



# Isotopic evidence of dietary variability in subadults at the Usu-moshiri site of the Epi-Jomon culture, Japan



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## ABSTRACT

This study reconstructs adult and subadult diets of a hunter-gatherer population of the Epi-Jomon culture (approximately 2300–1700 years BP) in Japan, using the stable isotopic analysis of carbon and nitrogen. The results suggest that the Usu-moshiri adults were highly dependent on marine resources such as seals for their dietary protein intake and that no significant dietary differences existed between the sexes. Among subadults we found two types of diet on the basis of different isotopic signatures. One group consisted of individuals with  $\delta^{13}\text{C}$  values below than those of the adult female mean minus two standard deviations and  $\delta^{15}\text{N}$  values lower than those of subadults in the other groups. These low- $\delta^{13}\text{C}$  subadults indicated relatively less enriched  $\delta^{15}\text{N}$  values by 3.5 years of age at the latest. They probably consumed more  $^{13}\text{C}$ -depleted foods during weaning than in the ordinary adult diet. In the other high- $\delta^{13}\text{C}$  group, their enriched  $\delta^{15}\text{N}$  values start to decline by four years of age and fall within the two-standard-deviations range of the total adult mean around five to six years of age. Isotopic values of children in this high- $\delta^{13}\text{C}$  group suggest that they would have been fed ordinary adult diets during weaning. Perinates could also be divided into two groups on the basis of the similar patterns in their carbon and nitrogen isotope ratios. Our results indicate variabilities in the diets of subadults, and similar variabilities were also seen in ethnographic studies of the Ainu populations.

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## 1. Introduction

The reconstruction of breastfeeding and weaning practices of past populations provides important evidence for the evolutionary, environmental, and cultural factors behind weaning practices (Dettwyler, 1995; Humphrey, 2010; Kennedy, 2005; Robson and Wood, 2008; Sellen, 2007). A number of studies have used stable carbon and nitrogen isotopic analyses of bone collagen to reconstruct the breastfeeding practices of past human populations (e.g., Choy and Richards, 2009; Fogel et al., 1989; Katzenberg et al., 1996; Prowse et al., 2008; Redfern et al., 2012). At and prior to birth, the  $\delta^{15}\text{N}$  values of perinates are equivalent to those of their mothers because the tissues of fetuses are formed from the same food constituents as those of their mothers, thus reflecting the foods

consumed by their mothers. In breastfed subadults, the  $\delta^{15}\text{N}$  values of tissues are significantly elevated as compared with those of their mothers; in exclusively breastfed subadults,  $\delta^{15}\text{N}$  values are elevated by 2–3‰ (Fogel et al., 1989; Fuller et al., 2006a). The elevation of isotopic values in subadults is a trophic level effect (bioenrichment) similar to what is commonly observed in food webs (Minagawa and Wada, 1984; Schoeninger and DeNiro, 1984), and breastfed subadults are one trophic level higher than their mothers in the food chain. If the weaning foods were prepared from materials similar to those consumed by adults, the introduction of weaning foods would gradually decrease subadult  $\delta^{15}\text{N}$  values during the weaning process. After subadults are fully weaned (cessation of breastfeeding), the  $\delta^{15}\text{N}$  values of bone collagen in subadults and adults should be similar. Thus, the analysis of  $\delta^{15}\text{N}$  values in subadults and adults can be used to reconstruct the weaning processes in ancient populations.

In contrast to the use of  $\delta^{15}\text{N}$  data to reconstruct weaning patterns, the  $\delta^{13}\text{C}$  values in subadults are used mainly to estimate the contents of weaning foods, such as the relative abundances of  $\text{C}_3$  and  $\text{C}_4$  plants and animal milk in the diet, and the ages at which

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they were introduced (Dupras et al., 2001; Fuller et al., 2006b; Katzenberg et al., 1993). Carbon isotopic values are useful as a source of solid foods consumed by mother and/or subadult because the elevation of  $\delta^{13}\text{C}$  values in exclusively breastfed subadults is relatively small (about 1.0‰; Fuller et al., 2006a).

Only a few isotopic reconstructions of breastfeeding practices have focused on prehistoric hunter-gatherer populations subsisting in the absence of agricultural foods. These studies have revealed variations of breastfeeding practices in ancient hunter-gatherer populations (Clayton et al., 2006; Fogel et al., 1989; Schurr and Powell, 2005; Waters-Rist et al., 2011). Previously, the introduction of agriculture has been assumed to alter breastfeeding practice drastically (Buikstra et al., 1986; Larsen, 1995). However, it is becoming clear that this assumption could be too simple (e.g., Sellen and Smay, 2001). This study reports isotopic evidence for breastfeeding practices of the skeletal population from the Usu-moshiri site in prehistoric Hokkaido, Japan. In Hokkaido, hunting and gathering of marine foods was the most important subsistence activity since the Jomon period and rice cultivation was not adapted until recently.

In this study, the term weaning is defined as the process of nutritional (especially for protein) independence for subadults, which starts with an evident decline in breast milk contribution as a dietary protein source and ends with the disappearance of this contribution. Infants aged six months and older need supplementary foods for their health (Kramer and Kakuma, 2004). However, Michaelsen et al. (2000: Chapter 3) have reported that supplementary foods mainly contribute to energy required (i.e., about 70% requirements in 12–23 months after birth) but not so much to protein (i.e., subadults in 1–3 years of age need only 16–23% additional weight of protein than subadults breastfed exclusively). Therefore, such foods are not necessarily detected isotopically because of the smaller contribution offered by these foods to dietary protein input.

## 2. The Esan culture and the Usu-moshiri site

The Usu-moshiri site (also known as Usu-10 site) was assigned to the Esan culture, which was distributed around southwestern Hokkaido (from the Oshima Peninsula to the Ishikari Plain) in the early Epi-Jomon, dated to 2300–1700 years BP (Aono and Ohshima, 2003). The Esan people were sedentary, lived in pit houses, and were hunter-gatherers highly dependent on marine resources. The studies on faunal remains at some sites suggest that the hunting of marine mammals, especially sealing, was of particular importance in winter in this region because it appears that female and infant fur seals (*Callorhinus ursinus*) overwintered around the bay (Nishimoto, 1984, 1985). Isotopic analyses of adult human bone collagen indicate that marine resources were the main protein source for the Epi-Jomon people (Chisholm et al., 1992; Minagawa, 2001; Yoneda, 2002). Chisholm et al. (1992) showed that the  $\delta^{13}\text{C}$  value in human bones from four different Epi-Jomon sites generally ranged between  $-17\text{‰}$  and  $-12\text{‰}$  although the actual values were not reported. Minagawa (2001) analyzed nine human skeletons from an Epi-Jomon site and reported mean  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of  $-13.3 \pm 0.7\text{‰}$  and  $18.1 \pm 0.6\text{‰}$ , respectively. Yoneda (personal communication, 2002) used carbon and nitrogen isotopic analysis on 32 Epi-Jomon skeletons from several different sites and found mean  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of  $-13.9 \pm 1.1\text{‰}$  and  $17.8 \pm 0.9\text{‰}$ , respectively.

The Usu-moshiri site is located on a rock reef islet (area of approximately 10,000 m<sup>2</sup>) in the Uchi-ura Bay of southwestern Hokkaido (Fig. 1); the site was excavated in 1985–1989 by the Sapporo Medical University (Ohshima et al., 1989, 1990; Ohshima, 2003). A series of Jomon and Epi-Jomon shell mounds occur on the shore of Uchi-ura Bay, and the Usu-moshiri site comprises of

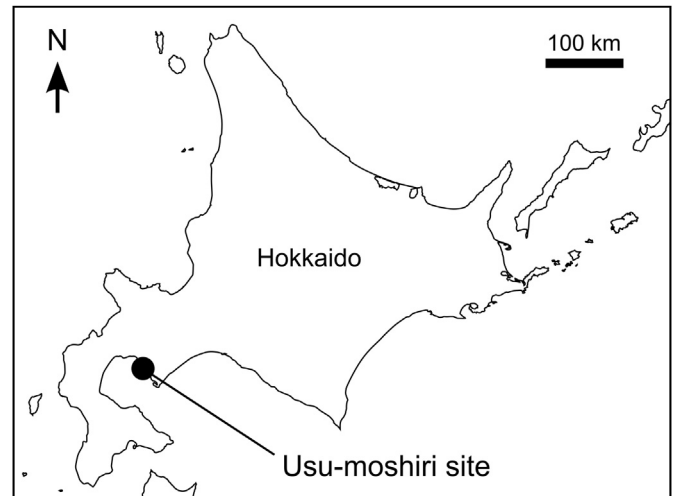


Fig. 1. Location of the Usu-moshiri site.

one such mound. Although the full report of the excavation has not yet been published, several archaeological and anthropological studies have revealed that the Usu-moshiri population was highly influenced by the Yayoi culture on the Japanese mainland. Buried, reburied and scattered human skeletons belonging to the Esan culture of the Epi-Jomon period were excavated, although the reburial practice is not common in prehistoric Hokkaido (Ohshima, 2003). The scattered bones were assumed to have originated from the reburial process. Some individuals wearing bracelets made of *Conidae* shells (*Conidae* live only in the southern sea) and sealing harpoons representing type similar to those excavated in the northeast region of mainland Japan were also found, suggesting that there was some contact with the mainland Yayoi culture (Aono and Ohshima, 2003; Ohshima, 2003). Meanwhile, morphometric analysis on tooth crowns has indicated a closer morphological affinity of the Usu-moshiri people for the Jomon people in Hokkaido than for those in mainland Japan (Mizoguchi, 1988).

## 3. Implications from ethnography of the Ainu populations

Several ethnographic studies have reported reproductive practices of the indigenous Ainu people in Hokkaido and Sakhalin. Ainu culture was formed around the fifteenth century upon the Satsumon culture, a culture that followed the Epi-Jomon, with influence from the Okhotsk culture. It is expected that some cultural traits of the Epi-Jomon people might have been inherited by the Ainu people.

There are variabilities in the observed breastfeeding practice of the Ainu populations. An ethnographic study of the Ainu population on the northwestern coast of southern Sakhalin during the first half of the twentieth century, conducted by Ohnuki-Tierney (1974: 57) reported that some form of breastfeeding continues as long as two to three years. Ohnuki-Tierney (1974: 57) also reported that the Ainu people often gave their subadults regular foods that had been pre-masticated by the mother, especially fish such as salmon, or items to relieve teething such as ribs of bear, hare, or dog. Another ethnographic account of the Ainu populations in southern Sakhalin in the beginning of the twentieth century also reported that they used a heated milk substitute in cases of low milk supply or death of the mother; the milk substitute consisted of mashed herring roe, cut cow parsnip root, boiled lily root, and seal oil (Kasai, 1943: 26–27). On the other hand, an ethnographic source of the Ainu populations in southern Sakhalin in the 1920–1930s reported that the age of weaning was not fixed and that breastfeeding continued until

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