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Isotopic perspectives of dietary patterns in Taiwan after the introduction of crops

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ABSTRACT

Bone collagen isotope data of 53 human individuals excavated from 11 sites were collected in order to trace the dietary patterns of these prehistoric people after rice and millet were introduced into Taiwan ca. 5000 cal. yr BP. The 11 sites were separated into two groups, with each belonging to 4600–2000 cal. yr BP and 2000–400 cal. yr BP, respectively. The result indicated that the prehistoric people did not focus on crops after the introduction of crops into Taiwan. A comparison of the diets of the 53 individuals in these two groups revealed that dependence on marine resources may have decreased along the coastal area during the later time interval, i.e. the Iron Age.

1. Introduction

Rice and millet cultivation and animal husbandry increased and stabilized the food supply in prehistoric China, which further supported population growth between 6000 and 4000 cal. yr BP (Fuller and Qin, 2009). This great achievement not only brought about a significant increase in the size and numbers of settlements (Fuller and Qin, 2009; Liu and Feng, 2012), but also triggered population migration and the spread of crops to new areas such as southern China and Taiwan ca. 5000 cal. yr BP, and northern Philippine ca. 4000 cal. yr BP (e.g. Bellwood, 2011; Chi and Hung, 2010; Fuller, 2011). The introduction of new crops is evidenced by the finding of rice grains at the Shixia site in Guangdong, the Tanshishan site in Fujian, and the Nanguanli and Nanguanlidong sites in Taiwan (Chi and Hung, 2010). In addition, foxtail millet grains were also found in Taiwan (Tsang et al., 2006). The emergence of these crops leads to the suggestion that crop cultivation was practiced for the first time in southern China and Taiwan (Chi and Hung, 2010; Tsang et al., 2006). Nevertheless, it seems that such a subsistence mode, i.e. crop cultivation, did not dominate the entire region. For example, in Taiwan, the crop remains were found, always accompanied by large amounts of faunal remains, especially deer, pigs, fish and shellfish, and some wild plant remains, as well as by hunting and fishing tools (Table S1). From this archaeological perspective, it has been suggested that prehistoric people in Taiwan relied on a variety of foods rather than focusing on crops (Tsang, 1999). Such a broad-spectrum subsistence mode, consisting of gathering, hunting, fishing, collection of shellfish, and crop cultivation, seemed to persist in Taiwan from the Neolithic period to the Iron Age (Tsang, 1999).

It is well known that the preservation of floral and faunal remains is strongly affected by the depositional environment (Fraser et al., 2013; Zhao, 2011), and this can hinder archeologists from a comprehensive understanding of the diet of prehistoric people. In addition, the appearance of one kind of ecofact remains is not necessarily evidence that this kind of food was the primary food consumed (e.g. Jørkov et al., 2010; Lightfoot et al., 2013; Liu et al., 2014). Rather, carbon and nitrogen isotopes of bone collagen have been routinely used to assist in confirming paleodietary components (Katzenberg, 2008; Lee-Thorp, 2008) and to estimate the contribution of each kind of food (e.g. Newsome et al., 2004), though some limitations of this technique have been addressed. For example, site-specific baseline requires reconstructing by stable isotope measurements on fauna and flora represented in deposits associated with the human burials (e.g. Milner et al., 2004) Also, it has been suggested that the bone collagen may directly come from the protein part of diet, thus may underestimate the contribution of low-protein foods, such as plants, to human diet (Ambrose and Norr, 1993; Tieszen and Fagre, 1993).

This study collected human bone isotope data that have been published in Taiwan. The objective is to understand the dietary patterns in prehistoric Taiwan after the introduction of rice and millet ca. 5000 cal. yr BP. In order to provide the baseline for the reconstruction of the human diet, the isotope values of potential foods from Taiwan, China and Japan were compiled as well. We found that the prehistoric people did not largely consumed millet and rice even if both crops have been introduced into Taiwan. Besides, marine resources are likely to

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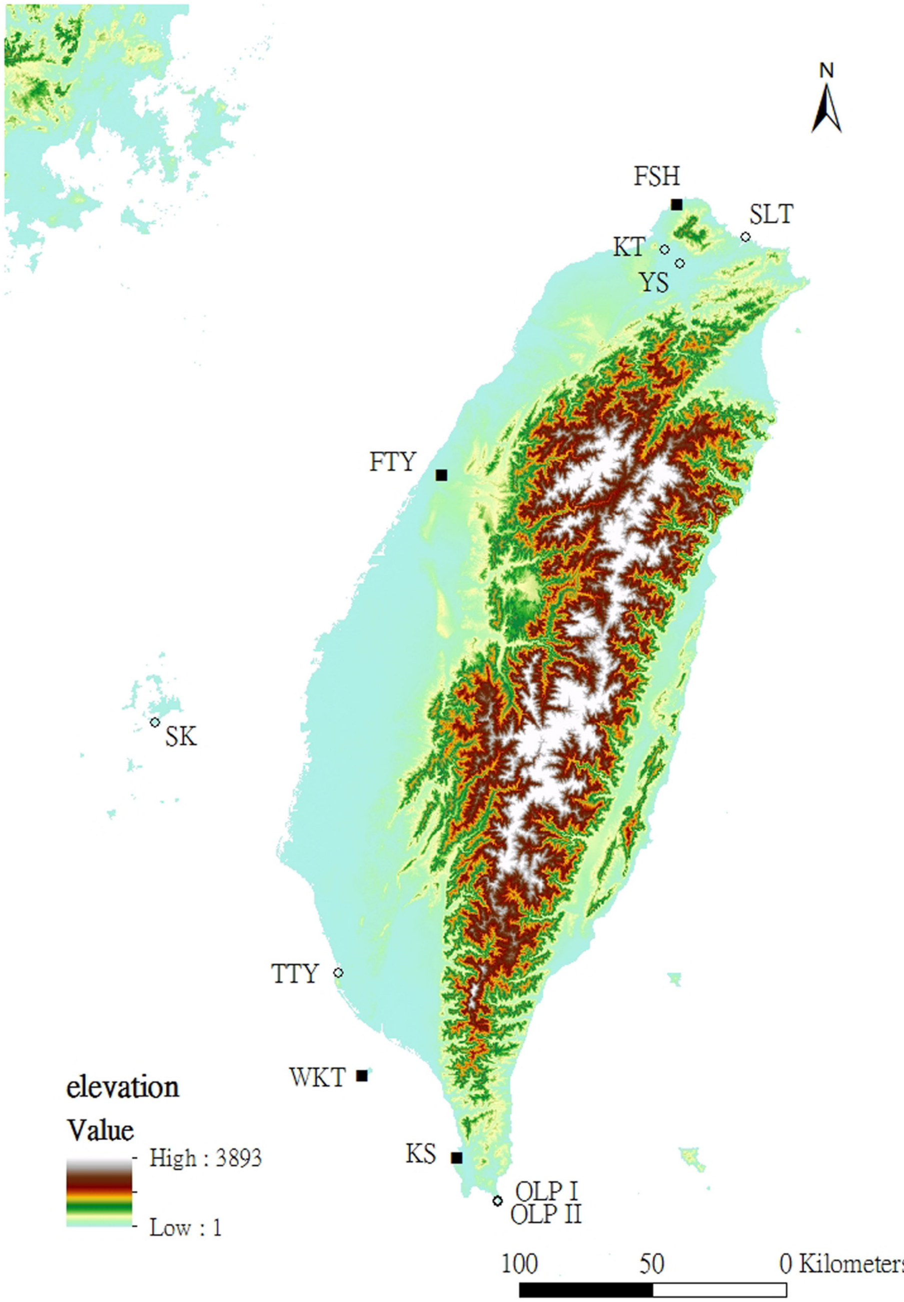

Fig. 1. The 11 sites mentioned in this study, open dots indicate the Neolithic sites while black squares represent the Iron Age sites. FSH: Fanshehou; FTY: Fantzuyuan; KT: Kuantu; KS: Kueishan; OLP I: Oluanpi I; OLP II: Oluanpi II; SLT: Sheliaotao; SK: Suokang; TTY: Taotsaiyuan; WKT: Wukueitung; YS: Yuanshan.

have been consumed at lower levels during the Iron Age. Three potential causes for the reduction in exploitation of marine resources are also discussed in this paper.

2. Data source

2.1. Human data

Published isotopic data were collected from the literature. In total, data from 53 individuals were gathered from 11 sites in Taiwan (Fig. 1 and Table 1), including the Fanshehou (FSH), Fantzuyuan (FTY), Kuantu (KT), Kueishan (KS), Oluanpi I (OLP I), Oluanpi II (OLP II), Sheliaotao (SLT), Suokang (SK), Taotsaiyuan (TTY), Wukueitung (WKT), and Yuanshan (YS) sites. All the reported data were produced from bone collagen (Fig. 2), while the mineral phase (apatite) of the sample from the SK site was also analyzed for its carbon composition (Tsang, 1992).

Chronologically, the dataset is separated into two groups. The first group dated between 4600 and 2000 cal. yr BP, including 17 data from the KT (n = 1), OLP I (n = 4), OLP II (n = 2), SK (n = 1), TTY (n = 2) sites STL (n = 1) and YS (n = 6) sites. The second group consists of 36 data from the FSH (n = 1), FTY (n = 32), KS (n = 2), and WKT (n = 1) sites, all belonging to the Iron Age (2000 to 400 cal. yr BP).

2.2. Data for reconstruction of isotope baseline

Based on the archaeological evidences, seven kinds of wild food are thought to have been consumed in prehistoric Taiwan. They are deer, pigs, freshwater fish, marine fish, shellfish, C_3 plants, and C_4 plants. In addition, rice and millet are also considered since both crops have been

Table 1
Basic information of the 11 sites from which the isotopic data of human bone collagen were cited.

Site name and site ID	Distance from the ocean	Site ages (cal. yr BP)	Lat.	Lon.	Elevation (m)	Data number	References
Fanshehou, FSH	< 1 km	2300–400[a]	25°16′35″	121°29′24″	15–20	1	Yoneda et al. (2008)
Fantzuyuan, FTY	6.5 km from the ocean	2000–400	24°21′35″	120°37′52″	60–80	32	Lee et al. (2017)
Kuantu, KT	8 km from the ocean	3800–2800[a]	25°07′25″	121°27′10″	3–5	1	Yoneda et al. (2008)
Kueishan, KS	< 1 km	1500	22°03′09″	120°41′36″	15–76	2	Li (1995)
Oluanpi I, OLP I	< 1 km	4500–3500[b]	21°54′21″	120°50′41″	8–12	4	Lee et al. (unpublished data)
Oluanpi II, OLP II	< 1 km	3500–3000	21°54′13″	120°50′32″	20–40	2	Li (1995)
Sheliaotao, SLT	< 1 km	3200–2000[a]	25°09′44″	121°45′26″	2–5	1	Yoneda et al. (2008)
Suokang, SK	< 1 km	4600	23°31′26″	119°35′41″	5–10	1	Tsang (1992)
Taotsaiyuan, TTY	< 1 km	4500–3000[b]	22°40′30″	120°15′28″	10	2	Yoneda et al. (2008)
Wukueitung, WKT	< 1 km	2000–400[b]	22°19′55″	120°20′50″	30–40	1	Yoneda et al. (2008)
Yunashan, YS	16 km from the ocean	3200–2300	25°04′31″	121°30′48″	3–36	6	Lee et al. (2016) and Yoneda et al. (2008)

[a] Liu (2004).
[b] Tsang (1994).

found in Taiwan. As a result, the isotope data of these foods were used as the dietary baseline for all the 11 sites in this study. The isotope data in the bone collagen of deer, pigs, freshwater fish and marine fish were derived from the archaeological samples in Taiwan (YS site, Lee et al., 2016; FTY site, Lee et al., 2017; OLP I site, unpublished data) (Fig. 2), while the isotope ratios in shellfish flesh, C_3 plants, and C_4 plants were from their modern counterparts in Japan (Yoneda et al., 2004, the plant data were cited from Shimojo, 1988). The data of rice and millet grains were derived from China (Lanehart et al., 2011; Pechenkina et al., 2005).

3. Reconstruction of isotope baseline

3.1. Fish

Marine fish isotope data were cited from the studies done at the YS ($n = 4$), OLP I ($n = 1$) and FTY ($n = 2$) sites. The first two sites belonged to the Neolithic period, while the third one belonged to the Iron Age. These marine fish samples showed similar isotope values regardless of the dates and locations of the sites. Therefore, the isotope values of the seven marine fish were combined to produce a baseline of this food type for all the sites. The mean $\delta^{13}C$ and $\delta^{15}N$ values of these fish are $-11.2 \pm 1.4‰$ and $12.1 \pm 1.4‰$, respectively (Fig. 2).

The freshwater fish samples were produced only from the YS site ($n = 4$). Their mean $\delta^{13}C$ value ($-20.8 \pm 2.2‰$) and mean $\delta^{15}N$ value ($7.7 \pm 2.0‰$) are strategically viewed as the baseline of freshwater fish for the other sites to make reconstruction possible.

3.2. Terrestrial animals - deer and pigs

The data of deer came from only two sites, YS and FTY. Although the mean $\delta^{15}N$ value at the YS site ($5.2 \pm 1.0‰$, $n = 24$) is slightly higher than that at the FTY site ($4.1 \pm 1.1‰$, $n = 28$), these $\delta^{15}N$ values are all below 7.0‰. This value, therefore, may be considered to be the upper limit for herbivore bone collagen in prehistoric Taiwan. By comparison, the mean $\delta^{13}C$ value at the FTY site ($-13.3 \pm 4.0‰$, $n = 28$) is remarkably higher than that at the YS site ($-17.0 \pm 4.3‰$, $n = 24$), providing evidence that the deer at the FTY site consumed more C_4 plants than deer at the YS site did.

The data of pigs were collected from these two sites as well. Their mean $\delta^{15}N$ values are similar, with $5.9 \pm 1.5‰$ ($n = 13$) at the FTY site and $5.6 \pm 1.6‰$ ($n = 19$) at the YS site. However, the mean $\delta^{13}C$ value at the FTY site ($-14.7 \pm 2.6‰$, $n = 13$) is higher than that at the YS site ($-18.5 \pm 2.3‰$, $n = 19$) as well, which again indicates a higher contribution of C_4 plants to the diet of FTY pigs.

The difference in $\delta^{13}C$ value of terrestrial animals between the YS and FTY sites may reflect the spatial differences in the percentage of C_3 and C_4 plants in natural vegetation between the two sites. This also emphasizes the importance of site-specific baseline when inferring human diet through isotope analysis. Unfortunately, neither deer nor pig data is available at the other sites. Therefore, the data from YS and FTY were combined to produce the broader baselines for these two species in this study, which may help to subsume inter-site difference in isotopic baseline. The mean $\delta^{13}C$ and $\delta^{15}N$ values are $-15.0 \pm 4.5‰$ and $4.6 \pm 1.2‰$, respectively, for deer ($n = 52$), while $-17.0 \pm 3.0‰$ and $5.7 \pm 1.5‰$, respectively, for pigs ($n = 32$) (Fig. 2).

3.3. Shellfish and plants

The isotope data of shellfish and plants (C_3 plants, C_4 plants, rice and millet grains) were derived from their modern counterpart samples from Japan and China (Lanehart et al., 2011; Pechenkina et al., 2005; Yoneda et al., 2004). Thus the Suess effect of +1.6‰ for plants and + 0.5‰ for shellfish has to be considered for the $\delta^{13}C$ values (Guilderson et al., 1998; Marino and McElroy, 1991). From calculation, the mean $\delta^{13}C$ and $\delta^{15}N$ values of C_3 plants are $-25.4 \pm 1.2‰$ and $1.6 \pm 2.4‰$, respectively. For C_4 plants, both isotope ratios are

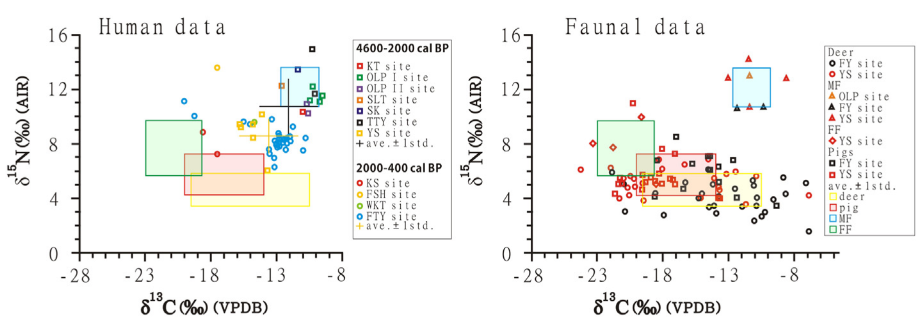

Fig. 2. Isotope data of human (left panel) and fauna (right panel) were shown as dots. Colored squares represent one sigma range of deer, pigs, marine fish (MF) and freshwater fish (FF) in both panels. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

−10.0 ± 0.5‰ and 1.0 ± 1.9‰. The ratios in shellfish flesh are −14.3 ± 1.6‰ and 8.3 ± 2.1‰. Although the limited sample size for rice and millet, the mean $\delta^{13}C$ and $\delta^{15}N$ values of millet are −10.2 ± 0.2‰ and 2.6 ± 0.9‰ (n = 3), respectively, while for rice, they are −23.0‰ and 5.2‰ (n = 1).

It is worth to note that the use of modern plant data as prehistoric baseline could be problematic because soil conditions such as water content and/or nutrient level may have changed over time, which would affect the nitrogen isotopic compositions in soil and plants (Szpak, 2014). In addition, modern crop $\delta^{15}N$ value may increase substantially due to the manuring effect (Bogaard et al., 2007), and maybe this is the reason for the higher $\delta^{15}N$ value of rice (Lanehart et al., 2011).

4. Diets of the 53 human individuals from the 11 sites

The reported data of the 53 human individuals were plotted in Fig. 2. General speaking, the Neolithic individuals presented higher mean $\delta^{13}C$ (−12.1 ± 2.2‰, n = 17) and $\delta^{15}N$ values (10.7 ± 2.0‰, n = 17) than the individuals of the Iron Age ($\delta^{13}C$ = −13.6 ± 2.3‰; $\delta^{15}N$ = 8.5 ± 1.3‰, n = 36). The result of statistical analysis (the Kruskal-Wallis one-way analysis) also confirmed this observation ($H = 4.684$, $p = 0.03$ for $\delta^{13}C$; $H = 17.281$, $p < 0.001$ for $\delta^{15}N$). This indicated that the marine resources may have been more important between 4600 and 2000 cal. yr BP. By comparison, the Iron Age people may have consumed more terrestrial resources and/or freshwater foods.

In order to reconstruct the dietary patterns of the 53 human individuals, the isotope values of human diet were calculated from their bone collagen values. As a result of metabolic fractionation, the carbon and nitrogen isotopic compositions in a consumer's bone collagen are higher than those of their diet. Therefore, isotope values for human diet can be estimated using the measured isotope values from human bone collagen. The $\delta^{13}C$ value of the diet consumed by the 53 human individuals is assumed to be 5‰ lower than the measured bone collagen $\delta^{13}C$ values, i.e. $\delta^{13}C_{diet} = \delta^{13}C_{collagen} - 5$ (Ambrose and Norr, 1993). The trophic shift of $\delta^{15}N$ values between the diet and the collagen of consumers is suggested to be 2–6‰ (Hedges and Reynard, 2007; O'Connell et al., 2012). Here, the $\delta^{15}N$ value of the diet is assumed to be 4‰, the median value, which is lower than the bone collagen $\delta^{13}C$ values, i.e. $\delta^{15}N_{diet} = \delta^{15}N_{collagen} - 4$.

Besides, the isotope values for muscle tissue of faunal remains were estimated using measured values of faunal bone collagen, taking into account the difference in isotope values between the two tissues. For fish and terrestrial animals, the $\delta^{13}C$ value of their muscle is assumed to be lower than associated bone collagen by ca. 4‰ and 1.5‰, respectively (reported value of 3.7‰ in Beavan-Athfield et al., 2008; 1.5‰ in Keegan and Deniro, 1988), whereas the muscle $\delta^{15}N$ value is assumed to be the same as that in collagen (Deniro and Epstein, 1981; Sealy et al., 1987).

The two panels in Fig. 3 are used to compare the estimated carbon and nitrogen isotope values in the human diet with those in potential food resources (edible part). Although these panels provide a visually direct comparison, it should be noted that because the relation between the isotope value of a consumer's bone collagen and his diet have not been understood thoroughly, this comparison may contain some uncertainties. In addition, the possibility of temporal and spatial variability among isotope dataset has to be kept in mind.

4.1. The Neolithic sites, 4600–2000 cal. yr BP

A comparison of isotope values between human diet and each food resource indicates that the diets of ten individuals from the KT, OLP I, OLP II, SK, and TTY sites were composed mainly of marine resources, with minor contribution from terrestrial foods (Fig. 3). This result is basically consistent with the findings of ecofact remains and artifacts which suggest that marine fish and shellfish were two important resources at these sites (Li, 1985; Liu, 2004; Tsang, 1992). This dietary pattern agrees with the site environments as well. For example the OLP I, OLP II, SK and TTY sites are located along coastal areas, and the KT site is located near the mangrove wetland.

Although the SLT site is located near the ocean as well, our result reveals that the SLT people may have consumed both terrestrial and marine foods. However, no ecofact remains have been found so far in the Neolithic layer at this coastal site to verify this (Borao Mateo and Hung, 2015).

Fig. 3 also shows that the YS people mainly consumed terrestrial animals, correspond to the inland setting of site in the Taipei Basin. This observation is supported further by the discovery of large amounts of terrestrial faunal remains at the YS site (Li, 2003; Sung, 1954). Besides, one individual subsisted more on plant foods, as his $\delta^{15}N$ value is lower than the others (the data from Yoneda et al., 2008). By comparison, the contribution of shellfish to the YS diet in this study seems to be not as significant as previously expected since shell middens were also found at this site (Li, 2003; Sung, 1954). One possible explanation is that most shellfish excavated from this site were identified to be the brackish-water species (Li, 2003), but no isotope data for these species are available currently.

4.2. The Iron Age sites, 2000–400 cal. yr BP

The isotope data indicated that the marine resources seemed to contribute less to the human diet during the Iron Age, even if the ocean is nearby (Fig. 3). For example, freshwater fish comprised a large portion of the diet at the FSH site, which is located along the coastal area. The individual at the WKT site on the Xiaoliuqiu Island consumed mostly terrestrial foods rather than marine resources. Another interesting finding is that apart from freshwater foods and terrestrial animals, the two KS individuals may have eaten large amounts of C_3 plant foods, implying that rice was likely an important resource at this coastal site.

The diet is dominated by terrestrial foods at the FTY site, while two individuals appear to have taken more freshwater resources. This

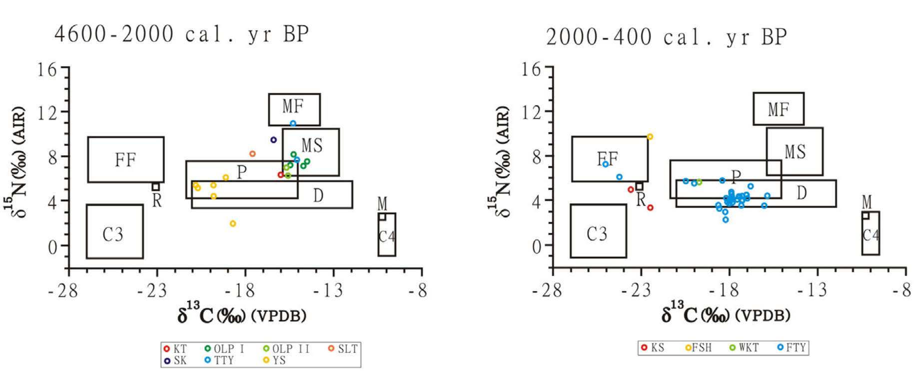

Fig. 3. $\delta^{13}C$ and $\delta^{15}N$ values of estimated human diets, with isotope range of potential food resources (edible part). Estimated human diets are shown as colored dots; squares represent one sigma range of food resources. C_3: modern C_3 plants; C_4: modern C_4 plants; M: modern millet grain; R: modern rice grain; D: deer flesh; P: pig flesh; FF: freshwater fish flesh; MF: marine fish flesh; MS: modern marine shellfish flesh. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

dietary pattern is consistent with the location of the FTY site, which is under the Houli Tableland and near the Daan River.

Both terrestrial faunal and shellfish remains were found at these sites (Li, 1985; Liu, 2004; Shih and Song, 1956; Yoneda et al., 2008), and some shellfish were identified as marine species, such as the Pacific oyster (*Crassostrea gigas*) at the FTY site (Shih and Song, 1956). In other words, although our isotope result indicates that a decrease in reliance on marine resources likely occurred along the coastal area during the Iron Age, the people still exploited these resources with varying degrees of dependence.

5. Causes for the reduction in reliance on marine resources

The isotope data revealed that the prehistoric people did not mainly relied on crops after the introduction of crops into Taiwan. This finding is basically consistent with the archaeological findings (Tsang, 1999). However, in comparison to the Neolithic period, the coastal groups may have depended less on marine resources, and, instead, more on terrestrial and freshwater foods during the Iron Age. If the sampling bias due to the limited sample size is excluded, this difference in dietary patterns might be explained in one of the following three ways.

First, there may have been some stresses in resource, particularly the depletion in marine resources, which forced the Iron Age people to turn more to terrestrial and freshwater foods. A similar interpretation was proposed by the isotope study conducted in Fiji and Remote Ocaenia (Jones and Quinn, 2009), in which the decline in marine resources associated with the major drops in sea level has been ascribed to the shift from a marine diet to a terrestrial one occurring at 650 cal. yr BP. However, the sea level of the Taiwan Strait has fallen to its present position without large fluctuations since ca. 5000 cal. yr BP (−0.5 m/1000 yrs, Chen and Liu, 1996). Such a gentle sea level change is unlikely to have had an impact on the availability of marine resources to the Iron Age people inhabiting the coastal areas of Taiwan.

Another potential cause is that a common ideology against consuming marine resources in favor of territorial resources may have prevailed along the coastal areas of Taiwan. A similar observation was presented in the isotopic dietary studies of Northwest Europe, in which there was a shift of marine foods as the primary resource in Mesolithic diets to the lack of these resources in Neolithic diets. This shift seems to have been sudden and widespread (e.g. Tauber, 1981; Schulting and Richards, 2001; Richards et al., 2003). As a result, some scholars suggested that the Neolithic people actively rejected marine resources due to food taboos, religious beliefs and myths about the sea (e.g. Thomas, 2003).

Although the ideological changes might be an explanation, archaeological evidences such as fishing tools and marine shellfish remains reveal that the exploitation of marine resources was not completely inhibited in Taiwan during the Iron Age. In addition, there were many groups which occupied Taiwan during the Iron Age, and hence it is not convincing to assume that a cross-cultural ideology was accepted simultaneously by these groups with different cultures and customs.

The third interpretation is an increasing reliance on crops by the Iron Age people, which not only fulfilled the food requirements but also resulted in a reduced dependence on marine resources. This scenario can be supported by the evidence from one palynological study, which indicates that the pollens of crops and agriculture-related secondary forest appeared significantly in central Taiwan from ca. 2000 cal. yr BP (Lee et al., 2014). Our isotope data, however, did not indicate a remarkable consumption of crops and/or the other plant foods by the Iron Age people, while the two KS individuals seemed to have consumed more C_3 plants or rice. One possible explanation is that the crops still did not become the staple in human diet during the Iron Age, even though the consumption of crops may have increased.

This scenario, if true, also implied a time lag between the introduction of crops into Taiwan and the development of a stronger reliance on crops. When comparing with the climate records reconstructed by the palynological studies, the climatic-related factors may have had an impact on the crops growing, and thus on the extent of crops cultivation and exploitation, in prehistoric Taiwan.

The palynological studies revealed that the climate changes occurring in Taiwan over the past 5000 years included a shift from a warm climate prevailing in the mid-Holocene epoch (8000–4000 cal. yr BP) to a cool climate ca. 4000 cal. yr BP (Lee et al., 2010; Lee and Liew, 2010; Liew et al., 2006a, 2006b). This cool climate lasted for 2000 years. The climate turned warm again ca. 2000 cal. yr BP.

Following the climate situation, rice and millet may have been cultivated well after their introduction in the warm mid-Holocene epoch, which also triggered the spread of the Dabenkeng culture throughout Taiwan. However, it is likely that crop cultivation was impeded by the cool climatic condition occurring ca. 4000 cal. yr BP. As a result, the prehistoric groups had to take advantage of any resources available around them. A change to a cool climate has also been considered to be the main cause for the decline in agricultural cultures in China, which induced reduction in size and numbers of sites and the disappearance of sophisticated architecture and artifacts of high quality (e.g. An et al., 2005, 2014; Liu et al., 2010; Liu and Feng, 2012; Liu et al., 2014). Instead, the amelioration in the climatic condition occurring at ca. 2000 cal. yr BP may have been favorable for crop growing, which stabilized the crop production during the Iron Age.

Although this study has given an overview and general picture for dietary patterns in prehistoric Taiwan, more effort is needed to improve the temporal and spatial resolutions. First, the data presented here were all collected from the sites located in the western part of Taiwan. The samples from the eastern part and inland area could provide a more comprehensive basis for comparison. If possible, continuous isotope data spanning the whole time frame in one single coastal site or direct radiocarbon dates on the 53 human bone samples are needed as well in order to confirm the chronology and rate of the change in dietary patterns observed in this study. This study also lacks isotope data from some resources, such as shellfish from brackish and freshwater habitats, which could be two more important resources for prehistoric people. In addition, the isotope baselines of plant foods were cited from Japan and China. However, the data may not be suitable to be used to evaluate the importance of crops in the diet of prehistoric people in Taiwan, since the difference in environmental conditions between Taiwan and other regions may have effects on the isotope compositions in each ecosystem (e.g. van Klinken et al., 2000). Finally, isotopic analysis from bone apatite may help to understand the intake of low protein foods, e.g. wild plants and crops, in human diet, since both carbon and nitrogen elements in bone collagen are directly acquired from dietary protein (Ambrose and Norr, 1993; Tieszen and Fagre, 1993).

6. Conclusion

Carbon and nitrogen isotope data derived from human bone collagen were collected in order to reconstruct the dietary patterns of 11 prehistoric groups in Taiwan after the introduction of crops. Marine resources or a mixed diet consisting of marine and terrestrial resources were consumed by the Neolithic coastal groups, while terrestrial resources were eaten by the people who occupied the inland area, e.g. at the YS site. During the Iron Age, the terrestrial and freshwater foods were the two most exploited resources by both coastal and inland groups. In addition, two KS individuals seemed to have consumed more C_3 plants or rice. In summary, even if the crops have been introduced into Taiwan ca. 5000 cal. yr BP, most prehistoric people did not focus on crops.

Dietary patterns were more related to the site locations during the Neolithic period. By comparison, the Iron Age groups seemed to depend less on marine resources, even though they lived along the coast. The cause for the reduced reliance on marine resources along the coastal areas during the Iron Age is still unknown. However, it concurred temporally with a climate change from cool to warm conditions occurring ca. 2000 cal. yr BP. This comparison may indicate that the warm climate in the Iron Age was favorable for crop growing, which increased food production and probably caused the coastal groups to choose to decrease dependence on marine resources during the Iron Age.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2018.04.039.

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