論 文 の 内 容 の 要 旨

論文題目

Stable isotopic reconstruction of breastfeeding practices in past human populations

(同位体分析による過去ヒト集団の授乳習慣復元)

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Although fertility is difficult to estimate directly for most archaeological human populations, breastfeeding period, one of the most important determinant of fertility, can sometimes be estimated by using stable isotopes. During the period of breastfeeding, resumption of ovarian activity in the breastfeeding mother is suppressed, owing to hormonal modifications and nutritional costs of lactation. Therefore, a longer period of breastfeeding generally leads to longer inter-birth intervals, and resulting lower fertility in a population. Stable carbon and nitrogen isotope analyses of subadult bone collagen have been used to estimate breastfeeding period in past human populations. The carbon and nitrogen isotope ratios in the tissue of exclusively breastfed infants are 1‰ and 2−3‰ higher than those of their mother's, respectively, because the bioenrichment occur between mothers and breastfed subadults. After the start of the weaning process, the nitrogen isotope ratio of newly formed tissue gradually decreases with decreasing breast milk intake, and finally stabilizes to adult values after the end of the weaning process. In archaeological human skeletal populations, breastfeeding period has been reconstructed by estimating the age at death of subadults and measuring the isotope ratios of the collagen extracted from the skeletons.

However, there are time lags between the actual dietary change and the incorporation of isotopic signals into the tissue because of the slower turnover rate of bone collagen. The equilibrium age of isotopic signals in bone collagen is several months or even years older than the past weaning age. Because of these time lags, weaning ages inferred from the change in isotope ratios of subadult bone collagens have never been directly comparable to those observed in ethnography and reported in historical demography.

To overcome this problem, I estimated temporal changes in human subadult bone collagen turnover rates based on tissue-level bone metabolism, and developed a mathematical model to correct the time lags. Temporal changes in human subadult bone collagen turnover rates were estimated from data on tissue-level bone metabolism reported in previous studies. A

model for reconstructing weaning ages was then developed using a framework of approximate Bayesian computation and incorporating the estimated turnover rates. The model is presented as a new open source R package, WARN (Weaning Age Reconstruction with Nitrogen isotope analysis), which computes the age at the start and end of weaning, ^{15}N-enrichment through maternal to infant tissue, and nitrogen isotope ratio of collagen synthesized entirely from weaning foods with their posterior probabilities.

Then, the developed model was applied to four skeletal populations in Japan to estimate actual weaning ages. Reconstructed weaning ages were used to infer fertility and discuss three demographic events in past Japanese archipelago. In the Hitotsubashi skeletal population, Tokyo (AD 1657–1683: the early Edo period), the age at the end of weaning was reconstructed as 3.1 years (2.1–4.1 years in 95% credible intervals), which agrees with descriptions in various historical documents of the period. The duration of breastfeeding in the Hitotsubashi population was relatively longer than those in modern industrial and traditional societies and four previously reported populations in medieval and in the industrial England. As later weaning closely associates with longer inter-birth interval for mothers, my data suggest a lower natural fertility for the Hitotsubashi population. Assuming that the proportion of married people was also lower in the major cities of the earlier Edo period, my results support the assumption that Edo developed and increased its population by attracting immigrants during urbanization.

In the Yuigahama-minami skeletal population, Kanagawa (AD 12th–14th centuries: the early medieval period), the age at the end of weaning was reconstructed as 3.8 years (2.1–4.1 years in 95% credible intervals). The age at the end of weaning in the Yuigahama-minami population was greater than that in the typical non-industrial populations, a premodern population in the Edo period Japan, and medieval populations in the UK. Kamakura experienced urbanization and population increase in the early medieval period. The younger age-at-death distribution and high nutritional stresses in the Yuigahama-minami population and later weaning, which is closely associated with longer inter-birth interval for mothers, suggests that Kamakura developed and increased its population by immigration during urbanization.

In the Moyoro skeletal population, Hokkaido (AD 6th–10th centuries), the age at the end of weaning was reconstructed as 1.8 years (1.4–2.2 years in 95% credible intervals), which is lower than that in another northern hunter–gatherer–fisher populations and typical modern traditional societies. It is assumed that the Okhotsk people originated from lower Amur River region and expanded rapidly along the northeastern coast of Hokkaido mostly during AD 600–700. Because weaning age is one of the most important determinants of fertility, a shorter breastfeeding period suggests increased fertility. Furthermore, previous

studies have shown better nutrition and lower mortality for them, which would further promote the population increase, and thus populations of the Okhotsk culture could expand into new habitats. These findings are consistent with recent emerging evidence of great contributions of the Okhotsk to the formation of later Ainu populations and culture.

The developed model in this study provides a framework for objectively and quantitatively analyzing, interpreting, and comparing subadult bone collagen nitrogen isotope ratios. By using the models to correct the lag time, researchers can compare weaning ages obtained by isotope analysis of past human skeletons with those obtained from participant observations in cultural anthropology and historical literatures as a uniform measure. Applications of this model indicate that process and cause of past human demographic events can be empirically discussed by inferring fertility from isotopically reconstructed age at the end of weaning. However, several proximate and remote factors, as well as breastfeeding period, affect fertility, and these factors are difficult to estimate in most archaeological settings. Furthermore, population dynamics are not only determined by fertility but also by mortality and migration as well. In order to discuss past human population dynamics, one needs to obtain demographic information other than breastfeeding period. Development and application of further methods to estimate demographic parameters would be important to reconstruct past human population dynamics from various aspects.