher than those where the women consume less protein and fat.
4) Cooperative childcare: Cooperative childcare allows mothers to spend more time and effort collecting food, which improves nutrition and increases fertility. In addition, many children can be cared for through cooperative childcare.

Hrdy deduces these factors from ethnographic case studies of peoples in various parts of the world. They provide one way to evaluate the differences of fertility for the Jomon and Yayoi people. Regarding the lifestyle of the Jomon and Yayoi populations examined in the present study, archaeological studies indicate that they lived in settlements (Amemiya

2009). Therefore, their lifestyle comes under the category of "sedentary," and cannot account for the differences of fertility. In relation to subsistence activity, the sedentary lifestyle can be equated with the ability to make soft baby food. Judging from foods believed to have been made in the Jomon and Yayoi periods soft food was made (Shitara 2014), although archaeological evidence of soft baby food in the Jomon and Yayoi periods has not been found. Considering that the diet was different from one area to another (Yoneda 2006), there is a possibility that the kinds of weaning foods and the duration of nursing also differed among the populations. Age of weaning can be estimated by isotopic analysis of bone (Tsutaya *et al.* 2016). Further minute study of the diet and the age of weaning in ancient populations will account for the differences in fertility. As for maternal nutrition, some skeletal markers of nutrition and disease (Fujita 2012) and isotopic analysis of diet (Yoneda 2006) could provide information about maternal nutrition, altough sufficient study has yet to be done. In the future, the results of such analyses are sure to account for the differences in fertility among populations. Regarding cooperative childcare, it may be difficult to prove the existence of cooperative childcare in ancient societies. At the moment, differences in the fertility of populations cannot be explained by this factor, although there is a possibility that factors such as the duration of nursing and maternal nutrition will be clarified, thereby helping to explain fertility in the future. Meanwhile, we can use the data on fertility anticipating these factors: diet, maternal nutrition, and cooperative childcare, which relate to gender differences in societies.

Data on fertility and survivorship alone cannot directly shed light on the nature of gender in prehistoric societies. Used in conjunction with archaeological data, however, these data will help deepen our understanding of prehistoric societies.

4. The importance of studying the Jomon and Yayoi periods

The Jomon and Yayoi periods are, roughly speaking, hunter-gatherer and agrarian societies, respectively, although some details about them still need to be examined, as discussed above.

The change from a hunting-gathering to farming is common in human societies. The *hominini* lineage dates back about 7 million years, and for most of this time, humans have lived as hunter-gatherers. However, farming, which began about 10,000 years ago, quickly swept the globe, and most humans now live in food-producing societies that involve farming and raising livestock. The change from a hunter-gatherer to an agricultural society might have significantly changed people's lives, society, and culture, including gender and the world of the mind. It is a future task to reconstruct the population structures of hunter-gatherers and agrarian societies, and to re-envision their lives, society, and culture, including gender and the world of the mind in both societies, and to compare them.

A comparative analysis of the Jomon and Yayoi cultures not limited to an analysis of

demographic structure is therefore considered to be extremely important, as it can serve as a model case for changes that occur worldwide during the transition from a hunter-gatherer to agrarian society.

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