HABITUAL ACTIVITY INDUCED MUSCULOSKELETAL STRESS MARKERS AMONG PREHISTORIC HUNTER-GATHERER-FISHERS AND FARMERS: A CASE STUDY FROM JAPAN

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Abstract

The transition from fishing, hunting, and gathering to full time agriculture occurred at different times in different places throughout the world. The global shift from foraging to agriculture is widely recognized to have intensified physical stress on the human body. This dissertation examines musculoskeletal stress markers (MSM) to assess the impact of habitual activity on the skeleton during this transition in prehistoric Japan. By analyzing skeletal remains from Jomon hunter-gatherer-fishers, Yayoi farmers, and historical modern Japanese farmers, this dissertation investigates changes in biomechanical stress associated with shifting subsistence strategies and labor demands.

This research uses a combination of a traditional scoring semi-quantitative method and an innovative three-dimensional quantitative methodology to enhance the precision of MSM assessment. The skeletal collections analyzed include well-preserved remains from 743 individuals from 24 archaeological sites across Japan. This research tests hypotheses related to increased physical stress with the intensification of rice paddy farming in Japan. The results indicate a considerable increase in MSM expression among Yayoi farmers compared to the Jomon hunter-gatherer-fishers, supporting the hypothesis that farming required greater physical stress. Furthermore, evidence suggests variation in MSM expression related to geographic location, with inland Yayoi groups displaying higher MSM levels than the coastal and riverine groups.

This study contributes to bioarchaeology by refining methodologies for MSM assessment and providing data on the skeletal impacts of different subsistence strategies. The findings have broader implications for understanding skeletal adaptations to habitual activity across time and geographic regions. By using both semi-qualitative and quantitative approaches, this research advances the study of MSM and entheseal change.

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Chapter 1: Introduction

The Problem

The transition from foraging to agriculture is one of the most significant shifts in human prehistory. The change in subsistence strategies led to a surplus and increase in social organization that changed the entire world and created the booming populations we see on the Earth today. This shift in subsistence strategies also led to alterations in biomechanical stress patterns that can be seen in the human skeleton. Understanding how this transition affected musculoskeletal stress markers provides insight into past human behaviors.

In Japan, the Jomon and Yayoi are two prehistoric groups that represent two distinct subsistence strategies that overlapped for approximately 300 years. The Jomon are the hunter-gatherer-fishers who inhabited Japan from approximately 16,500 to 2300 BP, while the Yayoi are the rice agriculturalists who inhabited Japan from 2600 to 1800 BP (Habu et al., 2017). The Jomon people practiced a broad-spectrum subsistence strategy and were semi-sedentary, utilizing marine and terrestrial resources to sustain their populations (Habu et al., 2017; Kobayashi and Kaner, 2004; Bellwood, 2008; Hanihara, 1991). They actively managed plants and influenced their environment through techniques such as the cultivation of lacquer trees, chestnut groves, and wild nettles (Crawford, 2011; Bleed and Matsui, 2010). It is important to note though, that they did not transition fully into agriculture. Despite this reliance on wild resources, some evidence suggests that the Jomon participated in rudimentary rice farming during the Final Jomon period. This evidence comes from the Kitashirakawa-Oiwakecho site, where there is archaeological evidence of primitive rice cultivation (Nasu and Momohara, 2016). However, these cultivation efforts were minimal in comparison to large-scale rice paddy farming.

The Yayoi period marked the actual shift toward full-time agriculture in Japan. The Yayoi migrated from China to Korea, and then Japan, bringing farming techniques, new tools, and new social structures along with them (Mason and Caiger, 1997; Barnes, 2019; Mizoguchi, 2013, Crawford, 2011). Wet-rice farming required significant labor, including woodland clearing, irrigation construction, and grain processing. Though Yayoi farmers used metal tools such as plows, axes, and sickles that were absent in Jomon sites, the labor was still intensive and would have been extremely physically stressful on their bodies (Hitchins, 1976; Hudson and Barnes, 1991; Mizoguchi, 2017; Barnes, 2015; Croft et al., 1992; Eshed et al., 2004; Santana-Cabrera et al., 2015).

The overlap between the Jomon and Yayoi periods was multiple centuries long. During this overlap, the Jomon in certain regions likely interacted with and learned from the Yayoi. Overall, the transition from a broad-spectrum foraging subsistence strategy to rice-paddy farming in Japan was shaped by environmental opportunities, population pressures, and cultural exchange. The Jomon maintained a relatively low intensity subsistence strategy, but due to this overlap in time periods, it is reasonable to believe that the Late Jomon and Early Yayoi could have been participating in similar subsistence activities. Perhaps the Late Jomon in some regions (particularly learned rice farming from the Early Yayoi. As stated, there is evidence of rudimentary rice farming in a Final Jomon site. If the Late Jomon and Early Yayoi were interacting and taking part in cultural exchange, it is feasible that the Late Jomon started to farm rice after learning the methods from the Early Yayoi. This can be investigated through the assessment of entheseal change and musculoskeletal stress markers.

Methodological Framework

It is widely held that full-time agriculture is more physically stressful on the body than foraging. This is due to the intensive labor that is included with farming, including preparation of land for cultivation, sowing, harvesting and processing of grains. Musculoskeletal stress markers (MSM) are defined as "osseous changes observed on the muscle attachment portions of bones, especially postcranial limb bones" (Takigawa, 2014, p.7) that reflect the activity of the attaching muscle (Villotte et al., 2009). By evaluating the MSM of individuals, we can learn about the physical demands experienced by populations and their habitual activities during this transition. In examining MSM of the Jomon and Yayoi, I am able to identify different habitual activities performed by the hunter-gatherer-fishers and farmers.

In order to conduct this research, I examined the postcranial remains from the historical modern sample of Ikenohata-shichikencho (late 17th to 19th centuries), an Edo site excavated in Japan where a great deal of evidence of long term farming is present. I then studied collections from Jomon hunter-gatherer-fisher and Yayoi agricultural sites in Japan. I developed a methodology that scored MSM on these Japanese skeletal collections using a modified Hawkey and Merbs (1995) method and a new three-dimensional quantitative method. The modified Hawkey and Merbs (1995) method uses a visual reference system to categorize MSM expression into three primary features: robusticity, stress lesion, and ossification exostosis. Each category is scored on a four-point scale (0: no expression; 1: faint expression; 2: moderate expression; 3: strong expression). This method has been widely used in bioarchaeological research due to its reliability, extensive use in the field, and the availability of visual reference materials. However, modifications were made to improve consistency, particularly regarding intermediate scores. The

MSMs of the known population were used as a baseline to compare against the MSMs of the Jomon and Yayoi.

To enhance objectivity and accuracy of MSM analysis, I developed a three-dimensional method alongside the traditional semi-quantitative scoring method. This method allows for the quantification of robusticity, pitting depth, and surface complexity. Photogrammetry was selected due to its affordability, accessibility in the field, and ability to produce high-resolution reconstructions of bone. This new method is useful for this research and will also be for countless other similar studies. The creation of this new method contributes significantly to the fields of bioarcheology and paleopathology.

Research Questions and Hypotheses

By using this methodology, I was able to answer a range of questions related to the behavioral activities of these prehistoric peoples. The hypotheses guiding this dissertation are as follows:

1. It is possible to determine if the inhabitants of different prehistoric hunting-gathering-fishing and agricultural sites were doing different activities.
2. Earlier sites were participating in a broad-spectrum subsistence economy, while sites from later time periods were relying heavily on farming.

This dissertation is also able to answer these specific questions:

1. What subsistence activities were the inhabitants of the sites participating in?
2. Generally, did the Jomon have a less physically stressful lifestyle than the Yayoi?
3. Were Late Jomon participating in rice farming?

4. Were the Early Yayoi participating more in broad-spectrum subsistence strategies than the Final Yayoi?
5. Were the Final Yayoi participating more in rice farming than the Early Yayoi?

Organization

This dissertation is structured into six chapters. Chapter 2 provides an overview of the archaeological background of Japan, outlining the Jomon and Yayoi cultures, their subsistence strategies, and the transition to agriculture. Chapter 3 explores the bioarchaeological significance of MSMs in assessing habitual activities. Chapter 4 presents the materials and methods used in this study, detailing the skeletal collections analyzed, the scoring system for MSMs, and the three-dimensional quantitative method developed for this dissertation. Chapter 5 reports the results of the MSM analysis, highlighting the patterns across general populations, time periods, location, and the sexes. Chapter 6 discusses the findings and how they align with archaeological evidence. Chapter 7 summarizes the key conclusions and suggests directions for future research.

Chapter 2: The Prehistory of Japan

The Peopling of Japan

The Jomon people were hunter-gatherer-fishers dispersed throughout much of the Japanese archipelago from 16,500 to 2300 BP (Habu et al., 2017; Kobayashi and Kaner, 2004; Bellwood, 2008; Hanihara, 1991). The Yayoi people were agriculturists identified as having lived in the northern Kyushu and Yamaguchi areas of Japan following the Jomon from 2600 to 1800 BP (Habu et al., 2017). The agriculturalists of the Yayoi period migrated to the Japanese islands from mainland East Asia, differing from the plant gathering, fishing, and hunting of the previous Jomon period. The most widely held model for the peopling of Japan is the dual-structure model, which proposes differential origins for the modern Japanese people from the contributions of the ancient peoples of the Japanese archipelago (Hanihara, 1991). The dual-structure model states that the Jomon are a continuation of Southeast Asian foragers that made up the Paleolithic Japanese and the Yayoi migrated to the Japanese islands from mainland East Asia. Thus, the morphological variation seen in the modern Japanese is the result of various degrees of admixture between the Jomon and Yayoi (Hanihara, 1991). This model includes the Ainu-Ryukyu common origin theory that the morphological variation seen in modern Ainu and Ryukyu Islanders is a result of them retaining more of the physical traits of the Jomon (Kudaka et al., 2013; Schmidt and Seguchi, 2014). Some agree that the Yayoi migrated from mainland East Asia and assimilated with the Jomon, while the Jomon contributed to the Ainu and Ryukyuans. However, many do not think that the Jomon are simply a continuation of Southeast Asian foragers that migrated to Japan during the Pleistocene, as there are too many genetic links between the Jomon and Siberians. In this first section, I will overview the current research on the peopling of Japan and the most supported theories.

Period	cal BP
Early Jomon	16500-5300
Middle Jomon	5300-4400
Late/Final Jomon	4400-2300
Early Yayoi	2600-2400
Middle Yayoi	2400-2200
Late/Final Yayoi	2000-1800

Table 2.1. Japanese Periods Habu et al., 2017

The First People in Japan

There are clear land connections to the Japanese archipelago during marine isotope stage (MIS) 16, 12, and 6 (Nakazawa and Bae, 2018; Bae, 2024). While there has been no evidence of hominins reaching the Japanese archipelago during MIS 16 or 12, there have been some proponents of an early arrival by hominins during MIS 6 (191 ka – 130 ka) (Matsufuji, 2010). This hypothesis has used evidence from the Kanedori site dated between 84 ka and 68 ka and the MIS 5e dated site of Sunabara in western Honshu where observations of purposeful knapping on recovered lithics have been found (Uemine, 2014; Matsufuji and Uemine, 2013; Bae, 2017). These “artifacts,” however, were found with naturally fractured debris as well (Matsufuji and Uemine, 2013), and consequently has been scrutinized (Nakazawa, 2017; Nakazawa and Bae, 2018; Bae, 2017; Norton and Jin, 2009; Norton et al. 2010). Therefore, there is currently no reliable evidence of early humans arriving in Japan during MIS 16, 12, and 6.

However, it is now known that during MIS 3 humans reached the islands, backed up by evidence of obsidian being moved from Kozu Island, which was always separated from Honshu, to the Kanto Plain (Nakazawa and Bae, 2018; Norton and Jin, 2009; Bae 2017). During glacial periods, numerous islands including the four larger islands of Japan were connected, so during MIS 4 and 2, Honshu, Shikoku, and Kyushu were connected to form a single island, commonly referred to as “Paleo-Honshu” (Nakazawa, 2017; Nakazawa and Bae, 2018). Hokkaido formed the southern end of a peninsula in northeastern Siberia, commonly called the "Paleo-Sakahalin/Hokkaido/Kurile Peninsula" (Paleo-SHK) (Nakazawa, 2017; Nakazawa and Bae, 2018).

Given the unique geographic features of the Japanese Archipelago, several different migration routes to the islands are viable. Saitou (2005) proposes six possible routes of human entry. All of the routes are viable if humans have advanced seafaring skills and the ability to navigate oceans over long distances even when landmarks are no longer visible. Given possible land connections, terrestrial human migrations are only achievable through one of the routes. The other five routes all require a certain level of seafaring capability, which was clearly present in the region by the advent of the previously stated obsidian transportation from Kozu to Paleo-Honshu. Paleolithic seafaring in the region has been shown to have been possible through experimental voyages. Although unsuccessful with bamboo rafts because of strong currents, it might have been possible if log boats were used (Kaifu et al., 2019; Kaifu, 2022). The supposed presence of log boats in the East Asian Late Paleolithic is realistic due to the occurrence of edge-ground axes in mainland Japan and evidence that these axes can cut down a large tree suitable for boat construction, in addition to the fact that no land connections were present during MIS 3 (Tsutsumi, 2012; Bae, 2017, 2024; Normile, 2019; Servick, 2019; Kaifu et al., 2019; Kaifu, 2022).

Of the six possible routes outlined by Nakazawa (2017) and Nakazawa and Bae (2018), three have support: the southward route from continental Northeast Asia into Hokkaido (route 1); the eastward route from continental East Asia to Kyushu (route 5); and the northward route from continental Southeast Asia to the Ryukyus (route 4). The Pleistocene human fossil record is primarily concentrated in the Ryukyus, implying that Late Paleolithic hunter-gatherers had already migrated into the far southern Japanese islands by seafaring, though that route is still not clear (Nakazawa, 2017) (see Bae, 2017, 2024 for the arguments for and against the use of the terms “Upper” vs “Late” Paleolithic in Japan). Ancient DNA data largely supports gene flow from eastern Siberia to Hokkaido, possibly since the Last Glacial Maximum (Adachi et al., 2011; Kanzawa-Kiriyama et al., 2013, Kanzawa-Kiriyama et al., 2017, Nakazawa, 2017). This would mean Pleistocene population dynamics were more complex than previously thought. It is likely that the peopling of Japan was the result of admixture of two opposite large migratory events, similar to the Korean Late Paleolithic and likely involved an influx of hunter-gatherers from the north and south (Nakazawa, 2017).

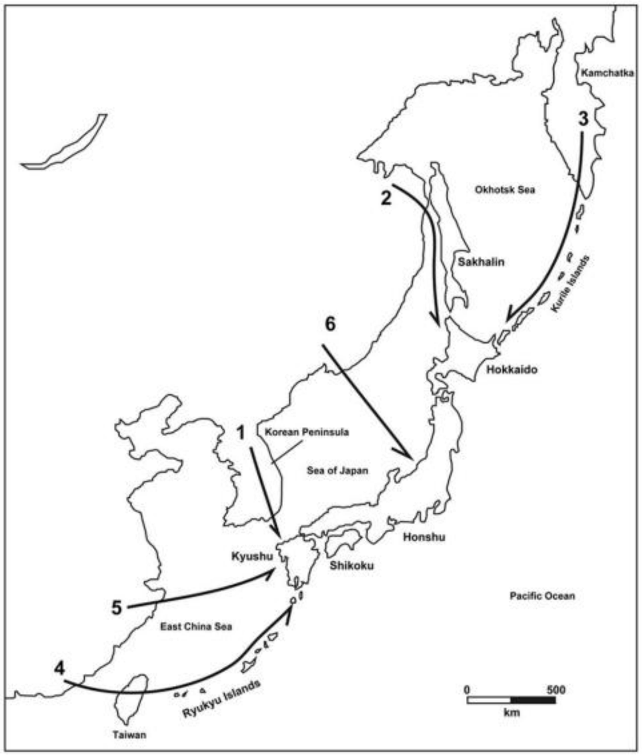

Figure 2.1. Map of the expected migratory routes to Japan from Nakazawa, 2017.

This timeline and theory that includes these routes is supported by evidence in the archaeological and human fossil record. Archaeologically, there is clear evidence of the Japanese Paleolithic appearing around 40 ka (Yamaoka, 2010). The similarity of retouch technologies between Japanese knives and Korean tanged points leads archaeologists to hypothesize that an immediate technological transmission of tools from Korea and Japan during the Late Paleolithic took place, which could be evidence that groups migrated to Kyushu from the Korean peninsula, emphasizing route 5 (Ambiru, 2010). The timing also coincides with the archaeological evidence in Korea. Korea has relatively few archaeological sites until the Late Pleistocene. Therefore, if there is a dispersal from the Korean Peninsula, it would make sense that humans would not be migrating to Japan from there before MIS 3, even with the presence of land bridges, if Korea was not densely populated until MIS 3 (Nakazawa and Bae, 2018). Perhaps this increase in population created the incentive for foragers to leave the Korean Peninsula and migrate to Japan at that time. When looking at the human fossil record, the majority of the Pleistocene remains have been on the Ryukyus with all of the ages falling in the second half of MIS 3 or MIS 2 (Nakagawa et al. 2010; Nakazawa, 2017). This further supports the argument that the migration to Japan occurred during MIS 3 through seafaring, and not during MIS 16, 12, or 6, when there were land bridges. Again, the earlier arrival hypothesis cannot be entirely discounted, it is only that little concrete evidence has been presented to support it.

The Jomon

The Jomon people were hunter-gatherer-fishers dispersed throughout Japan from approximately 16,500 to 2300 BP (Habu et al., 2017; Kobayashi and Kaner, 2004; Bellwood, 2008; Hanihara, 1991). Although the Jomon people had a hunting-gathering and fishing subsistence strategy, they developed a sedentary lifestyle and utilized pottery (Habu et al., 2017; Kobayashi and Kaner, 2004; Bellwood, 2008; Hanihara, 1991). The cord-marking on their pottery is how they received their name (Habu et al., 2017). Most of what is known about the

Jomon culture comes from the materials found in their pit dwellings and refuse heaps (Mason and Caiger, 1997; Kobayashi and Kaner, 2004; Sakaguchi, 2009). Jomon remains were first found by E. S. Morse in 1877 when he discovered “kitchen middens,” which are the garbage mounds or refuse heaps of primitive people, at Omori south of Tokyo (Varley, 2000). These mounds were mainly filled with discarded shells leading archaeologists to call them “shell mounds” or “kaizuka” (Varley, 2000). The mounds were able to reveal much about the diet of the Jomon people but also uncovered some tools, pottery and other objects belonging to the Jomon (Varley, 2000; Mason and Caiger, 1997; Kobayashi and Kaner, 2004; Sakaguchi, 2009; Oomi, 1984; Yoneda et al., 1996; Rowley-Conwy, 1984). In their later age, the Jomon established semi-permanent settlements, many of which were near rivers and springs in the mountains or by the sea where they had access to shellfish(Mason and Caiger, 1997; Varley, 2000; Rowley-Conwy, 1984; Akazawa, 1982; Kanaseki and Tabata, 1930; Kiyono, 1969; Matsui and Kanehara, 2006). The shell mounds left by the Jomon also show that they hunted deer, boar, and many other animals with bows and arrows, and fished with harpoons and bone fish-hooks (Mason and Caiger, 1997; Nishihara, 1988; Ikawa-Smith, 1980).

The skeletal record of Japan has focused on the physical differences between the Jomon and Yayoi. There have been numerous ideas proposing the population history of the Japanese using skeletal remains, leading to theories such as the hybridization theory (Kiyono, 1949), continuity theory (Hasebe, 1940), replacement theory (Howells, 1966), the widely held dual-structure model (Hanihara, 1991), and the newer tripartite theory (Cooke et al. 2021).

Hanihara’s dual-structure model proposes that humans entered Japan from Southeast Asia with a continual influx from the Jomon and then assimilated with the Yayoi, who migrated from Northeast Asia (1991). This model claims that those in Honshu, Shikoku, and Kyushu were the result of admixture between Jomon and Yayoi, and the Ainu and Ryukyuans retained Jomon morphology (Hanihara, 1991). Although genetic studies largely support this model for the admixture between Jomon and Yayoi and the Ryukyuan and Ainu populations (Kudaka et al., 2013; Schmidt and Seguchi, 2014; Igawa et al. 2009; Nakahashi and Iizuka, 2008; Takamuku, 2019; Jinam et al., 2012; Nakagome et al, 2015; Jinam et al. 2021a; Jinam et al., 2021b; Kanazawa-Kiryama et al., 2019; Gakuhari et al., 2020), the genetic relationship between Southeast Asia and the Jomon is less supported (Jinam et al., 2015). The Jomon was founded by both northward and southward gene flows and generally, as the Jomon and Yayoi both contributed to the current Japanese population, the Paleolithic population can be regarded as the likely founding population of the Jomon (Nakazawa, 2017). However, due to few genetic and human fossil records of the Paleolithic foragers of Japan, the extent to which Pleistocene Paleolithic populations contributed to modern Japanese is still poorly understood (Nakazawa, 2017). Because of this it is not known if the Jomon were direct descendants of the Paleolithic foragers; this part of the dual-structure model cannot be agreed on.

An alternative model is the tripartite hypothesis, which proposes that in addition to Jomon and Yayoi genetic contributions, there is a new contribution from a population migrating from the southern Korean peninsula during the more recent Yayoi-Kofun transition (Cooke et al., 2021). The Kofun period started approximately 1,700 years ago in Japan and saw the emergence of the political state and imperial reign in Japan (Mizoguchi, 2017). Cooke and colleagues suggest that the genetic profile of the Japanese was established during this Kofun period (2021). Some newer studies have suggested that the tripartite model fits more consistently than the dual structure model (Yamamoto et al., 2024; Cooke et al., 2023; Osada and Kawai, 2021). However, there have been studies that suggest issues with the tripartite model (Liu et al., 2024; Nakao et al., 2024; Gelabert et al., 2022; Kim et al., 2024). One issue is the limitations of the samples used in the creation of the tripartite model (Kim et al., 2024). The Yayoi remains excavated from northern Kyushu are separated by northwestern Kyushu and northern Kyushu and Yamaguchi. This is due to the northwestern Kyushu Yayoi exhibiting morphological traits similar to the Jomon, in contrast to the northern Kyushu and Yamaguchi area Yayoi exhibiting a higher face and taller stature (Kim et al., 2024). Yayoi samples used in the Cooke and colleagues (2021) study were from northwestern Kyushu, possessing genetic components from both the Jomon and the immigrants from the Asian continent; therefore, they are not considered indicative of a more traditional Yayoi genetic profile (Kim et al., 2024). Additionally, it has been argued that this "separate" Kofun strand overlapped with the previous Yayoi strand and was not "separate" after all (Nakao et al., 2024; Gelabert et al., 2022). Consequently, the dual structure model remains the most widely accepted theory (Kim et al., 2024).

While it is unknown if the Japanese Paleolithic population and the Jomon are genetically continuous at this time, we can review what is currently known of Jomon origins through skeletal remains. Multiple anthropologists have acknowledged a mismatch in Jomon postcranial variation in limb and body proportions. The Jomon have wide body breadths and large body-mass for cold adaptations, but their limbs are similar to those in a tropical climate (Fukase et al. 2012; Temple et al. 2008; Temple and Matsumura, 2011; Mizushima et al., 2016; Mizushima et al., 2023). When Temple and colleagues (2008) found that Jomon foragers have similar limb proportions to groups from temperate and/or tropical environments, they suggested two possible evolutionary scenarios. Firstly, the ancestors of Jomon may have originated from a temperate or tropical environment or secondly, their ancestors originally had limb proportions similar to high latitude groups from colder environments, but changed after experiencing the warmer environment of

Japan over time (Temple et al., 2008). The researchers believe that either of these scenarios is possible because Pleistocene Japan was climatically mild (Temple et al., 2008). Schmidt and Seguchi believe this mismatch actually points to multiple migration processes and possible routes (2014).

Additionally, some anthropologists have argued that variation in human tooth size and shape supports the grouping of the Jomon with the indigenous groups from Australia, Melanesia, and Southeast Asia, but more specifically, the Jomon people possess some dental traits associated with sundadonty (Hanihara, 1991; Matsumura, 2007; Matsumura and Hudson, 2005; Turner, 1990; Temple et al., 2008). Sundadonty is a dental pattern characteristic of Southeast Asia, while sinodonty is a dental pattern chracteristics of Northeast Asia (Hanihara, 1993; Matsumura and Hudson, 2006; Turner, 1990) (see footnote below)[1]. They claim these traits date to the Late Pleistocene and are associated with those who initially colonized Sundaland (Temple et al., 2008). If the Jomon were descendants of the prehistoric people of Sundaland it would likely be the ancestors of the Jomon that arrived in Japan with temperate/tropical limb proportions; thus leaning towards the first migration theory outlined by Temple and colleagues (2008). However, this has been criticized by other anthropologists who argue the dental metric evidence is not consistent with a southern origin interpretation, because the Jomon have smaller teeth than Southeast Asian and Australo-Melanesian peoples and the size reduction likely would not have taken place so quickly (Schmidt and Seguchi, 2014).

Genetics has been able to uncover different theories about the Jomon and their origins. While investigating the mitochondrial DNA haplogroups of four Jomon individuals from the

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[1] Turner (1990) stated sinodont populations had high frequencies of UI1 shoveling, UI1 double shoveling, one-rooted UP1, UM1 enamel extensions, pegged/reduced/missing UM3, LM1 deflecting wrinkle, and 3-rooted LM1. Sundadonts had lower frequencies of these traits and a higher frequency of four-cusped LM2.

Sanganji shell mound in Fukushima, the researchers were able to conclude there were some genetic similarities between the Tohoku Jomon and the indigenous southern Siberian people (Kanzawa-Kiriyama et al., 2013). In a different study using mtDNA from both teeth and compact bones for 101 Hokkaido Jomon and Epi-Jomon individuals, similar results were found indicating the main origin of the Hokkaido Jomon was the lower Amur region of Siberia (Adachi et al., 2011). Another link to Siberia is seen in the findings of Kanzawa-Kiriyama and colleagues (2017). They state that while some cranial metric and dental analyses suggest the Jomon people originated from Southeast Asia (Hanihara, 1991; Turner, 1987; Turner, 1990; Matsumura, 2007; Matsumura et al. 2009; Temple et al., 2008) and morphological analyses (Hanihara and Ishida, 2009; Nakashima et al. 2010) and mtDNA sequence data (Adachi et al., 2009) point to Northeast Asia, their Jomon nuclear genome sequences suggest that the Jomon people were descendants of an ancestral East Eurasian population (Kanzawa-Kiriyama et al., 2017). Conversely, in another study, one Jomon individual from Ikawazu, was found to be a mix between those from the Andaman Islands and East Asians (McColl et al., 2018). Nevertheless, the majority of recent genetic studies suggest that the Jomon have genetic similarities with Siberian populations, suggesting that perhaps the second hypothesis of Temple et al. (2008) is more likely. This hypothesis postulated that the Jomon originally had limb proportions suited for colder environments that changed over time. This suggests that Jomon origins are more complex than a simple migration from Southeast Asia that Hanihara (1991) suggested. Many more Jomon samples need to be analyzed. Additionally, DNA from the Paleolithic Japanese and the Jomon need to be studied extensively.

The Yayoi

The Yayoi are the agriculturalists of Japan that migrated from China, to Korea, and then Japan, bringing rice paddy farming with them. "Yayoi" is used to describe the pottery from this time period that also includes rice growing, metalworking, and cloth making (Mason and Caiger, 1997; Barnes, 2019; Mizoguchi, 2013, Crawford, 2011). The Yayoi age is believed to have lasted from 2600 BP to 1800 BP (Habu et al., 2017). The most important cultural changes during this time were the introduction of paddy-field rice cultivation and metal tools.

Elements of rice cultivation were included in the Yayoi culture, but it seems as if this new technology came a bit earlier than the start of the Yayoi culture (Barnes, 2015; Nasu and Momohara, 2016; Barnes, 2019). Despite some early resistance, rice farming did eventually spread throughout the Japanese archipelago, even as shellfish gathering and hunting continued through the Early Yayoi and beyond. Within a proposed two-stage model for the spread of rice the first wave includes diffusion through the western coastal areas at the waist of Honshu Island and the second stage is the eventual full adoption of rice within the Yayoi culture. However, there have been problems with this model as Early Yayoi sites have been identified on the far northern tip of Honshu. There is speculation that these northern Early Yayoi sites were short-lived and complete adoption of rice was not accomplished until later. At this time, rice did not yet reach Hokkaido so the Jomon way of life continued until the 8th century AD, known as the Epi-Jomon period (Barnes, 2015; Barnes, 2019).

It is evident that hunting and fishing were not as important in the Yayoi period than it was in the Jomon period, however protein was still necessary. The Yayoi still needed bird and animal meat, fish and shellfish (Kanaseki and Sahara, 1976; Bleed, 1972). Decoration on a bronze bell showed that the Yayoi used bow and arrows for hunting and were assisted by dogs

(Kanaseki and Sahara, 1976). Fish hooks, gaffs, and harpoons made of horn and animal bone were used, but were later replaced by bronze and iron fish hooks (Kanaseki and Sahara, 1976). The Yayoi later developed gill-net and drag-net techniques of fishing (Kanaseki and Sahara, 1976).

Though rice cultivation is a major technological advance received from the Korean Peninsula, this was not the only cultural trait adopted from the peninsula. One example of these Peninsular artifacts introduced to Japan is the red burnished pottery from Korea that probably inspired the burnished storage jar which accompanied early rice production in Kyushu (Barnes, 2015; Mizoguchi, 2013). Bronze mirrors and weapons, iron tools and weapons, glass ornaments and weaving cloth from a kind of linen thread were introduced and imported during the Yayoi period as well (Kanaseki and Sahara, 1976; Hudson, 1999). The Yayoi were still using stone tools during the earlier half of the Yayoi period. However, the types of stone axes for cutting wood were not the same as the Jomon types, but rather were imitations of stone tools found at Neolithic sites in China and Korea (Kanaseki and Sahara, 1976; Barnes, 2015; Mizoguchi, 2017). These tools include handled and tanged stone daggers, polished untanged arrowheads of triangular cross-section, disk axes, laurel-leaf shaped and triangular reaping knives and grooved adzes (Barnes, 2015). Burial customs were influenced during the Yayoi period as well. During the early and middle stages, the Yayoi in northern Kyushu built tombs similar to the dolmen in northern and Western Europe that also could be found throughout the Korean peninsula (Kanaseki and Sahara, 1976; Bleed, 1972; Mizoguchi, 2005). Wooden birds and bones that archaeologists believe were used for ceremonial purposes indicate that the Yayoi people were spiritual in a way that was also similar to the common continental burial rites (Kanaseki and Sahara, 1976; Mizoguchi, 2020).

While most of the major cultural elements of the Yayoi came from the Asian continent, some elements were those that survived from the Jomon. The Yayoi people kept the semi-subterranean dwellings of the Jomon, simply improving the structure (Kanaseki and Sahara, 1976; Barnes, 2015; Barnes, 2019). At the beginning of the Yayoi period, they were still making stone arrowheads, gimlets, and other stone tools by chipping which survived the Jomon tradition since chipping did not exist in areas surrounding Japan during that time (Kanaseki and Sahara, 1976). Combs, hairpins, comma-shaped beads, and jade came from the Jomon as well (Kanaseki and Sahara, 1976). Tooth extraction began during the Middle Jomon period to the first half of the Yayoi period (Kanaseki and Sahara, 1976; Funahashi, 2022). The Yayoi pottery technique was simply an extension of the Jomon. There was no longer a cord-impression pattern that gave the Jomon culture its name in western Japan, however it was still used during the Yayoi periods in eastern Japan (Barnes, 2015; Barnes, 2019; Kanaseki and Sahara, 1976; Mizoguchi, 2017). In general, it is said that Jomon traditions were more prominent in eastern Japan, while the continental influence was heavier in western Japan (Kanaseki and Sahara, 1976; Barnes, 2015).

The skeletal record further proves that the Yayoi migrated from mainland Asia. Hanihara (1984) found the crania of the Yayoi show morphological similarities to the populations in Mongolia, northeast China, and east Siberia who all are adapted to cold climates. This suggests that the Yayoi came from northeast Asia, probably following routes from their original places through the Korean Peninsula and north China to west Japan (Hanihara, 1984). Skeletal research also stressed that the Yayoi were grouped with northeast Asians and recent Japanese, while the Ainu and the Jomon formed a separate group, supporting the dual-structure model that would later be developed (Hanihara, 1991). These results suggest that a continuity theory was not acceptable. However, Kanaseki (1960), who opposed the continuity theory, had some problems as well. He supposed that the Yayoi migrants espoused native females because they consisted mainly of males, but the female crania from the Doigahama site resemble those found at the Yean-ri site in southern Korea (Hanihara, 1991). Nakahashi and Iizuka (2008) similarly find that Middle Yayoi skeletons resemble the ancient people of the Asian mainland such as those from Yean-ri or Linzi of Shandong Peninsula, rather than in intermediate morphology from admixture at that time. This would suggest that they could not have been native females that they were espousing at this time. This would imply that the Yayoi migrants would have to consist of both males and females and once again, the Yayoi looked similar to those on the mainland Asia.

In considering limb proportions of the Yayoi, returning to Temple and colleagues' (2008) study, one of their hypotheses was that Jomon limb proportions were similar to those from temperate/tropical climates at lower latitudes and the Yayoi limb proportions were similar to those from higher latitude / colder environments (Temple et al., 2008). The Yayoi people were characterized by short distal relative to proximal limb segments and grouped with those from colder environments at higher latitudes, including the modern Japanese (Temple et al., 2008). Temple and colleagues (2008) state that these findings indicate the Yayoi people were the descendants of Northeast Asian migrants to the Japanese Islands and that once the Yayoi migrants arrived in Japan from Northeast Asia, the majority of the Jomon people were genetically subsumed by the Yayoi (Temple et al., 2008).

Lastly, genetics can reveal much about the Yayoi origin story. As stated, physically, the skeletal remains of the Yayoi show a difference in morphological characteristics from the Jomon, as well as a closer similarity to the East-Asian populations (Igawa et al. 2009; Nakahashi and Iizuka, 2008; Takamuka, 2019). Though, it cannot be claimed that all of the Yayoi contributed to the modern Japanese population equally. Igawa and colleagues (2009) analyzed mitochondrial

DNA from human skeletal remains from the Doigahama site in Japan and found that the northern Kyushu Yayoi belonged to the groups that included most of the modern Japanese population, while most of the Doigahama Yayoi belonged to the group that includes a small amount of the modern Japanese population. Therefore, some Yayoi groups contributed more to the formation of the modern Japanese than others, but nevertheless, the Yayoi did contribute to the genetic formation of the modern Japanese, just as the Jomon did both with the modern Japanese (Hanihara, 1991; Habu, 2004; Watanabe et al. 2019; Kanzawa-Kiriyama et al., 2017) and the Ainu, with the Ainu-Ryukyu common origin theory (Hanihara, 1991; Kudaka et al., 2013; Schmidt and Seguchi, 2014; Habu, 2004). In 2017, a study yielded the first evidence verified on the genomic level that the Jomon genetically contributed to the modern Japanese populations, with the admixture proponent being probably lower than 20% (Kanzawa-Kiriyama et al.). The Jomon contribution to the Ainu has also been confirmed genetically (Omoto and Saitou, 1997; Jinam et al., 2012, Jinam et al., 2015; Nakagome et al., 2015). Since then, a new genomic study has also found that the proportion of Jomon ancestry is extremely high in individuals from the Ryukyu and Hokkaido sub cluster (Yamamoto, 2024). One study calls for the rethinking of the Ainu-Ryukyu half of this model due to recent findings of later admixture in Ainu mitochondrial DNA with populations other than Jomon (Adachi et al., 2018). However, the majority of this model is still widely held by biological anthropologists, archaeologists, and geneticists (Baba, 1990; Omoto and Saitou, 1997; Hudson, 1999; Ikawa-Smith, 1995; Habu, 2004; Kudaka et al., 2013; Schmidt and Seguchi, 2014; Jinam et al., 2012, Jinam et al., 2015; Nakagome et al., 2015; Barnes, 2015; Kanzawa-Kiriyama et al., 2017; Nagaoka et al., 2018; Watanabe et al., 2019) because it is consistent with both physical and cultural evidence in Japan suggesting hybridization of the Jomon and Yayoi resulted in the people of Japan today, rather than replacement (Mizoguchi, 2017).

Conclusion

Various theories have been proposed to link the Jomon and Yayoi with modern day Japanese, yet none seem to explain this relation better than the dual-structure model. This is interesting, as this model came about a few decades ago and is still so widely held in the more current research as genomic data becomes more readily available. While this model is helpful in determining Japan’s current population history, it does not comply with current evidence of the first populations in Japan. The notion that the Jomon are simply a genetic continuation of a population of Southeast Asian foragers during the Paleolithic is not supported by recent studies. The Paleolithic Japanese likely took one or more of three paths: the southward route from continental Northeast Asia into Hokkaido; the eastward route from continental East Asia to Kyushu; and the northward route from continental Southeast Asia to the Ryukyus. Though this third route from Southeast Asia has some support, it is not currently supported that the Jomon are descendants of those from Southeast Asia. Inconsistencies with the evidence pointing toward Southeast Asia as well as recent genetic data associating the Jomon with Eurasia prove that the process is more complex. Many more studies need to be done to understand where the Jomon came from and their ties to the Paleolithic Japanese. Thus, anthropologists must reconsider this part of the dual-structure model.

Shift in Subsistence Strategies

The discussion about the origins of the Jomon and Yayoi has been ongoing and changing, however, there has been a consistent consensus on the behaviors of the Jomon and Yayoi, due to the knowledge of their subsistence strategies. The Jomon and Yayoi of Japan have a unique journey to the reliance on domesticates. This is due to the high level of involvement the Jomon had with their environment. Niche construction theory can be used to explain how and why agriculture began without dependence on human decisions. It is known that organisms change their environment, but with niche construction there is a progression, focusing on how the adaptations organisms make to the environment influences the organism's own fitness (Bleed and Matsui, 2010). These specific modifications to the environment made by active organisms then pass on, creating short-term fitness that later on contributes to the organism's own biosocial evolutionary future. Therefore, when groups like the Jomon are extremely active within their environment, the modifications they make impact their fitness. An example of this is the Jomon altering the growth and reproduction of plants and animals in ways that increased their abundance and thus they were able to support their population and have sedentary lifestyles (Bleed and Matsui, 2010; Aikens and Rhee, 1992; Bellwood, 2008; Barnes, 2015).

Niche construction theory is evident in the numerous ways that the Jomon managed plants. The archaeological record shows that the Jomon had a vast knowledge about their environment, indicated by their skill with the complex task of lacquering as it involves use of the sap of poison oak. Rendering sap from lacquer trees requires clearing competitors, pruning the main stem to make it straight, and flowing, then tapping the tree by repeatedly scarring and regularly visiting to collect sap. This is an example of how they managed these poison oak trees for their benefit. Sweet chestnut groves also appear to have been encouraged in areas surrounding Late Jomon communities. Management in the creation of tools and other necessary resources is also exhibited. Making bows that would fit with the Jomon archery tradition would have required the use of staves that were carefully harvested from plants nurtured during growth. There was also an abundance of mats present in the Jomon communities that required huge amounts of straight, regular fibers, and stalks. Although it may be possible they were found abundant enough in nature, it is more likely that they could only have been produced at this level through pruning and coppicing (plant management that involves cutting down a tree to the stump). Lastly, wild nettles in Japan are currently scarce, so in order to clothe themselves with this nettle they must have increased the abundance of the resources they drew on. Essentially, the Jomon tended a number of plants and plant communities to influence the reproduction and productivity of plant communities (Crawford, 2011; Bleed and Matsui, 2010).

Though the Jomon were clearly very active within their environment, this was not sufficient to lead directly to agriculture. The Jomon did not lack human endeavor, as they were clearly quite knowledgeable and capable, but they lacked species that could respond to human manipulation in ways that encouraged increased investment. To have agriculture, domesticates must be able to outcompete other species that attract human attention. In the case of Japan, there were no species able to command the attention of the Jomon enough that they stopped fishing, hunting and harvesting other resources. In addition to broad spectrum subsistence, due to an abundance of resources, the Jomon were able to maintain relatively stable population density with what they had. Agriculture developed in China, but not Japan, simply because China did not have as many resources that could maintain high population density without large scale agriculture. In China, in order to create surplus, they had to turn to rice agriculture while Japan had a plethora of resources to choose from whilst maintaining a sedentary lifestyle, without the need to farm rice (Bleed and Matsui, 2010).

It is commonly held that the introduction of wet-rice agriculture into Japan started the agricultural revolution of the area after the Yayoi period. However, some believe that the beginnings of rice agriculture go back as far as the Middle to Late Jomon (Aikens and Akazawa, 1992; Nasu and Momohara, 2016; Barnes, 2015). This is because, similar to what is seen in China, there is evidence of not only dry rice, but also of primitive paddy fields before the Yayoi period (Fuller et al., 2010; Nasu and Momohara, 2016). This evidence is shown from the primitive rice cultivation site, Kitashirakawa-Oiwakecho, in Kyoto (Nasu and Momohara, 2016). There the Final Jomon level is covered by thick sand deposits because of multiple flooding events. There is evidence of rice and millet from the peaty wetland area, but no clear paddy field remains. When comparing the weed species of the wetland area of the Kitashirakawa-Oiwakecho site and the Initial and Early Yayoi paddy fields of the Nabatake site it is evident that at the Kitashirakawa-Oiwakecho site, there is no clear compartment made by paddy ridges to keep water in the wetland and there was little disturbance caused by human activity in comparison to the Nabatake site. This implies that the type of wet rice cultivation happening during the Final Jomon was not as sophisticated as during the Yayoi period. Because of this, the most reliable timing of rice agriculture dispersal is the end of the Final Jomon period which corresponds to the Initial and Early Yayoi period of northern Kyushu, rather than the Middle to Late Jomon period (Nasu and Momohara, 2016).

After the Yayoi came, there is a clear shift to agriculture in Japan. Throughout the world, climate change was the first factor in steps toward domestication of plants. In Japan, this amelioration of climate change is no different. Broadleaf temperate woodland of oak, walnut, and other species expanded in Japan after the global melting of Pleistocene ice, replacing cold coniferous forests (Aikens and Rhee, 1992; Aikens and Lee, 2013). This climatic shift led to the development of a broad-spectrum economy that allowed major plant food exploitation to aid hunter-gatherer-fishers (Aikens and Rhee, 1992; Aikens and Lee, 2013; Weber et al., 2013). In Japan there was intensive use of plant foods by the Middle Holocene to a degree that led scholars to suggest the emergence of a Jomon agriculture based on gathering, tending, and cultivating, however this has not been proven (Aikens and Rhee, 1992; Aikens and Lee, 2013; Weber et al., 2013). It was clear that the Jomon were obtaining, storing and processing plants but not cultivating yet (Aikens and Rhee, 1992; Barnes; 2015; Barnes, 2019, Mizoguchi, 2017). This shift in climate did not immediately lead to the reliance on domesticates that is seen elsewhere. Due to the abundance of resources in the region mentioned earlier, the Jomon’s heavy emphasis on terrestrial animals and plant foods that was possible after the amelioration of climate, was a precondition for the rapid spread of field cultivation once wet-paddy fields were introduced. Alternatively, others that were not as successful plant users had slower rates of acceptance (Aikens and Rhee, 1992).

Similar to other regions, population increase and social complexity also developed together with the growth of cultivation in Japan (Bellwood, 2008; Aikens and Rhee, 1992; Aikens and Lee, 2013; Weber et al., 2013). There is a possible population increase in Japan from 75,000 people during the Final Jomon to 5.4 million people in the 7th century AD (Bellwood, 2008). This is due to the adoption of rice cultivation in Japan towards the end of the Jomon period. We see that as the Late and Final Jomon approach, production of rice varies, but these surpluses lead to status and wealth not seen before this time (Price and Gebauer, 2007). The Jomon were already storing foods like nuts (Barnes, 2015), but the decision to start relying more heavily on rice in Japan helped facilitate a stable system so that even major environmental disturbances did not destroy their newly social complex system (Higham, 2007). The Jomon were already mostly sedentary due to their unusual abundance of resources, but this change to reliance on the high calorie food that is rice, allowed for population increase. As seen in other regions this population increase almost always then leads to social complexity and stratification.

Lastly, population depletion seen during this period was also a factor in committing to rice cultivation (Barnes, 2015). When the Initial Yayoi came to Japan with a new agricultural technology and new ways of thinking, the shift to rice cultivation only intensified (Barnes, 2015). This is when increased social stratification is really evident with new burial systems, new grave goods, and new technological innovations (Barnes, 2015); one might describe this as a second wave of social complexity invading Japan from increased reliance on agriculture. The Jomon rice is mostly interpreted as dry field rice with the occasional wet-rice paddy field, while the Yayoi were always paddy field rice farmers (Fuller et al., 2010). This difference in technique is seen as the reason the Yayoi were able to have even more increased social stratification, as their techniques were able to contribute to higher levels of wealth accumulation.

In conclusion, the climatic improvement seen during the Holocene allowed for the perfect environment for domesticating plants all over the world. In most areas, once the hunter-gatherer-fishers saw the increase in available domesticates in their area, they began taking advantage of it, but only when these domesticates were abundantly available more so than their previous subsistence. The Neolithic Revolution led people to stay in the regions longer, becoming sedentary. This sedentism causes the Neolithic Demographic Transition, which was a period of rapid population growth that followed the adoption of agriculture during the Neolithic Revolution (Bocquet-Appel and Bar-Yosef, 2008). There was an increase in population due to more infants being born. The demographic pressure gave even further incentive to rely more heavily on plant cultivation. This intensification of cultivation allowed for social stratification when people could accumulate wealth, seen through craft specialization. This demographic pressure also occasionally led to a decrease of their former resources either through environmental stress or overexploitation, causing even more reliance on cultivation and a shift to primarily relying on agriculture for subsistence. The Jomon and Yayoi are a unique case where it took longer for the Jomon to commit to cultivation because of their abundance of food resources due to climate change, but in turn, their environmental knowledge made it even easier for them when they did make the shift. This allowed for a much quicker transition than seen in other regions. There is also a multicausal explanation seen with the Jomon that includes climate amelioration, available domesticates, population increase, and social complexity that is seen in other areas, just on a different timescale. Overall, while many of the past theories postulate one cause for the reliance on agriculture, I suggest that multiple factors led to the transition.

Specific Subsistence Activities

The Yayoi agriculturalists mostly participated in activities that involved wet rice farming. While the Yayoi continued to consume fish, marine consumption was generally higher in the Jomon period sites than the Yayoi sites (Aikens and Akazawa, 1992; Chisholm et al., 1992; Barnes, 2015), though there may have been more fishing taking place during the Early Yayoi than the Middle and Late Yayoi periods (Hudson and Barnes 1991). This is consistent with the adoption of the common staple food, rice, as more people had to be involved with the lofty goal of undertaking the rice paddy farming activities, which occupied a considerable part of the year (Chisholm et al., 1992; Takahashi, 2009; Mizoguchi, 2017). Wet rice farming required many people and much labor to create sophisticated irrigation systems (Mizoguchi, 2017; Barnes, 2015). Large irrigation canals and/or triangular sectioned dams were constructed by placing logs across small rivers to create a dam (Mizoguchi 2013). This was only possible because of the development of wooden earth-digging and earth-moving tools with iron blade edges, such as ploughs and axes, brought from Korea (Hitchins, 1976; Hudson and Barnes, 1991; Mizoguchi, 2017; Barnes, 2015). Weeding with these new tools was also necessary (Mizoguchi, 2013). However, much was done with wooden hoes and spades, such as tillage, ditch digging and soil turning as well (Tsude, 2008). No similar tools were found at Jomon sites (Tsude, 2008). Later in the year, once rice was ripe, reaping knives and sickles were then used to harvest the rice (Hitchins, 1976; Hudson and Barnes, 1992; Tsude, 2008; Mizoguchi, 2017). Because of the strenuous work involved with rice paddy farming, these general farming activities including preparation of land for cultivation, sowing, and harvesting involved various muscles that are used during shoulder flexion, elbow flexion and extension, supination and pronation, arm adduction, arm internal rotation, hip flexion and extension, and knee flexion and extension (Croft et al., 1992; Eshed et al., 2004; Santana-Cabrera et al., 2015). Artifacts have indicated that the processing of grains during the Yayoi period took place with mortars and pestles (Tsude, 2008). Processing grains required repetitive use of the biceps (long head), triceps (long head), common flexors, common extensors, triceps brachii, and biceps brachii to cause shoulder flexion, elbow flexion and elbow extension (Eshed et al., 2004; Shuler et al., 2012). Woodland clearance was necessary for the Yayoi both when creating paddy fields and when creating settlements (Mizoguchi, 2017; Barnes, 2015). Yayoi settlements were moated and had watchtowers as well as storehouses that required clearance of woods to create an open space to build and also wood to build these structures (Hudson and Barnes, 1991; Tsude, 2008). Thick-butted tree-felling stone axes and iron woodworking tools were used (Hudson and Barnes, 1991; Mizoguchi, 2017). Elbow extension and adduction of the arm through the triceps brachii was used in woodland clearance (Dutour, 1986).

As seen from the tools that made many of the Yayoi farming activities possible, metalworking was prevalent during this period (Hitchens, 1976; Tsude, 2008; Barnes, 2015). To make the various bronze and iron tools, weapons and ritual items the triceps brachii, supinator, pronator quadratus, and pronator teres were activated during elbow extension, supination and pronation (Kelley and Angel, 1983; Dutour, 1986). Weaving and clothmaking is also an addition to Japan during the Yayoi period (Barnes, 2015). This loom weaving and use of spindle whorls that created a fine woven structure was different from the Jomon textiles made from twisted fibers of hemp or deadnettle on a matting loom (Hudson and Barnes, 1991; Barnes, 2015). The common extensor, common flexors, supinator, biceps brachii, brachioradialis, pronator quadratus and pronator teres were used in elbow flexion, supination and pronation needed to create the fabric (Shuler et al. 2012; Lawrence et al. 2018). The iliacus, iliopsoas, and gastrocnemius were used for hip flexion and knee flexion from the kneeling that took place during this activity (Shuler et al. 2012; Lawrence et al. 2018). Finally, pottery, though differently designed, was also important during this period (Barnes, 2015). Pottery making required long periods of squatting thus was using the gastrocnemius muscle (Charles, 1893-1894). It is expected that in the postcranial skeleton of the Yayoi, musculoskeletal stress markers involving the above muscles and activities should be higher than those that will be observed in the hunting-gathering-fishing activities of the Jomon, especially those involved in the strenuous general farming activities.

Conclusion

The Jomon and Yayoi have been the topic of much scientific research to complete the puzzle of Japanese prehistory. Skeletal remains and archaeological artifacts have revealed much both about the origins of the Japanese as well as their culture and the activities they were participating in. The Jomon took one or more of three paths to Japan mentioned earlier in this chapter, with the Yayoi then following behind from Korea bringing paddy rice farming and other new technologies along with them. With this new group of people and new technologies, a shift in subsistence happened in Japan that resulted in a need for new habitual activities that involved a physically stressful life and heavy muscle utilization to keep up with the demands of a booming population and sedentary lifestyle.

Chapter 3: Musculoskeletal Stress Markers

One of the many fascinating aspects of biological anthropology is the ability to use the human body as a storybook, learning the history of an individual just from the marks left on their skeletal remains. The skeleton can tell us what a person ate, where the person came from, and what the person did. This chapter focuses on what paleopathologies are and how paleopathologies, especially entheseal change and musculoskeletal stress markers, can be used to determine the activities of deceased individuals.

Bioarchaeology

Archaeologists use material artifacts to determine activities of those from the past. These artifacts can give insight into social complexity of a past site: who was wealthy; the items valued; the typical diet; the kind of tools made; the way the population traveled; the kinds of settlements built; and the climate. This exposes a fair amount of information about how the site was utilized and the people who once lived there, but this type of material has limitations. Skeletal material can complement the knowledge gained from artifacts and add to it as well. The use of skeletal material in archaeological contexts is now called bioarchaeology. But skeletal material was not always thought of as useful for archaeology. Owsley and coworkers stated: “many American archaeologists have not appreciated the full potential of osteological research as a source of information on biocultural behavior and human adaptation. Many of these views persist, as reflected in an archaeologist’s statement to a reporter visiting a field school excavation in Colorado: ‘Human bones don’t provide that much information. After all, we know that they are Indians'" (Larsen, 1997). However, this is currently not the case. Bioarchaeology is now a growing field and it is apparent that skeletal material found at archaeological sites is incredibly important for several reasons.

Hard tissues, like bone and teeth, preserve the greatest amount of biologically relevant information about the past (Larsen, 1997). Thus, it is important to examine skeletons of earlier human groups to understand their living conditions. During a person's life, their skeleton is extremely sensitive to their environment. Here, the term "environment" includes the food eaten, illnesses they developed, and activities taken part in (Larsen, 2000). Each skeleton tells a story about the life of that particular individual; therefore, bioarchaeology explores the lives and lifestyles of earlier human beings (Larsen, 2000). This is why bioarchaeology is now recognized for its enormous potential for understanding the past; through observing the modifications of the skeleton due to environment, we can collect information about physiological stress, nutritional ecology, and activity patterns. Bioarchaeology can help answer questions about mortality and morbidity rates, population demographics, and occupation in ways that other material artifacts could not.

Paleopathology

Paleopathology, the sub-discipline of biological anthropology focused on abnormal variation in human remains for archaeological sites, also contributes greatly to our knowledge of the past and ameliorates the archaeological limitations of artifacts (Roberts and Manchester, 2010). One way that paleopathology is useful in helping bioarchaeologists infer about the past is through the examination of entheseal change (EC). Bioarchaeologists have used EC to reconstruct the activity patterns of past populations for years (Michopoulou et al., 2015; Michopoulou et al., 2016; Rabey et al., 2015; Santana-Cabrera et al., 2015; Henderson and Cardoso, 2013; Lieverse et al., 2013; Shuler et al., 2012; Yonemoto, 2016; Carballo-Perez et al., 2021; Alonso-Llamazares et al., 2021; Dinkele and Gibbon, 2023; Zou et al., 2024; Mazza and Silva, 2023; Biehler-Gomez et al, 2025; Abarca-Labra et al., 2021). This association between activity and EC is based on clinical and biomechanical data that support that bone reacts to mechanical stress by increasing blood flow in the affected areas, which results in elevated bone growth and more pronounced EC (Michopoulou et al., 2015; Michopoulou et al., 2016). However, it is important to note that the area where a tendon or a ligament attaches to bone is called an enthesis, while an entheseopathy refers to any pathological change of this region (Villotte et al., 2009). Enthesopathies occur commonly in the elderly and in cases of seronegative spondyloarthropathies, overuse and traumatic injuries, and diffuse idiopathic skeletal hyperostosis (Villotte et al., 2009). Musculoskeletal stress markers are assumed to reflect the activity of the attaching muscle (Villotte et al., 2009). Some bioarchaeologists prefer the term "musculoskeletal stress markers" or "MSM" which has been defined as "osseous changes observed on the muscle attachment portions of bones, especially postcranial limb bones" (Takigawa, 2014, p.7). For this chapter, I will use the terms EC or MSM interchangeably depending on the preference of the study referenced.

There have been questions about whether MSMs are associated with activity at all. While some studies have shown no association (Cardoso and Henderson, 2010; Takigawa, 2014; Meyer et al., 2011; Rabey et al., 2015; Wallace et al., 2017; Zumwalt, 2006), many others have found MSM to correlate with habitual activity (Shigehara, 1994; Suzuki, 1998; Lukacs and Pal, 2003; Kimura, 2006; Kudaka et al., 2013; Takigawa, 2014; Eshed et al., 2004; Hawkey and Merbs, 1995; Shuler et al., 2012; Lieverse et al., 2013; Villotte et al., 2009; Villotte ,2006; Havelkova and Villotte, 2007; Yonemoto, 2016; Carballo-Perez et al., 2021; Alonso-Llamazares et al., 2021; Dinkele and Gibbon, 2023; Zou et al., 2024; Mazza and Silva, 2023; Biehler-Gomez et al, 2025; Abarca-Labra et al., 2021). Those against the use of EC for determining habitual activity have expressed problems with the methods used and also the pathology of EC.

One of these issues is difficulty in the determination between what is pathological and what comes from activity. To fix this issue, anthropologists have recommended that remains affected by disease or trauma should be excluded (Meyer et al., 2011; Henderson, 2008; Rhode, 2012). Numerous diseases are associated with enthesopathy formation, particularly in the seronegative spondyloarthropathies (ankylosing spondylitis) category, including diseases like diffuse idiopathic skeletal hyperostosis (DISH) (Henderson, 2008). These diseases cause bone changes at the entheses, the same area that we find many muscle attachments, however the damage done by these diseases are limited to the vertebrae (Henderson, 2008; Rhode, 2012). The spectrum of arthropathic diseases was studied by Henderson (2008) to determine if there were higher frequencies of MSM in the upper limb of medieval English skeletons with diseases associated with bone changes. Henderson found an increase in MSM frequency for the entheses of those with these diseases (2008). Though there were correlations between bone forming diseases and MSM in this study, clinical findings support that EC is not associated with periostistis or other diseases (Henderson, 2013). This suggests that diseases are not the cause and thus EC from habitual activity and these particular bone-forming diseases are different entities with separate causes (Henderson, 2013). However, while they appear to be separate with different causes, many scholars still agree that it is best to exclude individuals that show any sign of bone forming diseases to prevent over-diagnosing activity-related EC (Meyer et al., 2011;

Henderson, 2008; Rhode, 2012). Conversely, osteoarthritis is often associated with EC and thus they are not to be seen as different entities, but along a spectrum. Regarding secondary osteoarthritis that is related to "wear and tear," it falls within a spectrum that is included with EC from repetitive strenuous activity (Mann and Hunt, 2012). Primary osteoarthritis is idiopathic and occurs most often after the age of fifty, separate from the causes of EC (Mann and Hunt, 2012). Therefore, there is no need to exclude an individual with signs of EC and osteoarthritis who is young, as the osteoarthritis is indicative of EC in this case. Though, when it comes to the identification of diseases such as DISH, ankylosing spondylitis, and primary osteoarthritis, these diseases usually occur in older adults (Rhode, 2012).

Likewise, using elderly individuals in the examination of EC is also an ongoing issue in bioarchaeology. Several studies have found that age is a factor than can skew the results of EC analyses because the effects of age after biological maturity can override effects of physical activity (Henderson and Cardoso, 2013; Lieverse et al., 2013; Shuler et al., 2012; Niinimäki, 2011; Niinimäki et al., 2013; Michopoulou et al., 2015; Michopoulou et al., 2016; Havelkova and Villotte, 2007; Villotte et al., 2009; Cardoso and Henderson, 2009; Meyer et al., 2011; Villotte and Santos, 2022; Albee, 2023). Fibrocartilaginous entheses have been found to be better indicators of activity, particularly before the age of 50 years because of the way age dominates the entheseal modification (Michopoulou et al., 2015). As a result, it is recommended to not use individuals that are over the age of 50 in EC analysis.

Additionally, there are concerns about doing EC analysis with preconceived notions about the culture of the past. For example, physical activity for hunter-gatherers was often characterized as strenuous, but now it is understood that activity and physical behavior is highly variable (Larsen, 1997). Though there may be archaeological evidence that a group of people being studied were hunter-gatherers, it does not mean that one can use a blanket statement and immediately infer that the skeletal remains will reveal that they had a certain amount of physical stress. Meyer and colleagues also disclose issues with this problem in terms of sex-linked tasks where one would assume that men did a more laborious task and super-impose this biased assumption onto biological processes embodied by the skeletal remains (2011). However, associated with this, Meyer et al. also convey a larger concern with often having no behavioral context of what one may have been doing outside of the entheseal modifications found on skeletal material (2011). The authors prefer that there also be some archaeological evidence to supplement the skeletal evidence (Meyers et al., 2011). Likewise, the use of a suitable number of samples from the relatively same time period is needed to ensure that you can make a statement about a certain group of people (Meyer et al., 2011).

Perhaps the most troublesome of the problems associated with determining habitual activity is finding no correlations with EC and any activities. Interestingly, studies using animals are often referenced in human skeletal studies as evidence that there is no correlation between the two. This is most likely due to studies with animals having access to known activity levels. In a study by Rabey and colleagues, the authors used mice to test the influence of an exercise regime on the development of muscular fiber architecture, periosteal bone growth, and enthesis morphology (2015). The authors analyzed muscles that have fibrous attachments directly to the periosteum of the deltoid crest. The study found that variation in activity of subadult mice resulted in differences in muscle fiber architecture and periosteal bone growth. However, variation in activity failed to produce differences in the deltopectoral enthesis morphology. This suggests that enthesis morphology may provide little insight into activity type or level. They conclude that additional studies of how muscle influences enthesis development are needed because a lack of understanding about muscle attachment site development has led to oversimplified and unsubstantiated interpretations of entheseal morphology and activity patterns about past populations (Rabey et al., 2015).

A study using turkeys found something similar (Wallace et al., 2017). The results of this experiment indicate that variation in physical activity influences the structure of turkey hind limb bones but not their entheseal morphology. They then suggest that entheses should not be considered a reliable proxy for physical activity. However, they are not implying that researchers restrict their scope to only diaphyseal and trabecular structure, but use as many lines of evidence as possible (Wallace et al., 2017). It is worth noting that using these results as a comparison for humans requires caution due to biological differences and the influence of these differences on experimental data is currently unknown.

In addition to animal analyses, there have been findings on human skeletal remains that have also found that no correlation exists between EC and habitual activity. In Cardoso and Henderson's study (2009) humeral entheses of 111 Portuguese male skeletons were examined using the method of Hawkey and Merbs (1995). Only the lesions described as robusticity markers were used in this study, which does not include the other two categories of ossification exostosis and stress lesions typically recorded in this method. Results demonstrated no correlation between specific occupations and EC presence, or between labor patterns and EC presence. They did reveal a statistically significant correlation between older age at death and EC presence. They state that perhaps a better recording method is required which may capture more of the activity- related processes than the one used for this study (Cardoso and Henderson, 2009).

As shown, there are various problems associated with the use of MSM or EC in the determination of habitual activity. However, there are many anthropologists who believe these problems can be addressed and that there are indeed correlations between entheseal modification and habitual activity (Shigehara, 1994; Suzuki, 1998; Lukacs and Pal, 2003; Kimura, 2006; Kudaka et al., 2013; Takigawa, 2014; Eshed et al., 2004; Hawkey and Merbs, 1995; Shuler et al., 2012; Lieverse et al., 2013; Villotte et al., 2009; Villotte, 2006; Havelkova and Villotte, 2007; Yonemoto, 2016; Carballo-Perez et al., 2021; Alonso-Llamazares et al., 2021; Dinkele and Gibbon, 2023; Zou et al., 2024; Mazza and Silva, 2023; Biehler-Gomez et al, 2025; Abarca-Labra et al., 2021). Recent experimental work also has confirmed that EC reliably reflects differences in biomechanical load and repetitive muscle utilization (Deymier et al., 2019; Karakostis et al., 2019). Additionally, in every issue documented, changes can be made to avoid these problems. The majority of the issues are related to sample criteria. Using individuals younger than the age of 50 addresses the evidence that age overrides activity, as some anthropologists have already observed and began doing (Havelkova and Villotte, 2007). Using suitable samples both in size and in regards to pathology are also changes that can be made. Sample size issues may be difficult with materials that are not well-preserved, but this may mean that EC analysis simply cannot be done on remains that do not have a large amount of well-preserved remains or a suitable control group. Conversely, excluding pathological samples is an easy and feasible criterion and has already been done in some studies before the suggestion was made (Hawkey and Merbs, 1995). Avoiding using elderly individuals also facilitates the elimination of pathological samples, as bone-forming diseases are most prevalent in the elderly. In regards to handedness, the difference in limbs has been shown to not have any significance (Santana-Cabrera et al., 2015). This means that if only one side of an individual is available or well preserved, it is acceptable to use only the side available. However, in the event that both sides are available, it is most suitable to record the EC for both sides. Additionally, using artifacts to indicate how findings may or may not coincide with archaeological data facilitates the elimination of bias or confirming hypotheses with little skeletal data. It also aids in the justification of one's findings. Lastly, in regards to the use of animals in EC studies, the mice used in the study by Rabey and colleagues were not partaking in strenuous enough physical activity. They also were not using the most common method. Furthermore, these animal studies examined features that are not the same as those observed in the dry bone samples used in biological anthropology (Santana-Cabrera et al., 2015).

While some studies have shown no correlation between EC and activity, there are many studies that have shown correlations between the two. In a study that examined MSMs, osteoarthritis, the length of limb bones and their proportions, and stature of the Damdama, a North Indian Mesolithic population, the authors were able to better understand the activities and adaptations of the Damdama as well as determine how physically "stressful" the lives of the people were (Lukacs and Pal, 2003). They used the Hawkey and Merbs (1995) method as it provides more extensive visual documentation of skeletal variation. Lukacs and Pal were able to identify two patterns of the Damdama: overhand throwing and long distance or load-bearing locomotion. It was concluded that this throwing complex might be associated with the forceful launching of spears or projectiles coinciding with their hunter lifestyle. Assessing the lower extremities revealed much about the locomotive habits of the Damdama regarding distance, weight loads and the terrain they were traveling on, giving insight into their activity patterns (Lukacs and Pal, 2003).

One major use of MSM is to examine the transition from foraging to agriculture in a prehistoric society. The shift from a hunting-gathering lifestyle to a food producing, farming economy occurred in the Near East during the pre-pottery Neolithic period (Eshed et al., 2004). The authors compared the MSM scores of Natufian and Neolithic populations to look at this shift in subsistence strategies. They used 21 muscle/ligament attachment sites on the upper limb using the method of Hawkey and Merbs (1995). They only recorded for robusticity and stress lesions, leaving out the third category of ossification exostosis typically used in this method. Intermediate robusticity scores were assigned for expressions that fell between the original, standard scores. Rank ordering of mean MSM scores from high to low was used to examine the utilization of specific muscles and sets of muscles between the two populations and between males and females within a population. Strong similarities in rank ordering might suggest a labor system in which tasks were typically shared, or where both groups undertook tasks with similar muscular demands. Dissimilarities might suggest distinctive activity patterns. The activities the authors suggested were taking place in these populations based on their findings include cereal harvesting, food processing, leveling, terracing, digging, crafting body ornaments, hunting, producing stone tools, and tree-felling. They found that physical stress increased with the adoption of agriculture (Eshed et al., 2004).

Shuler and colleagues (2012) also studied subsistence activity patterns in the skeleton through the assessment of maize agriculturalists. Previous studies of upper body patterns in bone strength among maize agriculturalists of the Pickwick Basin in northern Alabama were consistent with ethnographically based predictions of greater mechanical demands among hoe agriculturalists, including significant bilateral upper arm use in females that likely was due to mortar and pestle maize processing. The authors of this study predicted that upper body entheses would likewise demonstrate increased prevalence in agricultural Mississippian populations compared to hunter-gatherers. Twelve primary fibrocartilaginous entheseal attachments from the upper limb were assessed using the Villotte et al. (2010) method. This study found that entheseal changes were greatest in association with attachments that function in flexion and extension of the elbow. These would have been used in a wide range of activities such as lifting, carrying heavy loads, weaving, and grinding grains. They also found low rates of change from activities that would have used the shoulders, such as hoe use. Their results suggest a trend towards increased labor intensity for both sexes with the adoption of maize agriculture at these sites (Shuler et al., 2012).

Alternatively, other studies have looked at EC correlation to activity in the lower limb. In a paper by Lieverse and colleagues, the authors investigate lower limb entheses in order to understand more fully the spatial and temporal variation among the Middle Holocene foragers of the Cis-Baikal region of Siberia (2013). Data were collected and the system of Hawkey and Merbs (1995) was applied, which included modifying the robusticity scores following the lead of Cardoso and Henderson (2010), so fibrous and fibrocartilaginous entheses were analyzed separately. Results supported their hypothesis that significant variation in lower limb activity patterns existed throughout the Middle Holocene, reflecting differences in sex and age at death, as well as in spatiotemporal distribution. It showed more reliance on logistical foraging and fishing (Lieverse et al., 2013).

To look at activity patterns and the lifestyle of southern African hunter-gatherer herders during the Holocene, the Coimbra method (Henderson et al., 2015) was used on the upper and lower limbs of 118 individuals. The findings showed that physical activity patterns were attributed to differences in regional ecology rather than age or sex. Those from forested areas were found to have higher EC than those in the areas of fynbos (a coastal belt with shrubs and healthy vegetation) or areas of succulent karoo (semiarid region with assorted succulents and low shrubs). Temporal differences in EC were only shown when the data were stratified by biome (Dinkele and Gibbon, 2023).

Lastly, a study on prehistoric fisher-hunter-gatherer populations from the Neolithic to Bronze age northeastern China was conducted that evaluated the relationship between EC and subsistence strategies. This research used the method of Mariotti et al. (2007). The findings showed that frequencies of EC differed between early and late populations and between males and females during the late population, suggesting a sex-based division of labor. There was an overall decrease in EC, but an increase in the occurrence of squatting surfaces during the late period (Zou, et al. 2024).

Semi-Qualitative Methods

There are several different methods for scoring EC. The Hawkey and Merbs method has been widely used to evaluate MSMs (Lukacs and Pal, 2003; Takigawa, 2014; Lieverse et al., 2013). This method has a wider range of traits and allows the researcher to better express differences, compared to the use of presence/absence in other methods. Hawkey and Merbs state that the use of MSM as an analysis for habitual activity operates under the assumption that the degree and type of MSM directly relate to the amount and duration of stress placed on a muscle habitually (1995). They created a method and tested iton human skeletal material recovered by the Northwest Hudson Bay Thule Project. They initially examined 318 skeletons, but only 136 individuals were chosen for descriptive statistical comparison due to many of the skeletons being poorly preserved, incomplete, showing signs of healed fractures, or severe degenerative joint disease that could increase the amount of stress placed on the non-pathological side. They did not include individuals who did not have reliable age or sex determinations, as well as all children and subadults. Since MSMs can vary in expression, Hawkey and Merbs created a visual reference system for the identification of marks. The authors scored MSMs using three main categories, each of which had four specific grades. These grades were given numerical representations of 0 for absence of expression, 1 for faint expression, 2 for moderate expression and 3 for strong expression (Hawkey and Merbs, 1995).

This first category scored is robusticity, which describes the normal reaction of the skeleton to habitual muscle usage (Hawkey and Merbs, 1995). This marker reflects activities that produce rugged markings at the site of the muscle attachment due to the stress of muscular pull. This appears as sharp ridges or crests of bone from resorption or formation of new bone at the attachment site. The second category is stress lesion, which is defined as pitting into the cortex. When a muscle is used beyond intended capacity, it begins to lose the ability to properly absorb stress. Habitual tension can cause small muscle tears that reattach and disrupt blood supply to the bone and bone necrosis can then occur. The last category is ossification exostosis where, due to abrupt macrotrauma such as a muscle rupture, the muscle ossifies (Hawkey and Merbs, 1995).

Villotte proposed a different method of studying enthesopathies based on current medical insights (Villotte, 2006; Villotte et al., 2009; Havelkova and Villotte, 2007). It is possible to distinguish two types of insertions. The first type, fibrous entheses, occurs in the regions of the appendicular skeleton that have a thick layer of cortical bone, while the second type, fibrocartilaginous entheses, is mainly associated with the epiphyses and apophyses (Havelkova and Villotte, 2007). The two types are said to differ in terms of mechanical properties and appearance (Havelkova and Villotte, 2007). Because of this, Villotte thinks that the evaluation of EC should take into account the type of entheses, and therefore, categorizes the insertion site according to these two types of entheses in this method (2006; Havelkova and Villotte, 2007).

Villotte's scoring method differentiates four scoring systems because it specifies four different muscle groups (Villotte, 2006; Havelkova and Villotte, 2007). Three of the groups include fibrocartilaginous entheses and the last group includes fibrous entheses, with each group classifying the EC using a three- stage scale of A, B, and C (Villotte, 2006; Havelkova and Villotte, 2007). The first group can include all types of remodeling such as enthesophytes, lesions, foramina, or cysts (Villotte, 2006; Havelkova and Villotte, 2007). The second group usually includes just enthesophytes (Villotte, 2006; Havelkova and Villotte, 2007). The third group mostly focuses on insertions of yellow ligaments in the medial part of the vertebrae (Villotte, 2006; Havelkova and Villotte, 2007). The fourth group is the most problematic and remodeling is expressed with irregularity of the surface (Villotte, 2006; Havelkova and Villotte, 2007). The three-stage scale is scored as "A" meaning healthy enthesis, "B" meaning slight EC, and "C" meaning major EC (Villotte, 2006; Villotte et al., 2009). Occasionally there is a simplified method that groups together B and C (Villotte, 2006; Villotte et al., 2009). This may seem problematic, but the creator does not seem to think so. In a study aiming to test the reproducibility of this method based on inter-observer error, 20 skeletons were examined using this scoring method (Havelkova and Villotte, 2007). This method was applied to 36 insertion sites (18 on each side) and 46 insertions (proximal and distal) of yellow ligament at the spinal column (Havelkova and Villotte, 2007). The overall agreement between the two observers for all the groups and all the variants of evaluation was 88% (Havelkova and Villotte, 2007). However, it is important to note that a small sample size was used and the defining terms for enthesophytes in the method seemingly only use new words for what Hawkey and Merbs describe with a smaller scale, especially if using the simplified method.

Like Villotte, Santana-Cabrera and colleagues were dissatisfied with the Hawkey and Merbs method so they set out to create their own method. This scoring method is described as both a visual and descriptive atlas, similar to Hawkey and Merbs (Santana-Cabrera et al., 2013; Santana-Cabrera et al., 2015). This method records two aspects: changes related to robusticity and expressions of pathology (Santana-Cabrera et al., 2013; Santana-Cabrera et al., 2015). Robusticity is graded from slight to extreme with 1 being slight and 3 being extreme (Santana-Cabrera et al., 2013; Santana-Cabrera et al., 2015). EC are divided into two groups (A and B) and follow the classification of Hawkey and Merbs (Santana-Cabrera et al., 2013; Santana-Cabrera et al., 2015). Type A are osteophytes or exostoses on the margins of insertion points and type B are cortical defects (Santana-Cabrera et al., 2013; Santana-Cabrera et al., 2015). They include photographs to ensure that one can correctly classify the entheseal change (Santana-Cabrera et al., 2013; Santana-Cabrera et al., 2015). They also note that the authors took into account recommendations of other authors with similar recording systems, including Hawkey and Merbs, as it is clear they do take from their method (Santana-Cabrera et al., 2013; Santana-Cabrera et al., 2015).

Finally, there is the Coimbra method (Henderson et al., 2015; Michopoulou et al., 2016). The latest version is described in detail by Henderson et al. (2015) with a small revision to the method in Henderson et al (2016). The method divides entheses into two zones and records alterations as new bone formation or resorption using an ordinal scale (Henderson et al., 2015). Zone 1 is where fibers attach obliquely to the bone and zone 2 is “the remaining fibrocartilaginous footprint of the enthesis and the remaining margin” (Henderson et al., 2015).

Six features are recorded: bone formation; erosion; textural change; fine porosity; macro-porosity; and cavitation (Henderson et al., 2015). Bone formation and erosions are scored in both zones and the other four features are scored only in zone 2 (Henderson et al., 2015). These features are either scored as a 1 or a 2, with 1 being less than a certain percentage of the surface, and 2 being more than a certain percentage of the surface, depending on the feature (Henderson et al., 2015). Only fibrocartilaginous entheses are used for this method because these have a "normal" baseline appearance that has no roughness or pores, unlike fibrous entheses (Henderson et al., 2013). A revision published in 2016 was simply a decision to amend the description of zone 2 to include the full radial tuberosity to reduce interobserver error (Henderson et al., 2016).

The Coimbra method hoped to refine the method for fibrocartilaginous entheses so it can be recommended for widespread use (Henderson et al., 2015). Michopoulou and colleagues decided that it would be interesting to see if the Coimbra method can capture activity-related stress more effectively (2016). They test the method on 78 male skeletons aged 24 to 96. Only fibrocartilaginous entheses of the upper limbs (namely, the subscapularis and bicep brachii) were used because their zones were most clearly described in the original publication of the Coimbra method and so they should be easily identified and accurately recorded. Based on their results they found that EC recorded using the new Coimbra method rarely exhibit a significant correlation with cross-sectional geometric properties.They concluded that their results suggest that recording EC using the revised Coimbra method does not reflect activity more effectively than earlier methods (Michopoulou et al., 2016).

Above are the most common methods created to reveal significant contributions of activity to EC expression. Hawkey and Merbs is one of the first and most commonly used of the methods. However, there continues to be the conception of new activity marker recording methods because of the issues with the Hawkey and Merbs method as originally described. There have been suggestions that when using the Hawkey and Merbs method ossification exostosis should be left out, or only robusticity should be recorded (Cardoso and Henderson, 2009; Eshed et al., 2004). Suggestions have also been made to add intermediate scores for robusticity when expressions fell between the original standard scores (Eshed et al., 2004). It is because of these suggested revisions to the method along with new medical data, that new methods to measure EC continue to emerge. However, many of these new methods either take from the Hawkey and Merbs method or have been proven inadequate. It is clear that the method of Hawkey and Merbs may benefit from a revision that is supplemented by extensive testing.

Quantitative Methods

The majority of the methods used for paleopathologies are qualitative, visual methods. This can be seen in the methods used to identify many of the bone diseases, dental pathologies, and trauma (Mann and Hunt, 2012). They usually consist of photographs along with written descriptions within these methods. At the moment, the qualitative, visual method for recording EC seems to be more widely used because it has been tested more often and requires less equipment. Regardless of qualitative or quantitative, scholars agree that there needs to be a more standardized method to interpret EC (Henderson et al., 2010; Perez-Arzak et al., 2022; Sick, 2021; van der Pas and Schrader, 2022).

The scoring of activity induced EC mostly come from visual methods, though there have been attempts to quantify these changes. Henderson attempted a method that used sliding calipers and a profile gauge to assess the relationship of the entheseal surface to a flat surface (2012). Henderson argues, the size and shape of the entheses both need to be taken into account to improve the use of visual methods (2012). Using the profile gauge, it would then be transferred and a line would be drawn on paper within a grid (Henderson, 2012). The line would then be scanned on a flatbed scanner (Henderson, 2012). Alhough not a lot of equipment was needed, it was low resolution and very slow to process. Further, training is needed as intra-observer error was low, but inter-observer error was high (Henderson, 2012). Also, the sample size was small, at 43 humeri (Henderson, 2012). Therefore, the author suggested further studies be done for quantifying EC with higher resolution (Henderson, 2012).

Unlike the Henderson (2012) method, the majority of the three-dimensional analysis of bone methods start with the use of micro-computed tomography (Ito et al., 1998; Hildebrand et al., 1999; Cooper et al., 2003; Jones et al., 2004; Cooper et al., 2007; Arlot et al., 2008; Chappuis et al., 2013; Campbell et al., 2014; Berthon et al., 2015; Turmezei et al., 2016; Berthon, 2019; Karakostis et al., 2019; Djukic et al., 2020; Kubicka and Myszka, 2020; Pelletier et al., 2020; Sartori and Stark, 2020). However, because most of these studies use micro-CT researchers are interested in the three-dimensional visualization of the skeletonized canal networks, rather than the external surface of bone (Ito et al., 1998; Hildebrand et al., 1999; Cooper et al., 2003; Jones et al., 2004; Cooper et al. 2007; Arlot et al., 2008; Chappuis et al., 2013; Campbell et al., 2014; Berthon et al., 2015; Turmezei et al., 2016; Berthon, 2019). Nevertheless, there are some studies using micro-CT that are more related to this research with regards to quantifying robusticity of bone or entheses. Some of these studies are interested in the exterior of the bone, yet they are simply measuring articular surfaces or the whole outline of the entheses, rather than trying to quantify the rugosity and depth of stress lesions that occur during habitual activity induced EC

(Djukic et al., 2020; Kubicka and Myszka, 2020; Pelletier et al., 2020; Sartori and Stark, 2020). While Turmezei and colleagues (2016) use CT imaging data to examine femoral cortical bone thickness, they analyze data with a technique called cortical bone mapping (CBM). They use a color map to show how thick the cortical bone is, rather than showing robusticity or rugosity indicative of EC (Turmezei et al., 2016). Karakostis et al. (2019b) also uses a color map to show changes in the skeleton. In this study, CT scanned rat bones are used to look at cortical thickness and delineate borders of the entheseal areas (Karakostis et al., 2019b). The color map is used to look at the elevation of the entheseal areas as it relates to loading. Interestingly, they do not appear to take actual measurements from these maps, but use them as a visual aid for the reader (Karakostis et al., 2019b). None of these approaches are actually quantifying the same aspects of the bone that the visual, or semi-qualitative, methods are measuring.

There are also several other forms of three-dimensional scanning used for bone analysis. One of which, is magnetic resonance imaging (MRI). Typically, these MRI scans either are used for compression testing (Benoit et al., 2009) or to look at the entheses of living patients (Chen et al., 2019), both of which do not apply to most bioarchaeological EC research interests. Other three-dimensional digitizing surface scanners have been used as well (Peyrin et al., 2000; Thali et al., 2003; Chappard et al., 2005; Sansoni et al., 2009; Seidel et al., 2012; Noldner and Edgar, 2013; Nolte and Wilczak, 2013; Karakostis and Lorenzo, 2016; Salmi and Niinimäki, 2016). In the study done by Karakostis and Lorenzo (2016), the examiners used a Breuckmann SmartScan structured-light scanner and Optocat software before putting their data into Meshlab. The observational data for the study were distinctive elevation, darker coloration and particular surface complexity (Karakostis and Lorenzo, 2016). The Z-painting tool in Meshlab was used to create a bone area of just the entheseal surface, before eliminating the rest of the bone to calculate raw surface size, a method similar to the Karakostis et al. 2019 study mentioned earlier (Karakostis and Lorenzo, 2016). The entheseal size relative to total bone surface was calculated in an attempt to combat the notion that strong correlations observed could indicate that raw dimensions of the entheses may not be exclusively regulated by biomechanical stress, but could be larger because the individual's hand is larger (Karakostis and Lorenzo, 2016). Noldner and Edgar (2013) and Nolte and Wilczak (2013) did similar size calculations of the entheseal surface. Conversely, in many studies about entheseal change (Hawkey and Merbs, 1995; Lukacs and Pal, 2003; Villotte, 2006; Havelkova and Villotte, 2007; Cardoso and Henderson, 2010; Santana-Cabrera et al., 2013; Takigawa, 2014; Henderson et al., 2015; Santana-Cabrera et al., 2015; Acosta et al., 2017) the width, length or entire size of the entheseal site is not of utmost importance, only the height of robusticity and osteophyte formation, and the depth of stress lesions can reveal substantial evidence of muscle use at an enthesis site. This is due to bone resorption and formation of new bone at the attachment site from the stress of muscular pull (Hawkey and Merbs, 1995). Alternatively, Salmi and Niinimäki (2016) were interested in quantifying the depth of pitting in the cortex due to muscle stress in reindeer bones. Unfortunately, the three-dimensional scan of the bones they created did not have adequate resolution and they were forced to use qualitative scoring methods instead (Salmi and Niinimaki, 2016).

Though the majority of the three-dimensional techniques used were from CT scans, MRI scans or other scanners, there were a few other techniques as well. Three-dimensional finite element studies based on high-resolution images have been done to look at stress distribution on bone, however none were done specifically looking at habitual activity induced EC (Pistoia et al., 2001; Podshivalov et al., 2011; Shamami et al., 2014). Cross sectional geometry can be calculated to look at entheseal change but is usually concerned only with cortical thickness (Sparacello et al., 2020). In an interesting study by Nikita and colleagues (2019), a Hirox KH 8700 digital microscope was used. Unfortunately, casts had to be made because the microscope was not portable (Nikita et al., 2019). They had to test their cast accuracy by scoring for roughness and bone resorption on two bones and their casts (Nikita et al., 2019). Three dimensional recreations were made from the microscope software and arithmetic mean roughness was automatically calculated by removing the standard length from the roughness curve in the direction of the mean line, totaling absolute values of deviations between the removed mean line and the measurement curve, and averaging them (Nikita et al 2019). They also created a color map showing surface elevations (Nikita et al 2019).

Though none of these methods are quantifying the criteria of the semi-qualitative methods efficiently, there are three other logistical issues with these previous methods. One is that they are incredibly expensive. Both CT and MRI machines are extremely expensive, and creating a method based on that assumes that a researcher has access to this expensive machinery. The second issue is that majority of these methods use machinery that is immobile. CT and MRI machines are certainly not mobile, and therefore not good options for bioarchaeological research where researchers often need to travel for access to the remains. Additionally, some scanners, and in the case of Nikita et al. (2019), digital microscopes, are not mobile either. This is not a feasible option for many researchers. Thirdly, some of these options were not high resolution enough. The methods attempted by Salmi and Niinimaki (2016) and Henderson (2012) were not successful because both of their methods needed higher resolution images to quantify EC. This could be resolved with an alternative form of three-dimensional rendering.

In more recent years, photogrammetry has also been used to make three-dimensional reconstructions of bone. This has been an increasingly used option, as photogrammetry is low cost, non-destructive, and mobile (Hosseinian and Arefi, 2017; Fau et al., 2016; Edelmers, 2022; Feddema and Chiu, 2024). Recent studies have demonstrated that reconstructions from photogrammetry are as high quality as those obtained with laser scanners (Fau et al., 2016; Brassey et al., 2015; Koutsoudis et al., 2013). Reconstructions from photogrammetry were also found accurate and reliable compared to physical measurements (Feddema and Chiu, 2024). This method is easily accessible for traveling researchers, especially in the current age of high-resolution cameras, because the equipment is easy to travel with and affordable.

As stated previously, the scoring of activity induced EC usually come from visual methods (Hawkey and Merbs, 1995; Santana-Cabrera et al., 2013; Santana-Cabrera et al., 2015), though clearly some attempts have been made to quantify these changes. As shown, there have been various three-dimensional bone analysis studies, however most have not been concerned with the same EC criteria that is traditionally used to measure EC. It is also worth noting that many of the methods used to obtain the three-dimensional reconstructions are not easily accessible or always reasonable for certain researchers to use. The photogrammetry technique seems to be the most feasible technique for use in the field. At the moment, the qualitative, visual method seems to be more widely used because it has been tested more often and requires less expensive equipment. The field would benefit from a three-dimensional quantitative method that was easy to use, affordable, and recorded for similar criteria to the current semi-qualitative methods already in use.

Conclusion

As seen in this chapter the history of entheseal change is not very long, but considerable research has been done in the past couple of decades on this topic. While many are hoping to create a better and more accurate method for analyzing entheses, it seems that there is no consensus on a new method. Therefore, the Hawkey and Merbs (1995) procedure remains the most useful and widely used. While there are clearly anthropologists and scientists from other fields questioning the procedures behind the analysis of MSM and EC, there are many who have made the necessary changes to do valid, unbiased work and find correlations that allow for insight on habitual activities of past individuals. It is clear that pathological factors and age should be addressed in future studies as many of the papers referenced here have found that these factors can skew the results (Hawkey and Merbs, 1995; Henderson and Cardoso, 2013; Lieverse et al., 2013; Shuler et al., 2012; Niinimäki, 2011; Niinimäki et al., 2013; Michopoulou et al. 2015; Michopoulou et al., 2016; Havelkova and Villotte, 2007; Villotte et al., 2009; Cardoso and Henderson, 2009; Meyer et al., 2011). In regards to the debate between fibrous and fibrocartilaginous entheses, data from both types of entheses are found in one study to be largely congruous (Lieverse et al., 2013). Not only can similar conclusions be drawn from both datasets, but correlation analyses also indicate statistically significant co-variation between the two entheseal types for most of the groups examined (Lieverse et al., 2013). Further analyses between the two entheseal types are needed in future examinations. Lastly, there is a need for a quantitative method that helps to eliminate subjectivity from the traditional semi-qualitative methods currently in use. The method needs to be easy to use, affordable, and mobile for bioarchaeologists who regularly travel to do fieldwork. This dissertation proposes a three-dimensional quantitative method in the next chapter.

Chapter 4: Materials and Methods

Materials

There were 24 sites across Japan used for this research. To understand broader patterns, the data were grouped by different criteria. Sites were classified as coastal, riverine or inland, depending on how close they were to a body of water. To group these sites, I created a guideline that anything less than 3 km from an ocean or river was considered a coastal or riverine site, respectively. Anything further was classified as inland. The data are grouped in these categories while discussing the site report information.

Inland Jomon Sites

The Inland Jomon sites consist of one Early Jomon site and two Late Jomon sites. The Early Inland Jomon site is Tochibara Iwakage, located in Nagano Prefecture in the Northern Japanese Alps (Nishizawa, 1982; Yoneda et al., 2002). Artifacts found at this site include obsidian tools, like projectile points and knives and Jomon cord-marked pottery shards (Nishizawa, 1982; Yoneda et al., 2002). The human teeth displayed pronounced dental wear suggesting a diet that consisted of hard and abrasive foods. The postcrania of the Tochibara Iwakage revealed robust lower limbs in males and slender upper limbs. This may be indicative of physical activity such as traversing the rugged mountainous terrain to hunt. The women show lower limb thickness similar to those of later Jomon females, but also with more slender upper limbs (Kohara, 2011). Several of the remains showed signs of enamel hypoplasia and Harris's lines, indicative of episodes of nutritional stress during childhood (Nishizawa, 1978; Kohara et al., 2011).

The Late Inland Jomon sites consist of Kou and Ota. Kou is located in Fujidera City, Osaka Prefecture on the Kokubu Plateau. Excavations there uncovered Late Jomon pottery fragments that included deep vessels used for storage and cooking. These types of pottery suggest a more sedentary lifestyle in the Late Jomon period in comparison to the Earlier Jomon periods (Osaka Prefectural Board of Education, 2013). Ota is a site located in Bingo Province (Kiyono, 1933).

Table 4.1 Overview of Inland Jomon sites.

Site	Temporal	Location	Proximity to Water	Pottery	Metal	All Other Findings
Tochibara Iwakage	Early Jomon	Inland	None	Cord-marked pottery	No	Human skeletal remains (HSR), Obsidian projectile points and knives
Kou	Late Jomon	Inland	Yamato River > 3 km	Late Jomon pottery	No	HSR, Stone tools
Ota	Late Jomon	Inland	None	None	No	HSR, Shell midden, HSR with pathologies

Coastal Jomon Sites

The Coastal Jomon sites consist of one Early Jomon site, two Middle Jomon sites and three Late Jomon sites. The Early Coastal Jomon site of Hikosaki is located in Okayama city on the southern shore of the former Kojima Bay facing the Seto Inland Sea. It has the largest shell mound from the Early Jomon period, covering 100 meters from the north to south and 80 meters from east to west. The site contained a substantial acorn storage pit, Jomon pottery, stone tools, and shellfish (Agency for Cultural Affairs, 2024).

The Middle Jomon Coastal sites are Ropponmatsu and Wakaumi. Ropponmatsu is located on a coastal plateau overlooking Tachibana Bay in Nagasaki Prefecture (Hamada, 1925a;

1925b). The site contains deep shell layers that uncovered marine resources, pottery, bone tools, and animal remains. The marine resources include species such as sea urchins, clams, oysters, snails, sardines, horse mackerel, tuna, and sharks (Nishihara, 1988). This suggests that inhabitants of this site were highly skilled at fishing and may have even constructed boats to deep-sea fish. The site also uncovered remains of wild boar and deer, suggesting that they were hunting as well. Bone and antler tools including points and spatulas were recovered as well (Nishihara, 1988). Conversely, not many archaeological findings are recorded about the Wakaumi site. Wakaumi is located in Ibaraki Prefecture less than a kilometer from the Sea of Japan. The human remains from the site contained femora that showed evidence of habitual loading, suggesting extensive walking or running (Kajigayama and Baba, 1999). This may be indicative of habitual activities associated with hunting or foraging.

The Late Jomon Coastal sites are Ikawazu, Tsukumo, and Yoshigo. The Ikawazu site is located on the Atsumi Peninsula in Aichi Prefecture along the coastline of the Pacific Ocean. The shell mound site contained artifacts such as stone tools and shell jewelry. The human remains found have been the subject of extensive research. One of the studies uncovered an infant and adult female double burial (Gakuhari et al., 2020). The original belief was that the infant was the child of the adult female, but after mitochondrial DNA analysis, they found that they were not maternally related, indicating that the Jomon period may have had complex social burial practices that went beyond familial relationships (Gakuhari et al., 2020). Additionally, complete mitochondrial genome sequencing on the remains found that the adult female belonged to haplogroup N9b1 that has been found in other Jomon populations, while the infant belonged to haplogroup M7a1, suggesting genetic diversity within the Jomon populations and also regional variation (Waku et al., 2022). As mentioned in Chapter 2 of this dissertation, the genetic analysis done on the Ikawazu remains also found that the Ikawazu Jomon share close genetic ties to the Ainu and with prehistoric populations from the Andaman Islands and Southeast Asia (McColl et al., 2018). Additionally, strontium isotope analysis revealed that a number of individuals buried at Ikawazu were not native to the site, suggesting that there were immigrants within the population (Kusaka et al., 2011). All of this is indicative of a socially complex society during the Late Jomon.

The Tsukumo site is a shell midden located 3 kilometers from the Seto Inland Sea, in present day Okayama Prefecture. A variety of shellfish and fishbones were found at this site, highlighting the likelihood of fishing as a subsistence strategy for the inhabitants (Kiyono, 1933). Artifacts uncovered at this site include fishhooks, stone axes, stone knives, and grinding stones (Yamanouchi, 1964; Matsui and Kanehara, 2006). Like Ikawazu, the burials at Tsukumo also uncovered personal ornaments like shell beads and pendants, suggesting social or symbolic significance (Matsui and Kanehera, 2006). The pottery found at Tsukumo consisted of deep vessels and storage jars that were decorated with the Jomon cord-marked pattern (Ishikawa, 1997; Kobayashi, 2017). Stable isotope analysis revealed that the inhabitants relied heavily on shellfish and fish (Matsui and Kanehara, 2006). This emphasis on marine resources is further bolstered by the evidence of a shark attack on an adult male at the Tsukumo site (White et al., 2021). This further indicates that inhabitants of this site, and the Coastal Jomon sites in general, were participating in deep-sea fishing. This marine diet must have been accompanied by nuts and roots as well though, as wear patterns on the teeth suggested the consumption of hard foods (Yamanouchi, 1964).

Lastly, the Yoshigo site is located in the Tokai region of Aichi Prefecture less than a kilometer from the sea (Kaner and Ishikawa, 2007; Matsui and Kanehara, 2006). The shell mound site included a shell midden with large quantities of shell fish remains, particularly clams and oysters (Kiyono, 1933). A variety of pottery was found at the site that included plain pieces and decorated ones (Yamanouchi, 1964). Polished stone axes and grinding stones were also found, suggesting some food processing was taking place (Kiyono, 1933). Additionally, fishhooks were found, further suggesting there was some sort of fishing subsistence strategy at this site (Zaz and Ikawa-Smith, 1984). Diet evidence is further bolstered here by the isotopic evidence of marine finfish, C3 plants and land herbivores (Matsui and Kanehara, 2006). Similar to the other Late Jomon coastal sites, shell beads and bracelets were found at this site (Kiyono, 1933).

Table 4.2. Overview of Coastal Jomon sites

Site	Temporal	Location	Proximity to Water	Pottery	Metal	All Other Findings
Hikosaki	Early - Middle Jomon	Coastal	On shore of former Kojima Bay	Jomon pottery	No	HSR, Stone tools, shellfish, acorn storage pit
Ropponmatsu	Middle to Late Jomon	Coastal	Coastal plateau	Late Jomon pottery	No	HSR, Marine faunal remains, terrestrial faunal remains, bone tools
Wakaumi	Middle Jomon	Coastal	1 km from Sea of Japan	Jomon pottery	No	HSR, Projectile points and grinding stones, bone and shell ornaments
Ikawazu	Late Jomon	Coastal	On coastline of Pacific Ocean	None	No	HSR, Shell middens
Tsukumo	Late Jomon	Coastal	3 km from Seto Inland Sea	Late Jomon cord-marked pottery	No	HSR, Shell middens, marine faunal remains, stone tools (axes, knives, fishing implements), grinding stones, shell beads and pendants, HSR with shark bites
Yoshigo	Late Jomon	Coastal	<1 km from Pacific Ocean	Jomon pottery	No	HSR, Shell middens, marine faunal remains, fishing implements, polished stone axes, grinding stones, shell beads and bracelets,

Riverine Jomon Sites

The Riverine Jomon sites consist of one Early Jomon site, three Middle Jomon sites, and one Late Jomon site. The only Early Jomon Riverine site is Ohashi. Ohashi is located in present day Okayama Prefecture on the eastern bank of the Yoshii River, near the mouth of Katakami Bay. Excavations uncovered a shell midden, Jomon pottery fragments, and stone tools (Hirohisa, 1979).

The three Middle Riverine Jomon sites are Ebishima, Tsubue, and Adaka. Ebishima is located in Iwate Prefecture near the Kitakami River (Yamaguchi, 1989). Tsubue is located in Kurashiki City, Okayama Prefecture near the Takashi River. The shell mounds at this site contained both human and faunal remains (Watanabe et al., 1982). Adaka is a shell midden located in the Kumamoto region of southern Kyushu on a small hill approximately one kilometer from nearby rivers (Kumamoto Prefecture Education Committee, 2005). Multiple shell deposits were found intermingled with layers of sand and clay, indicating episodes of human occupation (Kumamoto Prefecture Education Committee, 2005). The shells were mostly from species such as freshwater clams, hamaguri clams, and oysters (Tsuboi, 1965). The fish found were seabream, mullet and mackerel (Kumamoto Prefecture Education Committee, 2005). Artifacts found included Jomon pottery, projectile points, grinding stones, bone fishhooks, stone net sinkers, and ornaments crafted from bone, shell, and tusk (Kumamoto Prefecture Education Committee, 2005). The human remains found at Adaka revealed the presence of osteoarthritis and enthesopathies on the shoulder and elbow joints, most likely from habitual activity such as lifting, pulling, and digging (Kumamoto Prefecture Education Committee, 2005).

The Late Riverine Jomon site consists of Inariyama. Inariyama is a shell mound site but located in the eastern part of the Mikawa region in Aichi Prefecture overlooking the Toyokawa

River (Ishikawa, 1997; Yamanouchi, 1964). The large shell midden found there consisted of layers of clams, oysters, and fish bones (Ishikawa, 1997; Kiyono, 1933). Stable isotope analysis also showed that the diet of the inhabitants focused on shellfish along with terrestrial plants and mammals (Matsui and Kanehara, 2006). Artifacts from the site include stone axes, adzes, and grinding stones (Ishikawa, 1997). A variety of pottery fragments were found as well. These include deep bowls and jars, some of which were decorated with intricate cord-markings (Kiyono, 1933). Shell bracelets, pendants, and stone beads were also found at this site (Kiyono, 1933).

Table 4.3. Overview of Riverine Jomon sites.

Site	Temporal	Location	Proximity to Water	Pottery	Metal	All Other Findings
Ohashi	Early - Middle Jomon	Riverine	Eastern bank of Yoshii River	Early and Middle Jomon pottery	No	HSR, Shell middens, stone tools,
Ebishima	Middle Jomon	Riverine	<3 km Kitakami River	None	No	HSR
Tsubue	Middle Jomon	Riverine	<3 km Takashashi River	None	No	HSR, Shell middens
Adaka	Middle Jomon	Riverine	10 km from the Ariake Sea and 1-2 km from nearby rivers	Jomon pottery	No	HSR, Shell middens, projectile points, grinding stones, bone fishhooks, net sinkers, marine faunal remains, terrestrial faunal remains, ornaments made of bone, shell and tusk
Inariyama	Late Jomon	Riverine	<3 km Toyokawa River	Late Jomon cord-marked pottery	No	HSR, Shell middens, marine faunal remains, axes, adzes, grinding stones, shell bracelets and pendants, stone beads

Inland Yayoi Sites

The Inland Yayoi sites consist of four Middle Yayoi sites and one late Yayoi site. The Middle Inland Yayoi sites are Kanenokuma, Nagaoka, Mitsusawa, and Hasakonomiya. Kanenokuma is located on the southeastern part of Fukuoka on the southern slope of the Tsukushino Hills (Fukuoka City Education Committee, 1970; 1971; 1985). This site has numerous burials, with a total of 348 jar coffin burials, 119 pit graves, and 2 stone coffin burials discovered there in 1970 and 1971. In addition to the jar coffins, storage jars, cooking pots and serving dishes were also found at Kanenokuma. Additionally, artifacts were found such as stone tools, shell bracelets made from Gohoura shells, small bronze bells and weapons (Fukuoka City Education Committee, 1971). Nagaoka is located in Chikushino City in Fukuoka Prefecture near the entrance to the Chikushi Plains (Nakahashi, 1981). The artifacts found here were similar to those at Kanenokuma, including large storage jars and bowls and fragments of bronze tools and weapons (Nakahashi, 1981). Similarly, there were also numerous burials, with a total of 153 jar coffin burials, 21 wooden coffin burials, and 9 pit burials (Nakahashi, 1990). Mitsusawa and Hasakonomiya are both located in Ogori City, Fukuoka Prefecture and both sites uncovered Yayoi pottery and human remains (Kyushu University Museum, 2021; Fukuoka City Education Committee, 1979).

Figure 4.1. Example of a gohoura shell (*strombus latissimus*) bracelet at the National Museum of Nature and Science, Tokyo.

The Late Inland Yayoi site is Ichinotani, located in Kasuga, Fukuoaka Prefecture (Kasuga Town Education Committee, 1969). The pottery found were typical Yayoi deep bowls and jars (Miyao, 1968). Stone tools found included polished axes and hoes (Kondo, 1988). The skeletal remains found at Ichinotani revealed osteoarthritis in several of the individuals, particularly of the vertebral column and limb joints. The osteophytes, porosity, and eburnation found on articular surfaces suggests chronic physical stress on the body. Dental wear patterns revealed pronounced occlusal surface attrition, suggesting a diet of hard grains and fibrous plant materials, as well as enamel chipping and linear enamel hypoplasia (Sano and Watanabe, 1971). The most severe dental wear and osteoarthritis were seen in those buried in more elaborate burial structures, suggesting some sort of complex society and social stratification at Ichinotani (Kondo, 1988; Sano and Watanabe, 1971). Additionally, there is evidence of posthole patterns and traces of wooden structures discovered at Ichinotani, that may be indicative of semi-permanent or permanent dwellings (Miyao, 1968).

Table 4.4. Overview of Inland Yayoi sites.

Site	Temporal	Location	Proximity to Water	Pottery	Metal	All Other Findings
Kanenokuma	Middle Yayoi	Inland	None	Yayoi pottery	Yes (bronze)	HSR, Gohoura shell bracelets, jar coffins, stone coffins, stone tools, small bronze bells, bronze weapons,
Nagaoka	Middle Yayoi	Inland	Onga and Homan Rivers nearby	Yayoi pottery	Yes (bronze)	HSR, Jar burials, large storage jars and bowls, bronze tools and weapons, wooden coffins
Mitsusawa	Middle Yayoi	Inland	None	Yayoi pottery	No	HSR
Hasakonomiya	Middle Yayoi	Inland	None	Yayoi pottery	No	HSR
Ichinotani	Middle - Late Yayoi	Inland	None	Yayoi pottery	Yes (bronze)	HSR, Deep bowls and jars, polished axes, stone agricultural hoes, grain processing tools, bronze mirrors, finely crafted stone tools, posthole patterns, traces of wooden structures

Coastal Yayoi Sites

Coastal Yayoi sites consist of one Early Yayoi site and one Late Yayoi site. The Early Coastal Yayoi site is Doigahama, which is located in the northern part of Yamaguchi Prefecture in present-day Toyohoku Town in Toyoura District. This site is on a coastal sand dune along the northern tip of Honshu, where the Hibikinada Sea and the Sea of Japan converge (Yamaguchi Prefecture Toyohoku Town, 1999). The sand dune site is approximately 300 meters east to west and 160 meters north to south (Yamaguchi Prefecture Toyohoku Town, 1999, ;2001). The site uncovered a large array of bones and artifacts including remains of deer, wild boars, frogs and fish, stone and shell bracelets, and iron spearheads and knives (Yamaguchi Prefecture Toyohoku Town, 1997; 1999; 2001). Over 300 human burials were excavated from the site with an array of burial types, including extended supine burials, prone burials, secondary burials, and mass graves (Yamaguchi Prefecture Toyohoku Town, 1999; 2002).

Koura is a Late Coastal Yayoi site located in Shimane Prefecture on Honshu Island along the coast of the Sea of Japan. The artifacts include decorated pottery fragments, grinding stones, polished adzes, bronze ware, shell rings, and jade balls for ear decorations. Additionally, the excavators found deer antler fish hooks, bovine bones, sheep bones, and turtle shells (Koura Archaeological Report, 2005).

Table 4.5. Overview of Coastal Yayoi sites.

Site	Temporal	Location	Proximity to Water	Pottery	Metal	All Other Findings
Doigahama	Early Yayoi	Coastal	Coastal sand dune where Hibikinada Sea and Sea of Japan converge	Early Yayoi pottery	Yes (iron)	HSR, Terrestrial faunal remains (deer, wild boars, frogs), marine faunal remains, stone and shell ornaments, iron spearheads and knives, shell bracelets
Koura	Middle - Late Yayoi	Coastal	coast of the Sea of Japan	Yayoi pottery	Yes (bronze)	HSR, Grinding stones, polished adzes, deer horn fishing implements, faunal remains, bronze ware, shell rings, jade balls for ear decorations, clay figurines, clay ornaments, storage facilities, nonlocal pottery nonlocal stone tools

Riverine Yayoi Sites

The Riverine Yayoi sites consist of the two Middle Yayoi sites, Hara and Monden. Both sites are located in Kasuga City, Fukuoka Prefecture on Kyushu Island near the Mikasa River. Not much has been recorded about Hara, however at Monden there is evidence of an overlapping grave and several artifacts found including a bronze ploughshare discovered in a disturbed grave, short iron swords, iron halberds, bronze mirrors, Gohoura shell fragments, and a Gohoura shell ring (Fukuoka Prefectural Board of Education, 1978; 1979).

Table 4.6. Overview of Riverine Yayoi Sites

Site	Temporal	Location	Proximity to Water	Pottery	Metal	All Other Findings
Hara	Middle Yayoi	Riverine	along Mikasa River Basin	Yayoi pottery	No	HSR
Monden	Middle Yayoi	Riverine	floodplain of Mikasa River Basin	Middle Yayoi pottery	Yes (bronze and iron)	HSR, iron swords, iron halberds, bronze mirrors, Gohoura shell ring

Edo Site

The Ikenohata-shichikencho site is an archaeological site located in Taito-ku, Tokyo, Japan. The site was excavated between 1993 and 1995 and over 600 human skeletal remains from the Edo period (late 17th to 19th centuries) were recovered (Nagaoka, 2007). The site is key for studying the demographic and social structure of the Edo period, when there was a rigid social hierarchy including samurai, farmers, technical laborers, merchants, and lower classes such as butchers or "eta hinin" (poor or criminal outcasts who were seen as so low they were "non-humans") (Nagaoka, 2007).

The age-at-death distribution of the individuals at the Ikenohata-shichikencho site shows the majority of deaths are under 30 years old, with few individuals surviving beyond 60 years of age. Females had a significantly younger age-at-death distribution than males, which may be a reflection of high female mortality during reproductive years. The individuals were buried in ceramic and wooden coffins, which distinguished between samurai and commoners. The presence of both types of coffins suggests that the burials included both samurai and townsmen, providing a glimpse of both higher status and lower status individuals in the population (Nagaoka, 2007).

Isotopic analyses of the human remains at this site reveal that the diet of the inhabitants was predominantly based on C3 and terrestrial foods, which include rice, along with freshwater and marine fish. The mean carbon isotope ratios of the Ikenohata-shichikencho individuals suggest that rice was a primary staple of their diet. This finding is consistent with the historical records indicating that rice was a staple food for people living in Japan during this time period, supplemented by other local produce and fish (Tsutaya et al., 2015).

The Ikenohata-shichikencho site is a suitable baseline control group for prehistoric farmers because isotopic analyses confirm that the individuals buried at the site consumed rice as a staple food, which was the dietary norm for most populations in Japan during the Edo period. Additionally, the burials include commoners that would have been participating in agricultural activities to produce rice. This makes Ikenohata-shichikencho an ideal reference point for comparing the prevalence of agricultural activities in prehistoric populations, as it provides a definitive example of a group that relied heavily on rice.

Table 4.7. Number of individuals assessed for this research.

Location	Site	Temporal	Male		Female		Unknown		**Total**	
Inland Jomon	Tochibara Iwakage	Early Jomon	2	15	1	15	4	35	7	**65**
	Kou	Late Jomon	2		3		2		7	
	Ota	Late Jomon	11		11		29		51	
Coastal Jomon	Hikosaki	Early - Middle Jomon	1	75	0	64	3	130	4	**179**
	Ropponmatsu	Middle to Late Jomon	1		0		0		1	
	Wakaumi	Middle Jomon	1		0		0		1	
	Ikawazu	Late Jomon	5		4		24		33	
	Tsukumo	Late Jomon	13		15		4		32	
	Yoshigo	Late Jomon	54		45		99		108	
Riverine Jomon	Ohashi	Early - Middle Jomon	0	19	1	23	0	21	1	**63**
	Ebishima	Middle Jomon	13		14		11		38	
	Tsubue	Middle Jomon	0		1		2		3	
	Adaka	Middle Jomon	0		1		2		3	
	Inariyama	Late Jomon	6		6		6		18	
Inland Yayoi	Kanenokuma	Middle Yayoi	22	54	21	32	6	8	49	**94**
	Nagaoka	Middle	9		4		1		14	
	Mitsusawa	Middle	9		2		0		11	
	Hasakonomiya	Middle Yayoi	5		0		0		5	
	Ichinotani	Middle - Late Yayoi	9		5		1		15	
Coastal Yayoi	Doigahama	Early Yayoi	31	37	29	38	5	15	65	**90**
	Koura	Middle - Late Yayoi	6		9		10		25	
Riverine Yayoi	Hara	Middle Yayoi	0	3	2	4	0	0	2	**7**
	Monden	Middle Yayoi	3		2		0		5	
Edo	Ikenohata-shichikencho	Edo	93		112		40		245	**245**
TOTAL				**296**		**288**		**249**		**743**

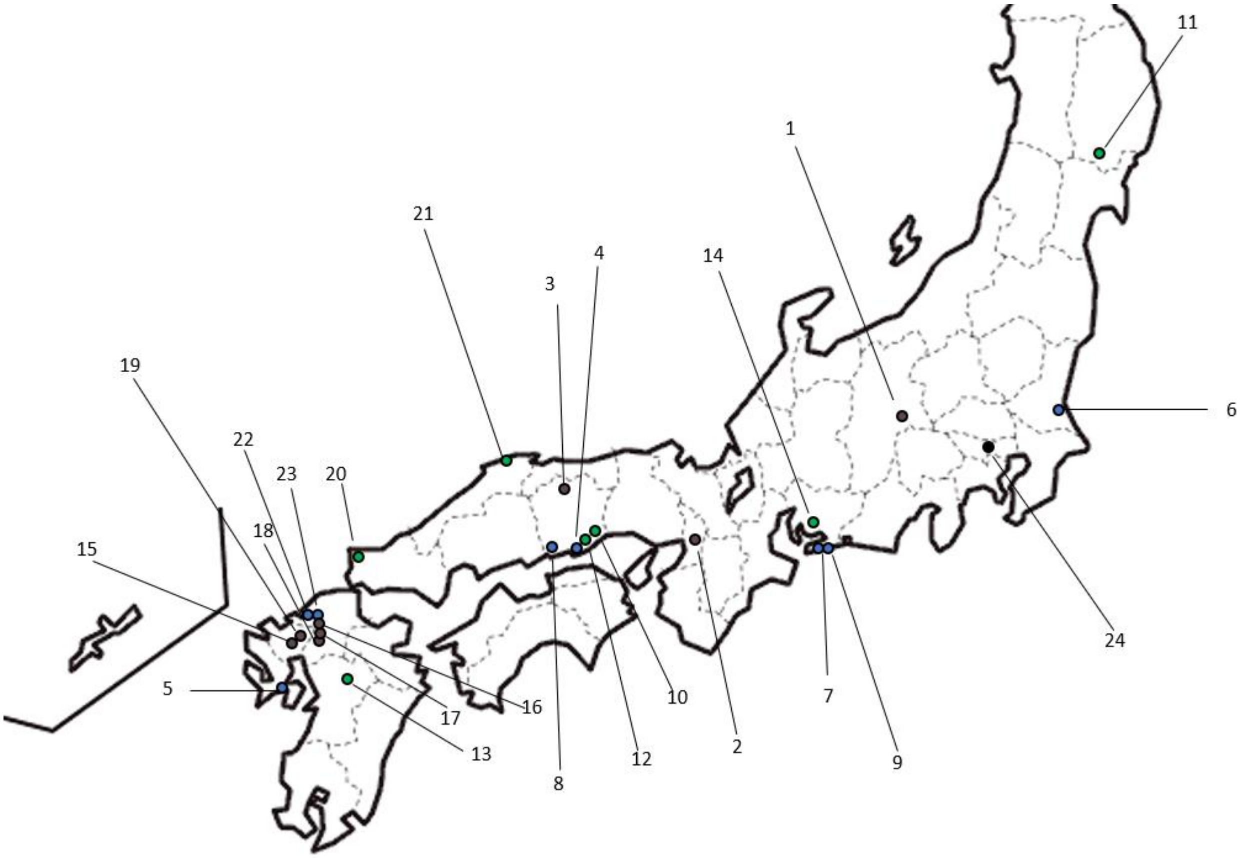


Figure 4.2. Map of the archaeological sites used in the sample. 1. Tochibara Iwakage; 2. Kou; 3. Ota; 4. Hikosaki; 5. Ropponmatsu; 6. Wakaumi; 7. Ikawazu; 8. Tsukumo; 9. Yoshigo; 10. Ohashi; 11. Ebishima; 12. Tsubue; 13. Adaka; 14. Inariyama; 15. Kanenokuma; 16. Nagaoka; 17. Mitsusawa; 18. Hasakonomiya; 19. Ichinotani; 20. Doigahama; 21. Koura; 22. Hara; 23. Monden; 24. Ikenohata-shichikencho. Inland – Brown. Coastal – Blue. Riverine – Green.

Methods

Entheseal changes on 14 bones (7 per side) were examined. Only adult (skeletally age 18 years or older) individuals with at least 7 mostly preserved bones were included. As long as half of the muscle attachments examined per bone were completely present (number of muscle attachments varies per type as there are 2 per clavicle, 4 per scapula, etc.), the bone was considered suitable for use. Seven preserved bones were necessary per individual, as the analysis required assessment of fourteen total bones (clavicles, scapulae, humeri, radii, ulnae, tibiae, and femora), but due to the preservation of the collections as a whole, having half of the 14 total bones was considered sufficient enough to provide meaningful data. The suitability of 50% of the total entheses being sufficient is in line with the method of Villotte and colleagues (2006) which required 5 of 10 entheses to be preserved per individual; Hawkey and Merbs (1995) did not include explicit guidelines on their preservation criteria. Likewise, only well-preserved bones were chosen for the photogrammetry portion. Adult males, females, and individuals of undetermined sex were assessed in this study.

Age and Sex

Age and sex were analyzed for all of the Jomon and Edo period remains. Age and sex determinations for the Yayoi period remains were based on previous osteological analyses conducted by Kyushu University Museum researchers. The individuals assessed by Kyushu University Museum were grouped into the following age group: 20+, 20-29, 40-59, or 60+. All other individuals were assigned to one of the following age groups: 20-29, 30-39, 40-49, 50-59, 60+, or unknown. If the individual received an age determination of "unknown" due to lack of suitable preservation of the os coxae, the adult age was determined by evidence of the eruption of at least one third molar. For the Jomon and Edo remains age determination was done using the Suchey-Brooks Pubic Symphysis Scoring System and the Lovejoy Auricular Surface Scoring System (Brooks and Suchey 1990; Lovejoy et al. 1985). Sex determination was done using the os coxae morphology, as documented in Standards for data collection from human skeletal remains (Buikstra and Ubelaker 1994). The individuals assessed were grouped into the following categories: Male; Female; Unknown.

Modified Hawkey and Merbs Method

The samples were first assessed for musculoskeletal stress markers using a data collection methodology I developed in collaboration with researchers from the Anatomy and Physiology Laboratory in the John A. Burns School of Medicine at the University of Hawai'i at Manoa. Seventy-two fibrocartilaginous muscle attachments (36 per side) from the upper and lower limbs to assess the musculoskeletal stress markers ("MSMs") of the groups were scored. These MSMs have been shown to have characteristic alterations on the entheseal surfaces (Eshed et al., 2004; Molnar, 2006; Shuler et al., 2012; Lieverse et al., 2013; Takigawa, 2014). Regarding the difference between fibrous and fibrocartilaginous entheses, data from both types of entheses were found in one study to be largely congruous suggesting similar conclusions may be drawn from different types of data (Lieverse et al., 2013). As such, this study includes both fibrous and fibrocartilaginous entheses.

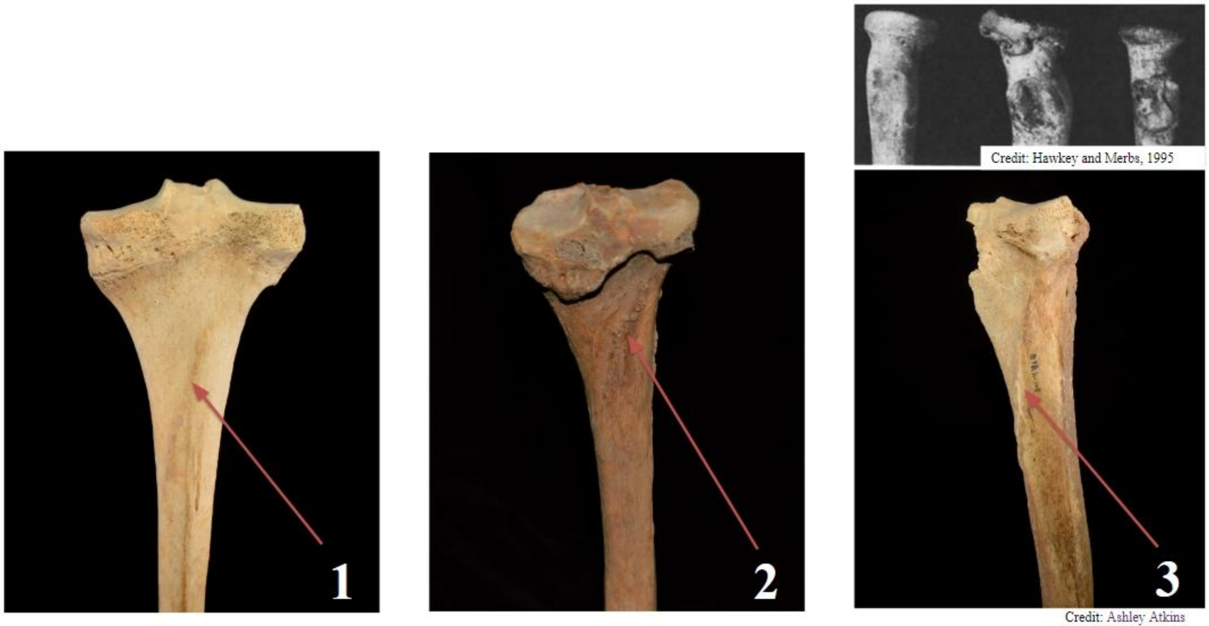
Due to the lack of consensus regarding an accurate method for analyzing entheses, the Hawkey and Merbs (1995) procedure is still the most widely used. Given the greater capture of variation in the traits, presence of a visual reference guide, and a longer-term reliable history within the discipline, the Hawkey and Merbs (1995) method was chosen and a modified version of the method was created. The original Hawkey and Merbs (1995) method is described as follows.

A visual reference system created by Hawkey was used because MSMs can vary in expression (Hawkey, 1988; Hawkey and Merbs, 1995). The authors scored MSMs using three main categories and within each category there were four specific grades. The first category scored is robusticity, which describes the normal reaction of the skeleton to habitual muscle usage. This marker reflects activities that produce rugged markings at the site of muscle attachment due to the stress of muscular pull. This appears as sharp ridges or crests of bone from resorption or formation of new bone at the attachment site. The second category is stress lesion, which is defined as pitting into the cortex. When a muscle is used beyond intended capacity, it begins to lose the ability to properly absorb stress. Habitual tension can cause small muscle tears that reattach and disrupt blood supply to the bone and bone necrosis can then occur. The last category is ossification exostosis where due to abrupt macrotrauma such as a muscle rupture, the muscle ossifies. The grades were 0 for absence of expression, 1 for faint expression, 2 for moderate expression and 3 for strong expression (Hawkey and Merbs, 1995).

The Hawkey and Merbs (1995) method offers a more nuanced approach to scoring MSMs, capturing a wider range of traits and effectively differentiating between activity patterns compared to the simpler presence/absence scoring used in some other methodologies (e.g., Cardoso and Henderson, 2010). In their assessment of the humerus, Cardoso and Henderson initially used the Hawkey and Merbs scoring technique but then reduced it to presence and absence. They argued that Hawkey and Merbs did not adequately account for normal variation in fibrous and fibrocartilaginous entheses (Cardoso and Henderson, 2010). Thus, they collapsed Hawkey and Merbs' grades 0 and 1 for fibrocartilaginous entheses, and grade 0 for fibrous entheses, into "absence," while combining grades 2–3 for fibrous entheses and grades 1–3 for fibrocartilaginous entheses into "presence." However, this simplification undermines the key advantage of the Hawkey and Merbs method: its ability to highlight a broader spectrum of enthesis variations, thus providing a more precise representation of habitual activity patterns within a population. This strength is evident in the widespread adoption of multiple-grade scoring systems inspired by the Hawkey and Merbs method (e.g., Villotte, 2006; Havelková and Villotte, 2007; Santana-Cabrera et al., 2013; Santana-Cabrera et al., 2015). Cardoso and

Henderson (2010) also suggest that when using the Hawkey and Merbs (1995) method only robusticity should be recorded. However, he provides no explicit reason(s); presumably it may be due to the same normal variation Hawkey and Merbs reference when changing the scoring method.

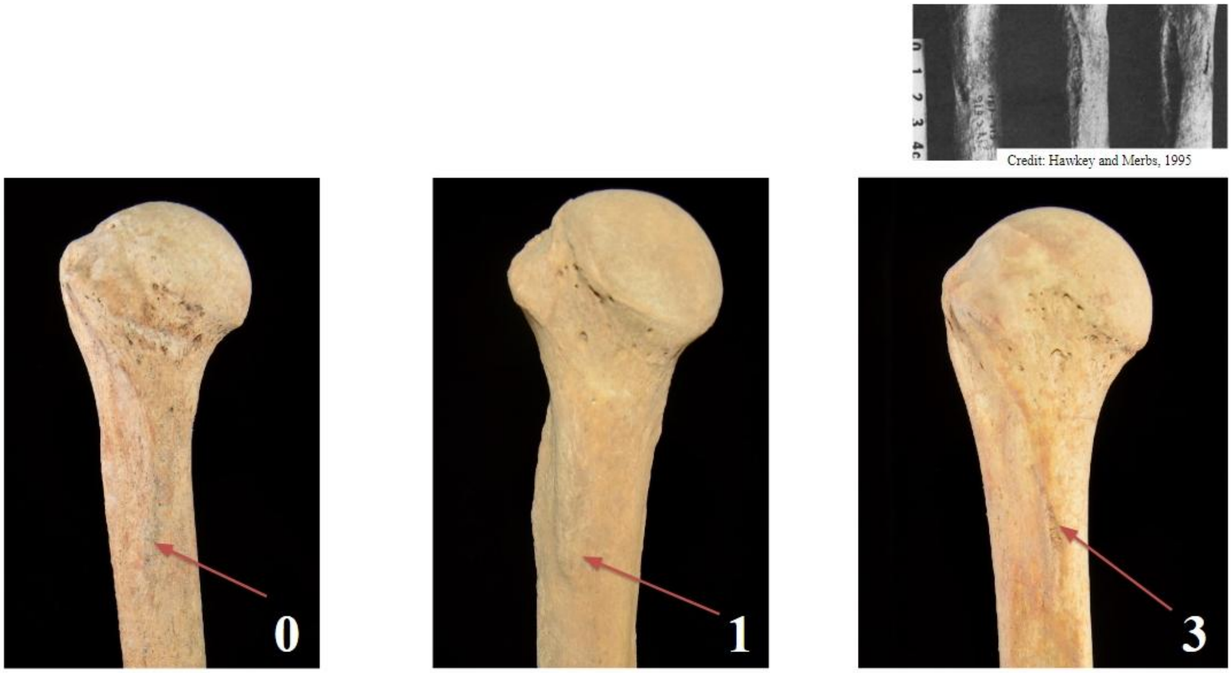
After preliminary testing of the Hawkey and Merbs (1995) method, it was found that the different traits scored within the method is one of its strengths. Thus, all three traits (robusticity, stress lesion, and ossification exostosis) were scored in this study. There have also been suggestions of adding intermediate scores for robusticity when expressions fell between the original, standard scores (Eshed et al., 2004). While conducting a preliminary analysis using the human osteological collection curated at the John A. Burns School of Medicine, I found that there were often times that MSMs did fall in between the standard Hawkey and Merbs scores, thus corroborating Eshed and colleagues' earlier observation. Therefore, this study employs intermediate scoring for each trait (0.5, 1.5, 2.5 etc.). Expression scores for statistical analysis are recorded with the following numerical values: 0- no expression, 1 = robusticity grade 1 (faint), 2 = robusticity grade 2 (moderate), 3 = robusticity grade 3 (strong), 4 = stress lesion grade 1 (faint), 5 = stress lesion grade 2 (moderate), and 6 = stress lesion grade 3 (strong) (Hawkey and Merbs, 1995) (see Figures 4.2-4.4). Because ossification is considered abrupt macrotrauma, it is analyzed separately as 0-3 (Hawkey and Merbs, 1995). The scores of all three traits are then summed to create a composite score. The higher the composite score, the more the muscle was used.



Credit: Hawkey and Merbs, 1995

Credit: Ashley Atkins

Figure 4.3. Robusticity category at the soleus attachment site. Scores from left to right are: 1 = faint; 2 = moderate; 3 = strong. Upper right depicts robusticity category from Hawkey and Merbs (1995) at the biceps brachii insertion site. Scores from left to right are: 1 = faint; 2 = moderate; 3 = strong.



Credit: Hawkey and Merbs, 1995

Credit: Ashley Atkins

Figure 4.4. Stress lesion category at the teres major attachment site. Scores from left to right are: 0 = absent; 1 = faint; 3 = strong. Upper right depicts stress lesion category from Hawkey and Merbs (1995) at the pectoralis major insertion site. Scores from left to right are: 1 = faint; 2 = moderate; 3 = strong.

Credit: Hawkey and Merbs, 1995

Credit: Ashley Atkins

Figure 4.5. Ossification exostosis category at the iliacus attachment site. Scores from left to right are: 0 = absent; 2 = moderate; 3 = strong. Upper right depicts ossification exostosis category from Hawkey and Merbs (1995) on the humerus (various insertion sites). Scores from left to right are: 1 = faint; 2 = moderate; 3 = strong.

Total weighted mean scores were calculated for each muscle in SPSS to determine the statistical breakpoints between stronger and moderate use of muscles within each site (IBM Corp, 2023). A statistical breakpoint is a point in a dataset where there is a significant shift in a trend, such as changes in the mean, variance, or other properties. This concept is essential to detect structural changes in the data (Shafer & Zhang, 2012). The breakpoints in Hawkey and Merbs (1995) were identified through running descriptive statistics to find the weighted mean scores calculated for each muscle. These shifts were analyzed statistically to detect points of significant change, or breakpoints, in physical activity, reflecting broader subsistence and lifestyle transitions. Muscles with composite scores higher than the statistical breakpoint were considered most utilized, while those below the statistical breakpoint were considered less utilized. A similar breakpoint method was used in this research. Descriptive statistics and mean scores are regularly used as a means to analyze MSMs due to the nature of the data (e.g., Hawkey and Merbs 1995; Eshed, 2004; Mariotti et al., 2004, 2007; Schrader 2012, 2015;

Cashmore and Zakrzewski, 2013; Dewey, 2018; Palmer et al., 2019). Transforming this type of ordinal data into averages for analysis is a valid and widely accepted method for identifying and explaining patterns in the data (as noted by Robb, 1998 based on Weisberg, 1992).

In this study, breakpoints were calculated for MSMs by using the mean score of each muscle as its own threshold, rather than combining all muscle scores into a single combined mean to define a generalized breakpoint. This approach ensures that each muscle's activity patterns are treated independently, reflecting the unique functional and habitual demands placed on different muscles. Unlike a generalized breakpoint, which assumes uniform thresholds for muscle use, this method accounts for the biological variability of specific muscles for specific activities. Additionally, Hawkey and Merbs (1995) used different breakpoints for each time period in their study because they lacked a known control group, requiring them to establish temporal-specific breakpoints. They also rounded the average up to the nearest 0.5, which introduces additional variability. However, this study had a control group, allowing the use of consistent breakpoints across all groups, ensuring comparability. It is particularly important to treat muscles individually, as the weighted scores for each muscle are combined with other associated muscles used to perform specific activities, making the precision of each muscle's score significant for accurate interpretations. By focusing on muscle-specific breakpoints, this method avoids issues that can occur when highly utilized muscles disproportionately influence a combined mean, which risks concealing subtle but meaningful variations in less utilized muscles. While Hawkey and Merbs (1995) attempted to simplify the analysis, the approach used in this dissertation aligns more closely with the biological reality of diverse muscle activity and provides a clearer understanding of habitual activity as well as labor divisions. It is important to acknowledge that other researchers have expressed concerns regarding the statistical analyses currently used to evaluate MSMs in all of the commonly discussed MSMs methods (Palmer et al., 2019). I believe the field would greatly benefit from the development of a standardized breakpoint database for specific actions or the adoption of a different but consistent statistical method to enable easier and more accurate analyses in future research.

For this research, descriptive statistics were run in SPSS on the Ikenohata-shichikencho data to determine the statistical breakpoint using the mean scores for each muscle (IBM Corp, 2023). Ikenohata-shichikencho was used as the control group because it is a known farming village from the Edo period (late 17th to 19th centuries). The Jomon and Yayoi composite scores were analyzed to see how many scores were above or below the breakpoint for each muscle. Each activity involves multiple muscles to perform the activity. The number of scores above the breakpoint for each muscle in an activity was summed, and then the percentage of individuals participating in that activity was noted for each site. By calculating the percentage of individuals above the breakpoint, the study revealed how much of the population was engaged in a particular physical activity.

As stated earlier in this chapter, to understand broader patterns, the data were then grouped by different criteria. Sites were classified as coastal, riverine or inland, depending on how close they were to a body of water. To group these sites, I created a guideline that anything less than 3 km from an ocean or river was considered a coastal or riverine site, respectively. Anything further was classified as inland. Sites were grouped by locale or temporal phase. The percentage of individuals over the breakpoints in each group was calculated to estimate how much of the group was engaged in the identified activity. This approach enabled a comparison between groups, such as how much of a coastal Jomon population was involved in specific tasks compared to inland or later Yayoi populations.

Independent t-tests were done to determine any differences between handedness and sex for the Jomon and Yayoi populations separately and in subsets of geographic location specific groups (e.g. Coastal Jomon, Riverine Jomon, etc.) (SPSS, IBM Corp, 2023). Handedness was analyzed to ensure that using either the right or left side of an individual would not introduce bias, and that the activities typically involved both sides of the body equally. Given the imperfect preservation of the skeletal remains, there were instances where only the left side or right side of an individual was available for analysis. If handedness significantly influenced skeletal markers, relying on a single side could potentially skew the data. Therefore, assessing handedness was crucial to confirm the validity of including unilateral data in the analysis. Sex was analyzed to investigate potential evidence of a division of labor, as differences in habitual activity patterns between males and females could provide insight into gender-specific roles within the population. Lastly, a Kruskal-Wallis test assessed the differences in MSM scores between each site by temporal period (SPSS, IBM Corp, 2023). They were also done to investigate groupings by locale and temporal period (e.g. Coastal Jomon, Inland Jomon, Riverine Yayoi, etc.).

Table 4.8. List of muscles to be used per activity.

Activities	***Muscles***	***Action***	***References***
General farming activities including conditioning and preparation of land for cultivation, sowing and harvesting*	Subclavius, biceps (o-long head), triceps (o-long head), pectoralis minor, trapezius, supraspinatus, infraspinatus, teres minor, common extensors, common flexors, subscapularis, teres major, pectoralis major, deltoideus, latissimus dorsi, triceps, brachialis, anconeus, supinator, biceps brachii, brachioradiais, pronator quadratus, pronator teres, gluteus maximus, adductor magnus, vastus medialis, vastus lateralis, gluteus medius, gluteus minimus, gastrocnemius, iliacus, iliopsoas	Shoulder flexion, elbow flexion and extension, supination and pronation, arm adduction, arm internal rotation, hip flexion and extension, knee flexion and extension	*Croft et al., 1992;* *Eshed et al., 2004;* *Santana-Cabrera et al., 2015*
Processing of grains	Biceps (o-long head), triceps (o-long head), common flexors, common extensors, triceps brachii, biceps brachii	Shoulder flexion, elbow flexion and extension	*Eshed et al., 2004;* *Shuler et al., 2012*
Woodland clearance	Triceps brachii	Elbow extension and adduction of the arm	*Dutour, 1986*
Making pottery	Gastrocnemius	Squatting	*Charles, 1983-1984*
Metal working	Triceps brachii, supinator, pronator quadratus, pronator teres	Elbow extension, supination and pronation	*Kelley and Angel, 1983;* *Dutour, 1986*
Weaving and clothmaking	Common extensor, common flexors, supinator, biceps brachii, brachioradialis, pronator quadratus, pronator teres, iliacus, iliopsoas, and gastrocnemius	Elbow flexion, supination and pronation, hip flexion and knee flexion from kneeling	*Shuler et al., 2012;* *Lawrence et al., 2018*

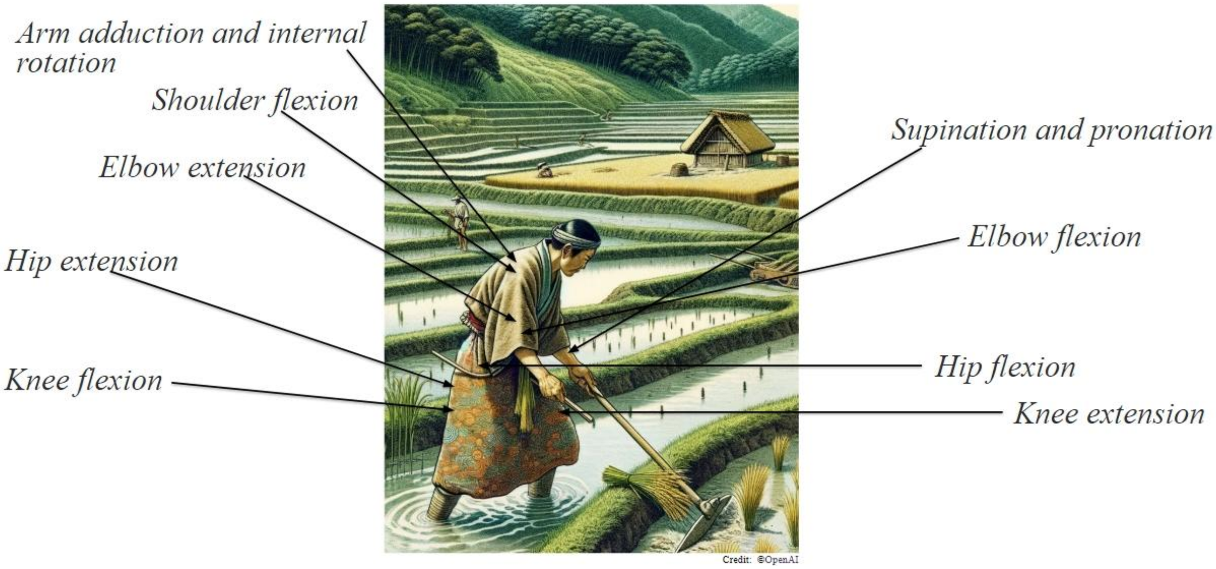
Table 4.9.List of the 36 muscles or ligament and their actions.

Muscle	Attachment	Action
Costoclavicular ligament	Costal tuberosity	Stabilizes the medial clavicle and anterior first rib
Subclavius	Subclavian groove	Steadies the clavicle in the sternoclavicular joint
Biceps (long head)	Supraglenoid tubercle	Elbow joint: Flexion
		Supination (with the elbow flexed)
		Shoulder joint: Flexion (forward motion of humerus)
		Stabilization of humeral head during deltoid contraction
		Abduction and internal (medial) rotation of the humerus
Triceps (long head)	Infraglenoid tubercle	Elbow joint: Extension
		Shoulder joint: Long head: Backward movement and adduction of the arm
Pectoralis minor	Coracoid process	Draws the scapula downward, causing its inferior angle to move posteromedially (lowers the raised arm), rotates glenoid inferiorly
		Assists in respiration
Trapezius	Spine of the scapula	Descending part: draws the scapula obliquely upward and rotates the glenoid cavity inferiorly (acting with the interior part of the serratus anterior)
		Tilts the head to the same side and rotates it to the opposite side (with the shoulder girdle fixed)
		Transverse part: draws the scapula medially
		Ascending part: draws the scapula medially downward (supports the rotating action of the descending part)
		Entire muscle: Steadies the scapula on the thorax
Supraspinatus	Greater tubercle (anterior, proximal)	Abduction
Infraspinatus	Greater tubercle (posterior, proximal)	External rotation
Teres minor	Greater tubercle (posterior, distal)	External rotation
		Weak adduction
Common extensors	Lateral epicondyle	Elbow joint: Weak flexor
		Wrist joints: Dorsal extension (assists in fist closure)
		Abduction (radial deviation) of the hand
Common flexors	Medial epicondyle	Elbow joint: Weak flexor
		Wrist joints: Flexion of the hand
		MCP and PIP joints: Flexion
Subscapularis	Lesser tubercle	Internal rotation
Teres major	Crest of lesser tuberosity (distal)	Internal rotation
		Adduction
		Retroversion
Pectoralis major	Crest of greater tuberosity	Entire muscle: Adduction
		Internal rotation
		Assists respiration when the shoulder girdle is fixed
		Clavicular and sternocostal part: Anteversion
Deltoideus	Deltoid tuberosity	Clavicular part: Anteversion (moves the arm and shoulder forward)

		Internal rotation
		Adduction
		Acromial part: Abduction
		Spinal part: Retroversion (moves the arm and shoulder backward)
		External rotation
		Adduction
		Between 60° and 90° of abduction, the clavicular and spinal parts assist the acromial part with abduction
Latissimus dorsi	Crest of lesser tuberosity (proximal)	Internal rotation
		Adduction
		Retroversion (moves the arm backward)
		Respiration (expiration, “cough muscle”)
Triceps	Olecranon process	Elbow joint: Extension
		Shoulder joint: Long head: Backward movement and adduction of the arm
Brachialis	Ulnar tuberosity	Flexion at the elbow joint
Anconeus	Olecranon process (lateral)	Extends the elbow and tightens its joint capsule
Supinator	Supinator crest	Supinates the forearm joint
Biceps	Radial tuberosity	Elbow joint: Flexion
		Supination (with the elbow flexed)
		Shoulder joint: Flexion (forward motion of humerus)
		Stabilization of humeral head during deltoid contraction
		Abduction and internal (medial) rotation of the humerus
Brachioradialis	Styloid process	Elbow joint: Flexion
		Forearm joints: Semipronation
Pronator quadratus	Anterior, distal surface	Pronates the hand
		Stabilizes the distal radioulnar joint
Pronator teres	Lateral body	Elbow joint: Weak flexor
		Forearm joints: Pronation
Supinator	Lateral proximal shaft	Supinates the forearm joint
Gluteus maximus	Gluteal tuberosity	Entire muscle: Extends and externally rotates the hip
		Stabilizes the hip in both the sagittal and coronal planes
		Upper fibers: Abduction
		Lower fibers: Adduction
Adductor magnus	Linea aspera	Adduction, external rotation, and extension of the hip joint (the tendinous insertion is also active in internal rotation)
		Stabilizes the pelvis in the coronal and sagittal planes
Vastus medialis	Spiral line	Knee joint: Extension
Vastus lateralis	Anterior greater trochanter	Knee joint: Extension
Gluteus medius	Lateral greater trochanter	Entire muscle: Abducts the hip
		Stabilizes the pelvis in the coronal plane
		Anterior part: Flexion
		Internal rotation
		Posterior part: Extension
		External rotation

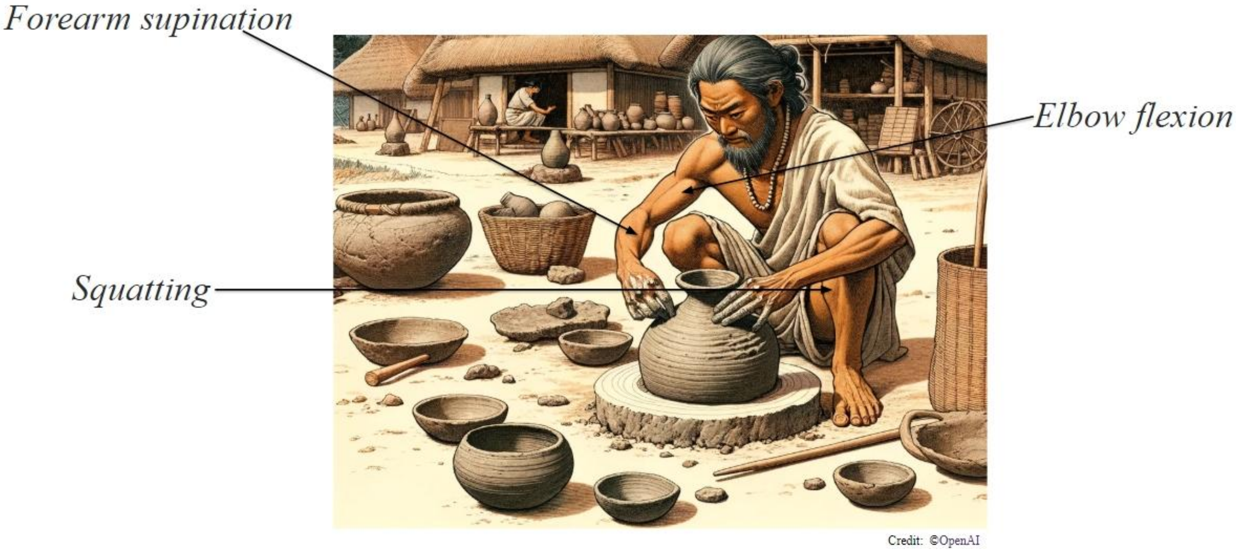
Gluteus minimus	Anterolateral greater trochanter	Entire muscle: Abducts the hip
		Stabilizes the pelvis in the coronal plane
		Anterior part: Flexion
		Internal rotation
		Posterior part: Extension
		External rotation
Obturator externus	Trochanteric fossa	Adduction and external rotation of the hip joint
		Stabilizes the pelvis in the sagittal plane
Gastrocnemius (medial head)	Medial condyle	Talocrural joint: Plantar flexion
		Subtalar joint: Inversion (supination)
		Knee joint: Flexion
Iliacus	Lesser trochanter (base)	Hip joint: Flexion
		External rotation
		Lumbar spine: Unilateral contraction (with the femur fixed) bends the trunk laterally to the same side
		Bilateral contraction raises the trunk from the supine position
Iliopsoas	Lesser trochanter	Hip joint: Flexion
		External rotation
		Lumbar spine: Unilateral contraction (with the femur fixed) bends the trunk laterally to the same side
		Bilateral contraction raises the trunk from the supine position
Soleus	Soleal line	Talocrural joint: Plantar flexion
		Subtalar joint: Inversion (supination)

Schünke et al. 2010



Credit: ©OpenAI

Figure 4.6. Depiction of actions required for general farming activities.



Credit: ©OpenAI

Figure 4.7. Depiction of actions required for pottery making.

Three-dimensional Method

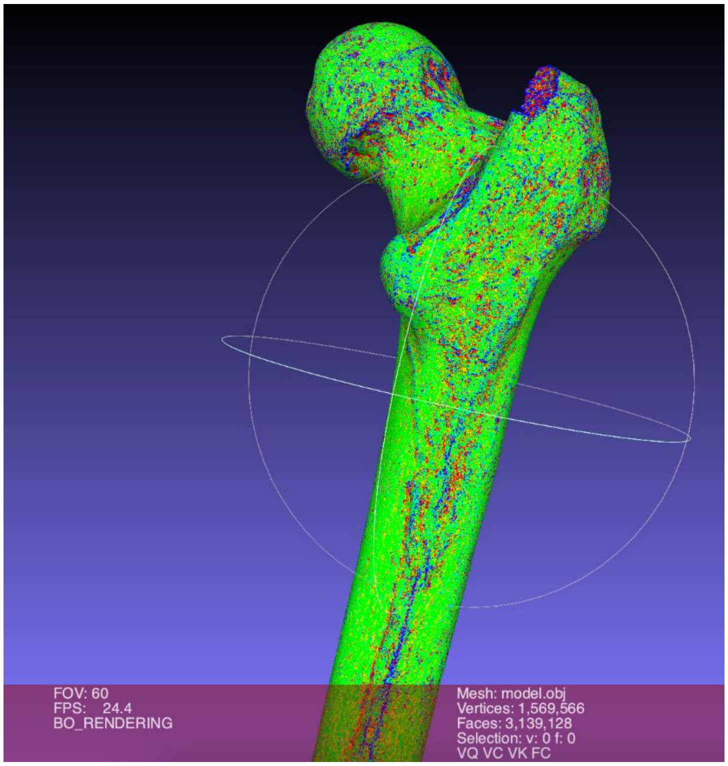
Additionally, in order to better quantify the data, a second method was created using photogrammetry to complement the already existing scoring method. The method is as follows. The bone is sat upright in a shallow container on an electronic turntable, so that the camera can get more than half of the bone in the viewfinder. For each bone, 108 photographs are taken from three different angles (36 photographs per angle) of the proximal half of the bone, then the bone is flipped upside down, and 108 more photographs are taken of the distal half of the bone. The three angles of the camera on the tripod are as follows: high angle, capturing the superior aspect of the bone; eye level; low angle, capturing the inferior aspect of the bone. This is done to ensure that there is a good view of the bone from all angles while there is also nothing shown holding the bone that could add data to the surface mesh made from these photographs. The 216 photographs of the bone are then uploaded into Reality capture, a photogrammetry software program. This software then combines the photographs from all angles of both sides of the bone to create a three-dimensional surface mesh of the bone, complete with realistic productions of the MSMs on the bone as the mesh is textured accurately.

Figure 4.8. Set up of bone in shallow container.

```
FOV: 60                          Mesh: model.obj
FPS:   25.0                      Vertices: 1,569,566
BO_RENDERING                     Faces: 3,139,128
                                 Selection: v: 0 f: 0
                                 VC FC
```

Figure 4.9. Three-dimensional surface mesh of a femur.

Using Meshlab, the discrete curvature is extracted (ISTI-CNR, 2023). The first step is downloading an obj. version of the surface mesh from Sketchfab (Pinson, 2024) and opening it in Meshlab (ISTI-CNR, 2023). The next step is to go to the menu and select "Discrete Mean Curvature Filter" from the Filters section. This filter computes the curvature of the surface mesh. Next, use the Z-Painting Tool to paint over and select the region of interest. This tool allows the user to highlight specific faces and/or vertices on the mesh. Once the region of interest is selected, the user can invert the selection by going to Filters > Selection > Invert Selection. This will invert the selection so that the faces and vertices the user does not need are highlighted instead. Now that the unwanted region is selected, the next step is to go to Edit > Delete Selected Faces/Vertices to delete it. This will remove the unnecessary parts of the mesh, leaving only the region of interest. Then, the processed mesh needs to be exported as a .ply (polygon) file by going to File > Export Mesh As... and selecting the PLY format (Meshlab, ISTI-CNR, 2023).



```
FOV: 60
FPS:    24.4
BO_RENDERING
```

```
Mesh: model.obj
Vertices: 1,569,566
Faces: 3,139,128
Selection: v: 0 f: 0
VQ VC VK FC
```

Figure 4.10. Three-dimensional surface mesh of a femur with discrete mean curvature filter.

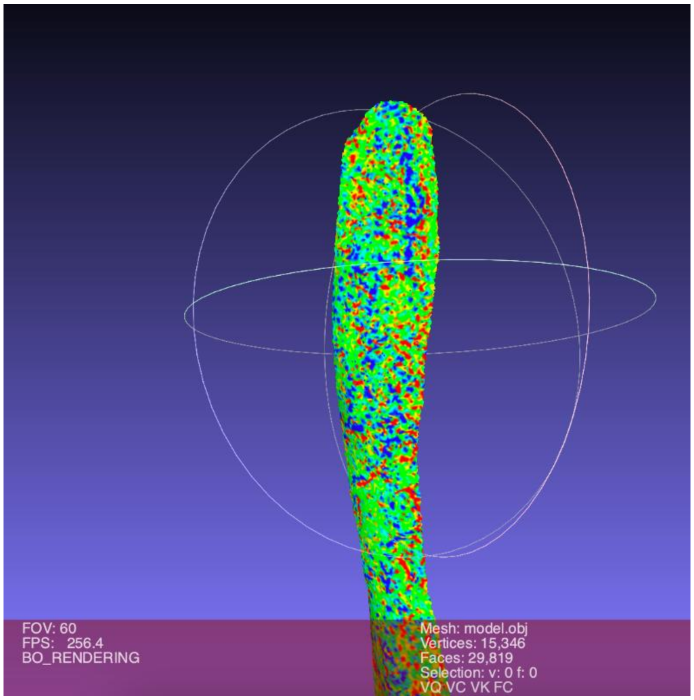


Figure 4.11. Three-dimensional surface mesh with discrete mean curvature and gluteal tuberosity selected.

After processing the mesh in MeshLab (ISTI-CNR, 2023), the ply file is input into DataSpell (JetBrains, 2023) to run a program created by Dao McGill, a computer science intern at the John A. Burns School of Medicine (McGill, n.d.). Dao's program is designed to extract and analyze mean curvature data from the surface mesh of the MSMs. The program views the triangular mesh as a piecewise linear approximation of a smooth surface. While the individual triangles have flat faces and no intrinsic curvature, the curvature at each vertex can still be estimated by looking at the relationships between the triangles and their neighboring vertices. The mean curvature KH is calculated as the average of normal curvatures at a vertex, using the formula: $KH = \frac{1}{2\pi}\int_0^{2\pi} K^N(\theta)d\theta$. The program retrieves all faces and vertices around each vertex. For each neighboring vertex, it computes the absolute angles, squared distances, and the Voronoi cell value which partitions the surface area around the vertex. These values are then plugged into the mean curvature equation to get an estimate for KH $(\mathrm{McGill, n.d.})$.

McGill's Python code automates various tasks before giving the mean curvature values. It imports necessary math libraries (such as NumPy) and helper functions. It confirms the existence of a .ply file saved from MeshLab, ensuring that it contains the quality parameter set to mean curvature. Lastly, it converts the mesh data into a pandas DataFrame (a 2 dimensional data structure) with float32 precision, organizing the data into columns for the vertices' x, y, and z coordinates and the associated mean curvature values (McGill, n.d.).

The code then performs a statistical analysis of the mean curvature data. First, it calculates the absolute values of the mean curvature at each vertex. Then, it removes outliers by calculating the Z-scores for the data and filtering out values with a Z-score above 3. This removes any extreme outliers that might distort the analysis. A Z-score is a statistical measure that describes the position of a data point in relation to the mean of a dataset. It is expressed in terms of standard deviations. It shows how many standard deviations a particular value is from the mean. Z-scores are calculated using the formula: $Z=(X-\mu)/\sigma$. X is the value of the data point, μ is the mean of the dataset, and σ is the standard deviation of the dataset. A Z-score of 0 indicates that the data point is exactly at the mean, while a positive or negative Z-score indicates that the data point is above or below the mean. For example, a Z-score of 2 means the data point is two standard deviations above the mean, while a Z-score of -1 means it is one standard deviation below the mean. Z-scores are used to detect outliers. A standard threshold is that Z-scores greater than 3 (or less than -3) are considered outliers because they lie far from the mean. (Field, 2013; McDonald, 2014; McGill, n.d.).

After filtering the outliers, the code generates a new DataFrame with the cleaned data. Histograms or distribution plots of the curvature data can be created. These help to analyze the distribution of the curvature values across the surface of the MSM. The code then outputs a final statistical summary of the filtered curvature data. In Dao's code, the mean of the curvature values calculated from the MSM mesh represents the average curvature across all vertices in the 3D model. This value gives insight into the general smoothness or roughness of the surface. A higher mean curvature suggests that the surface has more pronounced curvatures, indicating regions where the bone experienced significant stress due to repetitive use or more physical stress. A lower mean curvature indicates a flatter, less stressed MSM (McGill, n.d.).

After the initial development of this method, the intravariability of selecting the region of interest was tested to ensure that one could accurately and continuously select the MSMs of the surface meshes, as the region selection affects the entire curvature extraction of the mesh. It was also essential to ensure that even if the region selection was not exactly the same, the mean curvature values were similar. On August 9, 2022, the gluteal tuberosity, linea aspera, and spiral line from 5 femora curated in the osteological collection at the John A. Burns School of Medicine were analyzed using the above 3D method. On August 24, 2022 the same process was repeated with the same 5 femora. Afterwards, a Bland-Altman test was run in SPSS to assess the agreement between the two different measurements (IBM Corp, 2023).

Lastly, this new 3D method was done on the surface meshes of the femora from this research. The regions of interest were the gluteal tuberosity, linea aspera, trochanteric fossa, medial condyle, spiral line, base of the lesser trochanter, lesser trochanter, lateral greater trochanter, anterolateral greater trochanter, and anterior greater trochanter. Only well-preserved femora that were strong enough to be stood upright and with at least half of the MSMs present were chosen for this method. A total of 56 femora were used for this research. Spearman rho tests and scatterplots were done to show the correlation between the modified Hawkey and Merbs scores and the mean curvature values.

Chapter 5: Results

Analysis of Musculoskeletal Stress Markers using a Modified Hawkey and Merbs Method

Establishment of Statistical Breakpoints

Musculoskeletal stress markers (MSM) were analyzed to identify patterns of muscle usage and infer habitual activities in the Jomon and Yayoi. Statistical breakpoints were established based on the methodology originally developed by Hawkey and Merbs (1995), where breakpoints delineate the muscles most frequently and intensely used from those that were less engaged in daily tasks. In this study, the breakpoints were calculated using mean composite scores derived from skeletal remains of individuals from the Edo period farming village of Ikenohata, a well-documented agricultural community. The mean values were obtained using the descriptive statistics function in SPSS Version 29.0.2.0, following established procedures for determining activity-induced changes in skeletal muscle attachment sites (Hawkey and Merbs, 1995).

The Ikenohata sample serves as an ideal reference for this study due to its distinct agricultural context, providing a representative model of muscle usage patterns associated with farming activities. Mean composite scores from the Ikenohata data were calculated for each muscle insertion site using SPSS Version 29.0.2.0, and a statistical breakpoint was identified to demarcate muscles that were most utilized during repetitive farming activities (presented in Table 5.1). This approach follows the precedent set by Hawkey and Merbs (1995), where muscles exhibiting composite scores higher than the statistical breakpoint are interpreted as being most utilized, indicating higher levels of habitual activity and mechanical stress.

Conversely, muscles with composite scores below the breakpoint are considered less utilized, reflecting reduced involvement in daily tasks.

Table 5.1. Statistical Breakpoints between stronger and more moderate use of muscles from human remains from the known farming Edo village Ikenohata in Japan.

Muscle	Statistical Breakpoint
Costoclavicular ligament	2.388
Subclavius	1.364
Biceps (long head)	0.85
Triceps (long head)	1.657
Pectoralis minor	1.08
Trapezius	1.245
Supraspinatus	0.87
Infraspinatus	0.79
Teres minor	1
Common extensors	1.607
Common flexors	1.53
Subscapularis	1.376
Teres major	0.639
Pectoralis major	1.516
Deltoideus	1.414
Latissimus dorsi	1.655
Triceps	1.54
Brachialis	1.636
Anconeus	1.19
Supinator	1.558
Biceps	1.776
Brachioradialis	1.41
Pronator quadratus	0.41
Pronator teres	1.211
Supinator	0.978
Gluteus maximus	1.757
Adductor magnus	1.256
Vastus medialis	1.215
Vastus lateralis	0.88
Gluteus medius	1.114
Gluteus minimus	1.13
Obturator externus	1.053

Gastrocnemius (medial head)	1.28
Iliacus	1.156
Iliopsoas	1.12
Soleus	1.638

Muscular Utilization Patterns of General Groups

The analysis of MSMs highlights differences in activity levels between the Jomon and Yayoi periods, showing how subsistence strategies changed over time (Figures 5.1, Table 5.2). The Jomon period consistently shows lower MSMs than the Yayoi. When looking at the overall Yayoi period, general farming activities were above the statistical breakpoint 76% of the time, while the Jomon was only 36% of the time. The trend is shown again for all other activities. The Yayoi shows that grain processing, clearing woodland, pottery making, metalworking, and weaving and clothmaking had percentages over the breakpoint of 77%, 80%, 78%, 72% and 72% respectively. While the same activities for the Jomon were 39%, 29%, 32%, 28%, 31%, respectively; always falling well below the Ikenohata control group and much lower than the farming Yayoi group.

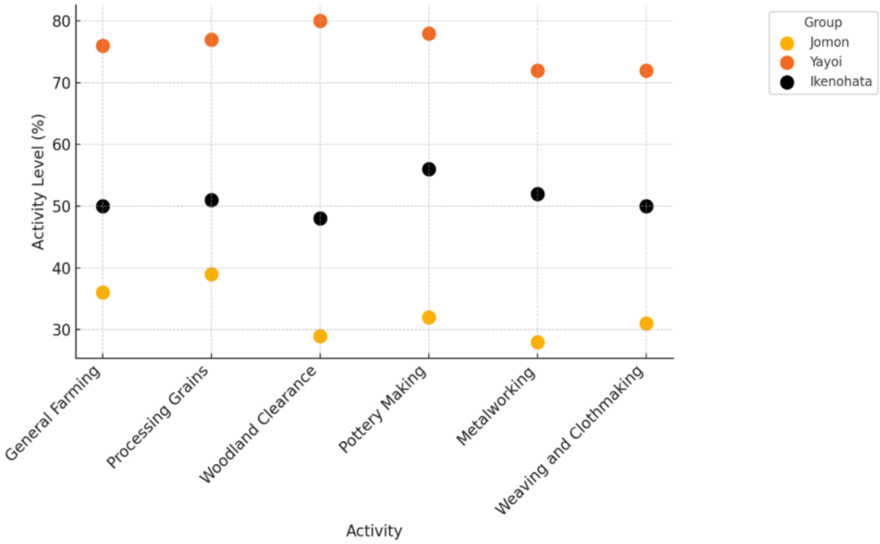


Figure 5.1 Scatterplot of activity frequencies above the statistical breakpoints across time periods.

Table 5.2. Activity frequencies above the statistical breakpoints across time periods.

	General Farming	Processing Grains	Woodland Clearance	Pottery Making	Metalworking	Weaving and Clothmaking
Jomon	36%	39%	29%	32%	28%	31%
Yayoi	76%	77%	80%	78%	72%	72%
Ikenohata	50%	51%	48%	56%	52%	50%

Kruskal-Wallis tests revealed significant differences in MSM scores for the majority of the muscle groups between the Jomon groups, with significant differences for 28 out of the 36 muscles (Table 5.3). For the Yayoi groups there are significant differences for half of the muscles (Table 5.4). This suggests that there is more of a diversity in muscle usage patterns within the Jomon groups than the Yayoi.

Table 5.3. Kruskal-Wallis test between Jomon muscles.

Muscle	**Kruskal-Wallis H**	**df**	**Asymp. Sig.**
Costoclavicular ligament	19.396	16	.249
Subclavius	**50.378**	17	**<.001**
Biceps brachii (long head)	**28.793**	15	**.017**
Triceps brachii (long head)	17.725	16	.340
Pectoralis minor	20.218	15	.164
Trapezius	17.582	11	.092
Supraspinatus	14.416	16	.568
Infraspinatus	**28.070**	17	**.044**
Teres minor	**33.698**	17	**.009**
Common extensors	**30.823**	19	**.042**
Common flexors	**63.133**	19	**<.001**
Subscapularis	**31.758**	17	**.016**
Teres major	**39.128**	19	**.004**
Pectoralis major	22.390	19	.265
Deltoideus	**33.432**	19	**.021**
Latissimus dorsi	17.584	19	.550
Triceps brachii	**61.188**	18	**<.001**
Brachialis	**77.792**	20	**<.001**
Anconeus	**37.814**	18	**.004**
Supinator	**33.727**	20	**.028**
Biceps brachii	**44.681**	19	**<.001**
Brachioradialis	18.649	11	.068
Pronator quadratus	**67.614**	19	**<.001**
Pronator teres	**83.995**	19	**<.001**

Supinator	**75.284**	19	**<.001**
Gluteus maximus	**107.530**	20	**<.001**
Adductor magnus	**57.404**	20	**<.001**
Vastus medialis	**47.589**	19	**<.001**
Vastus lateralis	**50.992**	19	**<.001**
Gluteus medius	**66.614**	20	**<.001**
Gluteus minimus	**59.106**	17	**<.001**
Obturator externus	**43.420**	16	**.002**
Gastrocnemius	**37.556**	20	**<.001**
Iliacus	**69.702**	19	**<.001**
Iliopsoas	**45.437**	20	**<.001**
Soleus	**39.541**	20	**.006**

Table 5.4. Kruskal-Wallis test between Yayoi muscles.

Muscle	Kruskal-Wallis H	df	Asymp. Sig.
Costoclavicular ligament	**23.949**	**8**	**0.002**
Subclavius	**17.58**	**8**	**0.025**
Biceps (o-long head)	**17.537**	**8**	**0.025**
Triceps (o-long head)	8.838	7	0.264
Pectoralis minor	14.663	8	0.066
Trapezius	1.715	2	0.424
Supraspinatus	**13.99**	**6**	**0.03**
Infraspinatus	8.474	5	0.132
Teres minor	**18.622**	**5**	**0.002**
Common extensors	10.079	6	0.121
Common flexors	7.111	5	0.212
Subscapularis	**17.282**	**8**	**0.027**
Teres major	**47.059**	**8**	**<.001**
Pectoralis major	**32.484**	**8**	**<.001**
Deltoideus	14.768	8	0.064
Latissimus dorsi	**21.03**	**8**	**0.007**
Triceps	8.318	6	0.216
Brachialis	**17.598**	**8**	**0.024**
Anconeus	10.631	6	0.1
Supinator	**21.165**	**8**	**0.007**
Biceps	15.194	8	0.055
Brachioradialis	13.151	8	0.107
Pronator quadratus	8.167	8	0.417
Pronator teres	**21.07**	**8**	**0.007**
Supinator	12.703	8	0.122
Gluteus maximus	**33.146**	**8**	**<.001**

Adductor magnus	**25.655**	**8**	**0.001**
Vastus medialis	10.286	8	0.246
Vastus lateralis	9.77	7	0.202
Gluteus medius	**13.06**	**6**	**0.042**
Gluteus minimus	9.608	6	0.142
Obturator externus	11.427	8	0.179
Gastrocnemius	**16.386**	**7**	**0.022**
Iliacus	13.786	8	0.088
Iliopsoas	**26.293**	**8**	**<.001**
Soleus	**15.96**	**8**	**0.043**

Less than half of the examined muscles showed significant differences between males and females, suggesting a somewhat shared division of labor for many activities in both the Jomon and Yayoi periods (Tables 5.5 and 5.6). For the Jomon there were only 11 muscles that were significantly different between the two sexes and for the Yayoi there were 12 muscles. Among the muscles with significantly different scores, the costoclavicular ligament in the Yayoi group exhibited the largest mean difference at 2.628, reflecting the disproportionate involvement of this muscle in agricultural activity between the sexes. This muscle also had the largest mean difference within the Jomon at 0.941. This is interesting as it shows possible division of labor when involving this muscle for both the Jomon and Yayoi.

Table 5.5. T-test between sexes of the Jomon.

Muscle	**t**	**df**	**Significance (Two-Sided p)**	**Mean Difference**
Costoclavicular ligament	**3.317**	**215**	**<.001**	**.9412**
Subclavius	-.813	235	.417	-.098
Biceps brachii (long head)	1.050	137	.296	.2247
Triceps brachii (long head)	1.787	129	.076	.3379
Pectoralis minor	1.754	96	.083	.276
Trapezius	1.740	42	.089	.442
Supraspinatus	.823	169	.412	.1694
Infraspinatus	**3.540**	**182**	**<.001**	**.379**
Teres minor	.423	173	.673	.075

Common extensors	.104	294	.917	.0111
Common flexors	1.656	314	.099	.1353
Subscapularis	1.210	193	.228	.234
Teres major	**2.108**	**303**	**.036**	**.137**
Pectoralis major	**2.554**	**321**	**.011**	**.2936**
Deltoideus	**3.444**	**344**	**<.001**	**.2824**
Latissimus dorsi	**2.936**	**322**	**.004**	**.4246**
Triceps brachii	.500	296	.617	.045
Brachialis	.992	353	.322	.1315
Anconeus	**2.871**	**273**	**.004**	**.2717**
Supinator	-.138	357	.890	-.0108
Biceps brachii	**2.436**	**294**	**.015**	**.2917**
Brachioradialis	.624	125	.534	.0803
Pronator quadratus	**2.978**	**320**	**.003**	**.3331**
Pronator teres	1.025	275	.306	.051
Supinator	.609	316	.543	.042
Gluteus maximus	-.465	395	.642	-.0468
Adductor magnus	**5.642**	**374**	**<.001**	**.4865**
Vastus medialis	**4.343**	**397**	**<.001**	**.340**
Vastus lateralis	1.266	244	.207	.1634
Gluteus medius	.907	246	.365	.0956
Gluteus minimus	1.595	256	.112	.2948
Obturator externus	-.914	278	.362	-.1400
Gastrocnemius	1.641	135	.103	.222
Iliacus	1.917	341	.056	.1774
Iliopsoas	.923	220	.179	.357
Soleus	1.374	316	.085	.171

Table 5.6. T-test between sexes of the Yayoi.

Muscle	**t**	**df**	**Significance (Two-Sided p)**	**Mean Difference**
Costoclavicular ligament	**7.785**	**159**	**<.001**	**2.6275**
Subclavius	.674	183	.501	.1110
Biceps brachii (long head)	.280	136	.780	.067
Triceps brachii (long head)	**3.449**	**122**	**<.001**	**1.3196**
Pectoralis minor	**2.126**	**111**	**.036**	**.7638**
Trapezius	1.239	67	.220	.1164
Supraspinatus	**2.418**	**105**	**.017**	**.5673**
Infraspinatus	1.103	87	.273	.346
Teres minor	-.438	71	.663	-.1324

Common extensors	1.818	109	.072	.4003
Common flexors	.879	117	.381	.1657
Subscapularis	-.551	133	.582	-.1643
Teres major	-.858	238	.392	-.2354
Pectoralis major	1.315	240	.190	.2428
Deltoideus	.183	232	.855	.0185
Latissimus dorsi	**2.377**	**220**	**.018**	**.5435**
Triceps brachii	.196	119	.845	.0710
Brachialis	-1.204	205	.230	-.3396
Anconeus	**2.236**	**106**	**.027**	**.2562**
Supinator	.119	194	.906	.0193
Biceps brachii	1.943	189	.054	.5561
Brachioradialis	.017	92	.987	.0014
Pronator quadratus	1.373	182	.171	.242
Pronator teres	**3.350**	**214**	**<.001**	**.6569**
Supinator	.109	204	.913	.0142
Gluteus maximus	-.986	255	.325	-.2507
Adductor magnus	**8.387**	**278**	**<.001**	**.8707**
Vastus medialis	**1.969**	**275**	**.050**	**.2206**
Vastus lateralis	.403	105	.688	.106
Gluteus medius	.979	84	.331	.234
Gluteus minimus	-.135	91	.893	-.0363
Obturator externus	.687	100	.494	.189
Gastrocnemius	**2.278**	**113**	**.025**	**.3055**
Iliacus	**2.569**	**193**	**.011**	**.4101**
Iliopsoas	1.290	144	.199	.2582
Soleus	**3.579**	**286**	**<.001**	**.4547**

T-tests analyzed handedness through side differences between the left and right limbs in each population. These tests showed that overall, there were no consistent patterns of asymmetry across most muscles in either the Jomon or Yayoi populations (Tables 5.7 and 5.8). There are only 4 muscles that indicate a significant difference between sides for the Jomon and 2 for the Yayoi. These findings imply that most activities performed by these populations, whether related to foraging, fishing, or farming, required a balanced use of both limbs.

Table 5.7. T-test between right and left sides of the Jomon.

Muscle	**t**	**df**	**Significance (Two-Sided p)**	**Mean Difference**
Costoclavicular ligament	-.854	270	.394	-.2307
Subclavius	.839	301	.402	.087
Biceps brachii (long head)	-.490	163	.625	-.0893
Triceps brachii (long head)	.527	151	.599	.1058
Pectoralis minor	-.213	113	.832	-.031
Trapezius	.518	48	.607	.132
Supraspinatus	.709	216	.479	.1351
Infraspinatus	-.212	232	.832	-.020
Teres minor	1.618	222	.107	.247
Common extensors	.123	380	.902	.0117
Common flexors	-.357	411	.721	-.0423
Subscapularis	.598	249	.551	.109
Teres major	**2.592**	**405**	**.010**	**.138**
Pectoralis major	-.197	425	.844	-.0245
Deltoideus	.194	460	.846	.0142
Latissimus dorsi	-.102	426	.919	-.0127
Triceps brachii	**-2.313**	**381**	**.021**	**-.191**
Brachialis	.529	467	.597	.0586
Anconeus	**-3.978**	**346**	**<.001**	**-.3287**
Supinator	.028	469	.978	.0019
Biceps brachii	1.409	388	.160	.1429
Brachioradialis	-1.181	169	.239	-.1287
Pronator quadratus	1.095	358	.274	.049
Pronator teres	-.259	415	.796	-.0268
Supinator	1.669	407	.096	.108
Gluteus maximus	.729	541	.467	.0618
Adductor magnus	**2.910**	**501**	**.004**	**.2427**
Vastus medialis	1.720	541	.086	.117
Vastus lateralis	-.433	316	.665	-.0483
Gluteus medius	-.883	311	.378	-.0813
Gluteus minimus	-1.080	322	.281	-.1719
Obturator externus	-1.407	348	.160	-.1914
Gastrocnemius	-.535	163	.593	-.065
Iliacus	.668	445	.504	.0517
Iliopsoas	-.092	281	.926	-.008
Soleus	-.012	433	.990	-.0011

Table 5.8. T-test between right and left sides of the Yayoi.

Muscle	t	df	Significance (Two-Sided p)	Mean Difference
Costoclavicular ligament	.511	179	.610	.1919
Subclavius	1.612	205	.108	.2739
Biceps brachii (long head)	-.450	150	.653	-.105
Triceps brachii (long head)	-.724	134	.470	-.2822
Pectoralis minor	.594	121	.553	.1972
Trapezius	1.205	74	.232	.1035
Supraspinatus	.210	119	.834	.0465
Infraspinatus	**2.004**	**98**	**.048**	**.582**
Teres minor	-.505	80	.615	-.1377
Common extensors	.139	123	.889	.0283
Common flexors	1.070	132	.286	.1830
Subscapularis	-.433	151	.666	-.1181
Teres major	-.621	267	.535	-.1680
Pectoralis major	.673	269	.501	.1140
Deltoideus	**-2.526**	**262**	**.012**	**-.2898**
Latissimus dorsi	-.131	249	.896	-.0275
Triceps brachii	1.487	132	.139	.4906
Brachialis	1.150	230	.251	.3030
Anconeus	1.469	115	.145	.1660
Supinator	-.666	218	.506	-.0978
Biceps brachii	-.921	211	.358	-.2536
Brachioradialis	.126	101	.900	.0112
Pronator quadratus	.409	204	.683	.068
Pronator teres	-.027	243	.979	-.0053
Supinator	-.104	229	.917	-.0132
Gluteus maximus	.573	289	.567	.1362
Adductor magnus	-.929	315	.354	-.1010
Vastus medialis	-1.568	313	.118	-.1685
Vastus lateralis	-.513	122	.609	-.136
Gluteus medius	.822	96	.413	.189
Gluteus minimus	.986	103	.327	.2371
Obturator externus	.000	116	1.000	.000
Gastrocnemius	-.437	126	.663	-.0630
Iliacus	-.828	219	.409	-.1264
Iliopsoas	-1.206	326	.229	-.1494
Soleus	-1.206	316	.229	-.1494

The analysis of MSMs reveals significant differences in activity patterns between the Jomon and Yayoi populations, reflecting changes in subsistence strategies over time. The Yayoi populations show consistently higher frequencies of activities over the statistical breakpoints compared to the Jomon. These differences indicate a more intensive use of the muscles examined in the Yayoi, consistent with the physical demands of agricultural activities. Sex differences suggest a shared division of labor for many tasks in both populations. Similarly, minimal differences in limb use in both groups suggest that activities required balanced muscle engagement.

Muscular Utilization Patterns of Geographic Site Categories

The comparison of MSMs across geographic site categories highlights distinct patterns in activity levels between Jomon and Yayoi populations, reflecting their differing subsistence strategies (Figure 5.2, Table 5.9). The Inland Yayoi group exhibited the highest activity frequencies overall, with 81% of general farming activities, 89% of grain processing, and 94% of woodland clearance exceeding statistical breakpoints. Pottery making and metalworking were also notably high, with 81% and 72%, respectively, reflecting their critical roles in agricultural storage and tool production. These elevated scores correspond to the intensive agricultural labor required for wet-rice cultivation, including land preparation, field maintenance, and associated craft production.

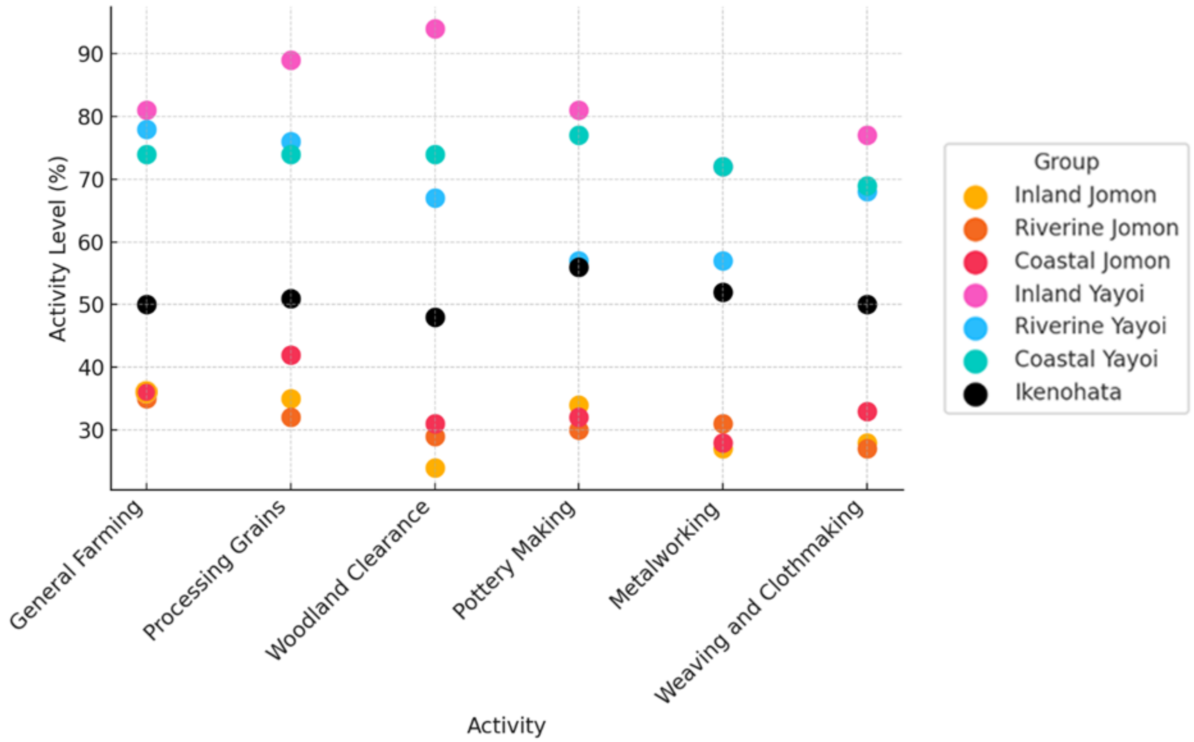


Figure 5.2. Scatterplot of activity frequencies above the statistical breakpoints across geographic locations and time periods.

Table 5.9. Activity frequencies above the statistical breakpoints across geographic site categories.

	General Farming	Processing Grains	Woodland Clearance	Pottery Making	Metalworking	Weaving and Clothmaking
Inland Jomon	36%	35%	24%	34%	27%	28%
Riverine Jomon	35%	32%	29%	30%	31%	27%
Coastal Jomon	36%	42%	31%	32%	28%	33%
Inland Yayoi	81%	89%	94%	81%	72%	77%
Riverine Yayoi	78%	76%	67%	57%	57%	68%
Coastal Yayoi	74%	74%	74%	77%	72%	69%
Ikenohata	50%	51%	48%	56%	52%	50%

The Coastal Yayoi group showed slightly lower but still substantial activity frequencies, with 74% for general farming, 74% for grain processing, and 74% for woodland clearance. Pottery making remained high at 77%, while metalworking was recorded at 72%. These figures indicate significant involvement in agricultural and craft activities, though slightly moderated by the availability of marine resources that supplemented their diet and reduced the overall intensity of agricultural labor.

The Riverine Yayoi group displayed activity frequencies between those of inland and coastal groups. General farming was recorded at 78%, grain processing at 76%, and woodland clearance at 67%. Pottery making was lower compared to Inland Yayoi at 57%, but still indicative of substantial activity, while metalworking activity stood at 57%. These scores suggest that riverine populations balanced agricultural labor with their access to aquatic resources, which likely diversified their economic and subsistence strategies.

In contrast, the Jomon groups demonstrated consistently lower activity frequencies, consistent with their hunter-gatherer-fisher subsistence strategies. The Inland Jomon group recorded 36% for general farming, 35% for grain processing, and 24% for woodland clearance. Pottery making and metalworking frequencies were 34% and 27%, respectively, suggesting their use was less labor-intensive and more associated with small-scale, localized production. The Coastal Jomon group showed slightly higher scores for some activities, with 36% for general farming, 42% for grain processing, and 31% for woodland clearance. Pottery making was similar at 32%, and metalworking reached 28%, indicating minor but meaningful engagement with these activities, likely tied to resource availability in coastal areas. The Riverine Jomon group exhibited activity frequencies in line with Coastal Jomon groups, with 35% for general farming, 32% for grain processing, and 29% for woodland clearance. Pottery making and metalworking were slightly higher, at 30% and 31%, respectively, reflecting the role of these crafts in supporting mixed subsistence strategies in riverine environments.

The data illustrate significant differences in activity levels between Jomon and Yayoi populations and across geographic site categories. Inland Yayoi groups showed the highest frequencies across all measured activities, particularly those directly linked to intensive agriculture and craft production. Coastal and Riverine Yayoi groups also demonstrated high activity levels, although their continued reliance on aquatic resources likely influenced their labor patterns. In contrast, Jomon populations exhibited much lower frequencies across all categories, reflecting the reduced physical demands of foraging subsistence. Pottery making and metalworking, while present in both populations, were more prominent and labor-intensive in the Yayoi, particularly in inland agricultural communities. These findings underscore the interplay between environmental contexts, resource availability, and habitual activities in shaping musculoskeletal development.

When running the Kruskal-Wallis test on the different geographic locales (Inland Jomon, Riverine Jomon, Coastal Jomon, Inland Yayoi, Riverine Yayoi, and Coastal Yayoi) there are significant differences for all 36 of the muscles (Table 5.10). This suggests that the differences in MSMs are strongly associated with the contrasting subsistence strategies of hunting and gathering versus farming from site to site. For instance, all but one of the 36 muscles had a highly significant p-value of <0.001, indicating a marked distinction in usage intensity between these populations. This emphasizes the diversity in habitual activity patterns shaped by geographic and environmental factors that could not be shown through analyzing remains in general groups of Jomon and Yayoi (see Tables 5.3 and 5.4)

Table 5.10. Kruskal-Wallis test between geographic site categories.

Muscles	Kruskal-Wallis H	df	Asymp. Sig.
Costoclavicular ligament	40.534	5	<.001
Subclavius	161.712	5	<.001
Biceps brachii (long head)	88.113	5	<.001
Triceps brachii (long head)	121.391	5	<.001
Pectoralis minor	94.946	5	<.001
Trapezius	36.881	4	<.001
Supraspinatus	59.178	5	<.001
Infraspinatus	94.824	4	<.001
Teres minor	27.298	4	.001
Common extensors	33.709	5	<.001
Common flexors	50.913	5	<.001
Subscapularis	34.68	5	<.001
Teres major	269.467	5	<.001
Pectoralis major	22.189	5	<.001
Deltoideus	82.926	5	<.001
Latissimus dorsi	87.266	5	<.001
Triceps brachii	138.645	5	<.001
Brachialis	253.884	5	<.001
Anconeus	81.516	5	<.001
Supinator	68.132	5	<.001
Biceps brachii	162.437	5	<.001
Brachioradialis	85.993	5	<.001
Pronator quadratus	85.884	5	<.001
Pronator teres	275.701	5	<.001
Supinator	155.529	5	<.001
Gluteus maximus	114.542	5	<.001
Adductor magnus	210.002	5	<.001
Vastus medialis	191.7	5	<.001
Vastus lateralis	102.102	5	<.001
Gluteus medius	95.621	5	<.001
Gluteus minimus	47.799	5	<.001
Obturator externus	56.839	5	<.001
Gastrocnemius	93.161	5	<.001
Iliacus	269.635	5	<.001
Iliopsoas	151.539	5	<.001
Soleus	114.496	5	<.001

Looking at the individual geographic locations can provide a more in-depth perspective. The t-tests revealed that 7 of the examined muscles were significantly different between males and females of the Inland Jomon (Table 5.11), while there were 4 muscles for the Riverine Jomon (Table 5.12) and 14 muscles that were significantly different for the Coastal Jomon (Table 5.13). The t-tests for the Yayoi showed 2 muscles were significantly different between males and females for the Inland Yayoi (Table 5.14), 2 muscles for the Riverine Yayoi (Table 5.15) and 12 muscles for the Coastal Yayoi (Table 5.16). This suggests that there may be a mild division of labor for those in the Coastal Jomon and Coastal Yayoi groups. As these are both coastal locales, this most likely has to do with the geographic and environmental aspects of the sites. Perhaps females and males had more distinct activities due to the nature of their subsistence practices.

Table 5.11. T-test between sexes of the Inland Jomon.

Muscle	t	df	Significance (Two-Sided p)	Mean Difference
Costoclavicular ligament	1.908	22.799	0.069	1.6397
Subclavius	-0.928	29	0.361	-0.514
Biceps brachii (long head)	**2.428**	**14.000**	**0.029**	**1.5667**
Triceps brachii (long head)	1.279	13	0.223	1.0500
Pectoralis minor	1.567	9	0.152	0.643
Trapezius	1.732	1	0.333	1.500
Supraspinatus	-0.177	18	0.861	-0.1010
Infraspinatus	0.361	18	0.722	0.100
Teres minor	0.364	24	0.719	0.238
Common extensors	1.011	33	0.319	0.500
Common flexors	-0.501	38	0.619	-0.1875
Subscapularis	1.136	19	0.270	0.764
Teres major	-0.103	37	0.918	-0.014
Pectoralis major	1.537	34.334	0.133	0.8571
Deltoideus	**2.039**	**41**	**0.048**	**0.8519**
Latissimus dorsi	1.326	37	0.193	0.8000
Triceps brachii	-0.676	28	0.504	-0.325
Brachialis	0.431	42	0.668	0.1547
Anconeus	1.185	31	0.245	0.4846
Supinator	0.585	40.848	0.562	0.1393
Biceps brachii	0.792	33	0.434	0.4710
Brachioradialis	1.342	3	0.272	0.500

Pronator quadratus	1.702	21.000	0.104	0.182
Pronator teres	**2.300**	**36**	**0.027**	**1.1935**
Supinator	**2.756**	**33.204**	**0.009**	**0.401**
Gluteus maximus	**2.164**	**32.490**	**0.038**	**0.7746**
Adductor magnus	**3.788**	**50**	**0.000**	**0.8095**
Vastus medialis	**3.414**	**55**	**0.001**	**0.622**
Vastus lateralis	1.586	21.268	0.128	0.9524
Gluteus medius	-0.197	43	0.845	-0.0417
Gluteus minimus	0.378	45	0.707	0.2871
Obturator externus	2.006	45	0.051	0.964
Gastrocnemius	-0.609	20	0.550	-0.219
Iliacus	0.886	50	0.380	0.1731
Iliopsoas	0.444	36	0.660	0.100
Soleus	0.388	38	0.700	0.1466

Table 5.12. T-test between sexes of the Riverine Jomon.

Muscle	**t**	**df**	**Significance (Two-Sided p)**	**Mean Difference**
Costoclavicular ligament	1.450	31.585	0.157	0.959
Subclavius	0.132	41	0.895	0.035
Biceps brachii (long head)	0.820	17	0.424	0.295
Triceps brachii (long head)	-1.388	18	0.182	-0.788
Pectoralis minor	1.332	10	0.213	0.625
Trapezius	1.852	6	0.114	1.000
Supraspinatus	**2.181**	**16.501**	**0.044**	**1.045**
Infraspinatus	1.697	17.249	0.108	0.671
Teres minor	1.504	11.718	0.159	0.879
Common extensors	-0.217	53	0.829	-0.0758
Common flexors	1.021	53	0.312	0.237
Subscapularis	0.790	42	0.434	0.425
Teres major	1.975	43.783	0.055	0.298
Pectoralis major	0.100	63	0.921	0.0265
Deltoideus	1.116	61	0.269	0.164
Latissimus dorsi	1.580	33.559	0.123	0.486
Triceps brachii	0.484	51	0.631	0.112
Brachialis	1.000	66	0.321	0.176
Anconeus	**2.615**	**40**	**0.013**	**0.577**
Supinator	0.181	67	0.857	0.038
Biceps brachii	0.468	55	0.642	0.071
Brachioradialis	1.318	27	0.199	0.327
Pronator quadratus	1.090	46.243	0.281	0.166
Pronator teres	**2.493**	**62**	**0.015**	**0.429**
Supinator	1.245	60	0.218	0.233
Gluteus maximus	1.218	51.384	0.229	0.233
Adductor magnus	-0.989	70	0.326	-0.0937

Vastus medialis	**2.907**	**65**	**0.005**	**0.531**
Vastus lateralis	0.345	72	0.731	0.071
Gluteus medius	0.687	51	0.495	0.158
Gluteus minimus	1.517	44	0.136	0.405
Obturator externus	0.895	44	0.375	0.217
Gastrocnemius	0.346	53	0.731	0.107
Iliacus	2.030	20	0.056	0.676
Iliopsoas	0.924	65	0.359	0.184
Soleus	1.240	40	0.222	0.286

Table 5.13. T-test between sexes of the Coastal Jomon.

Muscle	**t**	**df**	**Significance (Two-Sided p)**	**Mean Difference**
Costoclavicular ligament	**2.094**	**141.976**	**0.038**	**0.7047**
Subclavius	-0.184	155	0.854	-0.023
Biceps brachii (long head)	0.271	93	0.787	0.048
Triceps brachii (long head)	**2.351**	**89**	**0.021**	**0.4661**
Pectoralis minor	**2.176**	**68**	**0.033**	**0.430**
Trapezius	1.307	29	0.202	0.408
Supraspinatus	-0.162	108	0.871	-0.0436
Infraspinatus	**3.971**	**97.074**	**0.000**	**0.388**
Teres minor	-0.113	109	0.910	-0.021
Common extensors	-0.944	197	0.346	-0.0846
Common flexors	**2.299**	**197.427**	**0.023**	**0.1726**
Subscapularis	1.414	123	0.160	0.248
Teres major	1.388	190	0.167	0.117
Pectoralis major	**2.691**	**209**	**0.008**	**0.3001**
Deltoideus	**2.890**	**228**	**0.004**	**0.2503**
Latissimus dorsi	**2.589**	**188.223**	**0.010**	**0.4081**
Triceps brachii	1.108	206	0.269	0.101
Brachialis	0.787	234	0.432	0.1414
Anconeus	**2.160**	**191**	**0.032**	**0.220**
Supinator	-0.340	237	0.734	-0.0303
Biceps brachii	**2.010**	**194**	**0.046**	**0.2845**
Brachioradialis	-0.122	88	0.903	-0.0188
Pronator quadratus	0.005	176	0.996	0.000
Pronator teres	1.582	211	0.115	0.1974
Supinator	-0.423	210	0.673	-0.033
Gluteus maximus	-1.940	189.229	0.054	-0.2477
Adductor magnus	**3.736**	**245**	**0.000**	**0.4101**
Vastus medialis	**3.714**	**256**	**0.000**	**0.355**
Vastus lateralis	-0.116	147	0.908	-0.013
Gluteus medius	0.842	152	0.401	0.1092

Gluteus minimus	**2.040**	**159**	**0.043**	**0.3475**
Obturator externus	**-2.447**	**171**	**0.015**	**-0.4019**
Gastrocnemius	0.500	90	0.618	0.082
Iliacus	1.804	212	0.073	0.2147
Iliopsoas	-0.098	136	0.922	-0.012
Soleus	1.039	204	0.300	0.1305

Table 5.14. T-test between sexes of the Inland Yayoi.

Muscle	t	df	Significance (Two-Sided p)	Mean Difference
Costoclavicular ligament	**4.615**	**57.400**	**0.000**	**2.7344**
Subclavius	-0.327	76	0.744	-0.0979
Biceps brachii (long head)	0.420	45	0.677	0.188
Triceps brachii (long head)	0.656	33	0.516	0.503
Pectoralis minor	0.401	39	0.691	0.2715
Supraspinatus	0.521	25	0.607	0.329
Infraspinatus	0.112	11	0.913	0.250
Teres minor	-1.600	4	0.185	-4.400
Common extensors	-0.436	13	0.670	-0.330
Common flexors	-0.666	7	0.527	-1.071
Subscapularis	**-2.983**	**16.901**	**0.008**	**-1.8526**
Teres major	-1.497	55.724	0.140	-0.7429
Pectoralis major	-0.903	61.195	0.370	-0.3266
Deltoideus	0.167	40.824	0.868	0.0339
Latissimus dorsi	1.763	86	0.081	0.6617
Triceps brachii	-0.182	17	0.858	-0.159
Brachialis	-1.966	45.179	0.056	-1.0682
Anconeus	-0.383	12	0.708	-0.125
Supinator	0.140	65	0.889	0.0551
Biceps brachii	-0.474	69	0.637	-0.2500
Brachioradialis	0.096	34	0.924	0.0125
Pronator quadratus	1.126	78	0.264	0.363
Pronator teres	1.427	90	0.157	0.4976
Supinator	-1.058	79	0.293	-0.3030
Gluteus maximus	-1.510	70.722	0.136	-0.7004
Adductor magnus	**5.723**	**129**	**0.000**	**1.0043**
Vastus medialis	0.646	124	0.520	0.1345
Vastus lateralis	-0.779	19	0.445	-0.240
Gluteus medius	-0.124	2.196	0.912	-0.212
Gluteus minimus	-0.175	12	0.864	-0.212
Obturator externus	1.469	14	0.164	0.945
Gastrocnemius	-0.182	55	0.856	-0.0253
Iliacus	**2.323**	**75**	**0.023**	**0.7168**
Iliopsoas	0.346	53	0.731	0.1373
Soleus	3.137	139	0.002	0.6890

Table 5.15. T-test between sexes of the Riverine Yayoi.

Muscle	t	df	Significance (Two-Sided p)	Mean Difference
Triceps brachii (long head)	0.164	2	0.885	0.500
Pectoralis minor	-0.577	1	0.667	-0.500
Common flexors	0.000	2	1.000	0.000
Subscapularis	-0.531	8	0.610	-0.250
Teres major	1.190	5.000	0.287	1.167
Pectoralis major	-0.953	9	0.365	-0.367
Deltoideus	-0.849	10	0.416	-1.250
Supinator	0.250	2	0.826	0.333
Biceps brachii	1.342	2	0.312	0.750
Brachioradialis	0.293	3	0.789	0.167
Pronator quadratus	**5.000**	**2.000**	**0.038**	**1.667**
Pronator teres	0.000	2	1.000	0.000
Supinator	-0.887	6	0.409	-1.250
Gluteus maximus	**2.261**	**9**	**0.050**	**0.833**
Adductor magnus	1.519	10	0.160	0.375
Vastus medialis	-0.577	1	0.667	-0.500
Gluteus minimus		0		-4.000
Gastrocnemius	-0.447	3	0.685	-0.250
Iliacus		0		0.000
Iliopsoas	1.920	11	0.081	0.976

Table 5.16. T-test between sexes of the Coastal Yayoi.

Muscle	t	df	Significance (Two-Sided p)	Mean Difference
Costoclavicular ligament	**5.769**	**65.436**	**0.000**	**2.5172**
Subclavius	1.136	101	0.259	0.2280
Biceps brachii (long head)	0.177	85	0.860	0.054
Triceps brachii (long head)	**3.413**	**57.591**	**0.001**	**1.5999**
Pectoralis minor	**2.051**	**31.105**	**0.049**	**0.9940**
Trapezius	1.259	66	0.212	0.1195
Supraspinatus	**2.165**	**34.326**	**0.037**	**0.6519**
Infraspinatus	0.483	74	0.631	0.155
Teres minor	-1.504	60.454	0.138	-0.2655
Common extensors	**2.315**	**92**	**0.023**	**0.5263**
Common flexors	0.975	102.954	0.332	0.1659
Subscapularis	1.049	86	0.297	0.3758
Teres major	0.591	131	0.556	0.2141
Pectoralis major	**2.261**	**100.963**	**0.026**	**0.4952**
Deltoideus	0.443	130	0.658	0.0593
Latissimus dorsi	**2.165**	**102.762**	**0.033**	**0.6215**
Triceps brachii	0.182	99	0.856	0.0742

Brachialis	-0.101	125	0.920	-0.0359
Anconeus	**2.599**	**90**	**0.011**	**0.3110**
Supinator	-0.042	94.013	0.966	-0.0060
Biceps brachii	**0.024**	**0.000**	**0.024**	**0.000**
Brachioradialis	-0.650	52	0.518	-0.071
Pronator quadratus	0.704	97	0.483	0.141
Pronator teres	**2.904**	**65.697**	**0.005**	**0.6864**
Supinator	1.580	87.341	0.118	0.181
Gluteus maximus	0.029	137	0.977	0.0091
Adductor magnus	**5.803**	**136**	**0.000**	**0.7469**
Vastus medialis	**1.978**	**132.235**	**0.050**	**0.2350**
Vastus lateralis	0.883	81	0.380	0.291
Gluteus medius	0.623	69	0.535	0.147
Gluteus minimus	-0.526	76	0.600	-0.1457
Obturator externus	0.565	82	0.573	0.179
Gastrocnemius	2.111	16.323	0.051	0.7625
Iliacus	1.106	111	0.271	0.1910
Iliopsoas	1.199	87	0.234	0.2573
Soleus	0.690	132	0.492	0.0904

T-tests were done for the individual geographic locations to evaluate handedness. The results were generally similar to the results of the combined Jomon and Yayoi tests. The t-tests for the Inland Jomon showed no significant differences between right and left sides (Table 5.17). The Riverine Jomon yielded 2 muscles with significant differences (Table 5.18), while the Coastal Jomon exhibited 6 muscles with significant differences (Table 5.19). The t-tests for the Yayoi showed that there were significant differences between sides of 3 muscles for the Inland Yayoi (Table 5.20), 2 muscles for the Riverine Yayoi (Table 5.21), and no significant differences for the Coastal Yayoi (Table 5.22). This once again, suggests that both limbs are used equally regardless of subsistence strategy.

Table 5.17. T-test between right and left sides of the Inland Jomon.

Muscle	t	df	Significance (Two-Sided p)	Mean Difference
Costoclavicular ligament	-1.078	40	0.288	-0.8681
Subclavius	-0.369	48	0.714	-0.130
Biceps brachii (long head)	0.111	29	0.912	0.0777
Triceps brachii (long head)	1.151	24	0.261	0.7688
Pectoralis minor	-0.617	18	0.545	-0.222
Trapezius	1.414	2	0.293	1.000
Supraspinatus	-0.013	35	0.990	-0.0044
Infraspinatus	0.961	36	0.343	0.211
Teres minor	0.953	43	0.346	0.441
Common extensors	0.533	60	0.596	0.175
Common flexors	1.363	67	0.177	0.3256
Subscapularis	0.944	38	0.351	0.384
Teres major	-0.209	69	0.835	-0.021
Pectoralis major	0.604	69	0.548	0.3134
Deltoideus	-0.731	77	0.467	-0.2073
Latissimus dorsi	0.215	72	0.831	0.0946
Triceps brachii	-0.359	57	0.721	-0.101
Brachialis	0.658	81	0.512	0.1829
Anconeus	-0.730	56	0.468	-0.1897
Supinator	1.227	78	0.224	0.2517
Biceps brachii	1.672	62	0.100	0.6094
Brachioradialis	0.000	10	1.000	0.000
Pronator quadratus	0.956	54	0.343	0.098
Pronator teres	-0.660	64	0.512	-0.2833
Supinator	1.320	45.579	0.193	0.255
Gluteus maximus	0.563	97	0.575	0.1661
Adductor magnus	0.336	86	0.738	0.0902
Vastus medialis	1.128	98	0.262	0.167
Vastus lateralis	-0.111	58	0.912	-0.0488
Gluteus medius	-0.254	62	0.800	-0.0448
Gluteus minimus	-1.178	61.392	0.243	-0.6917
Obturator externus	-0.375	64	0.709	-0.156
Gastrocnemius	0.403	28	0.690	0.116
Iliacus	-1.228	81.544	0.223	-0.1750
Iliopsoas	0.903	58	0.370	0.170
Soleus	1.066	74	0.290	0.2778

Table 5.18. T-test between right and left sides of the Riverine Jomon.

Muscle	t	df	Significance (Two-Sided p)	Mean Difference
Costoclavicular ligament	-1.091	48	0.281	-0.685
Subclavius	0.696	55	0.489	0.166
Biceps brachii (long head)	0.583	22	0.566	0.175

Triceps brachii (long head)	1.712	22	0.101	0.811
Pectoralis minor	-1.487	12	0.163	-0.622
Trapezius	0.243	7	0.815	0.150
Supraspinatus	-0.257	48	0.798	-0.129
Infraspinatus	-1.295	50	0.201	-0.350
Teres minor	0.969	45	0.338	0.320
Common extensors	0.156	46.922	0.877	0.0457
Common flexors	0.959	73	0.341	0.177
Subscapularis	0.425	56	0.673	0.236
Teres major	1.851	77.968	0.068	0.203
Pectoralis major	-0.784	88	0.435	-0.2164
Deltoideus	0.877	88	0.383	0.111
Latissimus dorsi	-0.387	87	0.699	-0.082
Triceps brachii	-0.938	67	0.352	-0.181
Brachialis	-0.126	89	0.900	-0.020
Anconeus	**-2.667**	**53**	**0.010**	**-0.548**
Supinator	-0.285	90	0.776	-0.047
Biceps brachii	-1.435	76	0.155	-0.189
Brachioradialis	-1.020	35	0.315	-0.209
Pronator quadratus	0.672	75	0.504	0.085
Pronator teres	0.399	82	0.691	0.059
Supinator	1.148	81	0.254	0.184
Gluteus maximus	**-2.121**	**90.708**	**0.037**	**-0.1698**
Adductor magnus	1.623	97	0.108	0.246
Vastus medialis	-0.214	107	0.831	-0.036
Vastus lateralis	0.566	68	0.573	0.107
Gluteus medius	0.712	56	0.480	0.171
Gluteus minimus	0.081	57	0.936	0.018
Obturator externus	-0.355	67	0.723	-0.096
Gastrocnemius	0.203	24	0.840	0.061
Iliacus	-1.170	90	0.245	-0.190
Iliopsoas	-1.425	51	0.160	-0.289
Soleus	0.003	94	0.998	0.0004

Table 5.19. T-test between right and left sides of the Coastal Jomon.

Muscle	t	df	Significance (Two-Sided p)	Mean Difference
Costoclavicular ligament	0.092	166	0.927	0.0311
Subclavius	0.794	180	0.428	0.091
Biceps brachii (long head)	0.126	100	0.900	0.020
Triceps brachii (long head)	-1.215	92	0.227	-0.2359
Pectoralis minor	0.167	73	0.868	0.030
Trapezius	0.000	31	1.000	0.000
Supraspinatus	1.438	122	0.153	0.3550
Infraspinatus	0.943	134.853	0.347	0.097
Teres minor	1.338	123	0.184	0.223
Common extensors	-0.061	234	0.951	-0.0055

Common flexors	-1.145	253	0.253	-0.1912
Subscapularis	0.816	142	0.416	0.130
Teres major	**2.084**	**224.253**	**0.038**	**0.153**
Pectoralis major	0.042	247	0.966	0.0047
Deltoideus	0.879	272	0.380	0.0713
Latissimus dorsi	-0.548	245	0.584	-0.0799
Triceps brachii	**-2.327**	**237.442**	**0.021**	**-0.216**
Brachialis	0.354	278	0.724	0.0551
Anconeus	**-3.835**	**223**	**0.000**	**-0.355**
Supinator	-0.380	281	0.704	-0.0309
Biceps brachii	1.065	230	0.288	0.1320
Brachioradialis	-1.265	113	0.209	-0.1750
Pronator quadratus	0.525	212	0.600	0.028
Pronator teres	-0.258	251	0.797	-0.0281
Supinator	0.963	241.938	0.336	0.071
Gluteus maximus	1.163	310	0.246	0.1240
Adductor magnus	**3.277**	**293**	**0.001**	**0.3226**
Vastus medialis	**2.728**	**307**	**0.007**	**0.239**
Vastus lateralis	-1.049	176	0.296	-0.104
Gluteus medius	-1.655	180	0.100	-0.1966
Gluteus minimus	0.102	188	0.919	0.0156
Obturator externus	**-2.297**	**202**	**0.023**	**-0.3427**
Gastrocnemius	-1.042	103	0.300	-0.155
Iliacus	2.193	250	0.029	0.2320
Iliopsoas	0.345	163	0.730	0.040
Soleus	-1.045	243	0.297	-0.1243

Table 5.20. T-test between right and left sides of the Inland Yayoi.

Muscle	**t**	**df**	**Significance (Two-Sided p)**	**Mean Difference**
Costoclavicular ligament	0.181	61	0.857	0.1258
Subclavius	1.205	54.706	0.234	0.4055
Biceps brachii (long head)	0.888	47	0.379	0.372
Triceps brachii (long head)	-0.661	34	0.513	-0.500
Pectoralis minor	0.255	41	0.800	0.1645
Supraspinatus	-1.710	27	0.099	-0.907
Infraspinatus	0.938	5.505	0.388	1.250
Teres minor	0.365	4	0.733	1.000
Common extensors	0.722	14	0.482	0.583
Common flexors	1.035	5.000	0.348	1.000
Subscapularis	-0.051	44	0.960	-0.0265
Teres major	-0.334	100	0.739	-0.1551
Pectoralis major	0.714	100	0.477	0.2303
Deltoideus	**-2.730**	**94**	**0.008**	**-0.6526**
Latissimus dorsi	0.959	91	0.340	0.3479
Triceps brachii	-0.683	17	0.504	-0.591
Brachialis	0.374	76	0.709	0.1885
Anconeus	0.209	12	0.838	0.075

Supinator	-0.245	68	0.807	-0.0875
Biceps brachii	**-2.652**	**63.061**	**0.010**	**-1.2783**
Brachioradialis	-0.200	38	0.843	-0.0250
Pronator quadratus	0.534	83	0.595	0.172
Pronator teres	0.375	98	0.709	0.1242
Supinator	0.138	86	0.890	0.0396
Gluteus maximus	-0.167	119	0.868	-0.0684
Adductor magnus	-0.299	141	0.765	-0.0563
Vastus medialis	**-2.160**	**101.629**	**0.033**	**-0.4067**
Vastus lateralis	-0.417	21	0.681	-0.205
Gluteus medius	2.121	8.919	0.063	1.500
Gluteus minimus	-0.059	13	0.954	-0.056
Obturator externus	-0.046	15	0.964	-0.028
Gastrocnemius	0.132	60	0.896	0.0252
Iliacus	-0.372	83	0.711	-0.1130
Iliopsoas	-0.836	40.359	0.408	-0.3126
Soleus	-1.028	154	0.306	-0.2051

Table 5.21. T-test between right and left sides of the Riverine Yayoi.

Muscle	**t**	**df**	**Significance (Two-Sided p)**	**Mean Difference**
Costoclavicular ligament	0.000	2	1.000	0.000
Subclavius	0.000	2	1.000	0.000
Biceps brachii (long head)	0.000	2	1.000	0.000
Triceps brachii (long head)	0.289	2	0.800	1.000
Subscapularis	1.000	2	0.423	2.667
Teres major	0.000	8	1.000	0.000
Pecctoralis major	-0.822	10	0.430	-0.833
Deltoideus	0.953	9	0.365	0.367
Latissimus dorsi	-0.612	10	0.554	-0.917
Brachialis	0.707	4	0.519	0.333
Supinator	0.747	3	0.509	1.500
Biceps brachii	0.447	2	0.698	0.500
Brachioradialis	-0.333	2	0.771	-0.250
Pronator quadratus	1.549	3	0.219	0.667
Pronator teres	0.265	4	0.804	0.250
Supinator	0.000	2	1.000	0.000
Gluteus maximus	0.927	6	0.390	1.125
Adductor magnus	-0.627	9	0.546	-0.283
Vastus medialis	0.000	10	1.000	0.000
Vastus lateralis	-0.577	1	0.667	-0.500
Iliacus	-0.775	3	0.495	-0.333
Soleus	0.183	11	0.858	0.107

Table 5.22. T-test between right and left sides of the Coastal Yayoi.

Muscle	t	df	Significance (Two-Sided p)	Mean Difference
Costoclavicular ligament	0.526	112	0.600	0.2333
Subclavius	1.064	120	0.289	0.1874
Biceps brachii (long head)	-1.209	97	0.230	-0.349
Triceps brachii (long head)	-0.285	94	0.776	-0.1317
Pectoralis minor	0.666	75	0.507	0.2544
Trapezius	1.260	70.424	0.212	0.1071
Supraspinatus	1.661	69.030	0.101	0.3926
Infraspinatus	1.901	79.869	0.061	0.542
Teres minor	-0.618	74	0.538	-0.1220
Common extensors	-0.400	105	0.690	-0.0839
Common flexors	0.620	121	0.537	0.0984
Subscapularis	-1.092	98.229	0.277	-0.3330
Teres major	-0.529	155	0.598	-0.1835
Pectoralis major	0.481	155	0.631	0.0907
Deltoideus	-0.970	155	0.334	-0.1169
Latissimus dorsi	-0.804	144	0.422	-0.1986
Triceps brachii	1.778	104.331	0.078	0.6404
Brachialis	1.099	146	0.274	0.3489
Anconeus	1.191	99	0.237	0.1419
Supinator	-1.325	143	0.187	-0.1723
Biceps brachii	0.766	132	0.445	0.2517
Brachioradialis	0.598	57	0.552	0.074
Pronator quadratus	-0.188	114	0.851	-0.033
Pronator teres	-0.465	137	0.642	-0.1180
Supinator	-0.593	137	0.554	-0.061
Gluteus maximus	0.783	160	0.435	0.2270
Adductor magnus	-1.031	161	0.304	-0.1324
Vastus medialis	0.103	163	0.918	0.0134
Vastus lateralis	-0.392	96	0.696	-0.124
Gluteus medius	-0.598	80	0.552	-0.122
Gluteus minimus	1.071	87	0.287	0.2576
Obturator externus	-0.279	97	0.781	-0.076
Gastrocnemius	-0.668	62	0.507	-0.1461
Iliacus	-0.910	129	0.364	-0.1443
Iliopsoas	-0.149	100	0.882	-0.0294
Soleus	-0.777	157	0.438	-0.1200

The comparison of MSMs across geographic site categories reveals clear distinctions in activity patterns between the Jomon and Yayoi populations, reflecting their differing subsistence strategies. The Inland Yayoi group exhibited the highest activity frequencies, driven by the labor-intensive requirements of wet-rice agriculture. Coastal Yayoi populations showed slightly lower activity frequencies, likely due to the availability of marine resources that weakened the need for agricultural practices, while Riverine Yayoi groups balanced agricultural and aquatic resource use, resulting in intermediate activity levels. In contrast, Jomon groups across all geographic locations displayed significantly lower activity frequencies, consistent with a foraging lifestyle that demanded less physical labor. Statistical analyses highlight significant differences in muscle use across geographic site categories, underscoring the influence of environmental and subsistence factors on activity patterns. The most notable sex differences were in Coastal groups, suggesting a possible mild division of labor tied to environmental factors. Overall, these findings emphasize how geographic and environmental contexts shaped habitual activities and musculoskeletal development in these populations.

Muscular Utilization Patterns across Time Periods

In the Early Jomon period, activity levels were moderate (Figure 5.3, Table 5.23). General farming activities were above the statistical breakpoints 30% of the time, and grain processing was slightly higher at 33%. Woodland clearance was less frequent at 19%. Pottery making was reported at 35%, reflecting its role in cultural practices requiring moderate effort. Metalworking and weaving, which were less prominent, were 33% and 30%, respectively. Activity levels increased in the Middle Jomon period. General farming rose to 39%, and grain processing to 37%. Woodland clearance increased to 31%, likely indicating greater engagement in tasks like resource management or land modification. Pottery making stayed consistent at 35%, while metalworking and weaving showed modest increases to 34% and 39%. These shifts suggest growing resource use, possibly due to population changes or regional adaptations. However, by the Late Jomon period, activity levels declined slightly. General farming decreased to 35%, and woodland clearance dropped to 29%. Grain processing remained relatively steady at 40%. Pottery making fell to 30%, while metalworking and weaving declined to 26% and 35%. These patterns may reflect regional differences in resource use and subsistence strategies.

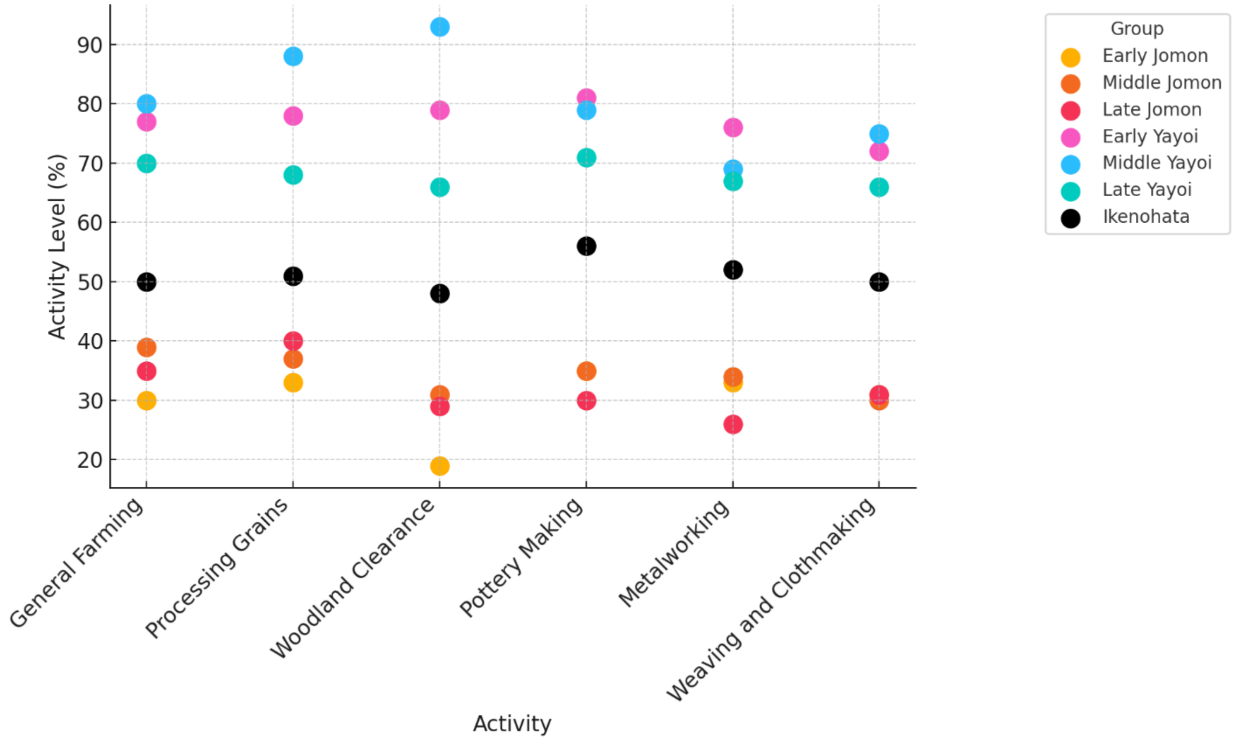


Figure 5.3. Scatterplot of activity frequencies above the statistical breakpoints across time periods.

Table 5.23. Activity frequencies above the statistical breakpoints across time periods.

	General Farming	Processing Grains	Woodland Clearance	Pottery Making	Metalworking	Weaving and Clothmaking
Early Jomon	30%	33%	19%	35%	33%	30%
Middle Jomon	39%	37%	31%	35%	34%	39%
Late Jomon	35%	40%	29%	30%	26%	35%
Early Yayoi	77%	78%	79%	81%	76%	77%
Middle Yayoi	80%	88%	93%	79%	69%	80%
Late Yayoi	70%	68%	66%	71%	67%	70%
Ikenohata	50%	51%	48%	56%	52%	50%

The Yayoi period saw a significant rise in activity frequencies, reflecting the shift to full-time agriculture. In the Early Yayoi period, general farming jumped to 77%, grain processing to

78%, and woodland clearance to 79%. Pottery making increased to 81%, highlighting its role in food storage and preparation. Metalworking and weaving also rose significantly, reaching 76% and 77%. These increases reflect the physical demands of establishing agricultural systems, such as land clearing and tool production. The Middle Yayoi period had the highest activity frequencies. General farming reached 80%, grain processing peaked at 88%, and woodland clearance rose to 93%. Pottery making stayed high at 79%, while metalworking and weaving reached 69% and 80%. These figures reflect the peak of agricultural intensification, with widespread land use and craft production supporting farming activities. Similarly seen in the Late Jomon, by the Late Yayoi period, activity frequencies declined slightly but remained high. General farming dropped to 70%, grain processing to 68%, and woodland clearance to 66%. Pottery making stayed steady at 71%, while metalworking and weaving decreased to 67% and 70%. These patterns suggest a stabilization of agricultural practices, with less labor required for expanding new fields.

Activity levels were much higher in the Yayoi than in the Jomon, reflecting the shift to agriculture. In the Jomon, general farming ranged from 30% to 39%, compared to 77% to 80% in the Early and Middle Yayoi. Grain processing rose from 33% to 40% in the Jomon to 78% to 88% in the Yayoi. Woodland clearance saw the largest jump, from 19% to 31% in the Jomon to 79% to 93% in the Yayoi. Pottery making also increased significantly, from 30% to 35% in the Jomon to 79% to 81% in the Yayoi.

These results show how the transition to agriculture brought higher labor demands, particularly in the Early and Middle Yayoi. In contrast, the Jomon period was characterized by more stable and moderate activity levels, consistent with their foraging lifestyle. Temporal variations within each period reflect shifts in resource use and labor intensity as populations adapted to their environments.

Muscular Utilization Patterns across Sexes

The analysis of MSMs across sexes reveals notable differences between males and females in both the Jomon and Yayoi populations, reflecting variations in labor roles and physical activity demands (Figure 5.4, Table 5.24). For Jomon males, general farming activities exceeded statistical breakpoints at 38%, while grain processing and woodland clearance were 44% and 33%, respectively. Pottery making, metalworking, and weaving frequencies were slightly lower, at 35%, 30%, and 35%, respectively. Jomon females displayed lower activity frequencies overall, with 31% for general farming, 35% for grain processing, and 29% for woodland clearance. Pottery making, metalworking, and weaving were similarly reduced, at 28%, 25%, and 27%, respectively.

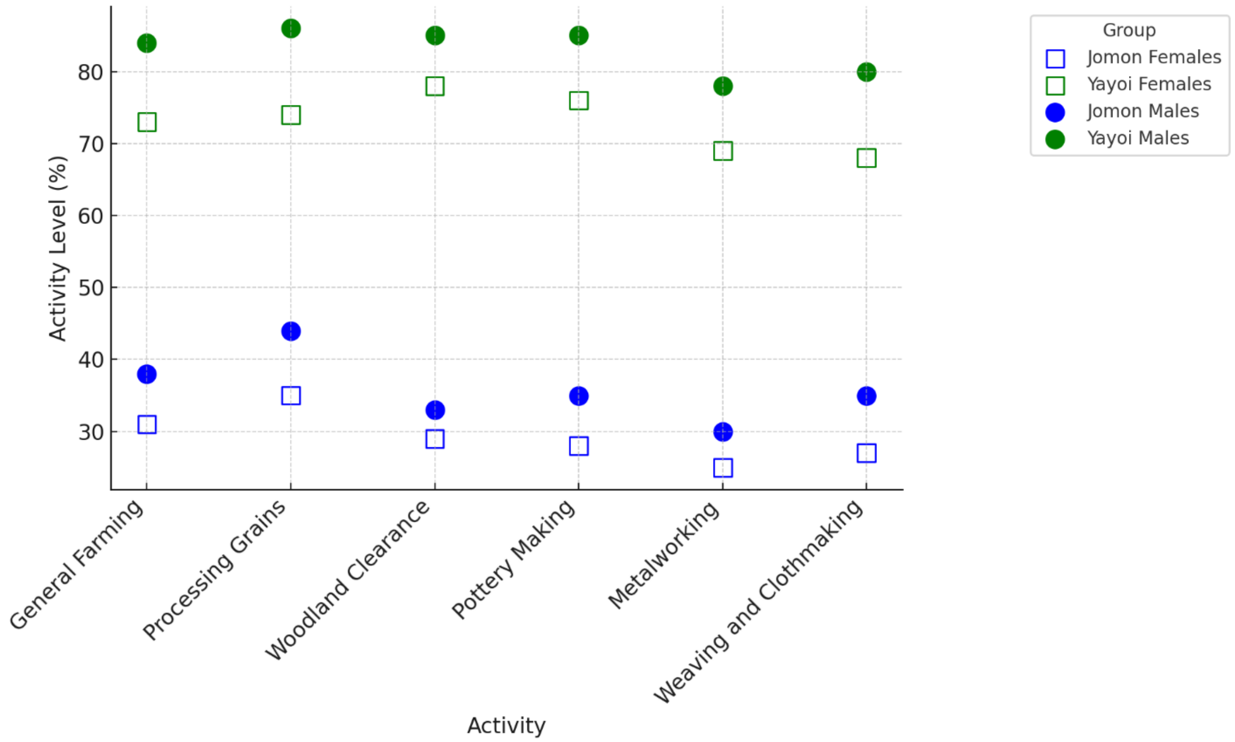


Figure 5.4. Scatterplot of activity frequencies above the statistical breakpoints across sex and time periods.

Table 5.24. Activity frequencies above the statistical breakpoints across sex and time periods.

	General Farming	Processing Grains	Woodland Clearance	Pottery Making	Metalworking	Weaving and Clothmaking
Jomon Females	31%	35%	29%	28%	25%	27%
Yayoi Females	73%	74%	78%	76%	69%	68%
Jomon Males	38%	44%	33%	35%	30%	35%
Yayoi Males	84%	86%	85%	85%	78%	80%

In the Yayoi populations, activity levels were significantly higher for both sexes. Yayoi males demonstrated general farming frequencies of 84%, grain processing at 86%, and woodland clearance at 85%. Pottery making and metalworking frequencies were 85% and 78%, respectively, with weaving at 80%. Yayoi females showed elevated activity levels compared to Jomon females but remained lower than Yayoi males. General farming activity frequencies were

73%, grain processing was 74%, and woodland clearance was 78%. Pottery making and metalworking frequencies were 76% and 69%, while weaving was recorded at 68%.

Geographic Variations and Sex

When broken down by geographic location, Inland Jomon males exhibited 40% for general farming, 41% for grain processing, and 24% for woodland clearance (Figure 5.5 Table 5.25). Pottery making, metalworking, and weaving were recorded at 42%, 34%, and 35%, respectively. Inland Jomon females had lower activity levels, with general farming at 27%, grain processing at 24%, and woodland clearance at 33%. Pottery making and weaving frequencies were 20% and 17%, while metalworking was notably lower at 16%.

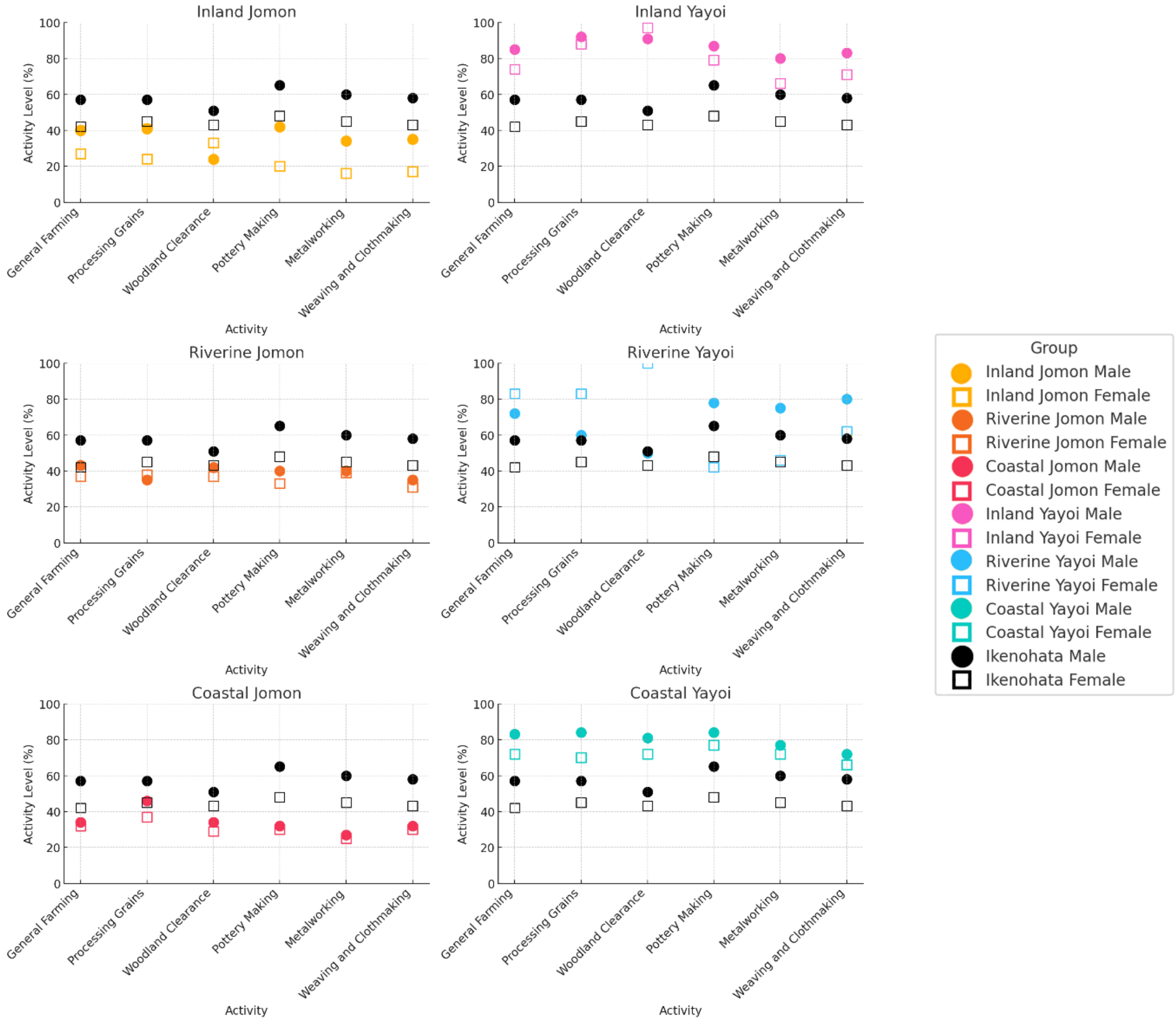


Figure 5.5. Scatterplot of activity frequencies above the statistical breakpoints across sex and geographic locations.

Table 5.25. Activity frequencies above the statistical breakpoints across sex and geographic locations.

	General Farming	Processing Grains	Woodland Clearance	Pottery Making	Metalworking	Weaving and Clothmaking
Inland Jomon Male	40%	41%	24%	42%	34%	35%
Inland Jomon Female	27%	24%	33%	20%	16%	17%
Riverine Jomon Male	43%	35%	42%	40%	40%	35%
Riverine Jomon Female	37%	38%	37%	33%	39%	31%
Coastal Jomon Male	34%	46%	34%	32%	27%	32%
Coastal Jomon Female	32%	37%	29%	30%	25%	30%
Inland Yayoi Male	85%	92%	91%	87%	80%	83%
Inland Yayoi Female	74%	88%	97%	79%	66%	71%
Riverine Yayoi Male	72%	60%	50%	78%	75%	80%
Riverine Yayoi Female	83%	83%	100%	42%	46%	62%
Coastal Yayoi Male	83%	84%	81%	84%	77%	72%
Coastal Yayoi Female	72%	70%	72%	77%	72%	66%
Ikenohata Male	57%	57%	51%	65%	60%	58%
Ikenohata Female	42%	45%	43%	48%	45%	43%

Riverine Jomon males showed slightly higher activity frequencies for some tasks compared to Inland Jomon, with general farming at 43%, grain processing at 35%, and woodland clearance at 42%. Pottery making, metalworking, and weaving frequencies were 40%, 40%, and 35%, respectively. Riverine Jomon females recorded 37% for general farming, 38% for grain processing, and 37% for woodland clearance. Pottery making and weaving were 33% and 31%, while metalworking stood at 39%.

Coastal Jomon males displayed 34% for general farming, 46% for grain processing, and 34% for woodland clearance. Pottery making, metalworking, and weaving were recorded at 32%, 27%, and 32%, respectively. Coastal Jomon females had lower frequencies, with general farming at 32%, grain processing at 37%, and woodland clearance at 29%. Pottery making was 30%, with weaving at 30% and metalworking at 25%.

Inland Yayoi males demonstrated the highest activity frequencies, with 85% for general farming, 92% for grain processing, and 91% for woodland clearance. Pottery making and metalworking frequencies were also high, at 87% and 80%, respectively. Inland Yayoi females had lower frequencies than males but still high compared to Jomon females, with 74% for general farming, 88% for grain processing, and 97% for woodland clearance. Pottery making and weaving were recorded at 79% and 71%, while metalworking was 66%.

Riverine Yayoi males recorded 72% for general farming, 60% for grain processing, and 50% for woodland clearance. Pottery making was higher at 78%, while metalworking and weaving were 75% and 80%, respectively. Riverine Yayoi females showed higher woodland clearance frequencies compared to males, at 100%, with general farming at 83% and grain processing at 83%. Pottery making and weaving frequencies were 42% and 62%, while metalworking was 46%.

Coastal Yayoi males recorded general farming frequencies of 83%, grain processing at 84%, and woodland clearance at 81%. Pottery making, metalworking, and weaving frequencies were 84%, 77%, and 72%, respectively. Coastal Yayoi females displayed 72% for general farming, 70% for grain processing, and 72% for woodland clearance. Pottery making and weaving were recorded at 77% and 66%, while metalworking stood at 72%.

These findings underscore significant differences in activity levels between sexes and geographic locations. The increased physical demands of agricultural practices in the Yayoi period are reflected in higher activity frequencies for both sexes, with regional variations highlighting the influence of local subsistence strategies and environmental conditions. The data also suggest a possible division of labor. The division of labor was wider for the Inland Jomon compared to the Riverine and Coastal Jomon, with males engaging more in physically demanding tasks and females contributing less intensively overall, except for woodland clearance where Inland Jomon females were more active. Among the Yayoi, the Riverine group exhibited the largest division of labor gap, with females surpassing males in farming-related activities such as general farming, grain processing, and woodland clearance, which is contrary to typical expectations. The Inland Yayoi had a smaller division of labor gap overall, with a notable difference in pottery making, metalworking, and weaving, while farming activities displayed a more balanced contribution. Coastal Yayoi showed a division gap similar to Inland Yayoi, but the roles were reversed; farming activities had a larger gap favoring males, whereas pottery making, metalworking, and weaving showed a smaller gap. The specific activities where females contributed more than males varied by group: Inland Jomon and Inland Yayoi females were more involved in woodland clearance, Riverine Jomon females excelled in grain processing, and Riverine Yayoi females dominated all farming activities. This indicates a nuanced division of labor, with sex roles evident in Jomon populations and task-specific specialization emerging in the Yayoi period.

Temporal Variations and Sex

For the Early Jomon period, males recorded 46% for general farming, 50% for grain processing, and 29% for woodland clearance (Figure 5.6, Table 5.26). Pottery making and weaving frequencies were 47% and 51%, while metalworking was 52%. Early Jomon females exhibited 25% for general farming, 22% for grain processing, and 25% for woodland clearance. Pottery making and weaving were recorded at 22% and 20%, while metalworking was 10%.

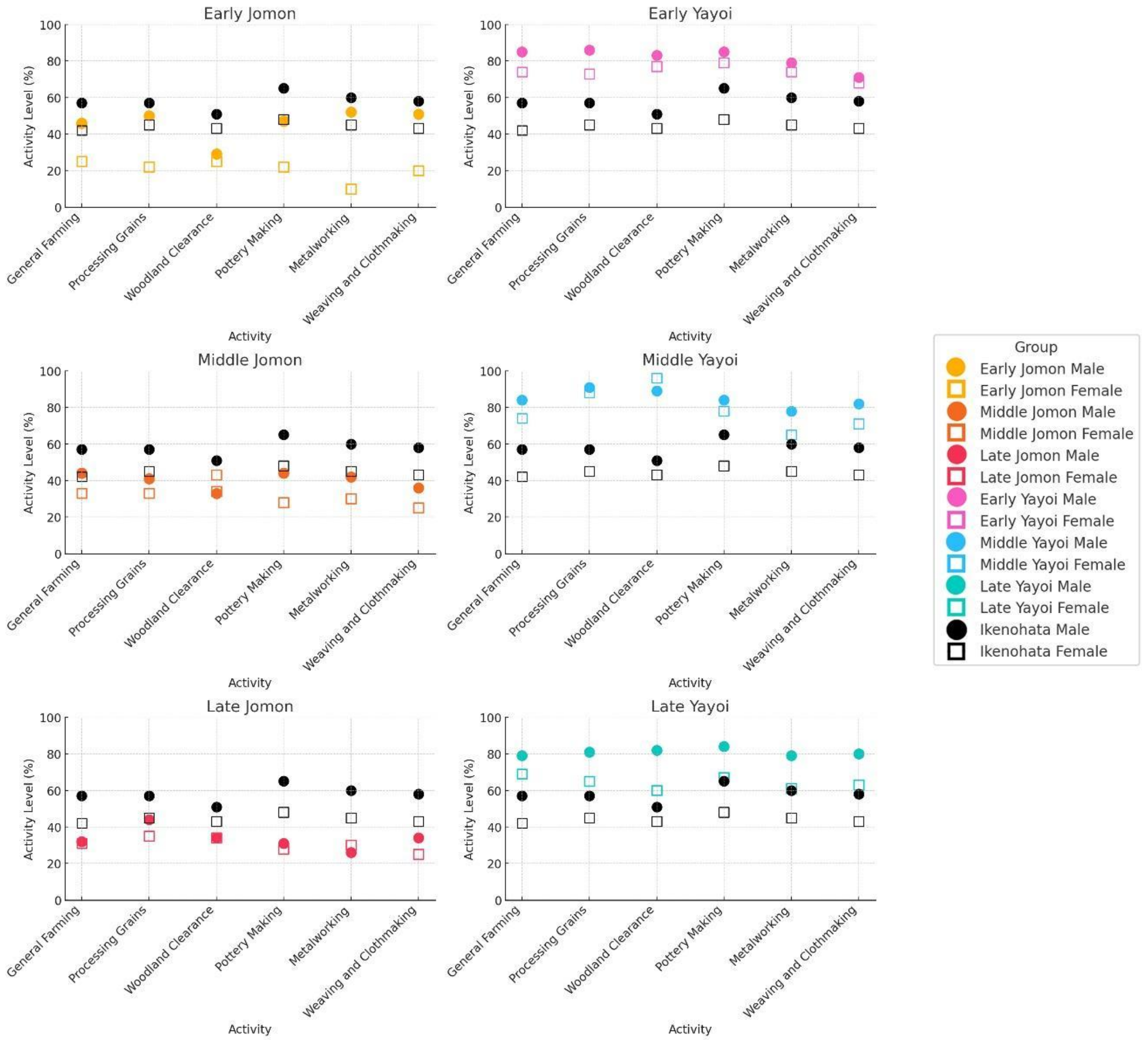


Figure 5.6. Scatterplot of activity frequencies above the statistical breakpoints across sex and time periods.

Table 5.26. Activity frequencies above the statistical breakpoints across sex and time periods.

	General Farming	Processing Grains	Woodland Clearance	Pottery Making	Metalworking	Weaving and Clothmaking
Early Jomon Male	46%	50%	29%	47%	52%	51%
Early Jomon Female	25%	22%	25%	22%	10%	20%
Middle Jomon Male	44%	41%	33%	44%	42%	36%
Middle Jomon Female	33%	33%	34%	28%	30%	25%
Late Jomon Male	32%	44%	34%	31%	26%	34%
Late Jomon Female	31%	35%	34%	28%	30%	25%
Early Yayoi Male	85%	86%	83%	85%	79%	71%
Early Yayoi Female	74%	73%	77%	79%	74%	68%
Middle Yayoi Male	84%	91%	89%	84%	78%	82%
Middle Yayoi Female	74%	88%	96%	78%	65%	71%
Late Yayoi Male	79%	81%	82%	84%	79%	80%
Late Yayoi Female	69%	65%	60%	67%	61%	63%
Ikenohata Male	57%	57%	51%	65%	60%	58%
Ikenohata Female	42%	45%	43%	48%	45%	43%

Middle Jomon males showed slight declines in some activities, with general farming at 44%, grain processing at 41%, and woodland clearance at 33%. Pottery making and weaving were 44% and 36%, while metalworking stood at 42%. Middle Jomon females recorded 33% for general farming, 33% for grain processing, and 34% for woodland clearance. Pottery making was 28%, with weaving at 25% and metalworking at 30%.

Late Jomon males displayed 32% for general farming, 44% for grain processing, and 34% for woodland clearance. Pottery making and weaving frequencies were 31% and 34%, while metalworking was 26%. Late Jomon females showed similar patterns, with general farming at 31%, grain processing at 35%, and woodland clearance at 34%. Pottery making was 28%, with weaving at 25% and metalworking at 30%.

For the Early Yayoi period, males recorded 85% for general farming, 86% for grain processing, and 83% for woodland clearance. Pottery making and weaving frequencies were

85% and 71%, while metalworking was 79%. Early Yayoi females exhibited 74% for general farming, 73% for grain processing, and 77% for woodland clearance. Pottery making was 79%, with weaving at 68% and metalworking at 74%.

Middle Yayoi males demonstrated the highest activity levels, with general farming at 84%, grain processing at 91%, and woodland clearance at 89%. Pottery making and weaving were recorded at 84% and 82%, while metalworking was 78%. Middle Yayoi females had similarly high frequencies, with general farming at 74%, grain processing at 88%, and woodland clearance at 96%. Pottery making and weaving were 78% and 71%, while metalworking was 65%.

Late Yayoi males displayed 79% for general farming, 81% for grain processing, and 82% for woodland clearance. Pottery making and weaving frequencies were 84% and 80%, while metalworking was 79%. Late Yayoi females recorded 69% for general farming, 65% for grain processing, and 60% for woodland clearance. Pottery making was 67%, with weaving at 63% and metalworking at 61%.

These data highlight clear differences in activity frequencies by sex and time period. The division of labor by sex varied over time, with notable differences emerging between the Jomon and Yayoi periods. In the Early Jomon, males engaged more in physically intensive tasks like farming, grain processing, and metalworking, displaying activity frequencies nearly twice as high as females for many categories. This gap narrowed slightly in the Middle and Late Jomon periods as female activity frequencies increased in woodland clearance and grain processing, indicating a more balanced division of labor. In the Early Yayoi, both males and females exhibited a rise in activity levels due to the demands of agriculture, but males maintained higher frequencies across all tasks. The Middle Yayoi period saw females contributing significantly to farming activities and woodland clearance, with a smaller gap between sexes compared to earlier periods. In the Late Yayoi, activity frequencies declined slightly for both sexes and the gap between the sexes widened a bit as well. These trends reflect a shifting division of labor shaped by the changing demands of subsistence and production over time.

Synthesis

Overall, the results presented here indicate that the transition from foraging to agriculture had a profound impact on the musculoskeletal development of prehistoric Japanese populations. The differences in MSMs between the Jomon and Yayoi, as well as between inland and coastal groups within each period, reflect distinct patterns of physical activity and provide insights into how environmental and social factors shaped the labor division and habitual behaviors of these communities. The Yayoi groups exhibited significantly higher activity frequencies across all tasks compared to the Jomon, reflecting the physical demands of wet-rice farming and associated craft production. Temporal patterns revealed an increase in activity levels from the Early Jomon to the Middle Jomon, followed by a slight decline in the Late Jomon. There was a sharp rise in activity levels during the Early Yayoi, which peaked in the Middle Yayoi, reflecting the intensification of agriculture. By the Late Yayoi, activity levels stabilized, indicating a shift from expansion to maintenance in agricultural systems. Geographic comparisons emphasized the greater role of environmental contexts, with Inland Yayoi populations displaying the highest activity frequencies, followed by Coastal and Riverine Yayoi groups. The Jomon populations exhibited lower activity levels across all geographic categories, consistent with their foraging lifestyle.

Sex differences in MSMs reflected broader trends in the division of labor. The Jomon exhibited wider gaps between males and females, with males engaging more in physically intensive tasks. In contrast, the Yayoi showed smaller gaps in certain groups, such as the Inland Yayoi, where females contributed significantly to farming activities, and the Riverine Yayoi, where females exceeded males in agricultural tasks. These findings suggest that the division of labor was shaped by both environmental factors and the demands of subsistence strategies, with sex roles becoming more specialized in the Yayoi. These findings contribute to a broader understanding of how subsistence strategies influenced skeletal morphology and offer a nuanced perspective on the variation in human activity patterns in prehistoric Japan.

Analysis of Musculoskeletal Stress Markers with New 3D Quantitative Method

The quantitative 3D method of curvature data extraction applied to the femora used in this research revealed significant correlations between the mean curvature data values and the semi-quantitative scores derived from the modified Hawkey and Merbs method (Tables 5.28 - 5.37). The extracted curvature data provides a novel approach to evaluating MSMs as it allows for a precise quantification of the skeletal responses to muscular use.

The scatterplots in this study play a crucial role in visually representing the relationship between mean curvature values and the semi-quantitative scores derived from the modified Hawkey and Merbs method across various femoral muscle attachment sites. Each scatterplot provides a depiction of how these two datasets correlate, highlighting patterns and trends that numerical tables alone may not fully convey (see appendices). The scatterplots illustrate a clear upward trend for all muscle attachment sites analyzed, demonstrating that as the semi-quantitative scores increase, so do the mean curvature values (Figure 5.7). This upward trend indicates that higher semi-quantitative scores, which reflect greater musculoskeletal stress, are associated with increased curvature values at the respective anatomical locations. Figure 5.7 collects all attachment sites and provides an overarching view of the relationships. While the overall trend remains upward, the figure highlights the differences in correlation strengths and variabilities across different anatomical locations, reinforcing the value of analyzing multiple muscles for this research.

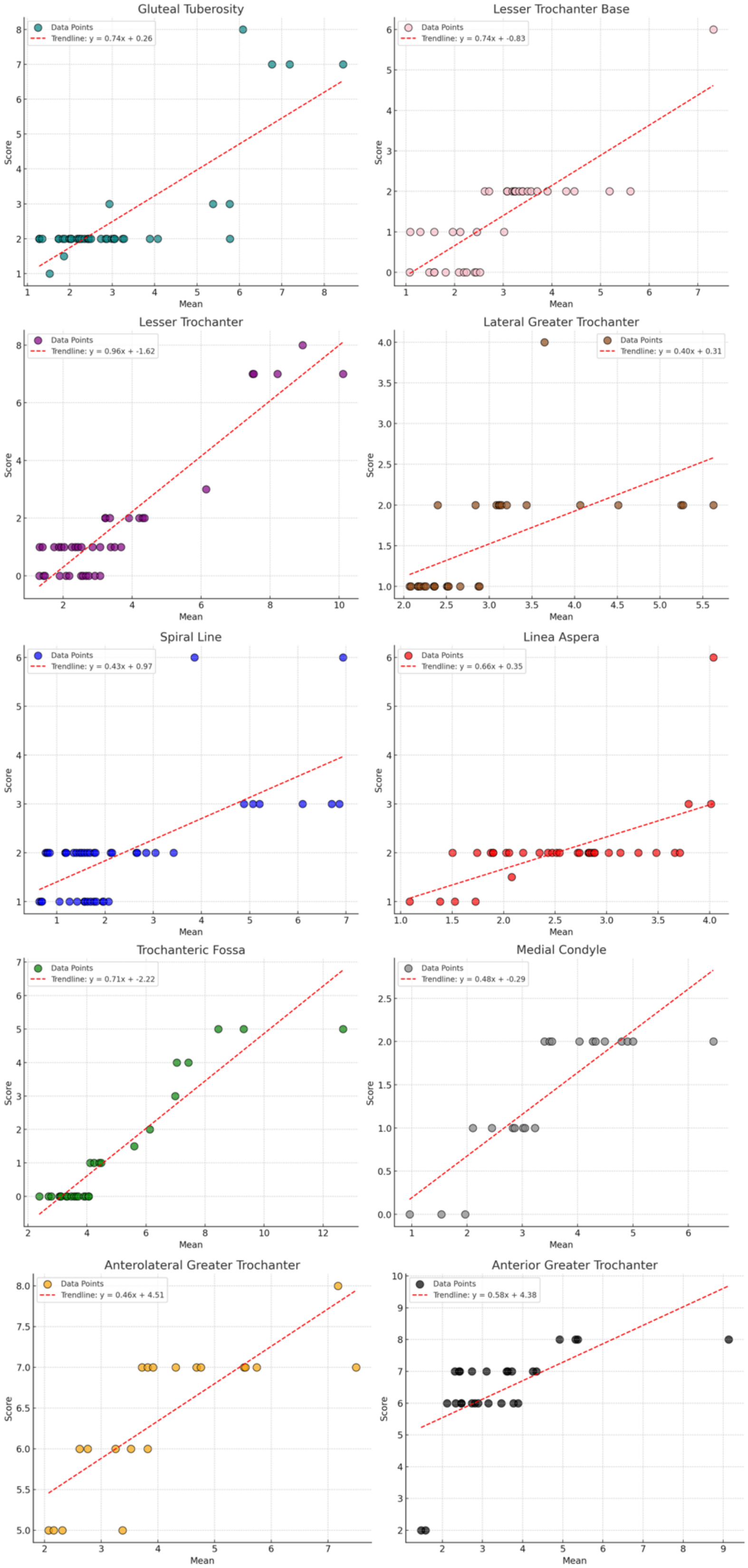


Figure 5.7. Scatterplot of mean curvature values and modified Hawkey and Merbs composite scores for all femora sites.

The scatterplot for the gluteal tuberosity shows a strong positive correlation, as indicated by a Spearman’s rho value of 0.617 (see Tables 5.27 and 5.28). The points trend upward, demonstrating that as semi-quantitative scores increase, so do mean curvature values. This relationship highlights the significance of this attachment site in response to musculoskeletal stress and the accuracy of the new 3D method. For the linea aspera, the scatterplot reveals a similarly positive relationship, with a Spearman’s rho of 0.685 (Table 5.29). This attachment site shows a tighter clustering of data points compared to the gluteal tuberosity. However, a few data points deviate slightly from the main trend, which could be reflective of individual differences or measurement variability. The scatterplot for the trochanteric fossa demonstrates one of the strongest correlations observed, with a Spearman’s rho value of 0.900 (Table 5.30). The upward trend signifies a very strong relationship between mean curvature and the semi-quantitative scores. The medial condyle exhibits the strongest correlation, with a Spearman’s rho of 0.905 (Table 5.31). The scatterplot shows tightly grouped data points along an upward trajectory. In contrast, the spiral line shows a strong correlation, with a Spearman’s rho of 0.534 (Table 5.32). The scatterplot reveals a wider spread of data points and more variability in the relationship between curvature values and the semi-quantitative scores. This could be due to the nature of the attachment curving around the bone. The 3D method may not pick up the region of interest as accurately as the other regions because of its complex location on the bone. For the base of the lesser trochanter, the scatterplot indicates a very strong positive correlation, with a Spearman’s rho value of 0.825 (Table 5.33). The scatterplot for the lesser trochanter also demonstrates a very strong relationship, with a Spearman’s rho of 0.722 (Table 5.34). Data points show a clear upward trend, but with slightly more variation compared to the base of the lesser trochanter. The lateral greater trochanter reveals a significant positive correlation, with a Spearman’s rho of

0.800 (Table 5.35). Data points are concentrated along an upward slope. A few data points deviate slightly from the main cluster at the semi-quantitative score 2.0, which could reflect the limitations of the semi-quantitative method. The assignment of a 2.0 score to a large number of specimens due to the method's limiting qualitative criteria suggests that these specimens likely exhibit varying levels of robusticity, with some being more robust and others less so. This variability introduces a wide range in mean curvature scores at one semi-quantitative marker. For the anterolateral greater trochanter, the scatterplot exhibits a very high correlation, with a Spearman’s rho of 0.881 (Table 5.36). The semi-quantitative scores for the anterolateral greater trochanter start higher compared to other attachment sites, reflecting the increased biomechanical demands placed on this region throughout the sample. Lastly, the anterior greater trochanter shows a strong correlation, with a Spearman’s rho of 0.637 (Table 5.37). The scatterplot reveals greater variability compared to other sites, most likely due to the very low data points at the semi-quantitative score of 2 as well as one outlier.

Table 5.27. Classification for values of the Spearman’s rho correlation coefficient in terms of strength of the correlation dependence.

Spearman’s rho	Correlation
≥0.70	Very strong relationship
0.40 – 0.69	Strong relationship
0.30 – 0.39	Moderate relationship
0.20 – 0.29	Weak relationship
0.01 – 0.19	No or negligible relationship

Adapted from Dancey and Reidy, 2004

Table 5.28. Spearman's rho correlation between mean curvature values and modified Hawkey and Merbs composite scores for gluteal tuberosity.

Correlations

			mean	Score
Spearman's rho	mean	Correlation Coefficient	1.000	.617**
		Sig. (2-tailed)	.	<.001
		N	44	44
	Score	Correlation Coefficient	.617**	1.000
		Sig. (2-tailed)	<.001	.
		N	44	44

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5.29. Spearman's rho correlation between mean curvature values and modified Hawkey and Merbs composite scores for linea aspera.

Correlations

			mean	Score
Spearman's rho	mean	Correlation Coefficient	1.000	.685**
		Sig. (2-tailed)	.	<.001
		N	35	35
	Score	Correlation Coefficient	.685**	1.000
		Sig. (2-tailed)	<.001	.
		N	35	35

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5.30. Spearman's rho correlation between mean curvature values and modified Hawkey and Merbs composite scores for trochanteric fossa.

Correlations

			Mean	Score
Spearman's rho	Mean	Correlation Coefficient	1.000	.900**
		Sig. (2-tailed)	.	<.001
		N	28	28
	Score	Correlation Coefficient	.900**	1.000
		Sig. (2-tailed)	<.001	.
		N	28	28

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5.31. Spearman's rho correlation between mean curvature values and modified Hawkey and Merbs composite scores for medial condyle.

Correlations

			mean	Score
Spearman's rho	mean	Correlation Coefficient	1.000	.905**
		Sig. (2-tailed)	.	<.001
		N	21	21
	Score	Correlation Coefficient	.905**	1.000
		Sig. (2-tailed)	<.001	.
		N	21	21

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5.32. Spearman's rho correlation between mean curvature values and modified Hawkey and Merbs composite scores for spiral line.

Correlations

			mean	Score
Spearman's rho	mean	Correlation Coefficient	1.000	.534**
		Sig. (2-tailed)	.	<.001
		N	46	46
	Score	Correlation Coefficient	.534**	1.000
		Sig. (2-tailed)	<.001	.
		N	46	46

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5.33. Spearman's rho correlation between mean curvature values and modified Hawkey and Merbs composite scores for lesser trochanter base.

Correlations

			mean	Score
Spearman's rho	mean	Correlation Coefficient	1.000	.825**
		Sig. (2-tailed)	.	<.001
		N	38	38
	Score	Correlation Coefficient	.825**	1.000
		Sig. (2-tailed)	<.001	.
		N	38	38

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5.34. Spearman’s rho correlation between mean curvature values and modified Hawkey and Merbs composite scores for lesser trochanter.

Correlations

			mean	score
Spearman's rho	mean	Correlation Coefficient	1.000	.722**
		Sig. (2-tailed)	.	<.001
		N	40	40
	score	Correlation Coefficient	.722**	1.000
		Sig. (2-tailed)	<.001	.
		N	40	40

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5.35. Spearman’s rho correlation between mean curvature values and modified Hawkey and Merbs composite scores for lateral greater trochanter.

Correlations

			mean	Score
Spearman's rho	mean	Correlation Coefficient	1.000	.800**
		Sig. (2-tailed)	.	<.001
		N	30	30
	Score	Correlation Coefficient	.800**	1.000
		Sig. (2-tailed)	<.001	.
		N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5.36. Spearman’s rho correlation between mean curvature values and modified Hawkey and Merbs composite scores for anterolateral greater trochanter.

Correlations

			mean	Score
Spearman's rho	mean	Correlation Coefficient	1.000	.881**
		Sig. (2-tailed)	.	<.001
		N	20	20
	Score	Correlation Coefficient	.881**	1.000
		Sig. (2-tailed)	<.001	.
		N	20	20

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5.37. Spearman’s rho correlation between mean curvature values and modified Hawkey and Merbs composite scores for anterior greater trochanter.

Correlations

			mean	Score
Spearman's rho	mean	Correlation Coefficient	1.000	.637**
		Sig. (2-tailed)	.	<.001
		N	27	27
	Score	Correlation Coefficient	.637**	1.000
		Sig. (2-tailed)	<.001	.
		N	27	27

**. Correlation is significant at the 0.01 level (2-tailed).

As shown above, these scatterplots illustrate variability in correlation strength among different muscle attachment sites of the femora. Sites such as the spiral line (0.534) and the anterior greater trochanter (0.637) show moderate correlations. While sites such as the medial condyle (0.905) and the trochanteric fossa (0.900) show very strong correlations, suggesting that these sites are particularly sensitive and reliable indicators of musculoskeletal stress. These strong correlations validate the method’s precision and reliability, as these regions show consistent relationships between mean curvature values and semi-quantitative scores. Conversely, the weaker correlations at the spiral line or anterior greater trochanter indicate that while the method is capable of detecting adaptations, it’s possible that its effectiveness can vary depending on the site. It is also possible that the limitations of the semi-quantitative method, which has numerous specimens with the same score but varying mean curvature values, can skew the scatterplot. The distortion then reduces the clarity of the relationship between semi-quantitative scores and mean curvature values. The semi-quantitative method may not fully capture the differences in robusticity for every muscle attachment site. Nonetheless, the fact that every muscle attachment site analyzed shows at least a moderate correlation between mean curvature values and semi-quantitative scores is a strong validation of the 3D quantitative curvature method. Even in regions with weaker correlations, such as the spiral line (0.534), the positive relationship indicates that bone robusticity and curvature consistently reflects musculoskeletal stress across all examined sites. This uniform trend, regardless of the strength of the correlation, demonstrates that the method is sensitive enough to detect skeletal adaptations to habitual mechanical loading. Generally, the variability shown underscores the complexity of interpreting skeletal adaptations and highlights the importance of using a quantitative method for a more precise understanding of MSMs.

Each scatterplot effectively pictures the data distribution, with clusters of points providing insights into the consistency of the data. Outliers, if present, are also shown, allowing for visibility of potential anomalies in the scoring processes. The scatterplots and the correlation coefficients are aligned to confirm the statistical significance of these findings, as reflected in the Spearman's rho analyses presented in Tables 5.27 through 5.36.

The 3D curvature analysis offers a more nuanced perspective compared to traditional scoring methods, as it captures subtle variations in bone morphology that are not fully expressed in ordinal semi-quantitative scores. The integration of these methods provides a comprehensive approach that quantitatively substantiates the qualitative observations made through the modified Hawkey and Merbs method. This approach shows the reliability of using curvature data to assess and interpret MSMs, contributing to a more detailed and objective analysis of habitual activity induced MSMs over time.

Chapter 6: Discussion

The primary hypotheses that were introduced at the beginning of this research are: 1) it is possible to determine if the inhabitants of different prehistoric hunting-gathering-fishing and agricultural sites were doing different activities and 2) earlier sites were participating in a broad-spectrum subsistence economy, while sites from later time periods were relying heavily on farming. This chapter includes a discussion of the results presented in Chapter 5 to answer these questions.

Muscular Utilization Patterns of General Groups

The patterns of musculoskeletal stress markers (MSMs) observed between the Jomon and Yayoi groups reflect a distinct shift in habitual activities and thus subsistence strategies. The Jomon consistently exhibited lower MSM frequencies, which is indicative of a lifestyle focused on hunting, gathering, and fishing. Alternatively, the Yayoi population displayed consistently higher MSM frequencies. While the Jomon population exhibits frequencies less than 40% for all activities, the Yayoi frequencies are double those of the Jomon with the highest frequency at 80%. This shows that a more physically stressful lifestyle is associated with the physical demands of wet-rice farming and increased craft production. Agriculture is incredibly difficult on the body due to the physical stress of land preparation, irrigation and crop cultivation. Increased frequencies for craft production activities, such as pottery making, metalworking, and clothmaking are expected to increase with the rise of agriculture due to increasingly sedentary lifestyles. The surplus of crops from the transition to full-time agriculture resulted in a substantial increase in the Yayoi population. This led to more complex societies that allowed for specialization within sites. The specialization and increase in craft production are evident in the archaeological record through findings such as Gohoura shell jewelry, jade balls, and clay ornaments. The need for pottery also increased due to higher demands for cooking and pots and jars for storage. Additionally, an increase in social complexity is evident from newly introduced jar burials and grave goods.

The notable increase in muscle use patterns from the Jomon period to the Yayoi period underscores the transition from hunting, gathering, and fishing to farming. This has been observed through the archaeological findings and is further proven by the skeletal remains used in this research. Overall, the stark contrast in MSM frequencies between the populations highlights the impact of agricultural adoption on daily activities and, in turn, the body. This aligns with the previous notion that transitioning to full-time agriculture creates more physical stress on the body. These patterns provide a narrative of the cultural evolution of the Jomon and Yayoi.

Muscular Utilization Patterns of Geographic Site Categories

The analysis of MSMs across geographic site categories reveals distinct activity patterns that correspond to the environment and subsistence strategies of the Jomon and Yayoi populations. These findings highlight the importance of geography in shaping habitual activities, labor demands, and ultimately, musculoskeletal development.

The Inland Yayoi exhibited the highest activity frequencies across all groups, with over 80% of general farming, grain processing, and woodland clearance activities exceeding statistical breakpoints. These high frequencies reflect the intensive labor demands of wet-rice agriculture, which required substantial land preparation, irrigation, and ongoing maintenance. This alignment of activity scores with archaeological evidence emphasizes the significant role of agriculture in Inland Yayoi society. Notably, Ichinotani is the only site in this study where stone agricultural hoes were uncovered. The hoes in addition to polished axes and finely crafted stone tools, further highlight the prevalence of specialty tools needed for agricultural activities in the Inland Yayoi sites.

The high scores for pottery making (81%) and metalworking (72%) and clothmaking (77%) reveal the critical role of these crafts in supporting agricultural storage and tool production. Increased pottery production likely served dual purposes. First, the demand for bowls and jars for cooking and storing rice would have risen with the intensification of rice cultivation. In turn, the demand for even more rice would rise as the surplus created an increase in population. Second, jar burials, which required very large ceramic vessels, were prevalent in the region, as seen at sites such as Kanenokuma, Ichinotani, and Nagaoka. These practices would have significantly driven the production of pottery in these areas. The high metalworking frequencies align with the artifacts found at Inland Yayoi sites, including small bronze bells, weapons, tools, and mirrors. These findings highlight the importance of metalworking in an agricultural society, particularly in inland societies where access to other subsistence strategies like fishing was minimal. The absence of fish and terrestrial faunal remains at these sites underscore their reliance on farming as a primary subsistence strategy. Lastly, clothmaking was at 77% which revealed an increase in the demand for clothing, most likely due to the increase in population, similar to the demand for more ceramics.

The Riverine Yayoi exhibited activity frequencies that were intermediate between the Inland and Coastal groups. General farming and grain processing activities were 78% and 76%, respectively, while woodland clearance was slightly lower at 67%. These frequencies suggest that agricultural practices played a significant role in the Riverine Yayoi subsistence strategy, but to a less extent than in the Inland Yayoi. The presence of aquatic resources in riverine environments likely diversified their subsistence practices, allowing a balance between intensive agricultural labor and activities such as fishing and hunting. This diversification would have reduced the overall labor demands associated with farming compared to the Inland Yayoi.

Pottery making, metalworking and weaving frequencies were considerably lower among the Riverine Yayoi group compared to the Inland group. Unlike the Inland Yayoi sites, no agricultural tools were discovered in Riverine Yayoi sites. Similarly, faunal remains were not documented at these sites, although this absence may reflect limitations in the site reports, which seem to focus more on artifacts associated with human skeletal remains as grave goods. Grave goods found at these sites included iron swords, halberds, bronze mirrors, and a Gohoura shell ring. These items point to a degree of social stratification similar to that seen in the Inland Yayoi, as well as evidence of metalworking practices. Weapons and grave goods found in the Riverine Yayoi sites suggests that they were stratified societies, similar to their Inland counterparts.

The Coastal Yayoi exhibited consistently high MSM frequencies, although lower than the Inland Yayoi and slightly lower than the Riverine Yayoi for specific activities. General farming, grain processing, and woodland clearance each were at 74%, reflecting agricultural activities despite the availability of marine resources. The archaeological record reflects that Coastal Yayoi inhabitants had a mixed subsistence strategy as well. Terrestrial faunal remains of deer, wild boar and frogs are indicative of hunting, while deer horn fishing implements are indicative of fishing. The addition of marine resources likely reduced the intensity of agricultural labor compared to inland groups, contributing to a difference in activity frequencies.

Pottery making (77%) and metalworking (72%) were also considerably high, though lower than the Inland Yayoi. However, pottery making and metalworking were significantly higher for the Coastal Yayoi than the Riverine Yayoi, increasing 20% for pottery making and 15% for metalworking. This suggests that while the Coastal Yayoi had less physical stress than the Inland Yayoi in regards to general farming, inhabitants of the Coastal Yayoi were participating in more craft production than the Riverine Yayoi. Evidence of this is reflected by the clay figurines, bronze ware, and iron tools found at the Coastal Yayoi sites. Clothmaking was only slightly higher than the Riverine Yayoi, but still lower than Inland Yayoi.

The Inland Jomon exhibited consistently low frequencies of MSMs across all activity categories when compared to the Yayoi sites, with all activities consistently below 40%. These patterns align with the subsistence activities of the Jomon period. It is possible that the Inland Jomon were participating in rudimentary rice farming, but also likely that they were involved heavily in foraging and hunting. The archaeological findings bolster this claim, with hunting materials such as obsidian projectile tools being found at these sites. Pottery making within the Inland Jomon group was the highest of the Jomon groups at 34%. This could be indicative of a demand for pottery to store the local crops they foraged.

The Riverine Jomon exhibits similar frequencies to the Inland Jomon. This is to be expected, as the Riverine Jomon were likely to have a mixed subsistance strategy, but with an addition of fishing to the foraging and hunting done by the Inland Jomon. Riverine Jomon sites exhibited a wealth of artifacts that included a plethora of materials related to fishing (e.g. shell middens, bone fishhooks, and net sinkers), hunting (e.g. faunal remains and projectile points), and foraging and plant cultivation (e.g. axes and grinding stones). The overall activity levels suggest a mixed subsistence strategy with minimal engagement with plant cultivation.

The Coastal Jomon exhibited MSM frequencies similar to their Riverine and Inland counterparts. With nearly all frequencies under 40% it is likely that the inhabitants of the Coastal Jomon sites participated in a mixed subsistence strategy that included hunting, gathering and fishing, with minimal, if any, rice cultivation. Similar to the other Jomon groups, pottery making is at 32%, reflecting a society that took part in craft production, though not done at the same high intensity level of the Yayoi. This frequency suggests a lack of demand for the types of pottery used for cooking and storing crops or the large size of ceramic vessels necessary for jar burials commonly seen in the Yayoi period.

The geographic variation in MSM patterns highlights the profound influence of environmental and subsistence factors on labor intensity and musculoskeletal development, particularly in the Yayoi groups. Inland Yayoi populations demonstrated the most intensive engagement in agriculture, consistent with the labor demands of wet-rice cultivation. Similar high frequencies are seen within the Inland Yayoi for craft production. This coincides with the transitions to a more complex society due to sedentism. The surplus created from full time rice farming increased the sedentary lifestyles of the Inland Yayoi, which facilitated societal complexity, social stratification, and specialization. All of which resulted in a need for more pottery making for storage, burials, and ornaments. Metalworking became more necessary as more agricultural tools were needed as well as special items such as mirrors. Lastly, weaving and clothmaking were highest with Inland Yayoi as well due to the specialization that accompanies complex societies. Coastal Yayoi groups showed a slightly reduced level of MSMs, due to their more mixed subsistence strategy with other local resources available. Riverine Yayoi also showed reduced levels compared to the Inland Yayoi, and craft production was often lower than the Coastal Yayoi. This may be due to cultural differences of the Riverine Yayoi or due to the

Riverine Yayoi having significantly fewer individuals in this sample size, skewing their data. In contrast, all Jomon populations exhibited significantly lower activity levels, reflective of a hunting-gathering-fishing lifestyle that is significantly less physically stressful than full time agriculture. Coastal and riverine groups in both periods show intermediate patterns, suggesting that accessibility to resource diversity moderates labor demands, thus resulting in less physically stressed populations. These findings emphasize the complex relationship between geography, subsistence strategy and habitual activity in shaping the skeleton.

Muscular Utilization Patterns across Time Periods

The patterns of MSMs across time periods do not offer as clear a narrative on the evolving subsistence strategies of prehistoric Japan as previously thought. The Early Jomon shows the lowest frequencies of muscle use for farming activities, reflecting a lifestyle characterized by hunting, gathering and fishing. This is anticipated as this group is the earliest and least likely to be participating in rice paddy farming. During the Middle Jomon, MSM frequencies slightly increased, suggesting a gradual shift toward more sedentary practices, likely due to an increase in subsistence related activity. The development of semi-permanent settlements most likely caused an increase in the demand for grain processing as well as pottery making for food storage. However, after the Middle Jomon it is expected that the Late Jomon MSM levels would increase due to a possible adoption of rudimentary rice farming as well as the need for a more sedentary lifestyle. This is not what is exhibited in the MSM frequencies. Alternatively, there is a dip in MSM frequencies in nearly all activities, with the exclusion of grain processing.

A similar pattern is shown in the Yayoi. The Early Yayoi MSMs are significantly higher than all of the Jomon periods. This is indicative of the transition to full time agriculture seen during the Yayoi period. Activities such as field preparation, planting and irrigation required consistent mechanical stress on the muscles and that is evident when looking at the Yayoi MSMs. However, instead of seeing a gradual rise over time in MSM, we see scores increasing and peaking in most activities during the Middle Yayoi and then decreasing again during the Late Yayoi. The Late Yayoi exhibit even lower scores than the Early Yayoi for all activities. This reveals two possibilities: 1) during the Middle Yayoi, the group hit its peak agricultural effort and during the Late Yayoi the activity levels were able to decrease due to new agricultural methods or tools; or 2) agricultural intensity does not increase over time. Alternatively, subsistence strategies are influenced heavily by geography, resulting in the Inland Yayoi sites exhibiting higher MSM frequencies than the Late Yayoi.

Division of Labor Variation in Sex

The analysis of MSMs in relation to sex reveals the division of labor in prehistoric Japan. In Inland Jomon, the division of labor was wider compared to the levels of those in the Riverine and Coastal Jomon groups. Overall, for each group, the males typically engaged in more physically demanding tasks than females, but the Riverine and Coastal Jomon groups exhibited extremely close numbers. This may indicate that for the Jomon, groups close to marine resources have a more equal society where male and females participate in similar activities and have similar physically stressful lifestyles.

Among the Yayoi, the Riverine group exhibited the largest division of labor gap, but this observation may be due to the small sample size of the Riverine group. It is interesting that the Inland Yayoi displayed the smaller division of labor gap of the Yayoi groups, while the Inland Jomon displayed the largest. However, Inland Yayoi males still exhibited higher levels for farming activities than females which is normally expected in an agricultural society. While there is evidence of small gaps between male and female activity levels, it is important to note that for the Inland and Riverine groups there were very few muscles that were significantly different. In contrast, the Coastal Jomon had 14 muscles that were significantly different and the Coastal Yayoi had 12 muscles that were significantly different. This suggests that there may have been a division of labor in coastal locations, regardless of cultural period. Perhaps males and females had more distinct activities that were associated with fishing and other marine activities like shellfish foraging.

Analysis of Musculoskeletal Stress Markers with New 3D Quantitative Method

The introduction of a 3D quantitative method for analyzing MSMs offers significant advancements in the precision of MSM analysis and thus provides more accurate insights into the physical activities of past populations. One of the advantages of the 3D method is its ability to quantify subtle variations in MSMs. Traditional methods rely on subjective scoring systems that categorize changes in broad terms that can be confusing for first time users of the method. Additionally, the broad qualitative terms used can potentially obscure differences. The semi-quantitative scores cannot fully express subtle variations in bone morphology as effectively as the 3D method. The 3D approach enables the calculation of precise values that can be objectively compared.

The statistical testing of the 3D method showed correlations between mean curvature values and modified Hawkey and Merbs composite scores for all ten of the MSMs. Though the 3D method values were not used to analyze the Jomon and Yayoi sites, the strong correlations validate the method's precision and reliability. Its ability to provide precise, reproducible, and detailed measurements of MSM makes it helpful in furthering this research and using it in other bioarchaeological and even forensic settings.

Discussion of Research Questions

It is evident from these results, that it is indeed possible to determine if people in different sites were doing different activities. The Jomon and Yayoi sites exhibit stark differences in MSM frequencies that coincide with the activities associated with their different subsistence strategies. Additionally, though the quantitative 3D method was not used to analyze the Jomon and Yayoi sites, the strong correlations indicate that this technique would also be useful in the assessment of bioarchaeological remains to identify activity patterns as well. However, hypothesis 2 was refuted. Contrary to the expectation of a uniform shift towards rice agriculture, the analysis revealed a dichotomy in subsistence strategies: riverine and coastal sites persisted in a broad-spectrum subsistence economy, whereas inland sites predominantly adopted rice cultivation. This is more prevalent in the Jomon than in the Yayoi, as agricultural intensification began during the Yayoi period.

In Chapter 1 of this dissertation, I stated that this research would also be able to answer five specific questions. I will highlight these questions and answers below.

1. What subsistence activities were the inhabitants of the sites participating in?

As stated earlier in this chapter, generally the Yayoi were participating in rice farming with particularly high MSM levels in general farming activities, processing grains, woodland clearance and pottery making. They also had high levels in metalworking, weaving and clothmaking, but not as high as the other activities. The Jomon had consistently lower MSM frequencies and thus were participating in more broad-spectrum subsistence strategy.

2. Generally, did the Jomon have a less physically stressful lifestyle than the Yayoi?

The Jomon did have a less physically stressful lifestyle than the Yayoi. This is supported by the consistently lower MSM scores. The lowest Yayoi MSM frequency was 72%, while the highest Jomon MSM frequency was 39%, considerably lower than the lowest of the Yayoi scores.

3. Were Late Jomon sites participating in rice farming?

    The Late Jomon sites generally have lower MSM frequencies than the Early and Middle Jomon. The only activity where they exhibit the highest frequency is processing grains at 40% which is still considerably lower than all of the Yayoi time periods. It is not likely that the Late Jomon were taking part in any more rice farming activities than their Early and Middle counterparts. However, it is possible that they could have participated in rudimentary rice farming, but no more cultivation than the Early or Middle Jomon and certainly not to the extent of large scale rice paddy farming.

4. Were Early Yayoi sites participating more in broad-spectrum subsistence strategies than Final Yayoi?

   Early Yayoi sites had consistently higher MSM frequencies than the Late Yayoi. This would suggest that the Early Yayoi were not participating more in broad-spectrum activities, but rather were heavily involved in rice-farming during this time period.

5. Were Final Yayoi sites participating more in rice farming than the Early Yayoi sites?

   Once again, Early Yayoi sites actually had higher MSM levels than the Late Yayoi for all activities. This suggests that they were not participating more in rice farming than the Early Yayoi or, more likely, advances in their toolkits eased the physical requirements of full time farming.

Conclusion

As previously stated in Chapter 2 of this dissertation, the Jomon and Yayoi have a unique story in their journey to rely on domesticates. Niche construction theory is the most accurate way to explore how the Jomon managed plants. Though the Jomon were highly active within their environment, this was insufficient to result in full-time agriculture because domesticates lacked the ability to outcompete other species that attract human attention, such as marine resources and plants that could be foraged. In Japan, the Jomon had a wealth of resources that were accessible to them through fishing, hunting and harvesting. It is commonly held that the introduction of wet-rice agriculture into Japan started the agricultural revolution of the area after the Yayoi, but there is evidence of rudimentary rice farming during the Jomon period. This evidence is shown from the primitive rice cultivation site, Kitashirakawa-Oiwakecho, dated to the Final Jomon (Nasu and Momohara, 2016). The evidence exhibited that this type of rice farming was not as sophisticated as the agricultural efforts of the Yayoi, however it was still considered rice cultivation. It is noteworthy that this site is an inland site, located approximately 5 kilometers from the nearest small river (Takano River) and 12 kilometers from Lake Biwa. This research has shown that resource availability facilitated by geographic location is what most influences subsistence strategies, so it is likely that the inhabitants of the site of Kitashirakawa-Oiwakecho would be participating in primitive rice cultivation. This is due to them possibly not having as much access to marine resources the way that coastal or riverine groups would have.

At the emergence of the Yayoi period, we see the shift to full-time agriculture in Japan. As stated earlier, population increase and social complexity developed alongside the growth of rice agriculture. The adoption of rice cultivation in Japan created surpluses and this change to reliance on high caloric foods fostered population increase, complex societies, and social stratification. This is evident in the skeletal record of the Yayoi. MSM frequencies for agricultural activities rise sharply alongside those for craft production. More importantly, are the geographic distinctions in frequencies. The Inland Yayoi exhibit the highest MSM frequencies for all six activities. The farming and craft production frequencies coincide with the idea that a population more heavily involved in farming will also be a population that becomes more complex and is more socially stratified. This is evident both in the archaeological record and the skeletal remains used for this dissertation, thus underscoring both the possibility of determining different activities in prehistoric sites as well as the influence of geography on subsistence strategies rather than chronology.

Chapter 7: Conclusion

The Jomon is such a fascinating group because of the skilled way they used their environment, allowing them to hold onto a broad-spectrum subsistence strategy while also having a sedentary lifestyle before the transition to full time agriculture in Japan. It is evident that they clearly were adept at using their resources through the 300-year overlap with the Yayoi. Overall, a broad-spectrum strategy led to a generally less physically stressful lifestyle than the Yayoi. The Jomon MSM frequencies never exceeded 42%, whether they were divided temporally or geographically, while Yayoi MSM frequencies reached 93% and never fell below 57%. Hypothesis 1 was supported by the results, as it is evident from the results of this research that we are able to determine that different sites were doing different subsistence activities.

There is archaeological evidence of rudimentary agriculture during the Late Jomon, suggesting they may have shared a cultural exchange with the Yayoi people during the 300-year overlap. However, this hypothesis was refuted. The transition to full time agriculture was not seen as a uniform shift dictated by chronology, but a strategy influenced by geography. This is very similar to the results of the 2023 study by Dinkele and Gibbon, whose findings showed that physical activity patterns of the southern African hunter-gatherer herders during the Holocene were caused by differences in regional ecology, rather than age, sex, or temporal period. For this study temporal differences were only shown when the data were separated by biome. Similarly, the Jomon adhered to ecology-based subsistence strategies as well as the Yayoi, but to a lesser extent. Though the Inland Yayoi exhibited the highest MSM frequencies for all six activities, it is still evident that the Riverine Yayoi and Coastal Yayoi were still farming rice, just at a lesser intensity than the Inland Yayoi because they had access to other food resources due to their proximity to seas and rivers. These results contribute to the overall understanding of the food systems and habitual activities of the Jomon and Yayoi and adds to bodies of work that are arguing that transitions to full time agriculture may not happen in all environments at once and are dependent on a multitude of factors.

Additionally, the quantitative method created during this research will make an excellent contribution to this field. There has been a plethora of issues with standardizing the way the semi-qualitative methods work both in the scoring practice and the statistical methods. Since it is now common for people to have access to high resolution cameras, now is the time for more objective, accurate and accessible methods. Though this method was not used in the analysis of the Jomon and Yayoi for this dissertation, the next steps for this research as a whole is to apply the three-dimensional quantitative method to additional samples. A total of 56 femora were used to test the quantitative method, but photogrammetry was actually collected on a total of 426 bones from 74 individuals (left for future research). There were 27 Jomon individuals with a total of 122 bones, 25 Yayoi individuals with a total of 84 bones and 22 Edo individuals from the Ikenohata-shichikencho site with a total of 206 bones. This resulted in too much data to be analyzed for this dissertation alone, but the next steps in this research would be to analyze these data as well. Additionally, I would like to test this quantitative method on a known occupation sample to see if this type of research could be used in a forensic setting. The Willed Body Program at John A. Burns School of Medicine has remains from individuals with known occupations and it would be interesting to see if I could create a database of information on MSMs of people with different occupations or hobbies as a reference so that it could be another factor used to help identify unknown individuals. This three-dimensional quantitative method tested in this dissertation could be a useful asset to many areas of biological anthropology.

References

Abarca-Labra, V., Herrera-Soto, M. J., Flores-Alvarado, S., Ulloa-Velásquez, C., Urrutia-Álvarez, C., Falabella-Gellona, F., & Sanhueza-Riquelme, L., 2022. Exploring physical activity in Central Chile during the Early Ceramic Period and Late Intermediate Period (200–1450 CE). *American Journal of Biological Anthropology*, *177*(4), 658-668.

Adachi N, Shinoda K, Umetsu K, Kitano T, Matsumura H, Fujiyama R, Sawada J, Tanaka M., 2011. "Mitochondrial DNA Analysis Of Hokkaido Jomon Skeletons: Remnants Of Archaic Maternal Lineages At The Southwestern Edge Of Former Beringia". American Journal Of Physical Anthropology 146 (3): 346-360.

Adachi, N., Kakuda, T., Takahashi, R., Kanzawa-Kiriyama, H., & Shinoda, K. I., 2018. Ethnic derivation of the Ainu inferred from ancient mitochondrial DNA data. American journal of physical anthropology, 165(1), 139-148.

Agency for Cultural Affairs (Japan)., 2024. '彦崎貝塚', *Cultural Heritage Online*. Available at 彦崎貝塚 文化遺産オンライン

Aikens CM, Akazawa T., 1992. Fishing and Farming in early Japan: Jomon Littoral tradition carried into Yayoi times at the Miura Caves on Tokyo Bay. In: Aikens CM, Rhee SN, editors. *Pacific northeast Asia in prehistory: hunter-fisher-gatherers, farmers, and sociopolitical elites*. Pullman, WA: WSU Press.

Aikens CM, Rhee SN., 1992. The Emergence of Hunter-Fisher-Gatherers Farmers and Sociopolitical Elites in the Prehistory of Pacific northeast Asia. In: Aikens CM, Rhee SN, editors. *Pacific northeast Asia in prehistory: hunter-fisher-gatherers, farmers, and sociopolitical elites*. Pullman, WA: WSU Press.

Aikens, C.M. and Lee, G.A., 2013. Postglacial inception and growth of anthropogenic landscapes in China, Korea, Japan, and the Russian Far East. *Anthropocene*, *4*, pp.46-56.

Akazawa, T., 1982. Jomon People Subsistence and Settlements: Discriminatory Analysis of the Later Jomon Settlements

Albee, M. E., 2023. A test of the New Coimbra method of recording entheseal changes as applied to the foot skeleton. *International Journal of Osteoarchaeology*, *33*(6), 1028-1041.

Alonso-Llamazares, C., Lopez, B., & F. Pardiñas, A., 2022. Sex differences in the distribution of entheseal changes: Meta-analysis of published evidence and its use in Bayesian paleopathological modeling. *American Journal of Biological Anthropology*, 177(2), 249–265.

Ambiru, M., 2010. History of the Japanese Archipelago in the Paleolithic period. Tokyo: Gakuseisha. [In Japanese with English summary.]

Arlot, M.E., Jiang, Y., Genant, H.K., Zhao, J., Burt-Pichat, B., Roux, J.P., Delmas, P.D. and Meunier, P.J., 2008. Histomorphometric and μCT analysis of bone biopsies from postmenopausal osteoporotic women treated with strontium ranelate. *Journal of Bone and Mineral Research*, *23*(2), pp.215-222.

Baba H., 1990. Ainu, Ryukyu-jin wa Jomon-jin no chokkei shison ka [Are the Ainu and Ryukyu people the direct descendants of the Jomon people?]. In: Suzuki K, editor. *Soten Nihon no Rekishi, I: Genshi-hen [Controversies in Japanese History, vol. I: Prehistoric Periods]*, Tokyo: ShinjinbutsuOrai-sha, pp.106-123.

Bae, C.J., 2017. Late Pleistocene human evolution in eastern Asia: behavioral perspectives. Current Anthropology. 58 (S17), S514–S526.

Bae, C.J., 2024. *The Paleoanthropology of Eastern Asia*. University of Hawaii Press.

Barnes, G. L., 2015. Archaeology of East Asia: The Rise of Civilization in China, Korea and Japan. Havertown: Oxbow Books.

Barnes, G.L., 2019. The Jōmon–Yayoi transition in eastern Japan: enquiries from the Kantō Region. *Japanese Journal of Archaeology*, *7*(1), pp.33-84.

Bellwood P., 2008. First farmers: the origins of agricultural societies. Malden: Blackwell.

Benoit, A., Guérard, S., Gillet, B., Guillot, G., Hild, F., Mitton, D., Périé, J.N. and Roux, S., 2009. 3D analysis from micro-MRI during in situ compression on cancellous bone. *Journal of biomechanics*, *42*(14), pp.2381-2386.

Berthon, W., Rittemard, H., Tihanyi, B., Pálfi, G., Coqueugniot, H. and Dutour, O., 2015. Three-dimensional microarchitecture of entheseal changes: preliminary study of human radial tuberosity. *Acta Biologica Szegediensis*, *59*(1), pp.79-90.

Berthon, W., 2019. *Bioarchaeological analysis of the mounted archers from the Hungarian Conquest period (10th century): Horse riding and activity-related skeletal changes* (Doctoral dissertation, PSL Research University; Szegedi Tudományegyetem).

Biehler-Gomez, L., Moro, C., del Bo, B., Mattia, M., Rodella, L., Manzi, G., & Cattaneo, C., 2025. Physical activity over 2,000 years in Milan: Using entheseal robusticity as indicator of occupational stress. *Journal of Archaeological Science: Reports*, *61*, 104966.

Bleed, P., 1972. Yayoi Cultures of Japan: An Interpretive Summary. *Arctic Anthropology*, *9*(2), 1–23.

Bleed P, Matsui A., 2010. Why Didn't Agriculture Develop in Japan? A Consideration of Jomon Ecological Style, Niche Construction, and the Origins of Domestication. *Journal of Archaeological Method and Theory, 17*(4), 356-370.

Bocquet-Appel, J.P. and Bar-Yosef, O. eds., 2008. *The Neolithic demographic transition and its consequences*. Springer Science & Business Media.

Brace, C.L., S.L. Smith, & K.d. Hunt., 1991. What big teeth you had Grandma! Human tooth size, past and present, in m.A. Kelley & C.S. Larsen (ed.) Advances in dental anthropology: 33–57. New York: Wiley-Liss.

Brassey, C. A., Maidment, S. C., & Barrett, P. M., 2015. Body mass estimates of an exceptionally complete Stegosaurus (Ornithischia: Thyreophora): comparing volumetric and linear bivariate mass estimation methods. *Biology Letters*, *11*(3), 20140984.

Brooks, S., Suchey, J.M., 1990. Skeletal age determination based on the os pubis: A comparison of the Acsádi-Nemeskéri and Suchey-Brooks methods. *Hum. Evol.* **5**, 227–238.

Buikstra, J.E., & Ubelaker, D.H., 1994. Standards for Data Collection from Human Skeletal Remains.

Campbell, G.M. and Sophocleous, A., 2014. Quantitative analysis of bone and soft tissue by micro-computed tomography: applications to ex vivo and in vivo studies. *BoneKEy reports*, *3*.

Carballo Pérez, Jared & Sánchez Cañadillas, Elías & Arnay, Matilde & Hernández-Marrero, Juan & González-Reimers, Emilio., 2021. Quotidian lives on isolated bodies: Entheseal changes and cross-sectional geometry among the aboriginal population of La Gomera (ca. 200–1500 AD, Canary Islands). International Journal of Osteoarchaeology. 31. 10.1002/oa.2956.

Cashmore, L.A. and Zakrzewski, S.R., 2013. Assessment of musculoskeletal stress marker development in the hand. *International Journal of Osteoarchaeology*, *23*(3), pp.334-347.

Chappuis, V., Engel, O., Reyes, M., Shahim, K., Nolte, L.P. and Buser, D., 2013. Ridge alterations post-extraction in the esthetic zone: a 3D analysis with CBCT. *Journal of dental research*, *92*(12_suppl), pp.195S-201S.

Charles RH., 1893-1894. The influence of function, as exemplified in the morphology of the lower extremity of the Panjabi. J Anat Physiology 28:1-18.

Chisholm B, Koike H, Nakai N., 1992. Fishing and farming in early Japan : Jomon littoral tradition carried into Yayoi times at the Miura Caves on Tokyo Bay. In: Aikens CM, Rhee SN, editors. Pacific northeast Asia in prehistory: hunter-fisher-gatherers, farmers, and sociopolitical elites. Pullman, WA: WSU Press.

Cooke, N. P., Mattiangeli, V., Cassidy, L. M., Okazaki, K., Stokes, C. A., Onbe, S., Hatakeyama, S., Machida, K., Kasai, K., Tomioka, N., Matsumoto, A., Ito, M., Kojima, Y., Bradley, D. G., Gakuhari, T., & Nakagome, S., 2021. Ancient genomics reveals tripartite origins of Japanese populations. *Science advances*, *7*(38), eabh2419.

Cooke, N. P., Mattiangeli, V., Cassidy, L. M., Okazaki, K., Kasai, K., Bradley, D. G., … Nakagome, S., 2023. Genomic insights into a tripartite ancestry in the Southern Ryukyu Islands. *Evolutionary Human Sciences*, *5*, e23.

Cooper, D., Turinsky, A., Sensen, C. and Hallgrimsson, B., 2007. Effect of voxel size on 3D micro-CT analysis of cortical bone porosity. *Calcified tissue international*, *80*(3), pp.211-219.

Chappard, D., Guggenbuhl, P., Legrand, E., Baslé, M.F. and Audran, M., 2005. Texture analysis of X-ray radiographs is correlated with bone histomorphometry. Journal of bone and mineral metabolism, 23(1), pp.24-29.

Crawford, G.W., 2011. Advances in Understanding Early Agriculture in Japan. *Current Anthropology, 52*, S331 - S345.

Croft P, Coggon D, Cruddas M, Cooper C., 1992. Osteoarthritis of the Hip: An Occupational Disease in Farmers. British Medical Journal, 304(6837), 1269-1272.

Dancey, C. and Reidy, J., 2004. Statistics without Maths for Psychology: using SPSS for Windows. Prentice Hall, London.

Dewey, J.K., 2018. *Evaluating entheseal changes from a commingled and fragmentary population: Republic Groves*. Florida Atlantic University.

Deymier, A. C., Schwartz, A. G., Cai, Z., Daulton, T. L., Pasteris, J. D., Genin, G. M., & Thomopoulos, S., 2019. The multiscale structural and mechanical effects of mouse supraspinatus muscle unloading on the mature enthesis. *Acta biomaterialia*, *83*, 302-313.

Dinkele, E., & Gibbon, V. E., 2024. Entheseal changes and activity patterns in southern African hunter-gatherer/herders from the Holocene. *American Journal of Biological Anthropology*, 183(1), 107–124.

Djukić, K., Milovanović, P., Milenković, P. and Djurić, M., 2020. A microarchitectural assessment of the gluteal tuberosity suggests two possible patterns in entheseal changes. *American Journal of Physical Anthropology*, *172*(2), pp.291-299.

Dutour O., 1986. Enthesopathies (lesions of muscular insertions) as indicators of the activities of Neolithic Saharan populations. American Journal of Physical Anthropoogy. 71(2), 221-224.

Edelmers, E., Kazoka, D., Bolocko, K., & Pilmane, M., 2022. Different techniques of creating bone digital 3D models from natural specimens. *Applied System Innovation*, *5*(4), 85.

Eshed V, Gopher A, Galili E, Hershkovitz I., 2004. Musculoskeletal stress markers in Natufian hunter-gatherers and Neolithic farmers in the Levant: The upper limb. American Journal of Physical Anthropology 123:303–315.

Fau, M., Cornette, R., & Houssaye, A., 2016. Photogrammetry for 3D digitizing bones of mounted skeletons: potential and limits. *Comptes Rendus Palevol*, *15*(8), 968-977.

Feddema, J. C., & Chiu, L. Z. F., 2024. Accuracy and repeatability of 3D Photogrammetry to digitally reconstruct bones. *Morphologie*, *108*(363), 100793.

Field, A., 2013. Discovering Statistics Using IBM SPSS Statistics: And Sex and Drugs and Rock "N" Roll, 4th Edition, Sage, Los Angeles, London, New Delhi.

Fukase, H., Wakebe, T., Tsurumoto, T., Saiki, K., Fujita, M., Ishida, H., 2012. Geographic variation in body form of prehistoric Jomon males in the Japanese archipelago: its ecogeographic implications. American Journal of Physical Anthropology, 149: 125-135.

Fukuoka City Education Committee. 福岡市教育委員会., 1970. 金隈遺跡発掘調査報告書*. 福岡市埋蔵文化財調査報告書第7集.

Fukuoka City Education Committee. 福岡市教育委員会., 1971. 金隈遺跡第二次調査概報*. 福岡市埋蔵文化財調査報告書第17集.

Fukuoka City Education Committee 福岡市教,1979. ハサコの宮遺跡

Fukuoka City Education Committee. 福岡市教育委員会., 1985. 金隈遺跡発掘調査及び遺跡整備報告書. 福岡市埋蔵文化財調査報告書第123集.

Fukuoka Prefectural Board of Education 福岡市教, 1978. 原遺跡

Fukuoka Prefectural Board of Education 福岡市教, 1979. 門田遺跡

Fuller DQ, Sato Y-I, Castillo C, Qin L, Weisskopf AR, Kingwell-Banham EJ, Song J, Ahn S-M, van Etten J., 2010. Consilience of genetics and archaeobotany in the entangled history of rice. *Archaeological and Anthropological Sciences* 2: 115-131

Funahashi, K., 2022. Gender Expression from the Jomon to Yayoi Periods in Western Japan: A Case Study of Ritual Tooth Extraction. *Japanese Journal of Archaeology, 9(2),* 145–172.

Gakuhari, T., Nakagome, S., Rasmussen, S., Allentoft, M. E., Sato, T., Korneliussen, T., Chuinneagáin, B. N., Matsumae, H., Koganebuchi, K., Schmidt, R., Mizushima, S., Kondo, O., Shigehara, N., Yoneda, M., Kimura, R., Ishida, H., Masuyama, T., Yamada, Y., Tajima, A., Shibata, H., … Oota, H., 2020. Ancient Jomon genome sequence analysis sheds light on migration patterns of early East Asian populations. *Communications biology*, *3*(1), 437.

Gelabert, P., Blazyte, A., Chang, Y., Fernandes, D. M., Jeon, S., Hong, J. G., Yoon, J., Ko, Y., Oberreiter, V., Cheronet, O., Özdoğan, K. T., Sawyer, S., Yang, S., Greytak, E. M., Choi, H., Kim, J., Kim, J. I., Jeong, C., Bae, K., Bhak, J., … Pinhasi, R., 2022. Northeastern Asian and Jomon-related genetic structure in the Three Kingdoms period of Gimhae, Korea. *Current biology : CB*, *32*(15), 3232–3244.e6.

Habu, J., 2004. Ancient Jomon of Japan. Cambridge: Cambridge University Press.

Habu, J. et al., 2017. Handbook of East and Southeast Asian Archaeology. New York, NY: Springer New York.

Hamada, K., 1925a. Hizen Koku Uki Kaizuka Hakku Hokoku (Upper Report on the Excavation of the Uki Shell Mound). *Journal of Anthropology 41(1)*: 1-10. Tokyo.

Hamada, K., 1925b. Hizen Koku Uki Kaizuka Hakku Hokoku (Lower Report on the Excavation of the Uki Shell Mound). *Journal of Anthropology 41(2)*: 79-93. Tokyo.

Hanihara, K., 1984.日本人の起源』, 朝日新聞社, 東京, 239 pp.

Hanihara, K., 1991. Dual structure model for the population history of the Japanese. *Nichibunken Japan Review*, pp.1-33.

Hanihara, T., 1993. Population prehistory of East Asia and the Pacific as viewed from craniofacial morphology: the basic populations in East Asia, VII. *American Journal of Physical Anthropology*, *91*(2), pp.173-187.

Hanihara, T. & Ishida, H., 2009. Regional difference in craniofacial diversity and the population history of Jomon Japan. *American Journal of Physical Anthropology*. 139, 311–322.

長谷部言人 Hasebe, 1940. 太古の日本人, 人類学雑誌, 55, 27-34.

Havelková P, Villotte S., 2007. Enthesopathies: Test of reproducibility of the new scoring system based on current medical data. *Slovenská antropológia 10(1):* 51-57.

Hawkey DE, Merbs CF., 1995. Activity-induced musculoskeletal stress markers (MSM) and subsistence strategy changes among ancient Hudson Bay Eskimos. *International Journal of Osteoarchaeology, 5(4)*: 324-338.

Henderson CY., 2008. When hard work is disease: the interpretation of enthesopathies. Proceedings of the 8th Annual Conference of the British Association of Biological Anthropology and Osteoarchaeology, M Brickley, M Smith (eds.). Archaeopress: Oxford; 17–25.

Henderson CY, Mariotti V, Pany-Kucera D, Perréard- Lopreno G, Villotte S, Wilczak C., 2010. Scoring entheseal changes: proposal of a new standardised method for fibrocartilaginous entheses. 18th European Meeting of the Paleopathology Association, Vienna, Austria. 23rd - 26th of August.

Henderson CY, Cardoso FA., 2013. Special Issue Entheseal Changes and Occupation: Technical and Theoretical Advances and Their Applications. *International Journal of Osteoarchaeology 23:*127–134.

Henderson, C. Y., Mariotti, V., Pany-Kucera, D., Villotte, S., & Wilczak, C., 2015. The new ‘Coimbra method’: a biologically appropriate method for recording specific features of fibrocartilaginous entheseal changes. *International Journal of Osteoarchaeology*, *26*(5), 925-932.

Higham C., 2007. The Transition to Rice Cultivation in Southeast Asia. In: Price TD, Gebauer AB, editors. *Last hunters - first farmers: new perspectives on the prehistoric transition to agriculture.* Santa Fe (N.M.): School of American Research Press.

Hildebrand, T., Laib, A., Müller, R., Dequeker, J. and Rüegsegger, P., 1999. Direct three-dimensional morphometric analysis of human cancellous bone: microstructural data from spine, femur, iliac crest, and calcaneus. *Journal of bone and mineral research*, *14*(7), pp.1167-1174.

Hirohisa, 1979. Ohashi Kaizuka Hakkutsu Chosa Hokokusho [Ohashi Shell Mound Excavation Report]. Okayama Prefecture Board of Education.

Hitchins, P., 1976. Technical Studies on Materials from Yayoi Period Japan: Their Role in Archaeological Interpretation. *Asian Perspectives 19(1)*: 156-171.

Hosseinian, S., & Arefi, H., 2017. Photogrammetry in 3D modelling of human bone structures from radiographs. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *42*, 115-121.

Howells, W.W., 1966. The Jomon population of Japan: A study by discriminant analysis of Japanese and Ainu crania. Pap. Peabody Mus. Archaeology. Ethnology., Harvard Univ., 57, 1-43.

Hudson, MJ., 1999. Ruins of Identity: Ethnogenesis in the Japanese Islands. Honolulu: University of Hawai’i Press.

Hudson, M., & Barnes, G., 1991. Yoshinogari. A Yayoi Settlement in Northern Kyushu. *Monumenta Nipponica*, *46*(2), 211-235. doi:10.2307/2385402

Hudson, M.J. and Matsumura, H., 2006. “Sundadonty” and the population history of Southeast Asia: A reply to Turner. *American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropologists*, *130*(4), pp.458-461.

IBM Corp., Released 2023. IBM SPSS Statistics for Windows, Version 29.0.2.0 Armonk, NY: IBM Corp

Igawa K, Manabe Y, Oyamada J, Kitagawa Y, Kato K, Ikematsu K, Nakasono I, Matsushita T, Rokutanda A., 2009. Mitochondrial DNA analysis of Yayoi period human skeletal remains from the Doigahama site. *Journal of Human Genetics 54*:581–588.

Ikawa-Smith, F., 1980: Current issues in Japanese archaeology. *American Scientist, 68*: 134-145.

Ikawa-Smith, F., 1995. The Jomon, the Ainu, and the Okinawans. In: Dicks DJ, editor. Communicating with Japan, pp. 43-55. Montreal: Concordia University.

Ishikawa, T., 1997. The Archaeology of the Jomon Period Shell Middens in Tokai Region. *Journal of Japanese Archaeology, 15*(2), pp. 145-170.

ISTI-CNR., 2023. P. Cignoni, M. Callieri, M. Corsini, M. Dellepiane, F. Ganovelli, G. Ranzuglia MeshLab: an Open-Source Mesh Processing Tool. Sixth Eurographics Italian Chapter Conference, page 129-136, 2008

Ito, M., Nakamura, T., Matsumoto, T., Tsurusaki, K. and Hayashi, K., 1998. Analysis of trabecular microarchitecture of human iliac bone using microcomputed tomography in patients with hip arthrosis with or without vertebral fracture. *Bone*, *23*(2), pp.163-169.

JetBrains, 2023. DataSpell

Jinam, T., Nishida, N., Hirai, M., Kawamura, S., Oota, H. et al., 2012. The history of human populations in the Japanese Archipelago inferred from genome-wide SNP data with a special reference to the Ainu and the Ryukyuan populations. *Journal of Human Genetics. 57*, 787–795.

Jinam, Timothy A., Hideaki Kanzawa-Kiriyama, and Naruya Saitou., 2015. Human genetic diversity in the Japanese Archipelago: dual structure and beyond. *Genes and Genetic Systems 90*:147–152.

Jinam, T., Kawai, Y., Kamatani, Y., Sonoda, S., Makisumi, K., Sameshima, H., Tokunaga, K., & Saitou, N., 2021. Genome-wide SNP data of Izumo and Makurazaki populations support inner-dual structure model for origin of Yamato people. *Journal of human genetics*, *66*(7), 681–687.

Jinam, T.A., Kawai, Y., & Saitou, N., 2021. Modern human DNA analyses with special reference to the inner dual-structure model of Yaponesian. *Anthropological Science*, *1*, 3–11.

Kaifu, Y., Lin, C., Goto, A., Ikeya, N., Yamada, M., Chiang, W.-C., … Wen, P., 2019. Palaeolithic seafaring in East Asia: testing the bamboo raft hypothesis. *Antiquity*, *93*(372), 1424–1441.

Kaifu, Y., 2022. A synthetic model of Palaeolithic seafaring in the Ryukyu Islands, southwestern Japan. *World Archaeology*, *54*(2), 187–206.

Kajigayama, M., Baba, Y., 1999. Human bones excavated from Wakami Shell Mound, Tamazoku Town, Ibaraki Prefecture, Ibaraki Prefecture, Japan Gyokuzo Town Archaeological Survey Committee, Tamazuri Town Board of Education, Tamazoku, pp. 1-14.

Kanaseki, H., and Sahara, M., 1976. "The Yayoi Period". Asian Perspectives XIX (I): 15-26.

Kanaseki, T., Nagai, M. and Sano, H., 1960. Craniological studies of the Yayoi-period ancients, excavated at the Doigahama site, Yamaguchi Prefecture. Jinruigaku Kenkyu, 7 (suppl.), 1-36. (In Japanese with English summary.)

Kanaseki, T. and Tabata, T., 1930: Uber die Korpergroe des Tsukumo-Steinzeitmenschen Japans. Folia Anat. Japon.,8: 265-282.

Kaner, S. and Ishikawa, T., 2007. Reassessing the concept of the 'Neolithic'in the Jomon of Western Japan. *Documenta Praehistorica*, *34*, pp.1-7.

Kanzawa-Kiriyama, H., Saso, A., Suwa, G., and Saitou N., 2013. "Ancient Mitochondrial DNA Sequences Of Jomon Teeth Samples From Sanganji, Tohoku District, Japan". *Anthropological Science 121* (2): 89-103.

Kanzawa-Kiriyama, H., Kryukov, K., Jinam, T.A., Hosomichi, K., Saso, A., Suwa, G., Ueda, S., Yoneda, M., Tajima, A., Shinoda, K.I. and Inoue, I., 2017. A partial nuclear genome of the Jomons who lived 3000 years ago in Fukushima, Japan. *Journal of human genetics, 62*(2), 213-221.

Karakostis, F.A. and Lorenzo, C., 2016. Morphometric patterns among the 3D surface areas of human hand entheses. *American journal of physical anthropology*, *160*(4), pp.694-707.

Karakostis, F. A., Jeffery, N., & Harvati, K., 2019a. Experimental proof that multivariate patterns among muscle attachments (entheses) can reflect repetitive muscle use. *Scientific Reports*, *9*(1), 16577.

Karakostis, F.A., Jeffery, N. and Harvati, K., 2019b. Experimental proof that multivariate patterns among muscle attachments (entheses) can reflect repetitive muscle use. *Scientific reports*, *9*(1), pp.1-9.

Kasuga Town Education Committee., 1969. Archaeological Report of the Yayoi Period Sites. Kasuga: Kasuga Town.

Kelley JO, Angel JL., 1983. The workers of Cotocin furnace. Md Archaeol 19(1):2-17.

Kim, J., Mizuno, F., Matsushita, T., Matsushita, M., Aoto, S., Ishiya, K., Kamio, M., Naka, I., Hayashi, M., Kurosaki, K., Ueda, S., & Ohashi, J., 2025. Genetic analysis of a Yayoi individual from the Doigahama site provides insights into the origins of immigrants to the Japanese Archipelago. *Journal of human genetics*, *70*(1), 47–57.

Kimura T., 2006. Robustness of the whole Jomon femur shaft assessed by cross-sectional geometry. *Anthropological Science, 114*: 13-22.

Kiyono, Y., 1933. Japan Shell Mounds Research. Tokyo: Anthropological Society of Nippon. In Japanese.

清野謙次 Kiyono, 1949.『古代人骨の研究に基づく日本人種論』, 岩波書店, 東京, 599 pp.

Kiyono, 1969. The Study of Japanese Shell Middens (Nihon Kaizuka No Kenkyu). In Japanese.

Kobayashi, T, Kaner S., 2004. Jomon reflections: forager life and culture in the prehistoric Japanese archipelago. Oxford: Oxbow Books.

Kobayashi, K., 2017. Jomon Jidai no Jitsu nendai. Doseisha, Tokyo (in Japanese).

Kohara, Y., Shigehara, N., Nishizawa, T., Fujita, S., Ootani, E., & Baba, H., 2011. Human skeletal remains from the Tochibara rock-shelter site (Earliest Jomon, Nagano Pref., Central Japan), and re-evaluation of the characteristics of the Earliest Jomon people. *Anthropological Science (Japanese Series), 119*(2), 91-124.

Kondo, T., 1988. "Burial Practices and Social Organization in the Yayoi Period: A Case Study from the Ichinotani Site." *Asian Perspectives 27* (2): 155-170.

Koura Archaeological Site Report., 2005. Unedited manuscript, Parts 1-3. In Japanese.

Koutsoudis, A., Vidmar, B., & Arnaoutoglou, F., (2013). Performance evaluation of a multi-image 3D reconstruction software on a low-feature artefact. *Journal of Archaeological Science*, *40*(12), 4450-4456.

Kubicka, A.M. and Myszka, A., 2020. Are entheseal changes and cross-sectional properties associated with the shape of the upper limb?. *American Journal of Physical Anthropology*.

Kudaka, M., Fukase, H., Kimura, R., Hanihara, T., Matsumura, H., Saso, A., Fukumini, T., Ishida, H., 2013. Metric characteristics of human limb bones in Asian and Japanese populations. *Anthropological Science, 121*(1): 49-62.

Kumamoto Prefecture Education Committee., 2005. 阿高貝塚発掘調査報告書 [Agao Shell Midden Excavation Report]. 熊本県文化財調査報告第223集. 熊本県教育委員会, 熊本, Japan.

Kusaka S., Nakano T., Yumoto T., and Nakatsukasa M., 2011. Strontium isotope evidence of migration and diet in relation to ritual tooth ablation: a case study from the Inariyama Jomon site, Japan. *Journal of Archaeological Science, 38*: 166–174

Kyushu University Museum, 2021. 三沢遺跡

Larsen C.S., 1997. Bioarchaeology: interpreting behavior from the human skeleton. Cambridge: Cambridge University Press.

Larsen C.S., 2000. Skeletons in our closet: revealing our past through bioarchaeology. Princeton: Princeton Univ. Press.

Lawrence AB, Sandberg PA Van Gerven DP, Sponheimer M., 2018. Evidence for differences in activity between socioeconomic groups at Kulubnarti, Nubia (550-800 CE0, from osseous modifications of the proximal femur. *International Journal of Osteoarchaeology*. 1-10.

Lieverse AR, Bazaliiskii VI, Goriunova OI, Weber AW., 2013. Lower limb activity in the Cis-Baikal: Entheseal changes among middle Holocene Siberian foragers. *American Journal of Physical Anthropology 150*:421–432.

Liu, X., Koyama, S., Tomizuka, K., Takata, S., Ishikawa, Y., Ito, S., Kosugi, S., Suzuki, K., Hikino, K., Koido, M., Koike, Y., Horikoshi, M., Gakuhari, T., Ikegawa, S., Matsuda, K., Momozawa, Y., Ito, K., Kamatani, Y., & Terao, C., 2024. Decoding triancestral origins, archaic introgression, and natural selection in the Japanese population by whole-genome sequencing. *Science advances*, *10*(16), eadi8419.

Lovejoy, C. O., Meindl, R. S., Pryzbeck, T. R., & Mensforth, R. P., 1985. Chronological metamorphosis of the auricular surface of the ilium: a new method for the determination of adult skeletal age at death. *American journal of physical anthropology*, *68*(1), 15–28.

Lukacs J.R., Pal J.N., 2003. Skeletal variation among Mesolithic people of the Ganga Plains: new evidence of habitual activity and adaptation to climate. *Asian Perspectives*, 42 (2): 329-351.

Mann R.W., Hunt D.R., 2012. Photographic Regional Atlas of Bone Disease: A Guide to Pathologic and Normal Variation in the Human Skeleton. Springfield: Charles C. Thomas Publisher, Ltd.

Mariotti, V., Facchini, F. and Giovanna Belcastro, M., 2004. Enthesopathies–proposal of a standardized scoring method and applications. *Collegium antropologicum*, *28*(1), pp.145-159.

Mariotti, V., Facchini, F., & Giovanna Belcastro, M., 2007. The study of entheses: proposal of a standardised scoring method for twenty-three entheses of the postcranial skeleton. *Collegium antropologicum*, *31*(1), 291–313.

Mason, R. H. P, and Caiger J.G., 1997. A History Of Japan. Rutland, Vt.: C.E. Tuttle Co.

Matsufuji, K., 2010. When were the earliest hominin migrations to the Japanese Islands. In: Norton, C.J., Braun, D.R. (Eds.), Asian Paleoanthropology: From Africa to China and Beyond. Springer, Netherlands, pp. 191–200.

Matsufuji, K., Uemine, A., 2013. Study of Sunabara Palaeolithic Site. Sunabara Iseki Gakujutsu Chosadan, Kyoto. (In Japanese with English summary).

Matsui, A., and Kanehara, M., 2006. Diet and Subsistence Patterns during the Jomon Period in Japan. *Journal of Anthropological Archaeology, 25*(2), pp. 290-310.

Matsumura H, Hudson M., 2005. Dental perspectives on the population history of Southeast Asia. *American Journal of Physical Anthropology 127*:182–209.

Matsumura, H., 2007. Non-metric dental trait variation among local sites and regional groups of the Neolithic Jomon period, Japan. *Anthropology. Sci. 115*, 25–33

Matsumura, H., Ishida, H., Amano, T., Ono, H. & Yoneda, M., 2009. Biological affinities of Okhotsk-culture people with East Siberians and Arctic people based on dental characteristics. *Anthropology. Sci. 117*, 121–132

Mazza, B., & Silva, A.M., 2023. Analyzing entheseal changes in commingled human remains from Mesolithic and Neolithic periods in Portugal. *International Journal of Osteoarchaeology*.

McColl, H., Racimo, F., Vinner, L., Demeter, F., Gakuhari, T., Moreno-Mayar, J. V., ... & Wasef, S., 2018. The prehistoric peopling of *Southeast Asia. Science, 361*(6397), 88-92.

McDonald, J.H., 2014. Handbook of Biological Statistics. 3rd Edition, Sparky House Publishing, Baltimore.

McGill, n.d. Mean curvature extraction code of Dao McGill.

Meyer C, Nicklisch N, Held P, Fritsch B, Alt KW., 2011. Tracing patterns of activity in the human skeleton: An overview of methods, problems, and limits of interpretation. *Homo 62*:202–217.

Michopoulou E., Nikita E., Valakos E.D., 2015. Evaluating the efficiency of different recording protocols for entheseal changes in regards to expressing activity patterns using archival data and cross-sectional geometric properties. *American Journal of Physical Anthropology 158*:557–568.

Michopoulou E., Nikita E., Henderson C.Y., 2016. A Test of the Effectiveness of the Coimbra Method in Capturing Activity-induced Entheseal Changes. *International Journal of Osteoarchaeology 27*:409–417.

Miyao, K., 1968. "Material Culture of the Yayoi Period in Northern Kyushu." *Journal of East Asian Archaeology 11* (3): 201-219.

Mizoguchi, K., 2005. Genealogy in the ground: observations of jar burials of the Yayoi period, northern Kyushu, Japan. *Antiquity*, *79*(304), 316–326.

Mizoguchi K., 2017. The Archaeology of Japan. Cambridge, UK: Cambridge University Press.

Mizoguchi, K., 2020. Making Sense of Material Culture Transformation: A Critical Long-Term Perspective from Jomon- and Yayoi-Period Japan. *Journal of World Prehistory*, *33*(1), 1-23.

Mizushima, S., Suwa, G., & Hirata, K., 2016. A comparative analysis of fetal to subadult femoral midshaft bone distribution of prehistoric Jomon hunter-gatherers and modern Japanese. *Anthropological Science, 124*, 1-15.

Mizushima, S., & Hirata, K., 2023. Limb segment proportions of prehistoric Jomon hunter-gatherers from fetal life to adolescence: comparison with four other chronological groups from Japan. *Anthropological Science*.

Nagaoka, T., 2007. Demographic Structure of the Human Skeletal Remains from the Ikenohata-Shichikencho Site, Tokyo. Bulletin of the National Museum of Nature and Science, Ser. D, 33, 21–38.

Nagaoka, T., Seike, H., Hoshino, K., & Hirata, K., 2018. Variation in cranial shape in medieval Japanese from Kamakura City. *Anthropological Science, 126*(2), 101-109.

Nakagawa, R., Doi, N., Nishioka, Y., Nunami, S., Yamauchi, H., Fujita, M., Yamazaki, S., Yamamoto, M., Katagiri, C., Mukai, H. and Matsuzaki, H., 2010. Pleistocene human remains from Shiraho-Saonetabaru Cave on Ishigaki Island, Okinawa, Japan, and their radiocarbon dating. *Anthropological Science*, *118*(3), pp.173-183.

Nakagome, S., Sato, T., Ishida, H., Hanihara, T., Yamaguchi, T., Kimura, R., Mano, S., Oota, H. and Asian DNA Repository Consortium, 2015. Model-based verification of hypotheses on the origin of modern Japanese revisited by Bayesian inference based on genome-wide SNP data. *Molecular Biology and Evolution*, *32*(6), pp.1533-1543.

Nakahashi, T., 1981. Nagaoka Yayoi Site, Chikushino City. Fukuoka City: Chikushino City Board of Education. In Japanese.

Nakahashi, T. 1990. Yayoi Period Human Remains from Nagaoka Site. Chikushino City: Chikushino City Board of Education. In Japanese.

Nakahashi T, Iizuka M., 2008. Anthropological Study of the Transition from the Jomon to the Yayoi Periods in the Northern Kyushu Using Morphological and Paleodemographical Features (2). *Anthropological Science (Japanese Series) 116*:131–143.

Nakao, H., Kaneda, A., Tamura, K., Noshita, K., & Nakagawa, T., 2024. Macro-Scale Population Patterns in the Kofun Period of the Japanese Archipelago: Quantitative Analysis of a Larger Sample of Three-Dimensional Data from Ancient Human Crania. *Humans*, *4*(2), 131-147.

Nakashima, A., Ishida, H., Shigematsu, M., Goto, M. & Hanihara, T., 2010. Nonmetric cranial variation of Jomon Japan: Implications for the evolution of Eastern Asian diversity. *Amer. J. Hum. Biol. 22*, 782–790.

Nakazawa, Y., 2017. On the Pleistocene population history in the Japanese Archipelago. *Curr. Anthropology. 58* (S17), S539–S551.

Nakazawa, Y., & Bae, C. J., 2018. Quaternary paleoenvironmental variation and its impact on initial human dispersals into the Japanese Archipelago. *Palaeogeography, palaeoclimatology, palaeoecology, 512*, 145-155.

Nasu, H., & Momohara, A., 2016. The beginnings of rice and millet agriculture in prehistoric Japan. *Quaternary International, 397*, 504-512.

Niinimäki S., 2011. What do muscle marker ruggedness scores actually tell us? *International Journal of Osteoarchaeology 21* (3), 292–299.

Niinimäki S., Niskanen M., Niinimäki J., Nieminen M., Tuukkanen J., Junno J-A., 2013. Modeling skeletal traits and functions of the upper body: Comparing archaeological and anthropological material. Journal of Anthropological Archaeology 32:347–351.

Nikita, E., Xanthopoulou, P., Bertsatos, A., Chovalopoulou, M.E. and Hafez, I., 2019. A three-dimensional digital microscopic investigation of entheseal changes as skeletal activity markers. *American journal of physical anthropology*, *169*(4), pp.704-713.

Nishihara, H., 1988. Uki Kaizuka no Doubutsu Izontai Chousa Houkoku (Report on the Animal Remains from the Uki Shell Mound). Isahaya City Cultural Property Report 8: 1-15. Nagasaki. In Japanese.

Nishizawa, T., 1978. Human skeletons from the Tochibara rockshelter site: its burial pattern and physical characters. In: [AANP] Archaeological Association of Nagano Prefecture, editor. Nagano: Archaeological Association of Nagano Prefecture. p 94–104. In Japanese.

Nishizawa, T., 1982. The Tochibara rockshelter site. In: Nagano Prefecture, editor. History of Nagano Prefecture (Nagano kenshi), archaeological material 1(2): main sites (northern and eastern Shinshu). Nagano: Nagano prefecture. p 559–84. In Japanese.

Noldner, L.K. and Edgar, H.J., 2013. 3D representation and analysis of enthesis morphology. *American journal of physical anthropology*, *152*(3), pp.417-424.

Nolte, M. and Wilczak, C., 2013. Three-dimensional surface area of the distal biceps enthesis, relationship to body size, sex, age and secular changes in a 20th century American sample. *International Journal of Osteoarchaeology*, *23*(2), pp.163-174.

Normile, D., 2019. Update: explorers successfully voyage to Japan in primitive boat in bid to unlock an ancient mystery. Available at: https://www.sciencemag.org/news/2019/07/explorers-voyage-japan-primitive-boat-hopes-unlocking-ancient-mystery

Norton, C.J., Jin, J., 2009. The evolution of modern humans in East Asia: behavioral perspectives. *Evol. Anthropology. 18*, 247–260.

Norton, C.J., Kondo, Y., Ono, A., Zhang, Y. and Diab, M.C., 2010. The nature of megafaunal extinctions during the MIS 3–2 transition in Japan. *Quaternary International*, *211*(1-2), pp.113-122.

Omoto K, Saitou N., 1997. Genetic origins of the Japanese: partial support for the dual structure hypothesis. *Am J Phys Anthropology 102*:437–446.

Oomi Y, editor., 1984. Excavation report of the Tochibara Rockshelter site in 1983. Matsumoto: Shinshu University. p 82. In Japanese.

Osada, N. & Kawai, Y., 2021. Exploring models of human migration to the Japanese archipelago using genome-wide genetic data. *Anthropological Science*, *1*, 45–58.

Osaka Prefectural Board of Education., 2013. Hayashi and Kou Sites: Excavation Report on Traffic Safety Project. Osaka, Japan: Osaka Prefectural Government. In Japanese.

Palmer, J.L.A., Quintelier, K., Inskip, S. and Waters-Rist, A.L., 2019. A comparison of two methods for recording entheseal change on a post-medieval urban skeletal collection from Aalst (Belgium). *Archaeometry*, *61*(1), pp.211-225.

Pelletier, M., Kotiaho, A., Niinimäki, S. and Salmi, A.K., 2020. Identifying early stages of reindeer domestication in the archaeological record: a 3D morphological investigation on forelimb bones of modern populations from Fennoscandia. *Archaeological and Anthropological Sciences*, *12*(8), pp.1-25.

Perez-Arzak, U., Villotte, S., Arrizabalaga, A., & Trancho, G. J., 2022. Looking for the most suitable method for the study of entheseal changes: Application to upper limb's fibrocartilaginous entheses in a human medieval sample. *International Journal of Osteoarchaeology*, *32*(3), 595-606.

Peyrin, F., Salome, M., Nuzzo, S., Cloetens, P., Laval-Jeantet, A.M. and Baruchel, J., 2000. Perspectives in three-dimensional analysis of bone samples using synchrotron radiation microtomography. *Cellular and molecular biology (Noisy-le-Grand, France)*, *46*(6), p.1089.

Pinson, 2024. Sketchfab

Pistoia, W., Van Rietbergen, B., Laib, A. and Ru¨ egsegger, P., 2001. High-resolution three-dimensional-pQCT images can be an adequate basis for in-vivo µFE analysis of bone. *J. Biomech. Eng.*, *123*(2), pp.176-183.

Podshivalov, L., Fischer, A. and Bar-Yoseph, P.Z., 2011. 3D hierarchical geometric modeling and multiscale FE analysis as a base for individualized medical diagnosis of bone structure. *Bone*, *48*(4), pp.693-703.

Price TD, Gebauer AB., 2007. New Perspectives on the Transition to Agriculture. In: Price TD, Gebauer AB, editors. *Last hunters - first farmers: new perspectives on the prehistoric transition to agriculture.* Santa Fe (N.M.): School of American Research Press.

Rabey KN, Green DJ, Taylor AB, Begun DR, Richmond BG, Mcfarlin SC., 2015. Locomotor activity influences muscle architecture and bone growth but not muscle attachment site morphology. *Journal of Human Evolution 78*:91–102.

Rhode MP., 2012. Entheseal Change. In: Mann RW, Hunt DR, editors. *Photographic Regional Atlas of Bone Disease: A Guide to Pathologic and Normal Variation in the Human Skeleton*, Springfield: Charles C. Thomas Publisher, Ltd. p. 203-211

Robb, J.E., 1998. The interpretation of skeletal muscle sites: a statistical approach. *International Journal of Osteoarchaeology*, *8*(5), pp.363-377.

Roberts CA, Manchester K. 2010. The archaeology of disease. Stroud: The History Press.

Rowley-Conwy, P., 1984. Postglacial foraging and early farming economies in Japan and Korea: a west European perspective. *World archaeology*, *16*(1), pp.28-42.

Saitou, N., 2005. DNA karamita Nihonjin [DNA derived from the Japanese]. Tokyo: Chikuma-Shobo. In Japanese.

Sakaguchi, T., 2009. Storage adaptations among hunter–gatherers: A quantitative approach to the Jomon period. *Journal of Anthropological Archaeology, 28*, 290-303.

Salmi, A.K. and Niinimäki, S., 2016. Entheseal changes and pathological lesions in draught reindeer skeletons–Four case studies from present-day Siberia. *International Journal of paleopathology*, *14*, pp.91-99.

Sano, K., and Watanabe, M., 1971. "Musculoskeletal Stress Markers among Yayoi Populations: Insights from Ichinotani and Related Sites." Bulletin of the National Museum of Japanese History 4: 23-47.

Sansoni, G., Cattaneo, C., Trebeschi, M., Gibelli, D., Porta, D. and Picozzi, M., 2009. Feasibility of contactless 3D optical measurement for the analysis of bone and soft tissue lesions: new technologies and perspectives in forensic sciences. *Journal of forensic sciences*, *54*(3), pp.540-545.

Santana-Cabrera J, Velasco-Vázquez J, Rodríguez-Rodríguez A., 2015. Entheseal changes and sexual division of labor in a North-African population: The case of the pre-Hispanic period of the Gran Canaria Island (11th–15th c. CE). *Homo 66*:118–138.

Sartori, J. and Stark, H., 2020. Tracking tendon fibers to their insertion–a 3D analysis of the Achilles tendon enthesis in mice. *Acta Biomaterialia*.

Schmidt, R. W., Seguchi, N., 2014. Jomon Culture and the peopling of the Japanese archipelago: advancements in the fields of morphometrics and ancient DNA. *Japanese Journal of Archaeology, 2*: 34-59.

Schrader, S.A., 2012. Activity patterns in New Kingdom Nubia: An examination of entheseal remodeling and osteoarthritis at Tombos. *American Journal of Physical Anthropology*, *149*(1), pp.60-70.

Schrader, S.A., 2015. Elucidating inequality in Nubia: An examination of entheseal changes at Kerma (Sudan). *American Journal of Physical Anthropology*, *156*(2), pp.192-202.

Schünke, M., Ross, L.M., Schulte, E., Schumacher, U. and Lamperti, E.D., 2010. *General anatomy and musculoskeletal system*. Thieme.

Seidel, R., Gourrier, A., Kerschnitzki, M., Burghammer, M., Fratzl, P., Gupta, H.S. and Wagermaier, W., 2012. Synchrotron 3D SAXS analysis of bone nanostructure. *Bioinspired, Biomimetic and Nanobiomaterials*, *1*(2), pp.123-131.

Servick, K., 2019. Paddlers to replicate ancient voyage. *Science 365*: 10–11.

Shafer, D.S. and Zhang, Z., 2012. *Introductory statistics*. Washington, DC: Saylor Foundation.

Shamami, D.Z., Karimi, A., Beigzadeh, B., Haghpanahi, M. and Navidbakhsh, M., 2014. A 3D finite element study for stress analysis in bone tissue around single implants with different materials and various bone qualities. *Journal of Biomaterials and Tissue Engineering*, *4*(8), pp.632-637.

Shigehara N., 1994. Human skeletal remains of the Middle to Late Jomon period excavated from the inland Kitamura site, Nagano Prefecture. *Anthropological Science, 102* (4): 321-344.

Shuler, K., Zeng, P., & Danforth, M., 2012. Upper limb entheseal change with the transition to agriculture in the southeastern United States: A view from Moundville and the central Tombigbee River valley. *HOMO - Journal Of Comparative Human Biology, 63*(6), 413-434.

Sick, J., 2021. Entheseal changes: Benefits, limitations and applications in bioarchaeology. *Pathways*, *2*(1), 14-35.

Sparacello, V.S., Samsel, M., Villotte, S., Varalli, A., Schimmenti, V. and Sineo, L., 2020. Inferences on Sicilian Mesolithic subsistence patterns from cross-sectional geometry and entheseal changes. *Archaeological and Anthropological Sciences*, *12*, pp.1-21.

Suzuki T., 1998. Indicators of stress in prehistoric Jomon skeletal remains in Japan. *Anthropological Science, 106*: 127-137.

Takahashi, R., 2009. Symbiotic relations between paddy-field rice cultivators and hunter-gatherer-fishers in Japanese prehistory: archaeological considerations on the transition from the Jomon Age to the Yayoi Age. *In: Ikeyea K, Ogawa H, Mitchell P (eds) Interactions between hunter-gatherers and farmers: from prehistory to present. Senri Ethnological Studies 73. National Museum of Ethnology, Osaka* 71-98

Takamiya, H., 2002 Introductory Routes of Rice to Japan: An Examination of the Southern Route Hypothesis. *Asian Perspectives* 40(2): 209-226

Takamuku, H., 2019. Does obstetric protection apply to small-bodied females?: A comparison between small-bodied Jomon foragers and large-bodied Yayoi agriculturalists in the prehistoric Japanese archipelago. *American Journal of Human Biology, 31*(3), e23236.

Takigawa W., 2014. Age changes of musculoskeletal stress markers and their inter-period comparisons. *Anthropological Science, 122* (1): 7-22.

Thali, M.J., Braun, M. and Dirnhofer, R., 2003. Optical 3D surface digitizing in forensic medicine: 3D documentation of skin and bone injuries. *Forensic science international*, *137*(2-3), pp.203-208.

Temple, D. H., Auerbach, B. M., Nakatsukasa, M., Sciulli, P. W., Larsen, C. S., 2008. Variation in limb proportions between Jomon foragers and Yayoi agriculturalists from prehistoric Japan. *American Journal of Physical Anthropology, 137*: 164-174.

Temple, D H., and Matsumura H., 2011. "Do Body Proportions Among Jomon Foragers From Hokkaido Conform To Ecogeographic Expectations? Evolutionary Implications Of Body Size And Shape Among Northerly Hunter-Gatherers". *International Journal Of Osteoarchaeology 21* (3): 268-282.

Tsuboi, T. 1965. 熊本県貝塚の研究 [Study of Shell Middens in Kumamoto Prefecture]. 熊本県教育委員会, 熊本, Japan.

Tsude H., 2008. [FORAGERS AND FARMERS IN THE JAPANESE ISLANDS] Yayoi farmers reconsidered: new perspectives on agricultural development in East Asia. Bulletin of the Indo-Pacific Prehistory Association 21.

Tsutaya, T., Nagaoka, T., Kakinuma, Y., Kondo, O., & Yoneda, M., 2015. The diet of townspeople in the city of Edo: Carbon and nitrogen stable isotope analyses of human skeletons from the Ikenohata-Shichikencho site. *Anthropological Science. 124*.

Tsutsumi, T., 2012. "MIS3 edge-ground Axes and the Arrival of the First Homo Sapiens in the Japanese Archipelago." *Quaternary International* 248: 70–78.

Turmezei, T.D., Treece, G.M., Gee, A.H., Fotiadou, A.F. and Poole, K.E., 2016. Quantitative 3D analysis of bone in hip osteoarthritis using clinical computed tomography. *European Radiology*, *26*(7), pp.2047-2054.

Turner, C. G. II, 1987. Late Pleistocene and Holocene population history of East Asia based on dental variation. *Amer. J. Phys. Anthropology. 73*, 305–321

Turner, C.G. II, 1990. Major features of Sundadonty and Sinodonty, including suggestions about East Asian microevolution, population history, and late Pleistocene relationships with Australian Aboriginals. *American Journal of Physical Anthropology 82*: 295–317.

Uemine, A., 2014. Phenocrysts microscopic observation method to distinguish artifacts from geofacts: a case study from Sunabara site, Japan. *Palaeolithic Archaeology 79,* 1–16 (In Japanese with English summary).

van der Pas, S., & Schrader, S., 2023. Toward standardization of statistical reporting in studies on entheseal changes. *International Journal of Osteoarchaeology*, *33*(3), 475-478.

Varley, P.H., 2000. Japanese Culture. Honolulu: Univ. of Hawai'i Press.

Villotte S., Castex D., Couallier V., Dutour O., Knusel C.J., Henry-Gambier D., 2009. Enthesopathies as occupational stress markers: Evidence from the upper limb. *American Journal of Physical Anthropology*.

Villotte, S., Polet, C., Colard, C., & Santos, F., 2022. Entheseal changes and estimation of adult age-at-death. *American Journal of Biological Anthropology*, *178*(2), 201-204.

Wallace IJ, Winchester JM, Su A, Boyer DM, Konow N., 2017. Physical activity alters limb bone structure but not entheseal morphology. *Journal of Human Evolution 107*:14–18.

Waku, D., Gakuhari, T., Koganebuchi, K., Yoneda, M., Kondo, O., Masuyama, T., Yamada, Y. and Oota, H., 2022. Complete mitochondrial genome sequencing reveals double-buried Jomon individuals excavated from the Ikawazu shell-mound site were not in a mother–child relationship. *Anthropological Science*, *130*(1), pp.39-45.

Watanabe, T., Wada, Y., & Kanda, S., 1982. A report on the excavated skulls of the Edo-period from the Tsubue site of Kurashiki City in Okayama Prefecture. *Journal of the Anthropological Society of Nippon, 90*, 61-71. (In Japanese with English summary).

Watanabe, Y., Naka, I., Khor, S. S., Sawai, H., Hitomi, Y., Tokunaga, K., & Ohashi, J., 2019. Analysis of whole Y-chromosome sequences reveals the Japanese population history in the Jomon period. *Scientific reports, 9*(1), 8556.

Weber, A.W., Jordan, P. and Kato, H., 2013. Environmental change and cultural dynamics of Holocene hunter–gatherers in Northeast Asia: Comparative analyses and research potentials in Cis-Baikal (Siberia, Russia) and Hokkaido (Japan). *Quaternary International*, *290*, pp.3-20.

Weisberg, H., 1992. *Central tendency and variability* (No. 83). Sage.

White, J.A., Burgess, G.H., Nakatsukasa, M., Hudson, M.J., Pouncett, J., Kusaka, S., Yoneda, M., Yamada, Y. and Schulting, R.J., 2021. 3000-year-old shark attack victim from Tsukumo shell-mound, Okayama, Japan. *Journal of Archaeological Science: Reports*, *38*, p.103065.

Whitman, J., 2012 Northeast Asian Linguistic Ecology and the Advent of Rice Agriculture in Korea and Japan. *Rice* 4: 149-158

Yamaguchi B., 1989. Limb segment proportions in human skeletal remains of the Jomon period. Bulletin of the National Science Museum Series D, 15: 41–48.

Yamaguchi Prefecture Tohoku Town, 1997. Doigahama Site: The 15th Excavation Report. Yamaguchi Prefecture Cultural Heritage Division. In Japanese.

Yamaguchi Prefecture Tohoku Town ,1999. Doigahama Site: The 17th Excavation Report. Yamaguchi Prefecture Cultural Heritage Division. In Japanese.

Yamaguchi Prefecture Tohoku Town, 2001. Doigahama Site: The 18th Excavation Report. Yamaguchi Prefecture Cultural Heritage Division. In Japanese.

Yamaguchi Prefecture Tohoku Town, 2002. Doigahama Site: The 19th Excavation Report. Yamaguchi Prefecture Cultural Heritage Division. In Japanese.

Yamaoka, T., 2010. Transitions in the early Upper Palaeolithic: an examination of lithic assemblages on the Musashino Upland, Tokyo, Japan. *Asian Perspectives 49*:251–277.

Yamamoto, K., Namba, S., Sonehara, K., Suzuki, K., Sakaue, S., Cooke, N. P., Higashiue, S., Kobayashi, S., Afuso, H., Matsuura, K., Mitsumoto, Y., Fujita, Y., Tokuda, T., Biobank Japan Project, Matsuda, K., Gakuhari, T., Yamauchi, T., Kadowaki, T., Nakagome, S., & Okada, Y., 2024. Genetic legacy of ancient hunter-gatherer Jomon in Japanese populations. *Nature communications*, *15*(1), 9780.

Yamanouchi, S., 1964. Late Jomon Pottery and its Implications for Social Organization. Tokyo: Japanese Archaeological Review.

Yoneda, M., Yoshida K., Yoshinaga J., Morita M., Akazawa T., 1996. Reconstruction of palaeodiet in Nagano Prefecture based on the carbon and nitrogen isotope analysis and the trace elemental analysis. *The Quaternary Research (Daiyonki-kenkyu) 35*(4):293–303. In Japanese with English summary.

Yoneda, M., Hirota, M., Uchida, M., Tanaka, A., Shibata, Y., Morita, M., & Akazawa, T., 2002. Radiocarbon and stable isotope analyses on the Earliest Jomon skeletons from the Tochibara rockshelter, Nagano, Japan. *Radiocarbon*, *44*(2), 549-557.

Yonemoto, S., 2016. Differences in the effects of age on the development of entheseal changes among historical Japanese populations. *American Journal of Physical Anthropology, 159*: 267-283.

Zou, R., Xing, H., Sun, X., Kong, S., Wang, L., Zhang, Z., Zhang, Q., & Wang, Q., 2024. Patterns of entheseal changes and other activity markers in an ancient population from Neolithic to Bronze Age (8000–2300 BP) at the Houtaomuga site, Northeast China with special references to climate changes, subsistence strategies, sex-based labor divisions, and regional variations. *International Journal of Osteoarchaeology*, 34(5), e3335.

Zaza, E., and Ikawa-Smith, F., 1984. Jomon Economy and Rituals. *Current Anthropology, 25*(3), pp. 321-342.

Table 48: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Ikenohata-shichikencho.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	204	396
Biceps brachii (o-long head)	166	345
Triceps brachii (o-long head)	180	341
Pectoralis minor	88	256
Trapezius	147	300
Supraspinatus	82	261
Infraspinatus	126	274
Teres minor	191	245
Common extensors	214	365
Common flexors	166	350
Subscapularis	100	291
Teres major	199	431
Pectoralis major	238	432
Deltoideus	230	432
Latissimus dorsi	236	428
Triceps brachii	194	394
Brachialis	242	425
Anconeus	139	405
Supinator	256	424
Biceps brachii	208	418
Brachioradialis	147	276
Pronator quadratus	143	417
Pronator teres	169	428
Supinator	322	424
Gluteus maximus	323	430
Adductor magnus	204	432
Vastus medialis	192	430

Vastus lateralis	204	346
Gluteus medius	120	317
Gluteus minimus	119	289
Gastrocnemius	88	191
Iliacus	165	401
Iliopsoas	127	331
Total	5929	11925
Percentage	50%	

Table 49: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Ikenohata-shichikencho.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	166	345
Triceps brachii	180	341
Common flexors	166	350
Common extensors	214	365
Triceps brachii	194	394
Biceps brachii	208	418
Total	1128	2213
Percentage	51%	

Table 50: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Ikenohata-shichikencho.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	194	394
Gastrocnemius	88	191
Total	282	585
Percentage	48%	

Table 51: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Ikenohata-shichikencho.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	88	191
Brachioradialis	147	276
Pronator teres	169	428
Supinator	322	424
Supinator	256	424
Total	982	1743
Percentage	56%	

Table 52: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Ikenohata-shichikencho.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	194	394
Supinator	322	424
Supinator	256	424
Pronator quadratus	143	417
Pronator teres	169	428
Total	1084	2087
Percentage	52%	

Table 53: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Ikenohata-shichikencho.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	214	365
Common flexors	166	350
Supinator	322	424
Supinator	256	424
Biceps brachii	208	418
Brachioradialis	147	276
Pronator quadratus	143	417
Pronator teres	169	428
Iliacus	165	401
Iliopsoas	127	331
Gastrocnemius	88	191
Total	2005	4025
Percentage	50%	

Table 54: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Tochibara Iwakage.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	2	10
Biceps brachii (o-long head)	0	3
Triceps brachii (o-long head)	1	1
Pectoralis minor	1	3
Trapezius	1	2
Supraspinatus	0	1
Infraspinatus	1	1
Teres minor	0	1
Common extensors	4	6
Common flexors	3	7
Subscapularis	1	2
Teres major	1	9

Pectoralis major	6	9
Deltoideus	5	9
Latissimus dorsi	2	9
Triceps brachii	2	4
Brachialis	0	6
Anconeus	1	3
Supinator	1	4
Biceps brachii	4	7
Brachioradialis	0	0
Pronator quadratus	2	5
Pronator teres	3	7
Supinator	7	7
Gluteus maximus	7	8
Adductor magnus	4	9
Vastus medialis	4	9
Vastus lateralis	2	6
Gluteus medius	0	5
Gluteus minimus	0	4
Gastrocnemius	0	2
Iliacus	0	6
Iliopsoas	0	1
Total	65	166
Percentage	39%	

Table 55: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Tochibara Iwakage.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	0	3
Triceps brachii	1	1
Common flexors	3	7
Common extensors	4	6
Triceps brachii	2	4
Biceps brachii	4	7
Total	14	28
Percentage		50%

Table 56: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Tochibara Iwakage.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	2	4
Gastrocnemius	0	2
Total	2	6
Percentage		33%

Table 57: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Tochibara Iwakage.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	0	2
Brachioradialis	0	0
Pronator teres	3	7
Supinator	7	7
Supinator	1	4
Total	11	20
Percentage	55%	

Table 58: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Tochibara Iwakage.

Metalworking		
Muscles	Over breakpoint	Total
V73	2	4
V103	7	7
V85	1	4
V97	2	5
V101	3	7
Total	15	27
Percentage	56%	

Table 59: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Tochibara Iwakage.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	4	6
Common flexors	3	7
Supinator	7	7
Supinator	1	4
Biceps brachii	4	7
Brachioradialis	0	0
Pronator quadratus	2	5
Pronator teres	3	7

Iliacus	0	6
Iliopsoas	0	1
Gastrocnemius	0	2
Total	24	52
Percentage	46%	

Table 60: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Kou.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	0	5
Biceps brachii (o-long head)	0	1
Triceps brachii (o-long head)	0	2
Pectoralis minor	0	1
Trapezius	0	1
Supraspinatus	0	2
Infraspinatus	0	3
Teres minor	0	4
Common extensors	1	7
Common flexors	4	8
Subscapularis	0	2
Teres major	1	9
Pectoralis major	6	8
Deltoideus	2	8
Latissimus dorsi	2	9
Triceps brachii	0	6
Brachialis	2	10
Anconeus	1	7
Supinator	2	10
Biceps brachii	2	6
Brachioradialis	0	2
Pronator quadratus	0	6
Pronator teres	0	8
Supinator	2	8

Gluteus maximus	9	12
Adductor magnus	1	11
Vastus medialis	2	12
Vastus lateralis	3	9
Gluteus medius	0	6
Gluteus minimus	1	8
Gastrocnemius	0	3
Iliacus	1	12
Iliopsoas	2	8
Total	44	214
Percentage		21%

Table 61: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Kou.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	0	1
Triceps brachii	0	2
Common flexors	4	8
Common extensors	1	7
Triceps brachii	0	6
Biceps brachii	2	6
Total	7	30
Percentage		23%

Table 62: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Kou.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	0	6
Gastrocnemius	0	3
Total	0	9
Percentage	0%	

Table 63: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Kou.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	0	3
Brachioradialis	0	2
Pronator teres	0	8
Supinator	2	8
Supinator	2	10
Total	4	31
Percentage	13%	

Table 64: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Kou.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	0	6
Supinator	2	8
Supinator	2	10
Pronator quadratus	0	6
Pronator teres	0	8
Total	4	38
Percentage	11%	

Table 65: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Kou.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	1	7
Common flexors	4	8
Supinator	2	8
Supinator	2	10
Biceps brachii	2	6
Brachioradialis	0	2
Pronator quadratus	0	6
Pronator teres	0	8
Iliacus	1	12
Iliopsoas	2	8
Gastrocnemius	0	3
Total	14	78
Percentage	18%	

Table 66: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Ota.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	5	30
Biceps brachii (o-long head)	11	25
Triceps brachii (o-long head)	10	20
Pectoralis minor	4	15
Trapezius	0	1
Supraspinatus	7	31
Infraspinatus	19	32
Teres minor	8	37
Common extensors	25	44
Common flexors	13	48
Subscapularis	10	33
Teres major	14	47

Pectoralis major	27	48
Deltoideus	22	55
Latissimus dorsi	19	50
Triceps brachii	8	45
Brachialis	36	63
Anconeus	9	46
Supinator	25	62
Biceps brachii	15	46
Brachioradialis	0	9
Pronator quadratus	2	41
Pronator teres	20	46
Supinator	10	44
Gluteus maximus	69	**71**
Adductor magnus	30	60
Vastus medialis	38	71
Vastus lateralis	26	41
Gluteus medius	9	49
Gluteus minimus	28	49
Gastrocnemius	10	22
Iliacus	7	60
Iliopsoas	6	47
Total	542	1388
Percentage	39%	

Table 67: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Ota.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	11	25
Triceps brachii	10	20
Common flexors	13	48
Common extensors	25	44
Triceps brachii	8	45
Biceps brachii	15	46
Total	82	228
Percentage	36%	

Table 68: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Ota.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	8	45
Gastrocnemius	10	22
Total	18	67
Percentage	27%	

Table 69: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Ota.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	10	22
Brachioradialis	0	9
Pronator teres	20	46
Supinator	10	44
Supinator	25	62
Total	65	183
Percentage	36%	

Table 70: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Ota.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	8	45
Supinator	10	44
Supinator	25	62
Pronator quadratus	2	41
Pronator teres	20	46
Total	65	238
Percentage	27%	

Table 71: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Ota.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	25	44
Common flexors	13	48
Supinator	10	44
Supinator	25	62
Biceps brachii	15	46
Brachioradialis	0	9
Pronator quadratus	2	41
Pronator teres	20	46
Iliacus	7	60
Iliopsoas	6	47
Gastrocnemius	10	22
Total	133	469
Percentage	28%	

Table 72: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Hikosaki.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	1	5
Biceps brachii (o-long head)	1	2
Triceps brachii (o-long head)	0	3
Pectoralis minor	0	1
Trapezius	0	0
Supraspinatus	0	3
Infraspinatus	0	2
Teres minor	0	3
Common extensors	1	5
Common flexors	2	6
Subscapularis	1	3
Teres major	1	6
Pectoralis major	3	6
Deltoideus	2	6
Latissimus dorsi	2	6
Triceps brachii	0	4
Brachialis	0	4
Anconeus	0	2
Supinator	1	4
Biceps brachii	2	5
Brachioradialis	1	1
Pronator quadratus	2	4
Pronator teres	0	5
Supinator	2	5
Gluteus maximus	5	8
Adductor magnus	1	8
Vastus medialis	3	8
Vastus lateralis	1	4

Gluteus medius	0	4
Gluteus minimus	0	4
Gastrocnemius	1	3
Iliacus	1	7
Iliopsoas	0	4
Total	34	141
Percentage	24%	

Table 73: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Hikosaki.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	1	2
Triceps brachii	0	3
Common flexors	2	6
Common extensors	1	5
Triceps brachii	0	4
Biceps brachii	2	5
Total	6	25
Percentage	24%	

Table 74: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Hikosaki.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	0	4
Gastrocnemius	1	3
Total	1	7
Percentage	14%	

Table 75: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Hikosaki.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	1	3
Brachioradialis	1	1
Pronator teres	0	5
Supinator	2	5
Supinator	1	4
Total	5	18
Percentage		28%

Table 76: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Hikosaki.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	0	4
Supinator	2	5
Supinator	1	4
Pronator quadratus	2	4
Pronator teres	0	5
Total	5	22
Percentage		23%

Table 77: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Hikosaki.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	1	5
Common flexors	2	6
Supinator	2	5
Supinator	1	4
Biceps brachii	2	5
Brachioradialis	1	1
Pronator quadratus	2	4
Pronator teres	0	5

Iliacus	1	7
Iliopsoas	0	4
Gastrocnemius	1	3
Total	13	49
Percentage	27%	

Table 78: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Ropponmatsu.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	0	2
Biceps brachii (o-long head)	0	2
Triceps brachii (o-long head)	0	2
Pectoralis minor	0	2
Trapezius	0	0
Supraspinatus	0	2
Infraspinatus	0	2
Teres minor	0	2
Common extensors	0	2
Common flexors	0	1
Subscapularis	0	2
Teres major	0	2
Pectoralis major	0	2
Deltoideus	0	2
Latissimus dorsi	0	2
Triceps brachii	1	2
Brachialis	0	2
Anconeus	0	2
Supinator	0	2
Biceps brachii	0	1
Brachioradialis	0	0
Pronator quadratus	0	2
Pronator teres	0	2
Supinator	1	2

Gluteus maximus	2	2
Adductor magnus	2	2
Vastus medialis	0	2
Vastus lateralis	1	2
Gluteus medius	0	2
Gluteus minimus	0	1
Gastrocnemius	0	2
Iliacus	0	2
Iliopsoas	0	2
Total	7	59
Percentage	12%	

Table 79: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Ropponmatsu.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	0	2
Triceps brachii	0	2
Common flexors	0	1
Common extensors	0	2
Triceps brachii	1	2
Biceps brachii	0	1
Total	1	10
Percentage	10%	

Table 80: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Ropponmatsu.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	1	2
Gastrocnemius	0	2
Total	1	4
Percentage	25%	

Table 81: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Ropponmatsu.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	0	2
Brachioradialis	0	0
Pronator teres	0	2
Supinator	1	2
Supinator	0	2
Total	1	8
Percentage	13%	

Table 82: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Ropponmatsu.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	1	2
Supinator	1	2
Supinator	0	2
Pronator quadratus	0	2
Pronator teres	0	2
Total	2	10
Percentage	20%	

Table 83: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Ropponmatsu.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	0	2
Common flexors	0	1
Supinator	1	2
Supinator	0	2
Biceps brachii	0	1
Brachioradialis	0	0
Pronator quadratus	0	2
Pronator teres	0	2
Iliacus	0	2
Iliopsoas	0	2
Gastrocnemius	0	2
Total	1	18
Percentage	6%	

Table 84: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Wakaumi.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	2	2
Biceps brachii (o-long head)	2	2
Triceps brachii (o-long head)	0	2
Pectoralis minor	1	1
Trapezius	2	2
Supraspinatus	0	2
Infraspinatus	0	2
Teres minor	0	2
Common extensors	2	2
Common flexors	2	2
Subscapularis	2	2
Teres major	1	2

Pectoralis major	2	2
Deltoideus	2	2
Latissimus dorsi	2	2
Triceps brachii	1	2
Brachialis	0	2
Anconeus	0	2
Supinator	1	2
Biceps brachii	1	1
Brachioradialis	0	0
Pronator quadratus	2	2
Pronator teres	1	2
Supinator	2	2
Gluteus maximus	2	2
Adductor magnus	1	2
Vastus medialis	0	2
Vastus lateralis	2	2
Gluteus medius	2	2
Gluteus minimus	0	2
Gastrocnemius	0	2
Iliacus	0	2
Iliopsoas	0	2
Total	35	62
Percentage	56%	

Table 85: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Wakaumi.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	2	2
Triceps brachii	0	2
Common flexors	2	2
Common extensors	2	2
Triceps brachii	1	2
Biceps brachii	1	1
Total	8	11
Percentage	73%	

Table 86: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Wakaumi.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	1	2
Gastrocnemius	0	2
Total	1	4
Percentage	25%	

Table 87: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Wakaumi.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	0	2
Brachioradialis	0	0
Pronator teres	1	2
Supinator	2	2
Supinator	1	2
Total	4	8
Percentage	50%	

Table 88: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Wakaumi.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	1	2
Supinator	2	2
Supinator	1	2
Pronator quadratus	2	2
Pronator teres	1	2
Total	7	10
Percentage	70%	

Table 89: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Wakaumi.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	2	2
Common flexors	2	2
Supinator	2	2
Supinator	1	2
Biceps brachii	1	1
Brachioradialis	0	0
Pronator quadratus	2	2
Pronator teres	1	2
Iliacus	0	2
Iliopsoas	0	2
Gastrocnemius	0	2
Total	11	19
Percentage	58%	

Table 90: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Ikawazu.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	6	21
Biceps brachii (o-long head)	0	2
Triceps brachii (o-long head)	0	2
Pectoralis minor	0	2
Trapezius	0	2
Supraspinatus	1	9
Infraspinatus	3	10
Teres minor	1	10
Common extensors	21	32
Common flexors	23	35
Subscapularis	5	10
Teres major	14	37
Pectoralis major	33	37
Deltoideus	25	40
Latissimus dorsi	9	35
Triceps brachii	10	29
Brachialis	8	37
Anconeus	6	21
Supinator	22	39
Biceps brachii	15	31
Brachioradialis	6	20
Pronator quadratus	13	28
Pronator teres	4	34
Supinator	17	30
Gluteus maximus	36	51
Adductor magnus	12	47
Vastus medialis	13	49
Vastus lateralis	18	21

Gluteus medius	8	21
Gluteus minimus	12	21
Gastrocnemius	4	11
Iliacus	7	31
Iliopsoas	4	21
Total	356	826
Percentage	43%	

Table 91: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Ikawazu.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	0	2
Triceps brachii	0	2
Common flexors	23	25
Common extensors	21	32
Triceps brachii	10	29
Biceps brachii	15	31
Total	69	121
Percentage	57%	

Table 92: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Ikawazu.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	10	29
Gastrocnemius	4	11
Total	14	40
Percentage	35%	

Table 93: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Ikawazu.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	4	11
Brachioradialis	6	20
Pronator teres	4	34
Supinator	17	30
Supinator	22	39
Total	53	134
Percentage	40%	

Table 94: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Ikawazu.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	10	29
Supinator	17	30
Supinator	22	39
Pronator quadratus	13	28
Pronator teres	4	34
Total	66	160
Percentage	41%	

Table 95: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Ikawazu.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	21	32
Common flexors	23	25
Supinator	17	30
Supinator	22	39
Biceps brachii	15	31
Brachioradialis	6	20
Pronator quadratus	13	28
Pronator teres	4	34

Iliacus	7	31
Iliopsoas	4	21
Gastrocnemius	4	11
Total	136	302
Percentage	45%	

Table 96: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Tsukumo.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	5	47
Biceps brachii (o-long head)	19	35
Triceps brachii (o-long head)	9	32
Pectoralis minor	5	30
Trapezius	6	12
Supraspinatus	10	39
Infraspinatus	7	43
Teres minor	8	37
Common extensors	26	50
Common flexors	33	57
Subscapularis	25	44
Teres major	8	55
Pectoralis major	35	54
Deltoideus	31	59
Latissimus dorsi	13	55
Triceps brachii	9	54
Brachialis	9	58
Anconeus	4	55
Supinator	25	60
Biceps brachii	10	51
Brachioradialis	5	28
Pronator quadratus	2	47
Pronator teres	5	51
Supinator	16	52

Gluteus maximus	62	63
Adductor magnus	12	58
Vastus medialis	24	62
Vastus lateralis	22	42
Gluteus medius	7	49
Gluteus minimus	25	52
Gastrocnemius	3	26
Iliacus	3	60
Iliopsoas	5	45
Total	488	1562
Percentage	31%	

Table 97: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Tsukumo.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	19	35
Triceps brachii	9	32
Common flexors	33	57
Common extensors	26	50
Triceps brachii	9	54
Biceps brachii	10	51
Total	106	279
Percentage	38%	

Table 98: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Tsukumo.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	9	54
Gastrocnemius	3	26
Total	12	80
Percentage	15%	

Table 99: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Tsukumo.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	3	26
Brachioradialis	5	28
Pronator teres	5	51
Supinator	16	52
Supinator	25	60
Total	54	217
Percentage	25%	

Table 100: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Tsukumo.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	9	54
Supinator	16	52
Supinator	25	60
Pronator quadratus	2	47
Pronator teres	5	51
Total	57	264
Percentage	22%	

Table 101: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Tsukumo.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	26	50
Common flexors	33	57
Supinator	16	52
Supinator	25	60
Biceps brachii	10	51
Brachioradialis	5	28
Pronator quadratus	2	47
Pronator teres	5	51
Iliacus	3	60
Iliopsoas	5	45
Gastrocnemius	3	26
Total	133	527
Percentage	25%	

Table 102: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Yoshigo.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	15	104
Biceps brachii (o-long head)	10	55
Triceps brachii (o-long head)	15	51
Pectoralis minor	6	37
Trapezius	3	16
Supraspinatus	24	69
Infraspinatus	23	78
Teres minor	9	72
Common extensors	84	146
Common flexors	104	155
Subscapularis	38	82
Teres major	56	127

Pectoralis major	122	148
Deltoideus	59	165
Latissimus dorsi	46	147
Triceps brachii	45	151
Brachialis	59	174
Anconeus	24	138
Supinator	87	173
Biceps brachii	34	142
Brachioradialis	22	65
Pronator quadratus	15	129
Pronator teres	15	157
Supinator	39	154
Gluteus maximus	170	187
Adductor magnus	57	178
Vastus medialis	69	187
Vastus lateralis	51	105
Gluteus medius	21	104
Gluteus minimus	32	108
Gastrocnemius	35	61
Iliacus	27	150
Iliopsoas	16	92
Total	1432	3907
Percentage	37%	

Table 103: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Yoshigo.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	10	55
Triceps brachii	15	51
Common flexors	104	155
Common extensors	84	146
Triceps brachii	45	151
Biceps brachii	34	142
Total	292	700
Percentage	42%	

Table 104: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Yoshigo.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	45	151
Gastrocnemius	35	61
Total	80	212
Percentage	38%	

Table 105: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Yoshigo.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	35	61
Brachioradialis	22	65
Pronator teres	15	157
Supinator	39	154
Supinator	87	173
Total	198	610
Percentage	32%	

Table 106: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Yoshigo.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	45	151
Supinator	39	154
Supinator	87	173
Pronator quadratus	15	129
Pronator teres	15	157
Total	201	764
Percentage		26%

Table 107: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Yoshigo.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	84	146
Common flexors	104	155
Supinator	39	154
Supinator	87	173
Biceps brachii	34	142
Brachioradialis	22	65
Pronator quadratus	15	129
Pronator teres	15	157
Iliacus	27	150
Iliopsoas	16	92
Gastrocnemius	35	61
Total	478	1424
Percentage		34%

Table 108: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Ohashi.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	0	1
Biceps brachii (o-long head)	0	0
Triceps brachii (o-long head)	0	1
Pectoralis minor	0	0
Trapezius	0	1
Supraspinatus	0	0
Infraspinatus	0	1
Teres minor	0	1
Common extensors	2	2
Common flexors	0	2
Subscapularis	0	1
Teres major	0	2
Pectoralis major	2	2
Deltoideus	1	2
Latissimus dorsi	2	2
Triceps brachii	0	2
Brachialis	0	2
Anconeus	0	2
Supinator	1	2
Biceps brachii	0	2
Brachioradialis	0	1
Pronator quadratus	0	2
Pronator teres	0	2
Supinator	0	2
Gluteus maximus	2	2
Adductor magnus	0	2
Vastus medialis	2	2
Vastus lateralis	0	1

Gluteus medius	0	0
Gluteus minimus	0	1
Gastrocnemius	0	0
Iliacus	1	2
Iliopsoas	0	1
Total	13	46
Percentage	28%	

Table 109: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Ohashi.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	0	0
Triceps brachii	0	1
Common flexors	0	2
Common extensors	2	2
Triceps brachii	0	2
Biceps brachii	0	2
Total	2	9
Percentage	22%	

Table 110: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Ohashi.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	0	2
Gastrocnemius	0	0
Total	0	2
Percentage	0%	

Table 111: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Ohashi.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	0	0
Brachioradialis	0	1
Pronator teres	0	2
Supinator	0	2
Supinator	1	2
Total	1	7
Percentage	14%	

Table 112: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Ohashi.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	0	2
Supinator	0	2
Supinator	1	2
Pronator quadratus	0	2
Pronator teres	0	2
Total	1	10
Percentage	10%	

Table 113: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Ohashi.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	2	2
Common flexors	0	2
Supinator	0	2
Supinator	1	2
Biceps brachii	0	2
Brachioradialis	0	1
Pronator quadratus	0	2
Pronator teres	0	2

Iliacus	1	2
Iliopsoas	0	1
Gastrocnemius	0	0
Total	4	18
Percentage	22%	

Table 114: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Ebishima.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	11	39
Biceps brachii (o-long head)	10	18
Triceps brachii (o-long head)	4	19
Pectoralis minor	4	11
Trapezius	5	8
Supraspinatus	12	35
Infraspinatus	17	35
Teres minor	6	31
Common extensors	21	44
Common flexors	22	44
Subscapularis	19	39
Teres major	14	49
Pectoralis major	44	51
Deltoideus	17	49
Latissimus dorsi	22	50
Triceps brachii	23	45
Brachialis	14	56
Anconeus	9	27
Supinator	26	56
Biceps brachii	9	44
Brachioradialis	5	21
Pronator quadratus	14	43
Pronator teres	9	49
Supinator	32	48

Gluteus maximus	51	61
Adductor magnus	13	52
Vastus medialis	28	59
Vastus lateralis	29	43
Gluteus medius	20	38
Gluteus minimus	21	33
Gastrocnemius	1	16
Iliacus	13	48
Iliopsoas	9	35
Total	554	1296
Percentage	43%	

Table 114: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Ebishima.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	10	18
Triceps brachii	4	19
Common flexors	22	44
Common extensors	21	44
Triceps brachii	23	45
Biceps brachii	9	44
Total	89	214
Percentage	42%	

Table 115: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Ebishima.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	23	45
Gastrocnemius	1	16
Total	24	61
Percentage	39%	

Table 116: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Ebishima.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	1	16
Brachioradialis	5	21
Pronator teres	9	49
Supinator	32	48
Supinator	26	56
Total	73	190
Percentage	38%	

Table 117: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Ebishima.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	23	45
Supinator	32	48
Supinator	26	56
Pronator quadratus	14	43
Pronator teres	9	49
Total	104	241
Percentage	43%	

Table 118: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Ebishima.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	21	44
Common flexors	22	44
Supinator	32	48
Supinator	26	56
Biceps brachii	9	44
Brachioradialis	5	21
Pronator quadratus	14	43
Pronator teres	9	49
Iliacus	13	48
Iliopsoas	9	35
Gastrocnemius	1	16
Total	161	448
Percentage	36%	

Table 119: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Tsubue.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	0	0
Biceps brachii (o-long head)	0	0
Triceps brachii (o-long head)	0	0
Pectoralis minor	0	0
Trapezius	0	0
Supraspinatus	0	0
Infraspinatus	0	0
Teres minor	0	0
Common extensors	0	2
Common flexors	1	1
Subscapularis	0	0
Teres major	0	3

Pectoralis major	1	2
Deltoideus	1	3
Latissimus dorsi	0	1
Triceps brachii	0	0
Brachialis	1	1
Anconeus	0	0
Supinator	1	1
Biceps brachii	0	1
Brachioradialis	0	0
Pronator quadratus	0	2
Pronator teres	0	3
Supinator	0	3
Gluteus maximus	1	3
Adductor magnus	0	3
Vastus medialis	1	5
Vastus lateralis	0	0
Gluteus medius	0	0
Gluteus minimus	1	1
Gastrocnemius	0	0
Iliacus	0	4
Iliopsoas	0	0
Total	8	39
Percentage	21%	

Table 120: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Tsubue.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	0	0
Triceps brachii	0	0
Common flexors	1	1
Common extensors	0	2
Triceps brachii	0	0
Biceps brachii	0	1
Total	1	4
Percentage	25%	

Table 121: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Tsubue.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	0	0
Gastrocnemius	0	0
Total	0	0
Percentage	0%	

Table 122: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Tsubue.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	0	0
Brachioradialis	0	0
Pronator teres	0	3
Supinator	0	3
Supinator	1	1
Total	1	7
Percentage	14%	

Table 123: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Tsubue.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	0	0
Supinator	0	3
Supinator	1	1
Pronator quadratus	0	2
Pronator teres	0	3
Total	1	9
Percentage	11%	

Table 124: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Tsubue.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	0	2
Common flexors	1	1
Supinator	0	3
Supinator	1	1
Biceps brachii	0	1
Brachioradialis	0	0
Pronator quadratus	0	2
Pronator teres	0	3
Iliacus	0	4
Iliopsoas	0	0
Gastrocnemius	0	0
Total	2	17
Percentage	12%	

Table 125: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Adaka.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	0	0
Biceps brachii (o-long head)	0	0
Triceps brachii (o-long head)	0	0
Pectoralis minor	0	0
Trapezius	0	0
Supraspinatus	2	3
Infraspinatus	1	4
Teres minor	0	4
Common extensors	1	5
Common flexors	0	5
Subscapularis	3	4
Teres major	3	6
Pectoralis major	4	6
Deltoideus	1	6
Latissimus dorsi	3	6
Triceps brachii	1	4
Brachialis	1	5
Anconeus	2	4
Supinator	3	5
Biceps brachii	1	4
Brachioradialis	0	3
Pronator quadratus	2	4
Pronator teres	0	4
Supinator	1	4
Gluteus maximus	3	3
Adductor magnus	2	3
Vastus medialis	2	3
Vastus lateralis	1	3

Gluteus medius	0	3
Gluteus minimus	0	3
Gastrocnemius	0	1
Iliacus	1	3
Iliopsoas	0	3
Total	38	111
Percentage	34%	

Table 126: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Adaka.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	0	0
Triceps brachii	0	0
Common flexors	0	5
Common extensors	1	5
Triceps brachii	1	4
Biceps brachii	1	4
Total	3	18
Percentage	17%	

Table 127: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Adaka.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	1	4
Gastrocnemius	0	1
Total	1	5
Percentage	20%	

Table 128: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Adaka.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	0	1
Brachioradialis	0	3
Pronator teres	0	4
Supinator	1	4
Supinator	3	5
Total	4	17
Percentage	24%	

Table 129: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Adaka.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	1	4
Supinator	1	4
Supinator	3	5
Pronator quadratus	2	4
Pronator teres	0	4
Total	7	21
Percentage	33%	

Table 130: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Adaka.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	1	5
Common flexors	0	5
Supinator	1	4
Supinator	3	5
Biceps brachii	1	4
Brachioradialis	0	3
Pronator quadratus	2	4
Pronator teres	0	4

Iliacus	1	3
Iliopsoas	0	3
Gastrocnemius	0	1
Total	9	41
Percentage	22%	

Table 131: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Inariyama.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	0	15
Biceps brachii (o-long head)	0	6
Triceps brachii (o-long head)	1	4
Pectoralis minor	0	3
Trapezius	0	0
Supraspinatus	1	12
Infraspinatus	2	12
Teres minor	1	11
Common extensors	8	17
Common flexors	5	22
Subscapularis	8	14
Teres major	1	28
Pectoralis major	24	27
Deltoideus	10	27
Latissimus dorsi	4	27
Triceps brachii	0	18
Brachialis	1	25
Anconeus	5	22
Supinator	5	26
Biceps brachii	0	25
Brachioradialis	1	12
Pronator quadratus	1	24
Pronator teres	0	24
Supinator	6	24

Gluteus maximus	23	34
Adductor magnus	3	35
Vastus medialis	8	36
Vastus lateralis	6	20
Gluteus medius	2	15
Gluteus minimus	3	19
Gastrocnemius	3	8
Iliacus	2	32
Iliopsoas	1	13
Total	135	637
Percentage	21%	

Table 132: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Inariyama.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	0	6
Triceps brachii	1	4
Common flexors	5	22
Common extensors	8	17
Triceps brachii	0	18
Biceps brachii	0	25
Total	14	92
Percentage	15%	

Table 133: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Inariyama.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	0	18
Gastrocnemius	3	8
Total	3	26
Percentage	12%	

Table 134: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Inariyama.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	3	8
Brachioradialis	1	12
Pronator teres	0	24
Supinator	6	24
Supinator	5	26
Total	15	94
Percentage	16%	

Table 135: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Inariyama.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	0	18
Supinator	6	24
Supinator	5	26
Pronator quadratus	1	24
Pronator teres	0	24
Total	12	116
Percentage	10%	

Table 136: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Inariyama.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	8	17
Common flexors	5	22
Supinator	6	24
Supinator	5	26
Biceps brachii	0	25
Brachioradialis	1	12
Pronator quadratus	1	24
Pronator teres	0	24
Iliacus	2	32
Iliopsoas	1	13
Gastrocnemius	3	8
Total	32	227
Percentage	14%	

Table 137: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Kanenokuma.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	35	47
Biceps brachii (o-long head)	23	23
Triceps brachii (o-long head)	20	20
Pectoralis minor	21	23
Trapezius	0	0
Supraspinatus	12	14
Infraspinatus	4	4
Teres minor	1	1
Common extensors	5	6
Common flexors	2	4
Subscapularis	21	25
Teres major	49	50

Pectoralis major	46	50
Deltoideus	37	47
Latissimus dorsi	23	45
Triceps brachii	14	14
Brachialis	42	46
Anconeus	7	9
Supinator	30	39
Biceps brachii	35	44
Brachioradialis	25	30
Pronator quadratus	33	59
Pronator teres	44	63
Supinator	47	56
Gluteus maximus	68	69
Adductor magnus	66	84
Vastus medialis	72	80
Vastus lateralis	10	10
Gluteus medius	8	8
Gluteus minimus	8	8
Gastrocnemius	40	45
Iliacus	40	49
Iliopsoas	32	37
Total	920	1109
Percentage	83%	

Table 137: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Kanenokuma.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	23	23
Triceps brachii	20	20
Common flexors	2	4
Common extensors	5	6
Triceps brachii	14	14
Biceps brachii	35	44
Total	99	111
Percentage	89%	

Table 138: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Kanenokuma.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	14	14
Gastrocnemius	40	45
Total	54	59
Percentage	92%	

Table 139: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Kanenokuma.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	40	45
Brachioradialis	25	30
Pronator teres	44	63
Supinator	47	56
Supinator	30	39
Total	186	233
Percentage	80%	

Table 140: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Kanenokuma.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	14	14
Supinator	47	56
Supinator	30	39
Pronator quadratus	33	59
Pronator teres	44	63
Total	168	231
Percentage		73%

Table 141: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Kanenokuma.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	5	6
Common flexors	2	4
Supinator	47	56
Supinator	30	39
Biceps brachii	35	44
Brachioradialis	25	30
Pronator quadratus	33	59
Pronator teres	44	63
Iliacus	40	49
Iliopsoas	32	37
Gastrocnemius	40	45
Total	333	432
Percentage		77%

Table 142: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Nagaoka.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	4	14
Biceps brachii (o-long head)	10	11
Triceps brachii (o-long head)	7	9
Pectoralis minor	6	8
Trapezius	0	0
Supraspinatus	3	4
Infraspinatus	2	3
Teres minor	0	1
Common extensors	0	1
Common flexors	0	0
Subscapularis	4	6
Teres major	10	23
Pectoralis major	15	21
Deltoideus	12	21
Latissimus dorsi	17	23
Triceps brachii	0	0
Brachialis	10	11
Anconeus	0	0
Supinator	9	11
Biceps brachii	9	12
Brachioradialis	4	4
Pronator quadratus	2	12
Pronator teres	11	14
Supinator	7	11
Gluteus maximus	14	17
Adductor magnus	15	21
Vastus medialis	16	19
Vastus lateralis	7	7

Gluteus medius	2	3
Gluteus minimus	2	3
Gastrocnemius	3	3
Iliacus	10	12
Iliopsoas	2	4
Total	213	309
Percentage	69%	

Table 142: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Nagaoka.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	10	11
Triceps brachii	7	9
Common flexors	0	0
Common extensors	0	1
Triceps brachii	0	0
Biceps brachii	9	12
Total	26	33
Percentage	79%	

Table 143: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Nagaoka.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	0	0
Gastrocnemius	3	3
Total	3	3
Percentage	100%	

Table 144: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Nagaoka.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	3	3
Brachioradialis	4	4
Pronator teres	11	14
Supinator	7	11
Supinator	9	11
Total	34	43
Percentage		79%

Table 145: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Nagaoka.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	0	0
Supinator	7	11
Supinator	9	11
Pronator quadratus	2	12
Pronator teres	11	14
Total	29	48
Percentage		60%

Table 146: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Nagaoka.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	0	1
Common flexors	0	0
Supinator	7	11
Supinator	9	11
Biceps brachii	9	12
Brachioradialis	4	4
Pronator quadratus	2	12
Pronator teres	11	14
Iliacus	10	12
Iliopsoas	2	4

Gastrocnemius	3	3
Total	57	84
Percentage	68%	

Table 147: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Mitsusawa.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	9	12
Biceps brachii (o-long head)	7	8
Triceps brachii (o-long head)	5	5
Pectoralis minor	5	5
Trapezius	0	0
Supraspinatus	5	8
Infraspinatus	4	4
Teres minor	2	3
Common extensors	3	3
Common flexors	2	2
Subscapularis	6	11
Teres major	13	17
Pectoralis major	13	17
Deltoideus	13	16
Latissimus dorsi	15	16
Triceps brachii	1	1
Brachialis	8	10
Anconeus	1	2
Supinator	4	9
Biceps brachii	10	10
Brachioradialis	3	3
Pronator quadratus	2	6
Pronator teres	6	8
Supinator	6	10
Gluteus maximus	14	16

Adductor magnus	14	16
Vastus medialis	16	18
Vastus lateralis	5	6
Gluteus medius	3	4
Gluteus minimus	4	4
Gastrocnemius	7	7
Iliacus	11	13
Iliopsoas	4	9
Total	221	279
Percentage	79%	

Table 148: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Mitsusawa.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	7	8
Triceps brachii	5	5
Common flexors	2	2
Common extensors	3	3
Triceps brachii	1	1
Biceps brachii	10	10
Total	28	29
Percentage	97%	

Table 149: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Mitsusawa.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	1	1
Gastrocnemius	7	7
Total	8	8
Percentage	100%	

Table 150: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Mitsusawa.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	7	7
Brachioradialis	3	3
Pronator teres	6	8
Supinator	6	10
Supinator	4	9
Total	26	37
Percentage	70%	

Table 151: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Mitsusawa.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	1	1
Supinator	6	10
Supinator	4	9
Pronator quadratus	2	6
Pronator teres	6	8
Total	19	34
Percentage	56%	

Table 152: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Mitsusawa.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	3	3
Common flexors	2	2
Supinator	6	10
Supinator	4	9
Biceps brachii	10	10
Brachioradialis	3	3
Pronator quadratus	2	6
Pronator teres	6	8
Iliacus	11	13
Iliopsoas	4	9
Gastrocnemius	7	7
Total	58	80
Percentage	73%	

Table 153: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Hasakonomiya.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	2	4
Biceps brachii (o-long head)	1	1
Triceps brachii (o-long head)	0	0
Pectoralis minor	1	1
Trapezius	0	0
Supraspinatus	0	0
Infraspinatus	0	0
Teres minor	0	0
Common extensors	0	0
Common flexors	0	0

Subscapularis	1	1
Teres major	3	4
Pectoralis major	4	4
Deltoideus	3	4
Latissimus dorsi	5	5
Triceps brachii	0	1
Brachialis	2	3
Anconeus	1	1
Supinator	2	3
Biceps brachii	2	3
Brachioradialis	1	2
Pronator quadratus	1	4
Pronator teres	4	5
Supinator	3	3
Gluteus maximus	6	6
Adductor magnus	9	9
Vastus medialis	5	6
Vastus lateralis	1	1
Gluteus medius	1	1
Gluteus minimus	1	1
Gastrocnemius	1	2
Iliacus	3	4
Iliopsoas	1	1
Total	64	80
Percentage	80%	

Table 154: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Hasakonomiya.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	1	1
Triceps brachii	0	0
Common flexors	0	0
Common extensors	0	0
Triceps brachii	0	1
Biceps brachii	2	3
Total	3	5
Percentage	60%	

Table 155: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Hasakonomiya.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	0	1
Gastrocnemius	1	2
Total	1	3
Percentage	33%	

Table 156: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Hasakonomiya.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	1	2
Brachioradialis	1	2
Pronator teres	4	5
Supinator	3	3
Supinator	2	3
Total	11	15
Percentage	73%	

Table 157: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Hasakonomiya.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	0	1
Supinator	3	3
Supinator	2	3
Pronator quadratus	1	4
Pronator teres	4	5
Total	10	16
Percentage	63%	

Table 158: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Hasakonomiya.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	0	0
Common flexors	0	0
Supinator	3	3
Supinator	2	3
Biceps brachii	2	3
Brachioradialis	1	2
Pronator quadratus	1	4
Pronator teres	4	5
Iliacus	3	4
Iliopsoas	1	1
Gastrocnemius	1	2
Total	18	27
Percentage	67%	

Table 159: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Ichinotani.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	6	8
Biceps brachii (o-long head)	7	7
Triceps brachii (o-long head)	2	2
Pectoralis minor	5	7
Trapezius	0	0
Supraspinatus	3	3
Infraspinatus	2	2
Teres minor	1	1
Common extensors	5	6
Common flexors	3	3
Subscapularis	3	4

Teres major	11	12
Pectoralis major	14	14
Deltoideus	12	12
Latissimus dorsi	6	9
Triceps brachii	4	4
Brachialis	11	11
Anconeus	3	3
Supinator	10	11
Biceps brachii	8	9
Brachioradialis	3	3
Pronator quadratus	4	8
Pronator teres	15	15
Supinator	10	11
Gluteus maximus	19	19
Adductor magnus	20	22
Vastus medialis	15	21
Vastus lateralis	0	0
Gluteus medius	0	0
Gluteus minimus	0	0
Gastrocnemius	7	7
Iliacus	8	11
Iliopsoas	8	9
Total	225	254
Percentage	89%	

Table 160: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Ichinotani.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	7	7
Triceps brachii	2	2
Common flexors	3	3
Common extensors	5	6
Triceps brachii	4	4
Biceps brachii	8	9
Total	29	31
Percentage	94%	

Table 161: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Ichinotani.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	4	4
Gastrocnemius	7	7
Total	11	11
Percentage	100%	

Table 162: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Ichinotani.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	7	7
Brachioradialis	3	3
Pronator teres	15	15
Supinator	10	11
Supinator	10	11
Total	45	47
Percentage	96%	

Table 163: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Ichinotani.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	4	4
Supinator	10	11
Supinator	10	11
Pronator quadratus	4	8
Pronator teres	15	15
Total	43	49
Percentage	88%	

Table 164: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Ichinotani.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	5	6
Common flexors	3	3
Supinator	10	11
Supinator	10	11
Biceps brachii	8	9
Brachioradialis	3	3
Pronator quadratus	4	8
Pronator teres	15	15
Iliacus	8	11
Iliopsoas	8	9
Gastrocnemius	7	7
Total	81	93
Percentage	87%	

Table 165: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Doigahama.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	58	85
Biceps brachii (o-long head)	68	70
Triceps brachii (o-long head)	64	71
Pectoralis minor	41	50
Trapezius	50	55
Supraspinatus	55	63
Infraspinatus	56	60
Teres minor	12	51
Common extensors	53	79
Common flexors	69	95
Subscapularis	40	67
Teres major	100	111
Pectoralis major	94	112
Deltoideus	81	115
Latissimus dorsi	65	100
Triceps brachii	64	81
Brachialis	98	105
Anconeus	37	70
Supinator	80	101
Biceps brachii	65	94
Brachioradialis	36	42
Pronator quadratus	44	80
Pronator teres	71	96
Supinator	89	99
Gluteus maximus	115	117
Adductor magnus	91	118
Vastus medialis	100	118

Vastus lateralis	69	71
Gluteus medius	37	60
Gluteus minimus	53	66
Gastrocnemius	41	50
Iliacus	64	92
Iliopsoas	40	70
Total	2100	2714
Percentage	77%	

Table 166: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Doigahama.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	68	70
Triceps brachii	64	71
Common flexors	69	95
Common extensors	53	79
Triceps brachii	64	81
Biceps brachii	65	94
Total	383	490
Percentage	78%	

Table 167: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Doigahama.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	64	81
Gastrocnemius	41	50
Total	105	131
Percentage	80%	

Table 168: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Doigahama.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	41	50
Brachioradialis	36	42
Pronator teres	71	96
Supinator	89	99
Supinator	80	101
Total	317	388
Percentage	82%	

Table 169: Frequency of muscles over the breakpoint for the pottery metalworking of the inhabitants of Doigahama.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	64	81
Supinator	89	99
Supinator	80	101
Pronator quadratus	44	80
Pronator teres	71	96
Total	348	457
Percentage	76%	

Table 170: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Doigahama.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	53	79
Common flexors	69	95
Supinator	89	99
Supinator	80	101
Biceps brachii	65	94
Brachioradialis	36	42
Pronator quadratus	44	80

Pronator teres	71	96
Iliacus	64	92
Iliopsoas	40	70
Gastrocnemius	41	50
Total	652	898
Percentage	73%	

Table 171: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Koura.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	18	33
Biceps brachii (o-long head)	21	28
Triceps brachii (o-long head)	19	25
Pectoralis minor	17	26
Trapezius	16	20
Supraspinatus	18	28
Infraspinatus	20	27
Teres minor	2	25
Common extensors	19	28
Common flexors	15	28
Subscapularis	14	35
Teres major	32	42
Pectoralis major	39	41
Deltoideus	27	38
Latissimus dorsi	23	41
Triceps brachii	18	32
Brachialis	36	40
Anconeus	16	30
Supinator	20	41
Biceps brachii	19	37
Brachioradialis	9	15
Pronator quadratus	18	32
Pronator teres	23	38

Supinator	33	37
Gluteus maximus	38	39
Adductor magnus	19	36
Vastus medialis	26	41
Vastus lateralis	24	26
Gluteus medius	10	21
Gluteus minimus	14	22
Gastrocnemius	7	12
Iliacus	19	35
Iliopsoas	17	31
Total	666	1030
Percentage	65%	

Table 172: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Koura.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	21	28
Triceps brachii	19	25
Common flexors	15	28
Common extensors	19	28
Triceps brachii	18	32
Biceps brachii	19	37
Total	111	178
Percentage	62%	

Table 173: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Koura.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	18	32
Gastrocnemius	7	12
Total	25	44
Percentage	57%	

Table 174: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Koura.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	7	12
Brachioradialis	9	15
Pronator teres	23	38
Supinator	33	37
Supinator	20	41
Total	92	143
Percentage	64%	

Table 175: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Koura.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	18	32
Supinator	33	37
Supinator	20	41
Pronator quadratus	18	32
Pronator teres	23	38
Total	112	180
Percentage	62%	

Table 176: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Koura.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	19	28
Common flexors	15	28
Supinator	33	37
Supinator	20	41
Biceps brachii	19	37
Brachioradialis	9	15
Pronator quadratus	18	32
Pronator teres	23	38
Iliacus	19	35
Iliopsoas	17	31
Gastrocnemius	7	12
Total	199	334
Percentage	60%	

Table 177: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Hara.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	2	2
Biceps brachii (o-long head)	2	2
Triceps brachii (o-long head)	1	1
Pectoralis minor	1	2
Trapezius	1	1
Supraspinatus	0	0
Infraspinatus	0	0
Teres minor	0	0
Common extensors	2	2
Common flexors	2	2
Subscapularis	2	2

Teres major	1	2
Pectoralis major	3	3
Deltoideus	3	3
Latissimus dorsi	3	3
Triceps brachii	1	1
Brachialis	4	4
Anconeus	2	2
Supinator	2	4
Biceps brachii	1	3
Brachioradialis	1	2
Pronator quadratus	1	2
Pronator teres	0	3
Supinator	1	2
Gluteus maximus	3	3
Adductor magnus	2	4
Vastus medialis	3	4
Vastus lateralis	2	2
Gluteus medius	0	0
Gluteus minimus	1	1
Gastrocnemius	0	0
Iliacus	4	4
Iliopsoas	1	1
Total	52	67
Percentage	78%	

Table 178: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Hara.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	2	2
Triceps brachii	1	1
Common flexors	2	2
Common extensors	2	2
Triceps brachii	1	1
Biceps brachii	1	3
Total	9	11
Percentage	82%	

Table 179: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Hara.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	1	1
Gastrocnemius	0	0
Total	1	1
Percentage	100%	

Table 180: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Hara.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	0	0
Brachioradialis	1	2
Pronator teres	0	3
Supinator	1	2
Supinator	2	4
Total	4	11
Percentage	36%	

Table 181: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Hara.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	1	1
Supinator	1	2
Supinator	2	4
Pronator quadratus	1	2
Pronator teres	0	3
Total	5	12
Percentage	42%	

Table 182: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Hara.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	2	2
Common flexors	2	2
Supinator	1	2
Supinator	2	4
Biceps brachii	1	3
Brachioradialis	1	2
Pronator quadratus	1	2
Pronator teres	0	3
Iliacus	4	4
Iliopsoas	1	1
Gastrocnemius	0	0
Total	15	25
Percentage	60%	

Table 183: Frequency of muscles over the breakpoint for the general farming activity of the inhabitants of Monden.

General Farming		
Muscles	Over breakpoint	Total
Subclavius	0	2
Biceps brachii (o-long head)	0	2
Triceps brachii (o-long head)	3	3
Pectoralis minor	0	1
Trapezius	0	0
Supraspinatus	0	1
Infraspinatus	0	0
Teres minor	0	0
Common extensors	0	0
Common flexors	0	0
Subscapularis	2	2
Teres major	4	8
Pectoralis major	9	9
Deltoideus	6	8
Latissimus dorsi	7	9
Triceps brachii	0	0
Brachialis	2	2
Anconeus	0	0
Supinator	1	1
Biceps brachii	1	1
Brachioradialis	2	2
Pronator quadratus	2	3
Pronator teres	3	3
Supinator	1	2
Gluteus maximus	5	5
Adductor magnus	7	7
Vastus medialis	8	8
Vastus lateralis	1	1

Gluteus medius	0	1
Gluteus minimus	0	0
Gastrocnemius	1	2
Iliacus	1	1
Iliopsoas	1	1
Total	67	85
Percentage	79%	

Table 184: Frequency of muscles over the breakpoint for the processing grains activity of the inhabitants of Monden.

Processing Grains		
Muscles	Over breakpoint	Total
Biceps brachii (o-long head)	0	2
Triceps brachii	3	3
Common flexors	0	0
Common extensors	0	0
Triceps brachii	0	0
Biceps brachii	1	1
Total	4	6
Percentage	67%	

Table 184: Frequency of muscles over the breakpoint for the woodland clearance activity of the inhabitants of Monden.

Woodland Clearance		
Muscles	Over breakpoint	Total
Triceps brachii	0	0
Gastrocnemius	1	2
Total	1	2
Percentage	50%	

Table 185: Frequency of muscles over the breakpoint for the pottery making activity of the inhabitants of Monden.

Pottery Making		
Muscles	Over breakpoint	Total
Gastrocnemius	1	2
Brachioradialis	2	2
Pronator teres	3	3
Supinator	1	2
Supinator	1	1
Total	8	10
Percentage	80%	

Table 186: Frequency of muscles over the breakpoint for the metalworking activity of the inhabitants of Monden.

Metalworking		
Muscles	Over breakpoint	Total
Triceps brachii	0	0
Supinator	1	2
Supinator	1	1
Pronator quadratus	2	3
Pronator teres	3	3
Total	7	9
Percentage	78%	

Table 187: Frequency of muscles over the breakpoint for the weaving and clothmaking activity of the inhabitants of Monden.

Weaving and clothmaking		
Muscles	Over breakpoint	Total
Common extensors	0	0
Common flexors	0	0
Supinator	1	2
Supinator	1	1
Biceps brachii	1	1
Brachioradialis	2	2
Pronator quadratus	2	3
Pronator teres	3	3
Iliacus	1	1

Iliopsoas	1	1
Gastrocnemius	1	2
Total	13	16
Percentage	81%	

Table 188: Scores for the femora used in the intravariability testing of the three-dimensional method.

First Attempt					
Bones	**2232**	**2465**	**2359**	**2287**	**1086**
Gluteal tuberosity	2.5878	3.3588	4.3646	3.9675	2.7242
Linea aspera	2.0534	2.5922	2.7984	3.0697	2.8907
Spiral line	2.3387	2.0061	2.6398	2.3631	2.1838
Second attempt					
Bones	**2232**	**2465**	**2359**	**2287**	**1086**
Gluteal tuberosity	2.4689	3.4064	4.4450	3.8781	2.7386
Linea aspera	1.9472	2.4803	2.6906	3.0667	2.8770
Spiral line	2.2730	1.9978	2.8379	2.3515	2.0527
Difference between first and second absolute value					
Bones	**2232**	**2465**	**2359**	**2287**	**1086**
Gluteal tuberosity	0.1189	0.0476	0.0804	0.0894	0.0143
Linea aspera	0.1062	0.1119	0.1078	0.0030	0.0137
Spiral line	0.0657	0.0083	0.1981	0.0116	0.1311

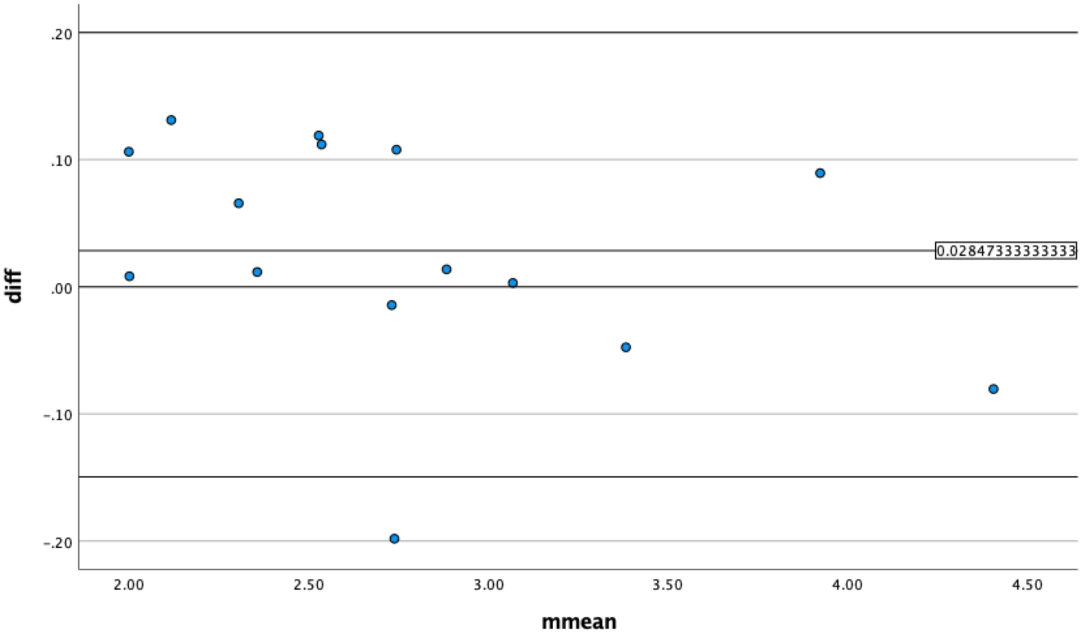


Figure 19. Bland-Altman test ran for intravariability testing of the three-dimensional method.

Table 189. Mean curvature values and modified Hawkey and Merbs composite scores for gluteal tuberosity.

Bone	Mean	Score
15-343-B-3 left femur	1.27896	2
KJ 673 left femur	1.279048	2
114-669-C-9 left femur	1.281745	2
15-343-B-3 right femur	1.34714	2
33-404-C-2 left femur	1.522756	1
29-157-C-2 right femur	1.73379	2
84-733-C-8 right femur	1.735177	2
124 right femur	1.837379	2
KJ 310 right femur	1.857903	1.5
97-644-D-8 part 1 left femur	1.876766	2
KJ 310 left femur	1.989647	2
97-644-D-8 part 1 right femur	1.993722	2
KJ 719 left femur	2.029956	2
124 left femur	2.031216	2
23-366-C-1 right femur	2.036086	2
KJ 684 right femur	2.174711	2
KJ 674 left femur	2.209859	2

KJ 386 right femur	2.232062	2
KJ 904 right femur	2.275916	2
36-22-C-3 right femur	2.349214	2
36-22-C-3 left femur	2.416816	2
KJ 719 right femur	2.442212	2
29-157-C-2 left femur	2.452781	2
23-366-C-1 left femur	2.499391	2
19-614-B-4 left femur	2.730675	2
29-338-C-2 right femur	2.848088	2
40-327-C-3 right femur	2.876874	2
40-327-C-3 left femur	2.93159	3
87-736-C-8 right femur	2.988694	2
87-736-C-8 left femur	3.041843	2
19-614-B-4 right femur	3.041972	2
20 right femur	3.044592	2
20 left femur	3.057763	2
235 left femur	3.247475	2
211 left femur	3.275054	2
95-835-D-8 right femur	3.888359	2
114-669-C-9 right femur	4.076719	2
106-208-E-8 left femur	5.377264	3
6 left femur	5.770911	3
210 left femur	5.774355	2
FY Ito A95 left femur	6.082527	8
202 right femur	6.768003	7
6 right femur	7.187044	7
FY Ito A95 right femur	8.440378	7

Table 190. Mean curvature values and modified Hawkey and Merbs composite scores for linea aspera.

Bone	mean	Score
KJ 672 left femur	1.086898	1
29-157-C-2 right femur	1.383889	1
FY Hakozaki D224 left femur	1.50359	2
33-404-C-2 left femur	1.527003	1
KJ 904 right femur	1.725902	1
KJ 719 left femur	1.742023	2
124 right femur	1.874883	2
114-669-C-9 left femur	1.897161	2
97-644-D-8 part 1 right femur	1.898006	2
36-22-C-3 left femur	2.024496	2
KJ 719 right femur	2.052099	2
29-157-C-2 left femur	2.078803	1.5
36-22-C-3 right femur	2.187103	2
87-736-C-8 right femur	2.346794	2
29-338-C-2 right femur	2.43012	2
97-644-D-8 part 1 left femur	2.469349	2
KJ 684 right femur	2.514609	2
124 left femur	2.542236	2
6 left femur	2.719296	2
20 right femur	2.733935	2
KJ 310 left femur	2.822954	2
20 left femur	2.828712	2
40-327-C-3 left femur	2.834177	2
23-366-C-1 left femur	2.855865	2
19-614-B-4 left femur	2.875666	2
FY Hakozaki D201 left femur	2.883641	2
210 right femur	3.018281	2
87-736-C-8 left femur	3.133479	2
KJ 386 right femur	3.306858	2
FY Ito A95 right femur	3.480099	2
6 right femur	3.661349	2
FY Ito A95 left femur	3.709199	2
106-208-E-8 left femur	3.795235	3
95-835-D-8 right femur	4.012984	3
114-669-C-9 right femur	4.034323	6

Table 191. Mean curvature values and modified Hawkey and Merbs composite scores for trochanteric fossa.

Bone	Mean	Score
33-404-C-2 left femur	2.382601	0
KJ 421 left femur	2.699056	0
29-157-C-2 right femur	2.788302	0
36-22-C-3 left femur	3.062664	0
84-733-C-8 right femur	3.103556	0
40-327-C-3 right femur	3.123505	0
97-644-D-8 part 1 left femur	3.299852	0
KJ 310 right femur	3.335978	0
36-22-C-3 right femur	3.468832	0
23-366-C-1 right femur	3.571815	0
KJ 310 left femur	3.635648	0
KJ 674 left femur	3.705393	0
20 right femur	3.89507	0
KJ 904 right femur	3.965119	0
40-327-C-3 left femur	4.053454	0
19-614-B-4 left femur	4.060601	0
23-366-C-1 left femur	4.10427	1
KJ 386 right femur	4.242238	1
97-644-D-8 part 1 right femur	4.421882	1
114-669-C-9 right femur	4.484417	1
202 left femur	5.603494	1.5
95-835-D-8 right femur	6.130858	2
FY Hakozaki D201 left femur	6.987827	3
124 left femur	7.044317	4
106-208-E-8 left femur	7.433114	4
210 left femur	8.450552	5
87-736-C-8 left femur	9.305083	5
6 right femur	12.669422	5

Table 192. Mean curvature values and modified Hawkey and Merbs composite scores for medial condyle.

Bone	mean	Score
KJ 671 femur	0.960885	0
KJ 672 right femur	1.533982	0
KJ 674 left femur	1.966584	0
KJ 684 right femur	2.105092	1
29-157-C-2 right femur	2.448926	1
23-366-C-1 right femur	2.82573	1
40-327-C-3 right femur	2.862027	1
29-157-C-2 left femur	3.012702	1
KJ 310 right femur	3.048921	1
23-366-C-1 left femur	3.22836	1
36-22-C-3 left femur	3.398427	2
87-736-C-8 left femur	3.492475	2
20 right femur	3.535367	2
124 left femur	4.032487	2
106-208-E-8 left femur	4.274793	2
114-669-C-9 right femur	4.322119	2
FY Ito A95 left femur	4.489628	2
19-614-B-4 right femur	4.796486	2
19-614-B-4 left femur	4.902721	2
84-733-C-8 right femur	5.002038	2
FY Ito A95 right femur	6.453061	2

Table 193. Mean curvature values and modified Hawkey and Merbs composite scores for spiral line.

Bone	mean	Score
15-343-B-3 right femur	0.634906	1
KJ 671 femur	0.675094	1
KJ 670 femur	0.692651	1
KJ 672 right femur	0.767609	2
KJ 672 left femur	0.798507	2
15-343-B-3 left femur	0.81228	2
2-180-B-1 right femur	0.852547	2
KJ 673 left femur	1.052239	1
33-404-C-2 left femur	1.173303	2
114-669-C-9 left femur	1.177928	2
124 right femur	1.193884	2
84-733-C-8 right femur	1.259334	1
36-22-C-3 right femur	1.34849	2
23-366-C-1 right femur	1.407152	2
29-157-C-2 left femur	1.419903	1
97-644-D-8 part 1 right femur	1.472417	2
KJ 421 left femur	1.515558	2
KJ 904 right femur	1.566337	1
KJ 719 left femur	1.567185	2
23-366-C-1 left femur	1.58134	1
97-644-D-8 part 1 left femur	1.62705	2
20 left femur	1.636578	1
KJ 719 right femur	1.682191	2
KJ 684 right femur	1.699877	1
29-157-C-2 right femur	1.770454	1
124 left femur	1.773378	2
KJ 674 left femur	1.799757	2
19-614-B-4 right femur	1.813187	1
20 right femur	1.950794	1
40-327-C-3 left femur	1.970724	1
KJ 310 right femur	2.076195	1
87-736-C-8 right femur	2.119418	2
6 left femur	2.146494	2
6 right femur	2.648453	2
KJ 421 right femur	2.665504	2
FY Hakozaki D224 left femur	2.85253	2

95-835-D-8 right femur	3.045923	2
114-669-C-9 right femur	3.422696	2
FY Hakozaki D201 left femur	3.853909	6
202 left femur	4.883212	3
106-208-E-8 left femur	5.065418	3
FY Ito A95 left femur	5.20608	3
202 right femur	6.101117	3
210 right femur	6.700184	3
87-736-C-8 left femur	6.859941	3
FY Ito A95 right femur	6.935053	6

Table 194. Mean curvature values and modified Hawkey and Merbs composite scores for lesser trochanter base.

Bone	mean	Score
KJ 672 left femur	1.072719	0
KJ 671 femur	1.083439	1
KJ 670 femur	1.290874	1
KJ 672 right femur	1.47565	0
2-180-B-1 right femur	1.578158	1
KJ 673 left femur	1.580669	0
33-404-C-2 left femur	1.581851	0
29-157-C-2 left femur	1.811936	0
97-644-D-8 part 1 left femur	1.962718	1
KJ 719 left femur	2.087419	0
84-733-C-8 right femur	2.112553	1
KJ 684 right femur	2.190373	0
23-366-C-1 right femur	2.245158	0
KJ 674 left femur	2.413147	0
FY Hakozaki D201 left femur	2.442899	0
15-343-B-3 left femur	2.455686	1
FY Hakozaki D224 left femur	2.51882	0
97-644-D-8 part 1 right femur	2.61654	2
15-343-B-3 right femur	2.70412	2
23-366-C-1 left femur	3.012698	1
36-22-C-3 right femur	3.074946	2
6 left femur	3.080707	2
19-614-B-4 left femur	3.190325	2
KJ 386 right femur	3.226683	2
KJ 719 right femur	3.245864	2
KJ 310 left femur	3.251368	2
40-327-C-3 right femur	3.322741	2
29-157-C-2 right femur	3.393089	2
87-736-C-8 left femur	3.397361	2
KJ 421 right femur	3.501554	2
87-736-C-8 right femur	3.569383	2
20 right femur	3.695671	2
19-614-B-4 right femur	3.904318	2
6 right femur	4.290149	2
36-22-C-3 left femur	4.460636	2
FY Ito A95 right femur	5.185095	2

FY Ito A95 left femur	5.613703	2
106-208-E-8 left femur	7.318228	6

Table 195. Mean curvature values and modified Hawkey and Merbs composite scores for lesser trochanter.

Bone	mean	score
2-180-B-1 right femur	1.307664	0
KJ 671 femur	1.314449	1
KJ 673 left femur	1.401454	1
KJ 670 femur	1.432021	0
KJ 672 left femur	1.474997	0
15-343-B-3 left femur	1.737116	1
15-343-B-3 right femur	1.878073	1
KJ 672 right femur	1.897513	0
KJ 421 left femur	1.948186	1
29-157-C-2 left femur	2.033926	1
KJ 719 left femur	2.087484	0
KJ 719 right femur	2.17226	0
97-644-D-8 part 1 right femur	2.255834	1
97-644-D-8 part 1 left femur	2.355416	1
33-404-C-2 left femur	2.426865	1
KJ 310 left femur	2.520849	0
23-366-C-1 right femur	2.526448	1
23-366-C-1 left femur	2.571193	0
KJ 310 right femur	2.667406	0
19-614-B-4 left femur	2.746809	0
36-22-C-3 right femur	2.850121	1
29-157-C-2 right femur	2.922631	0
KJ 674 left femur	3.070177	0
KJ 421 right femur	3.070827	1
FY Hakozaki D224 left femur	3.214743	2
29-338-C-2 right femur	3.226015	2
40-327-C-3 left femur	3.35639	2
FY Hakozaki D201 left femur	3.375507	1
87-736-C-8 right femur	3.492762	1
20 right femur	3.677714	1
19-614-B-4 right femur	3.910225	2
114-669-C-9 right femur	4.203827	2
106-208-E-8 left femur	4.308198	2
95-835-D-8 right femur	4.356351	2
6 left femur	6.142637	**3**
87-736-C-8 left femur	7.496163	7

202 left femur	7.526574	7
FY Ito A95 right femur	8.216118	7
210 left femur	8.94354	8
202 right femur	10.11012	7

Table 196. Mean curvature values and modified Hawkey and Merbs composite scores for lateral greater trochanter.

Bone	mean	Score
40-327-C-3 right femur	2.067734	1
40-327-C-3 left femur	2.084684	1
KJ 684 right femur	2.163619	1
KJ 719 right femur	2.169414	1
KJ 719 left femur	2.192204	1
KJ 674 left femur	2.239057	1
20 left femur	2.258761	1
KJ 904 right femur	2.351382	1
KJ 386 right femur	2.359308	1
23-366-C-1 right femur	2.360627	1
124 left femur	2.396345	2
97-644-D-8 part 1 left femur	2.504029	1
20 right femur	2.514067	1
KJ 310 right femur	2.52444	1
KJ 310 left femur	2.660074	1
97-644-D-8 part 1 right femur	2.838278	2
23-366-C-1 left femur	2.872202	1
29-157-C-2 left femur	2.886937	1
106-208-E-8 left femur	3.084022	2
19-614-B-4 left femur	3.110818	2
210 left femur	3.121075	2
29-338-C-2 right femur	3.143795	2
36-22-C-3 right femur	3.204551	2
19-614-B-4 right femur	3.436517	2
202 left femur	3.647262	4
FY Ito A95 left femur	4.064537	2
114-669-C-9 right femur	4.509813	2
95-835-D-8 right femur	5.247017	2
202 right femur	5.267361	2
FY Ito A95 right femur	5.622528	2

Table 197. Mean curvature values and modified Hawkey and Merbs composite scores for anterolateral greater trochanter.

Bone	mean	Score
KJ 421 left femur	2.070625	5
40-327-C-3 right femur	2.162103	5
124 left femur	2.311958	5
KJ 674 left femur	2.619474	6
KJ 386 right femur	2.763249	6
KJ 684 right femur	3.250735	6
202 left femur	3.374242	5
20 left femur	3.525639	6
KJ 310 left femur	3.716715	7
36-22-C-3 right femur	3.817484	6
114-669-C-9 right femur	3.819596	7
FY Ito A95 left femur	3.913669	7
19-614-B-4 left femur	4.315459	7
19-614-B-4 right femur	4.681234	7
87-736-C-8 right femur	4.7589	7
87-736-C-8 left femur	5.518628	7
210 right femur	5.544576	7
210 left femur	5.74229	7
FY Ito A95 right femur	7.178377	8
6 right femur	7.499491	7

Table 198. Mean curvature values and modified Hawkey and Merbs composite scores for anterior greater trochanter.

Bone	mean	Score
84-733-C-8 right femur	1.46865	2
124 right femur	1.580394	2
40-327-C-3 right femur	2.115791	6
KJ 674 left femur	2.309585	7
KJ 310 right femur	2.331513	6
23-366-C-1 right femur	2.414618	7
KJ 719 right femur	2.431507	7
124 left femur	2.473927	6
36-22-C-3 left femur	2.474386	6
97-644-D-8 part 1 right femur	2.732281	6
KJ 684 right femur	2.736387	7
97-644-D-8 part 1 left femur	2.807865	6
20 right femur	2.887241	6
FY Ito A95 left femur	3.100337	7
23-366-C-1 left femur	3.143885	6
87-736-C-8 right femur	3.468856	6
114-669-C-9 right femur	3.599887	7
106-208-E-8 left femur	3.63062	7
202 left femur	3.733903	7
19-614-B-4 left femur	3.774403	6
95-835-D-8 right femur	3.887882	6
87-736-C-8 left femur	4.256549	7
19-614-B-4 right femur	4.342789	7
210 right femur	4.924283	8
202 right femur	5.315763	8
210 left femur	5.373988	8
6 right femur	9.131979	8