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An osteobiography of a remarkable protohistoric Chamorro man from Taga, Tinian

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Abstract—This work offers skeletal evidence-based interpretations of the life of a 16th–17th century Chamorro man, designated *Taotao Tagga'*, who was buried on the island of Tinian. We focus on osteological changes that illuminate chapters of his life history, and additionally examine these changes in relation to his society and culture. An eventful, arduous, traumatic yet fortunate life is revealed by his physical remains. During the span of the late 17th century Spanish-Chamorro Wars, or perhaps an earlier period of inter-village skirmishing, he suffered a serious penetrating wound to his face, but complete healing of this wound suggests that he benefitted from effective traditional medical interventions, of which we suggest a few. We advance the proposition that work activities, likely initiated at a young age and focusing on megalithic stone processing and building, produced many of the activity-related changes to his skeleton, including the development of posterior cranial superstructures, adaptive remodeling and enthesopathic changes at tendon and ligament attachment sites on his appendicular skeleton, arthritic changes to his joints, and the development of extremely robust long bones, especially those of the upper limb. An index of his humeral robusticity, and related musculo-

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skeletal strength, is close the upper end of the range of known variation for modern and archaic humans. As *Taotao Tagga'* was part of a cohort of other Chamorro "strong men," we examine the quality of life and evolutionary underpinnings of their large body size and great strength. Additionally, we consider how and why *Taotao Tagga'*'s skeletal changes may bear the signature of a semi-specialist stoneworker and builder, reflecting demographic and socio-political trends during his life, in his home district in Tinian.

Introduction

In the past three decades, considerable progress has been made in the study of skeletal remains of earlier Mariana Islanders, at the population level. A symposium, organized in 1995 on the then current status of bioarchaeological research in the Marianas, resulted in a selection of papers being published in a special issue of the *American Journal of Physical Anthropology* (Hanson & Pietrusewsky 1997). An overview of research trends in that issue (Hanson and Butler 1997) cited 36 mostly unpublished human osteology reports, dating from 1980-1994, that collectively provided descriptions and analyses of the remains of over 1,500 individuals from archaeological sites in Guam, Rota, Tinian and Saipan. Since that symposium, a nearly equal number of osteological studies, also largely unpublished, have been completed. Some of the more substantive or ambitious of these, in terms of sample size and/or attempts at regional synthesis, include proprietary reports (e.g. Trembly 1999; Trembly with Tucker 1999; Pietrusewsky & Douglas 2001; Sava 2001; Eakin 2002, 2007; Pietrusewsky et al. 2009), a thesis (Ryan 2010) and international conference presentations (Pietrusewsky et al. 2010, 2011; A. Stodder & M. Douglas unpublished).

Even the most thorough and broadly comparative of these studies, given their group focus, provide little illumination about the lives of individual pre-Colonial and early historic inhabitants and visitors to these islands. Given editorial and organizational expectations, attention to individuals typically does not extend beyond standardized burial descriptions with commentary about notable or anomalous or pathological features. We contend that there is a complementary need for detailed, contextualized and, when possible, behavioral interpretation of the remains of individuals and that, furthermore, such studies are essential to incremental construction of robust profiles of the composite lives of such communities in the Marianas. The present osteobiography is offered as a step in this direction.

Osteobiography, a word coined by Frank Saul in 1961 (Saul and Saul 1989), refers to recognizable changes to the skeleton that reflect on an individual's life history. Often the term is used more inclusively, to refer to skeletal studies that address the "composite lives of the general population," as well as questions about ancestry and historical relationships to other populations (Robb 2002:160). We employ the term more in accordance with the former (literal) definition, as we focus on a single Chamorro (CHamoru) individual, *Taotao Tagga'* (a man of *Tagga'*, Tinian), situating him within his culture, society, and historical times.

Chamorros are the indigenous people of the Mariana Islands, an archipelago in the Western Pacific divided since 1978 into two polities: the U.S. Territory of Guam (Guåhan) and the Commonwealth of the Northern Mariana Islands (CNMI), which includes the island of Tinian.

The individual featured in this paper is represented in "The Man of Taga" exhibit at the CNMI Museum of History and Culture in Saipan, featuring a facial reconstruction by forensic artist Sharon Long (Figure 1). He is surely not the famous Chief *(Maga Lahi) Taga* of legend (see Spoehr 1957:89–90), nor is it likely that he is the historically-documented 17th century man from Tinian, named Taga (Lévesque 1995a:487–488). *Taotao Tagga'* has been the subject of an earlier non-technical report, written for the general public (Heathcote 2006). Compared to the earlier work, the present osteobiography is based on additional laboratory study, and is both more substantive and contextualized, as well as more scholarly in presentation. Further, the present article is distinguished by sections that relate extraordinary skeletal features of *Taotao Tagga'* and other hyperrobust contemporaries to Chamorro settlement history, environment, and evolutionary ecology, as well as to socio-cultural and demographic changes in the Marianas. Elsewhere (Heathcote et al. 2012), we have written at greater length and rigor on the upper body musculoskeletal strength and proposed chronic motor activity patterns of *Taotao Tagga'* and some of his compatriots, preceding these discussions with reviews of both legends and historical accounts about the extraordinary strength of ancestral Chamorros.

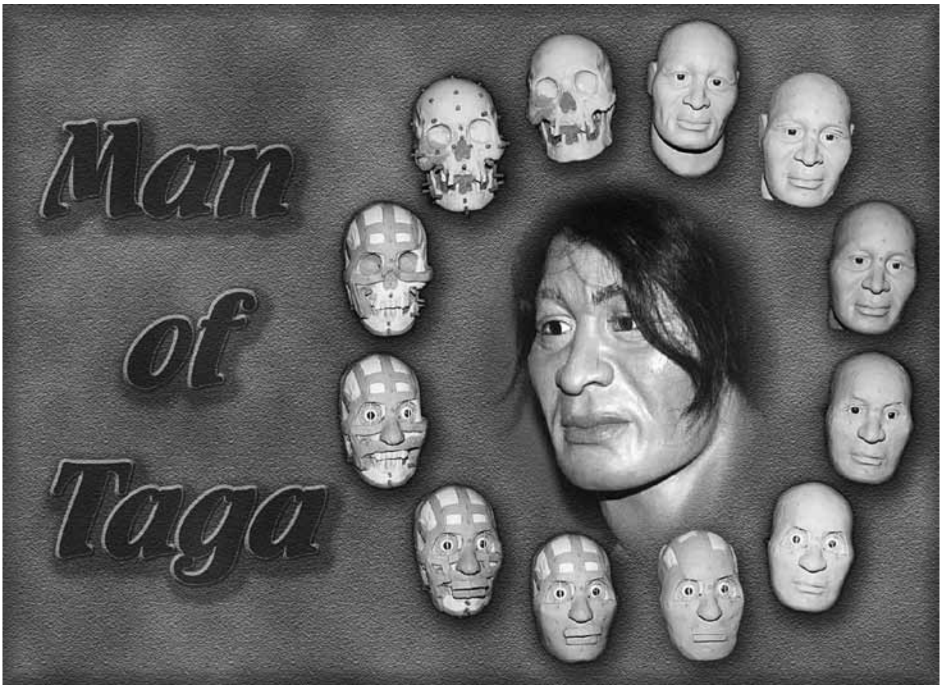

Figure 1. Stages of the reconstruction of Taotao Tagga''s face and head (Courtesy of Sharon Long).

Archaeological and Historical Background

Taotao Tagga' probably lived during late Pre-Colonial to early Spanish Colonial times, viz. during the 16th –17th centuries, based on archaeological context and historical considerations. His burial in association with a *guma' latte (latte* house) does not necessarily situate him within the Latte Period (AD 1000–1521), and therefore pre-Spanish times (see Table 1). While Magellan's AD 1521 arrival serves as a conventional pre-Colonial/post- (Spanish) Colonial history boundary, Chamorro society and culture (including *latte* building) did not undergo a significant transformation immediately thereafter. The late Latte Period cultural complex of the Chamorros must have persisted – with varying degrees of integration, depending on geographic location - into the time of the Spanish conquest (AD 1672–1698).

Table 1. Chronological sequence for Mariana Islanders' cultural history (Moore and Hunter-Anderson, 1999)

Periods	Time Frame
Early Pre-Latte	1800 BC – 500 BC
Intermediate Pre-Latte	500 BC – AD 400
Transitional Pre-Latte	AD 400 – AD 800-1000
Latte	AD 1000 – AD 1521
Early Historic	AD 1521 – AD 1700

It was probably not until the last two decades of the Early Historic Period (AD 1521–1700), that Chamorro culture, society and demography were profoundly transformed by a stepping up of hostilities and the Spaniards' increasingly strident program of forced resettlement, known as the *reducción* (Rogers 1995; Russell 1998). This differentially harsh phase of Spanish imperial rule and social engineering, beginning in the early 1680s, led to widespread abandonment of villages (see Graves 1986; Hunter-Anderson 2005), except in places more remote from loci of Spanish control. Morgan (1988) has suggested that latte construction continued in the Marianas up to around 1650 or even later, but that *guma' latte* may have continued to be used until the mid-1700s.

Taotao Tagga' was buried at a late prehistoric to early historic village along the southwest coast of Tinian that later became known as the Taga site. In 1924, his remains were excavated by Hans Hornbostel, an agent of the Bernice P. Bishop Museum (BPBM) in Honolulu (Hornbostel 1924). His bones (Field Number 8363) and associated records were subsequently curated at the BPBM for nearly three quarters of a century, where they were given the catalogue number of 881. In 1999 his residency changed; *Taotao Tagga'* and compatriots (comprising the so-called Tinian Hornbostel Collection) were repatriated to the CNMI Museum of History and Culture in Saipan (Heathcote 2006).

The archaeology of the Taga site is best known for its sole remaining megalithic structure, the ruins of the monumental House of Taga (Figure 2), constructed atop hewn coral limestone *haligi* (latte pillars) and *tasa* (capstones) which together rose 16 feet above ground level (Morgan 1988; Russell 1998). *Taotao Tagga'*'s remains were excavated from one of the 17 other smaller *guma' latte* structures then present at Taga, viz. the structure identified by Hornbostel as Latte 28-5-24 (Thompson 1932; Yamato 1990; K. Montgomery pers. comm.), and depicted as latte set number 17 in Spoehr (1957:36) (Figure 3a), after an original sketch by Hornbostel (Figure 3b). At the time of Spoehr's fieldwork, Latte 17 was a 12-shaft structure, second in size to the House of Taga (Morgan 1988:133), with shafts standing approximately 5.4 feet above the ground, and capstones measuring 5.3 feet in diameter (Spoehr 1957:89). Unique among the 16 other latte structures, it was situated near the center of the site, directly opposite the House of Taga, approximately 400 feet seaward from the latter (Spoehr 1957:87) and about 130 feet from the shoreline (Morgan 1988:133). The latte set's penultimate size and location suggests that this structure and, by extension, *Taotao Tagga'* had special significance within the community.

Figure 2. Last remaining upright *haligi* and *tasa* of the House of Taga. Photo taken in 2008. (Courtesy of Janice Lavergne)

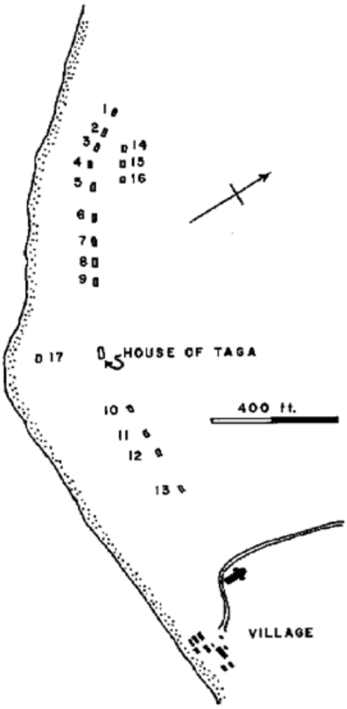

Figure 3. (a) Map of Taga site, on the southwest coast of Tinian, as recorded in 1924, when the site consisted of 18 *latte* structures (Spoehr, 1957). (Courtesy of the Chicago Natural History Museum)

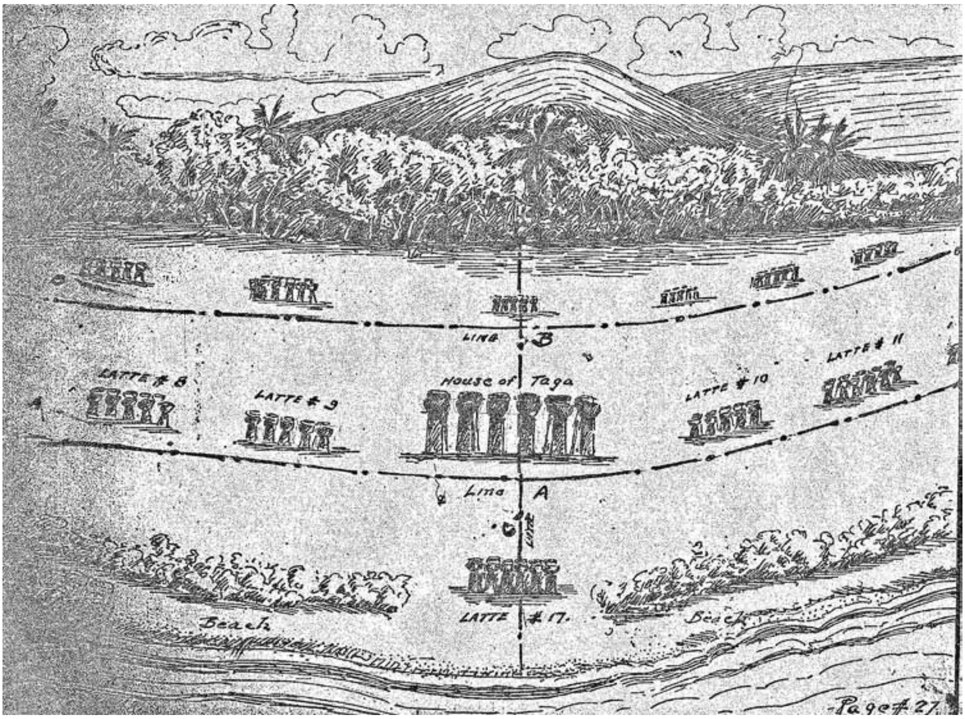

Figure 3. (b) Sketch of the Taga site by Hans Hornbostel (1924) (Courtesy of the Guam Museum)

The Remains of *Taotao Tagga'* and his Basic Demographics

More of *Taotao Tagga'*'s skeleton was encountered in the field than is currently present at the CNMI Museum of History and Culture, or was previously curated at the Bernice P. Bishop Museum, prior to repatriation. The missing remains appear to have resulted from either a decision made in the field to ship only a portion of his skeletal elements back to the Bishop Museum or by one made, after the bones reached the museum, to keep only better preserved skeletal elements. It is unclear exactly how much of *Taotao Tagga*'s skeleton was encountered at the site, but the following summary is provided in field notes: “Skull on left side. Body on left side. Pottery fragments 2 (inches) over head and feet. Hands in pelvis. Two human jaw bones (mandibles) directly over knees. Fish hook 6 (inches) west of feet. A few scattered human bones 10 (inches) over body (Hornbostel 1924).” However imprecise, these notes indicate unambiguously that bones of the hands, feet and pelvis were encountered in the field, yet there is no record of these bones having been accessioned by the Bishop Museum.

The skeletal elements of *Taotao Tagga'* made available for our study consisted of his skull, and left and right clavicles, humeri, radii, ulnae, femora, tibiae, fibulae and tali. Of these elements, virtually all were in an excellent state of preservation and structurally complete, with the following exceptions: the head of the right humerus is missing (post-mortem damage), and there is some breakage of the more delicate bones of the medial wall of the right orbit of the cranium, viz. the lacrimal and ethmoid. A detailed dental inventory is presented in the Appendix, Table A1a.

Skull morphology, e.g. the mental eminence of the mandible, prominent glabella and supraorbital ridges, and large mastoid processes (Figure 4) are all decidedly male-like, and the size, robusticity and rugosity of the long bones are consistent with this ascription. The very slight uncertainty about the sex of *Taotao Tagga'* is due to the skeleton being incomplete, with ossa coxae (hip bones) being among the missing parts. As hip bones are the most sexually dimorphic elements of the skeleton, sex estimations are necessarily on firmer ground when they can be examined (Buikstra & Ubelaker 1994; Mays 1998). At the time of death, *Taotao Tagga'* was a (late) middle adult to (early) old adult, probably between 45-55 years of age. This estimate is based on dental attrition, tooth loss (Appendix, Table A1a), ectocranial suture closure (Appendix, Table A2), and arthritic changes to various joints. Fourteen of his teeth had been lost premortem, and of the eight remaining teeth in an observable state, enamel loss from attrition ranged from moderate to severe. Greater weight was given to dental wear than other aging criteria, since a provisional benchmark has been established by two independent studies of skeletal samples from the Marianas (Leigh 1929; Stodder 1993), viz. that, until the age of about 40, "minimal" dental attrition characterizes individuals in these series (Stodder 1997:370). The absence of hip bones prevents a more confident esti-

Figure 4. Right lateral view of the skull of *Taotao Tagga'*.

mate of age at death, as two of the best non-invasive adult aging methods involve examination of metamorphic changes to the auricular surface of the ilium and, especially, the pubic symphyseal face (Buikstra & Ubelaker 1994).

Taotao Tagga''s estimated stature is 176.6 ± 1.57 cm, or around 5 foot 9 ½ inches, plus or minus ½ inch, based on his right femur length of 462 mm (Appendix, Table A5), and using the regression formula for Polynesian Maori (Houghton et al. 1975). His height is toward the upper end of the range of variation for prehistoric Chamorro males, whose average height has been determined as around 173.1 cm or 5 foot 8 inches (Pietrusewsky et al. 1997). In relative terms, *Taotao Tagga'* and most of his male compatriots had statures that fall within the lower end of the "tall" range (viz. 170 to 179cm) of mid-20th century global variation (Comas 1960:315). In contrast, average male heights for four groups of near contemporaneous (mid-18th century) European-born and European-resident soldiers, ranges from 164.6 to 167.4 cm, or approximately 5 foot 5 to 5 foot 6 inches (Table 2).

Table 2. Estimated stature for *Taotao Tagga'* vs. average adult male stature for prehistoric Mariana Islanders and mid-18th century Europeans

Individual/Population sampled[1]	Stature (cm)
Taotao Tagga' (BPBM 881)	176.6 ± 1.57
Prehistoric Mariana Islands	173.1
Hungary	167.4
France	167.1
Bohemia	166.1
Saxony	164.6

[1] The Mariana Islanders' average is from Pietrusewsky et al. (1997: 337). European data are from Komlos and Cinnirella (2005), and represent birth cohorts of European-born and European-resident soldiers from the first half of the 18th century. Dispersion metric for *Taotao Tagga'* is the standard error of the estimate; standard deviations were not provided for the sample means.

Methods

Three of us (GMH, HI and VJS) have studied the skeletal remains of *Taotao Tagga'* and other Taga Site individuals. In 1989, HI studied the morphology and morphometry of limb bones of Mariana Islanders from the Hornbostel Collections from Guam, Saipan and Tinian (Ishida 1993). The following year, GMH produced metric and nonmetric data on crania from Tinian, as well as a photographic record and notes on anatomical variation; in 2008, he undertook a second study of the Tinian individuals, focusing on dentitions, upper limb robusticity, and activity-induced musculoskeletal stress markers. VJS scored Hornbostel Collection crania from all three Mariana Islands for occipital superstructures in 1995.

Standard osteological methods were followed in estimating sex and age at death, measuring teeth, and systematically recording data on dental wear and dental pathology (Buikstra and Ubelaker 1994), while descriptions of skeletal pathology employ current concepts and terminology (Aufderheide & Rodríguez-Martin 1998). HI and GMH followed Martin & Saller (1957) in producing infracranial metric data; additional measurements by GMH followed Buikstra and Ubelaker (1994), Knüsel (2000), and Rhodes (2004). Cranial measurements were made in accordance with Howells (1973), Heathcote (1986) and others (see Appendix), while those of the mandible follow Ashley Montagu (1951) and Ossenberg (see Wright 1987). The scoring of non-metrical variations of the skull follows Molto (1983), after Ossenberg (1969) and others (see Appendix), except for occipital superstructures (OSS), which were scored using a protocol developed by GMH (Heathcote et al. 1996). Recording of upper limb musculoskeletal stress markers (MSM) followed Steen (2003), after Hawkey (1988) and Hawkey & Merbs (1995).

It is generally agreed that strongly expressed MSM are a signature of chronic, repetitive tasks, likely started at a young age and continued into adulthood (Weiss 2009). However, the interpolation of specific motor behaviors or chronic motor activity patterns from MSM (and, relatedly, OSS) expressions is fraught with difficulties. To begin with, such behavioral constructions must take into account that muscles do not operate in isolation, but as synergistic groups. Because of this, attempts at reconstruction of particular activities cannot be arrived at straightforwardly through reporting degrees of inferred muscle use and hypertrophy at single attachment sites. One must further be mindful that many different forms of work are carried out using similar muscle groups, e.g. delivering downward blows in tilling the soil and in felling trees. Thus, many activities and activity regimes “probably do not result in MSM signatures sufficiently unique or idiosyncratic to allow specific activity reconstructions (Peterson 2000:46-47),” a position endorsed by Pearson and Buikstra (2006) in a comprehensive review on behavioral interpretation from bones.

Notwithstanding these cautions and caveats, there is good reason to think that some activities may produce unique or idiosyncratic signatures, depending on whether individuals lived as specialists, as opposed to generalists, within their societies. Generalist individuals who carry out a wide range of economic behaviors, even if they are very active and their tasks are biomechanically stressful, can be expected to have less within-skeleton variation in the expression of MSM than those who specialize in a smaller range of activities (Robb 1998; Peterson 2000). We will return to this issue, regarding changes to *Taotao Tagga*'’s skeleton, below.

As osteobiographical interpretation is the focus of this paper, discussion of all data produced to date on *Taotao Tagga*' is neither attempted nor warranted here. However, selected data that are not referenced prominently in the text are placed on record in the Appendix. Appendix tables cover dental inventory and wear (Table A1a), dental pathology (Tables A1b and A1c), dental measurements (Table A1d), ectocranial suture closure (Table A2), upper limb measurements (Table A3), a humeral shaft robusticity index (Table A4), lower limb measurements (Table A5), skull measurements (Table A6), and non-metric traits of the skull (Table A7).

Osteobiographical Interpretations

In the discussions below, evidence-based narratives pertaining to *Taotao Tagga*'’s life history, in varying degrees of contextual analysis, are presented by anatomical groupings.

Facial Skeleton

In this section, we focus on the serious injury to *Taotao Tagga*'’s face, and consider the weaponry that could have inflicted the injury, the functional and clinical consequences of the injury, and both an anatomical variation and indigenous medical interventions that may have contributed to the healing of this serious wound.

THE INJURY

It is clear that *Taotao Tagga*' narrowly escaped death on the occasion of a very serious penetrating stab wound to his midface, caused by a thrust downwardly-directed weapon tip at, and extending lateral to, the midpoint of the lateral margin of his right orbital cavity (Figure 5). The tip of the pointed weapon penetrated completely through the stoutly built frontal process of the zygomatic, and the force of the blow displaced the zygomatic downward and outward at the zygo-maxillary

Figure 5. Close-up of the right side of mid-facial skeleton, showing fully-healed penetrating wound into the frontal process of the zygomatic bone (arrow). Note four zygomatico-facial foramina on the facial surface of the body of the zygomatic, indicating enhanced vascularization in the vicinity of the wound.

suture, while the other two articulations, with the frontal and temporal bones, were not displaced. Such a pattern – where one suture "gives" and the other two hold firm – is not common in facial fractures involving the zygomatic today (Banks & Brown 2001). This may indicate either the infrequency of contemporary people receiving a penetrating blow to this part of their face with such weaponry, or to the relative robusticity of *Taotao Tagga*'s midface, or both. It is clear that the wound healed completely, as the rounded wound edges were completely remodeled, and there is no sign of overlying soft tissue or bone infection at the time of his death (see Roberts & Manchester 1995). Pre-existing hypervascularization of his face, in the region of the injury, may have contributed to the healing process. He has four zygomatico-facial foramina (one foramen is "normal") on the facial surface of his zygomatic bone on the injured side (Table A7; see Figure 5), indicating that blood supply (and healing potential) was enhanced. The completeness of the healing suggests that the injury was sustained some years prior to his death, perhaps when he was in his 20s or 30s.

WEAPONRY

Only two weapons used in inter-personal combat have been archaeologically-documented for Latte Period times: sling stones hurled from slings, and lances tipped with spear points made from human long bones, usually femora or tibiae (Cunningham 1992; Russell 1998). A third weapon, fire-hardened wooden-tipped lances, is documented for the Early Historic period (Lévesque 1995b:88). Due to the linearity and clean edge of the wound, the injury could not have been made by a sling stone but could have been made by a lance tip. Clearly, the injury was caused by some type of sharp-edged and sharp-tipped weapon, and the dimensions of the cut appear consistent with published measurements and illustrations of bone spear points (Hanson 1997; McNeill 2002, 2005).

The presence of human bone spear points (and sling stones) in Latte Period archaeological assemblages attest to inter-group skirmishing, if not more intensive warfare, and periodic internecine hostilities are mentioned in early historic accounts (Russell 1998). Among people who were interred at various Latte Period sites in the Marianas, e.g. Apurguan *(Apotguam),* Guam, there is direct skeletal evidence of inter-personal violence and homicide (Douglas et al. 1997; McNeill 2005). Douglas and colleagues interpret the evidence of violence at Apurguan to mean that the people who lived in that society were at "some degree of physical risk" from assault (Douglas et al. 1997:305). Thus, historical, archaeological, and osteological evidence or documentation of strife within and possibly between groups of Latte Period Chamorros indicates that *Taotao Tagga*' could have been injured by a fellow Chamorro prior to the Spanish-Chamorro Wars, or otherwise.

It may be significant that *Taotao Tagga*'s penetrating wound healed completely, with no visible signs of any long-standing infection, because human bone spear points were known for their deadliness, no doubt because they were carved with a series of sharp barbs. Once these barbs entered the body, they became difficult to remove without tearing flesh (Russell 1998), thus promoting infection, localized tissue death and consequent septicemia. Because of this, Spanish chroniclers came to believe that the bone spear points were "poisonous", and that wounds involving them were invariably fatal, especially if portions of the points could not be freed (Lévesque 1995b:88; Lévesque 1996:241). This issue may be moot, however, as the penetration depth of the wound suggests that if the weapon was a bone spear point, the barbs may not have engaged any tissue.

Notwithstanding the possibility that a bone or wooden lance tip caused *Taotao Tagga*'s facial wound, we think it more likely that the damage was produced by a metal weapon. While there is archaeological evidence that Chamorros secured metal (perhaps from the Philippines) by at least the 14th century (Egami & Saito 1973), metal tools and weapons likely did not become commonplace until after Spanish contact. We know from abundant documentation (see Rogers 1995; Russell 1998) that Chamorros were virtually obsessed with acquiring iron in any form during the Early Historic Period, beginning with peaceful commercial as well as violent encounters with Magellen's crew (AD 1521). Means of acquiring iron objects and metal weapons included fair trade, deceptive trading, theft, expropriations from skirmishes and battles, and retrieval from shipwrecks. Opportunities for iron acquisition were many during the Early Historic Period (Table 2). During the period from AD 1521 to AD 1668 (when the Marianas mission was founded) alone, Chamorros of Guam and the other Mariana Islands encountered crews from at least 63 ships taking part in 34 different European expeditions (Heathcote et al. 1998). It is entirely possible that weapons so obtained (or manufactured from raw materials) may have been used by Chamorros in Tinian and elsewhere in the Marianas not only for inter-village skirmishes, but in resisting Spanish soldiers as well.

Use of iron weapons by the Spanish, on the other hand, is not hypothetical. Pointed iron weapons employed by the Spanish in the 16th-17th centuries include daggers, cutlasses, sabers, and machetes (Brinckerhoff & Chamberlain 1972; Wise & McBride 1980). Presently, we can only say that the wound made to *Taotao Tagga*'s face might have been made by one such metal weapon; further research involving measurements of their working ends may be able to narrow down the range of possibilities. Of possible relevance to the timing of *Taotao Tagga*'s wounding is that the first armed clashes between Spanish forces and Chamorros – in what developed into the Spanish-Chamorro Wars - began in Tinian in 1669 (Lévesque 1995a:74ff., 492ff.). By 1695, survivors of the Tinian Chamorros' "last stand" against the Spanish (fought on nearby Aguijan) were removed to Guam for resettlement (Lévesque 1997:676, 685). Thus, if *Taotao Tagga*' received his wound from a Spaniard (or Spanish-allied Filipino, Mexican, or fellow Chamorro) during the Spanish-Chamorro Wars, the event would have occurred after 1668 but well before 1695 (recall the complete remodeling at the wound site).

CONSEQUENCES OF THE INJURY

The functional and clinical consequences of *Taotao Tagga*'s injury were many. It is clear that the point of the weapon would have severed most of the middle part of the *orbicularis oculi* muscle that encircles the orbital cavity. The part of this muscle that was cut through is responsible for closing the eyelid, during both sleep and blinking, and directing the flow of tears across the eyeball. In addition, a small branch of the superficial temporal artery was likely severed, as well as small veins in the area, and probably a branch of the facial nerve. If the latter nerve was cut, paralysis of the undamaged portions of the *orbicularis oculi* would have prevented the eyeball from being closed, and this would have led to the cornea becoming irritated and opaque. The lower eyelid would likely have fallen away from the eyeball, and tears would have collected in a pond, spilling over onto his face (see Romanes 1986:20). If such paralysis occurred, *Taotao Tagga'* may have worn a covering over the injured area, for protection against irritation from grit and infection.

In addition to the penetrating wound, the corresponding fracture where the zygomatic meets the maxilla would have involved the floor of the orbital cavity, further impairing *Taotao Tagga'*'s vision. If damage occurred to one or both muscles on the underside of the eyeball, any restriction to the movements would lead to temporary or permanent diplopia, where single objects appear double. It is likely that the position of the affected eyeball was altered, and probably displaced backward, a condition known as enopthalamos. Also, if the outside angle of the eyelids was injured in the penetrating wound, the upper eyelid would have had a droopy, “hooded” appearance, known as pseudoptosis (Banks & Brown 2001:9).

POSSIBLE MEDICAL INTERVENTIONS

The seriousness of this injury coupled with there being no indication of a long-term infection in and around the injured area, suggests an effective medical intervention. Contemporary “traditional” Chamorro medical practitioners, *suruhåna* (♀ ♀) and *suruhånu* (♂ ♂) (see McMakin 1978; Workman et al. n.d.), use combinations of plants in preparing *amot hirida* and *amot gotpe*. The former refers to a medicine applied to a wound, and the latter refers to a medicine for severe cuts and broken bones (Topping et al. 1975). The particular medicinal plants used in these amot (multiple-plant) preparations are guarded, as contemporary *suruhåno siha* (♀ + ♂ practitioners) are protective of this information. Some specific (single-ingredient) contemporary treatments for trauma are more generally known, however. *Alalak tasi* (boiled beach morning glory leaves; *Ipomoea pes-caprae)* is used today to treat infections where there is swelling with pus, and *kakayon hagon lemmai* (sap from stems of seedless breadfruit tree leaves; *Artocarpus altilis)* is used to treat painful eyes (Lawrence J Cunningham, personal communication, 2005). Likewise, it is known that poultices using *fadang* (false sago palm; *Cycas circinalis)* seed preparations have been used recently to treat hard to heal wounds (Debbie Quinata, personal communication, 2003).

In one of the very few early historic references to native medical practices in the Marianas, Fr. Coomans noted in 1670 that a “rough mixture” of ginger leaves was used by Chamorros on Agrihan to bandage a priest’s badly wounded hand (Lévesque 1995b:113). This was likely an effective intervention, as antimicrobial, anti-ulcer, antioxidant and anti-inflammatory properties are established for a number of ginger species within the Zingiberaceae family (Somchit 2003; Tan & Vinitha, 2004). Three species of ginger were documented on Guam by Safford

(1905:403), including *hasngot halom-tano* (wild ginger; *Zingiber zerumbet),* which has an anti-inflammatory effect (Somchit 2003). In the early 19th century, Louis Freycinet (Freycinet and Freycinet 2003:103) recorded that resin from the *rima* or *lemmai* (seedless breadfruit) and *daok* (palomaria; *Calophyllum inopyllum)* trees were applied to wounds before wrapping them. Additionally, Freycinet noted that ground up preparations of a plant called tolan manuk or, alternatively, Santa Maria grass (bitterweed; *Parthenium hysterophorus)*, or *fofgu* (ivy-leaved morning glory; *Ipomoea hederacea)* were used to counter persistent bleeding.

William Safford (1905:320), in his early 20th century treatise *The Useful Plants of the Island of Guam,* listed a total of 20 medicinal plants brought to his attention. Of this total, three were described as being used for the treatment of wounds: *Mumutan sable* (coffee senna; *Cassia occidentalis); Amot-tumaga* (edible senna; *Cassia sophera)* and *Cinamomo* (henna; *Lawsonia inermis)*. For the two senna species, paste was made of fresh leaves to treat wounds and ulcers, while an ointment was made from the leaves of henna, for treating wounds, bruises and ulcers (Safford 1905:218-219, 306). University of Guam biologist Lynn Raulerson (personal communication, 2006) reports that henna is a cultivar and the variety that Safford observed was likely lost to Guam during WWII. The henna specimens that Safford collected have been examined by Raulerson, and now reside in the Smithsonian herbarium.

It appears that the historically-recorded pharmacopoeia of the Chamorro for injury treatment is not widely-shared by fellow Pacific Islanders. There is good reason to suspect that more similarities are shared with traditional medical systems in island Southeast Asia, but this has not yet been explored by us. Of the above-mentioned trauma medicine plants of the Chamorros, DaSilva et al. (2004) only list the use of milky sap from *Artocarpus altilis* (generally used for treating boils), and grated *Zingiber zerumbet* (generally used for treating mouth infections) as having widespread traditional usage throughout the Pacific Islands. Cox (1994) adds that *Ipomoea pes-caprae* was known for its anti-inflammatory properties throughout the Pacific and Southeast Asia, where topical applications are used to treat rashes and swellings. Whistler (1996) elaborates that, in Samoan herbal medicine, both *Ipomoea pes-caprae* leaf sap and juice from a chewed or crushed *Artocarpus altilis* leaf petiole are used for treating eye problems.

While the "traditional" medicine practiced by Chamorro specialists of today is a syncretic complex that includes a number of obvious post-European contact influences (McMakin 1978), surely a significant proportion of their knowledge, beliefs and practices has deep roots. Thus, it is altogether reasonable to think that native medicines related to those prepared by suruhåno siha today and to those historically documented during the late 17th, early 19th, and early 20th centuries, enabled *Taotao Tagga*'s survival and recovery from his attack.

Teeth and Jaws

A range of dentognathic observations and interpretations are presented here, beginning with considerations of physiological stress during *Taotao Tagga*'s boyhood, proceeding to various dental pathologies (and pains) experienced as an adult

– some remediated and another exacerbated by the same cultural practice *(pugua* chewing) – and culminating in discussions of infections involving his jaws, healing and possible tooth extractions.

PHYSIOLOGICAL STRESS DURING BOYHOOD

During his boyhood, *Taotao Tagga'* experienced at least one period of physiological stress that led to an interruption in the formation of enamel in adult teeth that were then in the process of developing within dental crypts above/below his deciduous teeth. The evidence for this is the presence of hypoplastic enamel defects, the most telling of which are linear enamel hypoplasias (LEHs), which are bands of deficient enamel thickness that are markers of periodic developmental disruptions. Such interruptions of enamel formation can arise from a variety of causes, including hereditary anomalies and physical or psychological trauma, but are usually linked to systemic physiological stress, most often malnutrition (particularly vitamin A and D deficiencies and hypocalcemia), and febrile infectious disease episodes (y'Edynak 1989; Katzenberg et al. 1996; Guatelli-Steinberg et al. 2004). Because LEHs do not remodel, they provide a useful chronological record of such stress episodes from birth to around 12 to 16 years of age (Goodman et al. 1980; Lewis 2000), with a hiatus from age 8 to 9, when enamel is typically not being formed (Skinner & Goodman 1992).

The only teeth providing a clear macroscopic indication of growth interruption in *Taotao Tagga'* are his maxillary molars, both of which bear a single LEH, in the form of wide hypoplastic bands on buccal surfaces. The maximum vertical heights of these bands are 1.4 and 2.1mm for the left and right antimeres, respectively (Appendix, Table A1c). The left M^1 has no such linear band(s), but does bear a large, diamond-shaped enamel defect, exposing underlying dentin, on the buccal surface (Figure 6). His other teeth bear no macrodefects of the enamel, LEH or otherwise. A distance of 4.8mm was measured from the cemento-enamel junction (CEJ) to the occlusal border of the best defined LEH, viz. on the right M^2 (Appendix, Table A1c), suggesting that *Taotao Tagga'* experienced a systemic disruption in enamel development around the age of 4.5 years of age (Goodman & Rose 1990). An alternative estimate of 4.9 to 5.2 years of age is obtained from extrapolating the approximate mid-crown locations of both second molar defects onto visual standards published in Reid & Dean (2006). As for the proposition that vertical height of LEH bands may relate to duration or severity of physiological stress, general studies of tooth development and experimental studies using animal models offer general support for this meaning (Larsen 1997), but precise duration times of such physiological stress, for individuals, cannot at present be estimated from such macroscopic data alone (Guatelli-Steinberg et al. 2004; Hubbard et al. 2009).

Taotao Tagga''s estimated age of morbidity (4.5 – 5.2 years) overlaps with one of the three peak periods of hypoplasia formation (4 to 4.5 years) determined in a study of the dentitions of 293 Latte Period individuals from Guam by Stodder (1997) thus, as a boy, he may well have endured the same stressor(s) that impacted on Latte phase children of his age cohort on Guam. As Stodder (1997) found an inverse relationship between life expectancy and numbers of LEHs in her Guam

Figure 6. Angled infero-anterior view of left maxilla alveolar region. From L to R, note (1) the site of a pygogenic infection, which developed within an apical periodontal cyst of PM^1, and led to pre-mortem loss of that tooth; (2) remodeled alveolus of PM^2 with roughened walls and small area of necrotic bone, peri-apically; (3) alveolar bone loss well above the furcation of M^1 buccal roots; and (4) diamond-shaped enamel defect on buccal surface of M^1 crown.

samples, *Taotao Tagga*''s survival into late middle adult years is "predicted" by a single LEH per M^2 teeth, and the absence of enamel defects in his anterior teeth.

DENTAL LOSS, MALERUPTION, PAIN, CULTURAL INTERVENTION, AND PERIODONTAL DISEASE

By the time of his death, *Taotao Tagga*' had lost nine mandibular and five maxillary teeth (Appendix, Table A1a), probably due to extreme dental wear and periodontal disease. Like many people today, he did not possess a full set of wisdom teeth (third molars), for the simple reason that there was not enough room in the alveolar portion of the jaws for these teeth to properly develop and erupt. A single, late emerging mandibular wisdom tooth, mal-positioned and horizontally impacted, was in the process of erupting mesially into the space vacated by the roots of the left second molar, which was lost premortem (Figure 7).

The impacted wisdom tooth may well have caused him pain, prior to and/or after loss of the second molar (see Cawson 1968:151). Some remediation from chronic pain was likely achieved through a self-medicating practice common to most of his societal contemporaries, viz. chewing *pugua* (betel nut; *Areca catechu)* with *afok* (lime), probably wrapped in a pepper leaf *(Piper betel)* bundle (quid). An important physiological effect of mixing the former two ingredients together

Figure 7. Angled antero-lateral view of mandible. From L to R, note labial staining of lateral incisor and canine; (2) evidence for a clinically insignificant apical periodontal cyst at the site of peri-mortem loss of PM_1; (3) pre-mortem loss of PM_2, M_1 and M_2; and (4) impacted third molar.

is that lime hydrolizes the betel nut alkaloids arecoline and guvacoline into arecaidine and guvacine. These four alkaloids are implicated in bringing about changes to the nervous systems that result in feelings of well-being and euphoria (Chu 2001; Boucher & Mannan 2002). Evidence of such betel chewing is provided by the color and spatial patterning of enamel staining on *Taotao Tagga*''s eight *in situ* teeth (Appendix, Table A1a): All three extant mandibular teeth have labial surfaces stained dark brown (see Figure 7), and of the maxillary teeth in place, the two anterior teeth have brown labial surface staining (not as dark as on the mandibular teeth), while the first molar has only slight staining on the buccal surface of the mesio-buccal cusp, and the two second molars bear no staining. Notwithstanding the absence of posterior mandibular teeth, the above staining pattern suggests that betel quids were placed in the lower buccal sulcus or retromolar area of the lower jaw, as is often done in contemporary betel quid chewers (International Agency for Research on Cancer 2004).

Pugua chewing of the sort practiced by *Taotao Tagga*' provided both benefit and harm to his oral health (Chatrchaiwiwatana 2006). The benefit was that he had no detectable dental caries, as chewing betel nut both cleanses the teeth (betel is fibrous and induces salivation) and – when lime is added - changes the oral pH level in an alkaline direction, neutralizing bacteria-produced acids, which are the proximate cause of carious lesions. But betel quid chewing also predisposed him to periodontal disease, as the same pH change leads to the build up of calculus (Appendix, Table A1b), which irritates and inflames the gums (gingivitis) and leads to gum disease (periodontitis) and alveolar bone loss (Hanson & Butler 1997). Indeed, we documented that *Taotao Tagga*' had moderate to severe periodontal disease, as measured by significant bone loss across the entire alveolar border, not just where tooth loss occurred and/or periapical inflammations once flared (Appendix, Table A1c).

INFECTION, PERI-APICAL CAVITIES, HEALING AND POSSIBLE TOOTH EXTRACTIONS

Taotao Tagga''s pre-mortem loss of 14 teeth was substantial, and when coupled to the moderate to severe degrees of dentin exposure on his extant teeth (Appendix, Table A1a), questions arise as to the particular foods he was eating, as well as non-food processing uses to which his jaws and teeth were subjected. These questions cannot be addressed presently, as further studies – e.g., determination of stable isotope profile, enamel microwear and phytolith analysis from calculus samples – are needed to address them. The general relationship between his dental wear and tooth loss is straightforward enough, however: Extreme wearing away of enamel exposed the inner pulp to infection, which spread down the root canals and through the apical foramen into the periapical regions of his jaws. Inflammatory responses ensued (acute or chronic depending on his immune response at the time, as well as the virulence of the infection) and this led to osteoclastic activity that compromised the periodontal ligament and surrounding alveolar bone, leading to subsequent loss of that tooth (Dias & Tayles (1997).

His three periapical cavities (Appendix, Table A1b) were examined macroscopically and with a hand lens for evidence that an abscess had produced any of them. Differential diagnosis of periapical alterations was conducted, using the criteria of Dias & Tayles (1997; cf. Alt et al. 1998). From the changes observed, it appears that one periapical cavity (along the buccal surface where the left second mandibular premolar was located) was the site of a clinically insignificant apical periodontal (or radicular) cyst (Figure 7). Such cysts form as a sequel to a periapical granuloma, the most common response to periapical inflammation. As the pathogenesis of these granulomas relates to a low-grade infection, both osteoclastic and osteoblastic activity is stimulated, and this produces smooth cavity walls. *Taotao Tagga*''s cavity walls at this mandibular site are indeed smooth and that, taken together with the size of the cavity (>6mm), indicates that an apical periodontal cyst, benign in nature, contributed to the premortem loss of this second premolar (see Dias & Tayles 1997).

The other periapical cavities on the left maxilla, located on the buccal surface of the alveolar process, at the first and second premolar positions (Figure 6), are adjacent and nearly confluent. Each was affected by bone destruction from chronic periodontal tissue inflammation (periodontitis), which included resorption of the alveolar crests surrounding the teeth and eventually led to their exfoliation. While the impact of chronic periodontal disease complicates interpretation, enough remodeled alveolar structure remains at the PM^1 site to suggest that an acute pyogenic (i.e. pus-producing) infection developed there, within an apical periodontal cyst. The walls of the cavity are roughened, and that, taken together with the dimension of the cavity (>8mm), suggests that an acute abscess developed within an apical periodontal cyst. The adjacent PM^2 cavity, at the septum between the two premolars, is small (3mm) with roughened walls, and there is a small area of necrotic bone in the apical region of the alveolus. Such a combination of features suggests that a primary, chronic abscess produced these changes (see Dias & Tayles 1997:552-553).

Left unchecked, microorganisms from such dental abscesses can gain entrance to the blood with fatal consequences. Presently, in developed countries, deaths from sequelae related to odontogenic abscesses are rare (Currie & Ho 1993; Alt et al. 1998), but only 200 years ago they were a leading cause of death in England (Clarke 1999). Access to effective antibiotics must account in part for the rarity of fatal consequences of dental abscesses in privileged countries today, but Clarke (1999) has argued that the advent of chemical anesthesia and the development of anatomic forceps were the most important contributors to reduced mortality from such infections. He reasons that the longer a dead tooth remains in the jaw, the greater the likelihood that the infection will continue to fester and spread. Thus, the ability to effectively pull diseased teeth in a painless fashion increased the compliance of people needing such an intervention.

From examination of the cortical surface of the remaining alveolar portion and maxillary body proximal to the confluent cavities, it appears that inflammation (and infection) had subsided and that healing was underway at the time of *Taotao Tagga*''s death. This is the expected sequel to the pre-mortem loss of his PM^1 and PM^2 (removing the focus of the infection), and further supported by the presence of mixed woven and sclerotic new bone, immediately superior to the confluent periodontal cavities (Figure 6). Such mixed reactive new bone is sometimes the signature of a chronic disease process and may indicate that the bone is in a healing phase (Buikstra & Ubelaker 1994:118). Healing indicates one of two things, and possibly both: *Taotao Tagga*' had a healthy immune system and/or the infected teeth exfoliated or were removed before the infection became systemic. Extraction know-how, it must be conceded, may not have required much dentistry, for such dental pulp infection can sometimes spread from the immediate periapical tissues to involve the periodontal ligament (Wayne et al. 2001). This could have led to *Taotao Tagga*''s maxillary premolars becoming loose enough for him to remove simply with finger and thumb, especially as the remnants of their root sockets indicate that both were single-rooted.

Posterior Cranium

In life, *Taotao Tagga*' – like many adult Chamorro males of his time – possessed great upper body strength. Such strength is inferred, in part, from degree of occipital superstructure (OSS) development at three pairs of neck and pectoral girdle muscle attachment sites on his posterior cranium (Heathcote et al. 1996). Superstructures located where the upper trapezius muscles originate are referred to as tubercles on the occipital torus (TOT), the pair associated with the insertions of sternocleidomastoid muscles are known as posterior supramastoid tubercles (TSP), and those located where the superior oblique muscles insert are known as retromastoid processes (PR) (Figure 8). The contention that pronounced OSS development is related to upper body strength is supported by our finding of a significant positive linear correlation (r = +0.70, $p < .003$) between an additive expression of three OSS (see below) and an index of upper arm robusticity (Heathcote et al. 2012). In this latter study, we present a multifactorial model for the morphogenesis and continued development of these superstructures, positing that they are genetically-underpinned but triggered by chronic activities related to long-term, strenuous, repetitive muscle use, probably starting at a young age.

All three OSS, especially in advanced degrees of development, are far more common in skulls of anatomically modern humans of Oceania (Pacific Islanders and aboriginal people of Australia and New Guinea) than in peoples from elsewhere. Within Oceania, pre-European contact and Early Historic period Chamorros stand out in having exceptionally high frequencies of well-developed OSS. In a survey of over 100 males from the three largest Mariana Islands – Guam, Saipan and Tinian – markedly developed and frequently co-occurring TOT, PR and TSP were documented on 29.7%, 39.4% and 20.8% of protohistoric Chamorro crania, respectively (Heathcote et al. *in preparation)*. A small sample of Pre-European contact Tongans with similarly high frequencies of well-developed and co-occurring OSS suggests a wider spatial distribution to such morphological patterning (Heathcote et al. 1996). Among his fellow Chamorros, *Taotao Tagga'* is one of the more robustly developed individuals with respect to OSS (Figure 9). Individual superstructures vary in expression from moderate TSP to markedly developed PR and TOT (see Table A7).

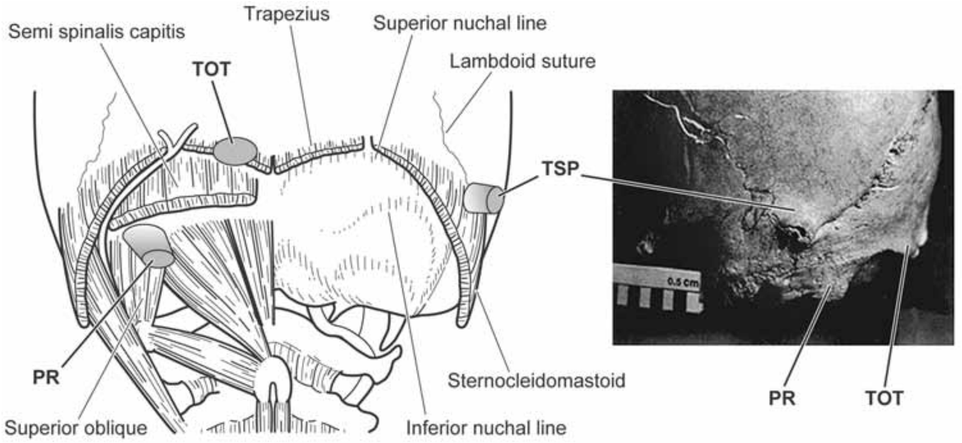

Figure 8. Drawing (left): Schematic view of posterior cranium and upper cervical vertebral region, showing locations of the retromastoid process (PR), tubercle on the occipital torus (TOT), and posterior supramastoid process (TSP), with associated and proximal muscles. Photo (right): Lateral posterior view of these three superstructures on the cranium of a 40–50 year old male (Burial No. 123) from the Gognga-Gun Beach site, Guam.

Table 3. Muscles associated with occipital superstructures (OSS)[1]

Muscle (Associated OSS)	Origin	Insertion	Actions
Upper trapezius *(m. trapezius occipitalis)*, more medial fascicle (TOT)	Medial third of superior nuchal line	Posterior border of the lateral third of the clavicle	Acting alone, the upper trapezius elevates and rotates the scapula and elevates the tip of the shoulder. Working with the middle and lower fiber groups, it retracts the scapula. With the scapula fixed, it helps in extending the neck, and bending it from side to side. It also helps in supporting the clavicle and scapula when heavy weights are held by the hands, with arms down at the side.
Superior oblique *(m. obliquus capitis superior)* (PR)	Superior surface of the transverse process of the atlas	Just inferior to the developmental boundary of the intramembranous and endochondral parts of the occipital squamous, laterally where the posterior (superior) branch of the inferior nuchal line converges with the lateral portion of the superior nuchal line	Involved in bending the neck backwards and rotating the neck to the same side. Also serves as a postural muscle.
Sternocleidomastoid *(m. sternocleidomastoideus)* (TSP)	Sternal head originates on the superior surface of the ventral manubrium. Clavicular head originates medial to the clavicular notch, and from the superior border of the medial third of the clavicle	Mastoid process of temporal bone (sometimes crossing the parietomastoid suture onto the mastoid angle of the parietal) and lateral portion of the superior nuchal line on the occipital	Draws the neck forward, raises the neck when supine, slightly elevates the chin, raises chest in forced breathing, tilts neck towards shoulder and rotates the neck.

[1] After Waldeyer (1909), Crouch (1985), Heathcote et al. (1996 and references) and Steen (2003 and references).

Figure 9. Inferior view of *Taotao Tagga*"s posterior cranium, showing co-occurrence of two sets of markedly developed occipital superstructures, viz. bilaterally expressed retromastoid process (PR) and tubercle on the occipital torus (TOT).

While actions of the OSS-related muscles are well established (Table 3), interpreting specific occupational activities from degree of OSS development is problematic, for reasons elaborated elsewhere (Heathcote et al. 2012). However problematic, we hypothesize that well-developed OSSs are related, in (extra-genetic) part, to work involved in quarrying, masonry, transport and emplacement of the stone pillars and caps that were the infrastructure for *guma' latte* construction. Eyewitness accounts of such stone working are unknown to us from early historic times, but such information – while limited – is available for Tongans (see Ferdon 1987), who share strongly developed OSS with Chamorros (Sava 1996; Heathcote et al. *in preparation)*.

Tongans did not build latte structures, but their stone masons processed large stones used in the construction of burial vaults and burial mound facings. While Tongan and Chamorro megaliths are structurally and functionally different, the work activities involved in extracting, dressing, moving and emplacing large, heavy limestone (or other stone) structures were likely quite similar. The same would hold for parallels in supportive work activities involved in megalithic processing, transport and construction. For example, Tongans are known to have used carrying poles for transporting loads. While transport of larger megaliths would not be possible with this method, carrying poles were probably used to remove rock debris from quarry sites, as well as provision workers with water and other supplies. Used singly, loads were slung from the ends and the poles were balanced on one shoulder in the fore and aft position or across both shoulders, similar to a yoke. The poles were also used in tandem with each end resting on a shoulder of both carriers, and loads were slung in the middle (Beaglehole 1967). In transporting heavier loads, Tongans used carrying frames and litters, attached to carrying poles. In addition, excessively heavy loads were placed on wooden sleds, which were pushed and pulled (with heavy ropes). Ferdon (1987) has suggested that such sleds could have been used to transport stone blocks weighing up to five tons. The use of rigging (heavy ropes) and hoists in Tonga were directly observed in connection with the emplacement of megalithic stones. In the first decade of the 19th century, William Mariner observed 150–200 men operating a hoist to lower a large stone cap, in a trap door like manner, to seal the top of a grave vault (Ferdon 1987:167). Hoists were also employed to load quarried blocks onto barge canoes for inter-island transport (Spennemann 1989).

Lawrence J. Cunningham has provided informed speculations about latte stone quarrying, transport and emplacement, and these converge with what is known and hypothesized about Tongan megalithic processing (see Sava 1996). He illustrates how Chamorros may have used bipods with rigging to hoist and pull (“walk”) heavier latte stones. Illustrations are also provided of a carrying litter used for hoisting lighter capstones, a land-filled inclined plane for pushing and pulling heavier *tasa* for emplacement atop *haligi*, and the cramped workspaces, and uncomfortable working postures necessitated by subsurface quarrying (Cunningham 1992: 51–52).

Stone quarrying and dressing would have involved repetitive motions of arm and shoulder muscles used in pounding, pecking, and chiseling, with implements made of igneous rock (usually basalt), namely a variety of hammerstones, adzes, axes, chisels and gouges (see Thompson 1932:32-37; Renfrew & Bahn 2000: 316, 319). A lone experimental study (Hornbostel 1926) indicates that in order for such stone tools to have been used in quarrying – without becoming badly chipped – the source limestone would need to be “softened” first, by controlled burning. Craib (1986:95) has pointed out that this process would have been already familiar to Chamorros in connection with extracting “lime” from limestone for use in betel nut chewing.

As for the impacts that these documented and theorized activity patterns could have had on the muscles associated with OSS in both *Taotao Tagga'* and his cohorts, the following is suggested: TOT developments could relate, in part, to the use of carrying poles in the yoke position (Sava 1996), as such shouldering of loads forces the head down, which is resisted by the trapezius muscle (Steen 1966). Pulling on ropes to move sleds or operate hoists involves repetitive extension of the back, drawing the clavicle and scapula backwards, flexion of the upper and lower arm muscles, and flexion, rotation and extension of the neck. These repetitive motions would have exercised many muscles groups, including those associated with the TOT, TSP and PR. Furthermore, carrying litters at waist level with the arms at the side requires elevation of the shoulder blades, which would also impact on the TOT and possibly the TSP and PR sites. When objects are hefted onto the shoulder, stabilization of the load is achieved by bracing the head against the object, providing an additional point of contact (Sava 1996). The sternocleidomastoid and superior oblique muscles would be involved, here, in head posturing and lateral resistance (Steen 1996), involving entheses at the TSP and PR sites, respectively.

Infracranial Skeleton

The above section offers provisional support for the hypothesis that strong OSS development on the posterior cranium relates, in part, to stone working activities over the course of much of *Taotao Tagga*"s lifetime. Less problematic than such occupational claims is our contention that the changes to his and other hyper-robust Chamorro males' posterior crania are bony signatures of great upper body strength (Heathcote et al. 2012). As strenuous work activities are seldom specific to just one part of the body, and muscles do not work in isolation from other muscles, if his OSS were part of a muscle overuse syndrome, it follows that there would be correlated changes to his infracranial skeleton, including enthesopathies (MSM), geometric changes to his long bones, degenerative changes to his skeleton, such as arthritis, and spinal injuries (Dutour 1986; Hawkey & Merbs 1995; Larsen 1997; Knüsel 2000; Ruff & Larsen 2001; Mariotti et al. 2004).

Use of classical indices of skeletal robusticity represents the simplest approach to approximating geometric changes to long bones. Such robusticity indices express the thickness of long bone shafts (diaphyses), relative to their lengths, where thicknesses are measured as either breadths or circumferences, at specified sites along the shaft. As index values express ratios of breadth or circumference to length, higher values indicate greater robusticity of the long bone and, thus, bone strength, given that these external long bone measures are reliable substitutes for biomechanical cross-sectional properties (Wescott 2006). Further, such classical indices provide good proxy indicators of muscularity, given that bone strength has been shown to be positively correlated with muscle size (Ruff 2005), and muscle size is positively correlated with muscle force (Folland & Williams 2007) and the amount and intensity of strength-building activities (Wernbom et al. 2007). As such, bone robusticity indices provide information on lifestyle and muscle activity levels throughout life (Pearson 2000), for it is known that mechanical loading, including muscular pull and torsion forces, cause long bones to become thicker during life (Martin & Burr 1989; Phillips, 2003).

THE UPPER LIMBS

Activity-related changes observed and measured on *Taotao Tagga*"s upper limb bones consist of robusticity markers, stress lesions and ossification exostoses at attachment sites for tendons and ligaments, and the development of stout long bones, best documented for the humeri. Differences between individuals and groups in upper limb robusticity are generally regarded as relating to habitual volitional behavior (Stock & Pfeiffer 2004), and we contend that the patterning of his MSM, many of which are extreme in expression, together with the general robusticity of his upper limb bones, are a consequence of frequent heavy load bearing over a long period of time, and reflect the development of great upper body strength. Relatedly, right-handedness of *Taotao Tagga'* is indicated by the fact that 12/15 instances of bilateral asymmetry of MSM expression of upper limb bones involve stronger expression on the right side (Table 4), together with our finding that right side values are greater than left for virtually all asymmetrical long bone metrical variables (Table A3).

Table 4. *Taotao Tagga'*'s Upper Limb Musculoskeletal Stress Markers[a]

Clavicle[b] (Origins)	L	R	Clavicle[b] (Insertions)	L	R
Sternocleidomastoideus	3	3	Trapezius	2	2
Pectoralis major	3	2	Subclavius	2	2
Deltoideus	2	2	Costoclavicular ligament	5	5
			Conoid ligament	2[c]	2[c]
			Trapezoid ligament	4	4
Humerus (Origins)	L	R	Humerus (Insertions)	L	R
Brachialis	0	1	Infraspinatus	2	3
Brachioradialis	2	2	Supraspinatus	2	2
Extensors & Supinators	2	3	Coracobrachialis	1	2
Pronator teres	1	2	Subscapularis	3	9
Triceps (lateral head)	3	3	Latissimus dorsi	1	1
Anconeus	2	4	Teres major	2	2
			Pectoralis major	4	4
			Deltoideus	3	4
			Teres minor	2	2
Ulna (Origins)	L	R	Ulna (Insertions)	L	R
Pronator teres	2	3	Brachialis	3	4
Flexor pollicis longus	9	9	Triceps brachii	OE3	OE1
Supinator	3	3	Anconeus	3	3
Flexor digitorum profundis	3	3			
Pronator quadratus	3	3			
Radius (Origins)	L	R	Radius (Insertions)	L	R
Flexor pollicis longus	2	3	Biceps brachii	4	4/OE1
Abductor pollicis longus	3	4	Supinator	3	2
			Pronator quadratus	1	1
			Pronator teres	3	3

[a] Scoring scheme follows Steen (2003), adapted from Hawkey (1988) and Hawkey and Merbs (1995): 0 = No expression: barely visible, palpable, discernable; 1 = Faint expression: slightly visible, palpable and enlarged; 2 = Moderate expression: definitely visible and palpable and somewhat enlarged; 3 = Strong expression: definitely enlarged, and rough/rugose; 4 = Faint stress lesion: first stages of lesion; 5 = Moderate stress lesion: penetrates outer table; 6 = Strong stress lesion: penetrates the medullary cavity; 9 = Cannot be observed; OE1 = Faint ossification exostosis; OE2 = Moderate ossification exostosis; OE3 = Strong ossification exostosis.

[b] Photographic prints and scanned slide images were consulted in scoring clavicular MSMs; all other upper limb MSMs were scored directly (macroscopically).

[c] The conoid tubercles do not fit well into Steen's scoring scheme; they manifest a moderate degree of robusticity expression together with faint stress lesions (Figure 11).

Clavicles: Similar to many of his Chamorro male contemporaries, *Taotao Tagga'*'s clavicles are very stoutly built (see Table A3, footnote [a]) with moderately to strongly expressed muscle and ligament robusticity markings, three of which additionally bear stress lesions. We focus here on the five MSM sites with, at minimum, strong robusticity expressions (Table 4). On the superior surfaces, attachment sites for the clavicular head of the sternocleidomastoid muscle (SCM) are strongly expressed bilaterally, and attachment sites on the medial half of the clavicle for the *pectoralis major* muscle are strongly to moderately marked. The SCM primarily acts upon the cervical vertebral column, flexing the neck and drawing the head forward or bringing it closer to the shoulder on same side, as well as lifting the chest in forced breathing (Table 3). The *pectoralis major* runs from the clavicle, manubrium and rib costal cartilages to the anterior surface of the humerus, near its proximal end. The primary action of this muscle depends on the position of the humerus, but the clavicular portion ordinarily functions in elevating or pulling it forward. If the humerus is fixed in a pendant position, the *pectoralis major* depresses the shoulder and assists in forced inspiration by elevating the ribs (Crouch 1985).

As expected, the inferior surfaces of the clavicles bear more dramatically transformed robusticity markers at ligament attachment sites related to the functional complex of the shoulder (Mariotti et al. 2007). These changes are accompanied by stress lesions, attesting to tremendous forces exerted on *Taotao Tagga'*'s clavicles. Robusticity scores are maximally strong and stress lesions are moderately expressed at the costal tuberosities, i.e. attachment sites for the costoclavicular ligament, while both the trapezoid and conoid ligament sites have faint stress lesions accompanying strong and moderate robusticity changes, respectively (Figure 10). The conoid and trapezoid ligaments bind the clavicles to the acromial process of the scapulae, holding the shoulder blades laterally (Anderson 1983), while the costoclavicular ligament binds the clavicles to the costal cartilage of first ribs, at once stabilizing the joints where the clavicles meet the manubrium, and allowing free movement at their lateral ends (Crouch 1985).

As testimony to the fact that different chronic activity patterns can produce convergent phenotypic changes, *Taotao Tagga'*'s costal tuberosities are similar in

Figure 10. Inferior views of *Taotao Tagga'*'s clavicles, showing strongly expressed robusticity changes at the trapezoid ligament site (A), moderate robusticity changes at the conoid tubercle site (B), and strongly expressed robusticity at the costal tuberosities (C), where the costoclavicular ligaments attached. Note faint stress lesions at the former two sites, and strong stress lesions at the costal tuberosities, especially on the right side.

morphology to those documented in (mostly) males from a Medieval site in Spain (Galera and Garralda 1993) and among 16th century English crew members of King Henry VIII's great ship, the Mary Rose (Stirland 2000). The Spanish remains were those of agriculturalists, and changes to their clavicles were attributed to such activities as moving heavy loads with the shoulders bent forward (as in pushing ploughs that were pulled behind oxen), carrying heavy weights hanging from their shoulders, and stone-house building. In the case of the Mary Rose crew members, the use of long bows and positioning heavy bronze cannons are implicated in the stress lesions to their clavicles. While *Taotao Tagga'* neither pushed plows, wrestled cannons into place, nor engaged in archery, his constellation of work activities stressed his clavicles in ways biomechanically equivalent to the Spanish peasants and Mary Rose crew members.

Robust and pathological changes at *Taotao Tagga'*'s aforementioned three ligamentous attachment sites attest to stressing of the conoid and trapezoid ligaments at two points of attachment to the scapula, and especially at the proximal end of the clavicles, where the costoclavicular ligaments resisted superior displacement from the manubrium (Steen 2003). These changes are consistent with heavy weight bearing involved in megalithic stone working, with the arms held down at the sides, for example as in carrying litters at waist level, as previously noted regarding the functional meaning of OSS. Such proposed work would have been aerobically challenging, leading to forced breathing, and this is consistent with the moderate to strong MSM expressions noted for the origin sites of the SCM and pectoralis major muscles on the superior surface of *Taotao Tagga'*'s clavicles. Additionally, if not alternatively, these clavicular changes could relate to maritime activities, as robust costal tuberosities and stress lesions have been noted in canoe paddling populations (Hawkey & Merbs 1995; Lieverse et al. 2009), including Polynesians and Micronesians.

Humeri: *Taotao Tagga'*'s humeri bear moderately to strongly expressed robusticity changes at 8 of 9 muscle insertion and 5 of 6 muscle origin sites (Table 4). MSM sites with strongly expressed changes for at least one side are those associated with insertions of the infraspinatus, pectoralis major, and deltoideus, and origins of the hand extensors & supinators, lateral head of the triceps, and anconeus. MSMs for the right deltoideus and anconeus, and the left and right pectoralis major also manifest first stage stress lesions. The infraspinatus, pectoralis major and deltoid muscle should be conceptually "aggregated", as their actions overlap (Weiss 2003b). All three share in the activity of rotating the arm; the infraspinatus with lateral rotation and the pectoralis major and deltoideus with internal arm rotation. Additionally, both the pectoralis major and deltoid muscles flex and extend the arm. As for non-overlapping actions, the infraspinatus adducts the arm, the pectoralis major depresses the arm and shoulder, and the deltoid muscle abducts the arm. The hand extensors & supinators (uniquely) extend and abduct the hand at the wrist and turn the palm upward or anteriorly, respectively, while the triceps (lateral head) and anconeus aggregate in extending the forearm, and the triceps alone extends the arm (Steen 2003; Weiss 2009).

Focusing on *Taotao Tagga*''s more pronounced MSM lessens the complexity of deciphering chronic activity patterns involving use of his arm. While the overall pattern of his humeral MSM changes fits a wide range of chronic work activities, this range would include the megalithic stone working activities posited above regarding OSS interpretation, especially actions involving pulling ropes to move sleds or operate hoists in transporting and emplacing heavy stoneworks. These activities require the rotational, flexion, extension, adduction, abduction and supination actions associated with, and aggregating among, *Taotao Tagga*''s six strongly marked arm muscles

Figure 11 documents the strong (and asymmetrical) expressions of MSMs for the pectoralis major and deltoideus insertions and common origin site for the hand extensors & supinators, as well as the extreme robusticity (and asymmetry) of *Taotao Tagga*''s humeri, regarding external shaft thickness to length proportionality. Stoutness was quantified by calculating two indexes of humeral shaft robusticity. Humeral shaft robusticity index no. 1 (HSRI-1) expresses the ratio of minimum shaft circumference to length (Table A4), while humeral shaft robusticity index no. 2 (HSRI-2) reflects the sum of the shaft's minimum and maximum diameters at midshaft in proportion to length (Table 5), with higher values for both indices indicating thicker bones in relation to their lengths. We focus on HSRI-2, as a greater amount of comparative data, representing wider ecogeographic coverage, are available for calculating this index. Table 5 presents these data, in descending order of robusticity, for recent and subfossil groups and fossil groups, separately.

Taotao Tagga''s left side (non-handed) HSRI-2 value of 16.1 (and estimated right side value of 16.5) exceeds the means of all comparative groups by a considerable margin with the exception of a Jomon series of hunter-fisher-gatherers from central and western Japan, with a mean of 16.0 ± 1.3. Biomechanical studies of Jomon humeri have documented their extreme robusticity and strength, especially regarding resistance to overall bending and torsional loading (Sakaue 1998; Shackelford, personal communication). While approximately equal to *Taotao Tagga*' and other hyperrobust Chamorros in bone strength, the Jomon individuals were far less than equivalent in overall body size, as estimated from maximum humerus length (see Buikstra & Ubelaker 1994), and, therefore, musculoskeletal massiveness (Table 5). With the exception of the Jomon sample, HSRI-2 means for non-Chamorros range from 89% of his index value (northern Alaskan series from Point Hope) to 67% of it (Aboriginal Australians from Western Australia). These comparative samples represent a wide range of ecogeographic zones and modal economic and other work activities. As skeletal robusticity is a joint function of genetic and epigenetic (developmental growth) factors, economic and other work behaviors and climate, and since both climate and ecology influence culturally determined patterns of activity (Collier 1989; Pearson 2000), it is not surprising that comparative values of HSRI-2 fail to reveal a pattern of ascending/descending values associating with single factors, such as subsistence pattern, climatic adaptations, or population historical closeness. The findings in Table 5 support a multifactorial etiology of humeral robusticity, where phenotypic outcomes in adults result from multiple interwoven co-determining factors.

Figure 11. Anterior views of *Taotao Tagga*''s right and left humeri, with plastic model of a right humerus (PS-1) placed in the center for reference. Attachment sites for the pectoralis major, deltoideus and common origin for the hand extensors and supinators are labeled P, D and E, respectively. Comparative measurements and robusticity derivatives for PS-1 are H1 = 310mm; H5 = 22mm; H6 = 19mm; H7 = 65; HSRI-1 = 20.2 and HSRI-2 = 13.2 (cf. *Taotao Tagga*''s values in Tables A4 and 5)

Table 5. Comparative Data and Metric Derivatives for Humeral Shaft Robusticity Index No. 2 (HSRI-2): Males

Individual or Population Sampled[1] (Valid n)	Maximum Humerus Length (H1) Value or Mean / S.D.	Maximum Diameter of Midshaft (H5) Value or Mean / S.D.	Minimum Diameter of Midshaft (H6) Value or Mean / S.D.	HSRI-2 Index 100 X ((H5+H6) H1)) Value or Mean / S.D.	Reference
RECENT (AND SUBFOSSIL) GROUPS					
Taotao Tagga' BPBM 881	L: 322.0 R: (322.0)	L: 29.0 R: 29.0	L: 23.0 R: 24.0	L: 16.1 R: (16.5)	Heathcote (unpublished)
Jomon series, western and central Japan; 4-2.5 ky BP(23)	286.4 / 11.1	23.7 / 2.5	21.8 / 1.7	16.0 / 1.3	Shackelford (unpublished); see Shackelford (2005)
Chamorros[2], Latte to early Historic periods, Mariana Islands (32)	320.8 / 9.7	26.2 /2.1	20.7 / 1.6	14.6 / 1.1	Ishida (unpublished)
Point Hope series, combined Ipiutak and Tigara, horizons Alaska; 1619 – 300 BP (26)	307.6 / 17.0	22.6 / 1.7	21.3 / 1.7	14.3 / 1.2	Shackelford (unpublished); see Shackelford (2005)
Hawaiians, WARC site, Wai'anae, O'ahu (4)	314.0 / 17.9	25.4 / 2.1	18.8 / 1.1	14.1 / -	Pietrusewsky and Douglas (1990)
Neolithic Tsukumo, Japan (15)	291.5 / 12.4	23.9 / 1.8	17.5 / 1.4	13.9 / -	Baba and Endo (1982)
Mesolithic, France and Denmark (4)				13.8 / 1.3	Pearson (2000)
Sami, Lapland, region(s) unspecified (34)				13.7 / 0.9	Pearson (2000)

Northwest Coast cultural area, North America (72)				13.7 / 1.1	Cybulski (2010)
Inuit, region(s) unspecified (25)				13.6 / 1.1	Pearson (2000)
Tongans, pre-European contact (7)	332.6 / 12.3	25.6 / 1.7	19.6 / 1.9	13.6 / -	Sava and Pietrusewsky (1995 and unpublished)
Recent Kinai Japanese (30)	294.2 / 15.6	22.3 / 1.5	17.4 / 1.5	13.5 / -	Baba and Endo (1982)
Hsiao T'un, Sui-T'ang Dynasties, Anyang, China (11)	312.9 / -	23.4 / -	18.1 / -	13.3 / -	Woo (1943)
Lapps (Sami), region(s) unspecified (141)	308.0 / 10.3	23.2 / 1.2	17.8 / 1.2	13.3 / -	Schreiner (1931, 1935 in Woo (1943)
Aboriginal Australians, region(s) unspecified (17)				13.2 / 0.8	Pearson (2000)
Hickleton, medieval rural village, Yorkshire, England (15)	318.6 / 14.9	23.1 / 1.8	19.0 / 1.2	13.2 / -	Rhodes (2004 and unpublished)
U.S. “Whites”, collection unspecified (25)				13.1 / 0.9	Pearson (2000)
Mary Rose crew, sunken Tudor warship, Portsmouth Harbour, England, AD 1545 (165)	332.5 / 17.4	23.4 / 2.4	18.9 / 2.0	13.1 / -	Rhodes (2004 and unpublished)

Individual or Population Sampled[1] (Valid n)	Maximum Humerus Length (H1) Value or Mean / S.D.	Maximum Diameter of Midshaft (H5) Value or Mean / S.D.	Minimum Diameter of Midshaft (H6) Value or Mean / S.D.	HSRI-2 Index 100 X ((H5+H6) H1)) Value or Mean / S.D.	Reference
RECENT (AND SUBFOSSIL) GROUPS					
Towton, battlefield casualties, North Yorkshire, England, AD 1455-1487 (45)	337.5 / 17.4	24.4 / 1.6	19.7 / 1.4	13.1 / -	Rhodes (2004 and unpublished)
Fishergate, medieval urban priory, York, England, southern cemetery: low status workers and craftsmen (34)	329.2 / 11.5	23.7 / 1.6	19.3 / 1.5	13.1 / -	Rhodes (2004 and unpublished)
Zulu, region(s) unspecified (31)				13.0 / 0.9	Pearson (2000)
Chichester, medieval leprosarium and later almshouse, West Sussex, England (191)	321.1 / 17.0	23.4 / 1.8	18.6 / 1.6	13.0 / -	Rhodes (2004 and unpublished)
Fishergate, medieval urban priory, York, England, blade-injured, presumed weapon trained cohort (26)	341.4 / 16.3	24.8 / 1.5	19.7 / 1.2	13.0 / -	Rhodes (2004 and unpublished)

Fishergate, medieval urban priory, York, England, eastern cemetery: ecclesiastical community (55)	328.8 / 18.1	23.4 / 1.9	19.2 / 1.7	13.0 / -	Rhodes (2004 and unpublished)
Fishergate, medieval urban priory, York, England, intramural cemetery: high status townspeople (90)	327.5 / 14.4	23.7 / 1.5	19.0 / 1.5	13.0 / -	Rhodes (2004 and unpublished)
Wharram Percy, medieval rural village, Yorkshire, England (156)	327.6 / 16.6	23.3 / 1.4	18.9 / 1.4	12.9 / -	Rhodes (2004 and unpublished)
Central California Native Americans, Early Horizon (27)	325.0 / 17.1	24.0 / 2.3	17.8 / 2.5	12.9 / -	Dittrick and Suchey (1986)
Ban Chiang, Thailand, 2100 B.C. –A.D. 200 (12)	311.2 / 10.2	22.5 / 1.5	17.5 / 1.4	12.9 / -	Pietrusewsky and Douglas (2002)
African Americans, collection unspecified (41)				12.8 / 0.9	Pearson (2000)
Northern Chinese, modern (20)	311.7 / -	22.7 / -	17.2 / -	12.8 / -	Black (1925) in Woo (1943)
Terry Collection “Whites”, largely indigent group, St. Louis, Missouri, USA, born between AD 1841-1943 (358)	331.9 / 17.5	23.4 / 1.9	18.8 / 1.6	12.7 / -	Rhodes (2004 and unpublished)

Individual or Population Sampled[1] (Valid n)	Maximum Humerus Length (H1) Value or Mean / S.D.	Maximum Diameter of Midshaft (H5) Value or Mean / S.D.	Minimum Diameter of Midshaft (H6) Value or Mean / S.D.	HSRI-2 Index 100 X ((H5+H6) H1)) Value or Mean / S.D.	Reference
RECENT (AND SUBFOSSIL) GROUPS					
Hawaiians, Mokapu site, O'ahu (72)	319.2 / 13.0	23.2 / 1.5	17.4 / 1.1	12.7 / -	Ishida (1993)
Hsiu Chiu Shan, modern Chinese, poorer classes, E. China (61)	310.3 / 14.5	22.4 / 1.1	17.2 / 1.2	12.7 / -	Woo (1943)
Norwegians, region(s) unspecified (161)	337.3 / 11.9	24.0 / 1.3	19.0 / 1.3	12.7 / -	Wagner (1927) in Woo (1943)
Chinese, region(s) unspecified (27)				12.6 / 1.0	Pearson (2000)
Recent Fukien Formosans (102)	313.4 / 14.4	22.4 / 1.5	17.1 / 1.2	12.6 / -	Baba and Endo (1982)
Libyan Sahara series, 7- 1.6 ky BP (11)	332.9 / 23.1	21.6 / 1.8	20.1 / 1.8	12.6 / 1.0	Shackelford (unpublished); see Shackelford (2005)
Plateau cultural area, North America (24)				12.5 / 1.3	Cybulski (2010)
Central California Native Americans, Middle and Late Horizon (122)	323.9 / 14.0	23.3 / 1.6	17.3 / 1.5	12.5 / -	Dittrick and Suchey (1986)
Early Palauans, Orrak cemetery (3)	302.0 / 13.1	21.8 / 2.4	15.6 / 1.5	12.4 / -	Nelson (unpublished); see Nelson and Fitzpatrick (2006)

Neolithic Yang Shao Tsun, China (2)	332.6 / -	23.5 / -	17.7 / -	12.4 / -	Baba and Endo (1982)
Watom Island, Papua New Guinea, Lapita complex (2)	337.5 / 17.5	23.0 / 1.7	18.7 / 1.2	12.4 / -	Pietrusewsky (1989)
Egyptian series, Sheik Fanag site, Pre-Dynastic (>5050 BP) to Middle Kingdom (3941-3736 BP) (19)	318.5 / 14.8	20.2 / 1.3	19.0 / 1.3	12.3 / 0.7	Shackelford (unpublished); see Shackelford (2005)
Aboriginal Australians, southeastern Australia (106)	320.3 / 16.4	20.7 / 2.2	16.2 / 1.8	11.5 / -	van Dongen (1963)
Khoisan, region of SW Africa unspecified (21)				11.1 / 0.9	Pearson (2000)
Aboriginal Australians, Western Australia (16)	331.2 / 11.7	20.0 / 2.4	15.8 / 1.6	10.8 / -	Buck and Freedman (1991)
FOSSIL GROUPS					
Neandertals, Europe and Middle Eastern (6)				13.7 / 1.3	Pearson (2000)
Epigravettian-associated, Italy (6)				13.7 / 0.8	Pearson (2000)
Upper Paleolithic, European and non-European, pooled (25)	325.3 / 25.5	22.3 / 1.6	20.2 / 2.2	13.1 / 0.8	Shackelford (unpublished); see Shackelford (2007)
Magdalenian-associated, Europe (3)				12.9 / 1.6	Pearson (2000)

Individual or Population Sampled[1] (Valid n)	Maximum Humerus Length (H1) Value or Mean / S.D.	Maximum Diameter of Midshaft (H5) Value or Mean / S.D.	Minimum Diameter of Midshaft (H6) Value or Mean / S.D.	HSRI-2 Index 100 X ((H5+H6) H1)) Value or Mean / S.D.	Reference
FOSSIL GROUPS					
Gravettian-associated, Europe (10)				12.0 / 1.2	Pearson (2000)
Minatogawa I, Upper Pleistocene, Okinawa	287.0	20.5	15.5	12.5	Baba and Endo (1982)
Skhūl/Qafzeh “Early moderns”, Israel (2)				11.6 / -	Pearson (2000)
Jebel Sahaba, Upper Paleolithic, Sudan				11.4	Pearson (2000)
Paviland I, Aurignacian-associated, Wales	337.0	19.4	15.7	10.4	Trinkaus and Holliday (2000)

(Values in parentheses were estimated)

Taotao Tagga'”s left side values were directly measured; right side values assume same mid-shaft measuring point as for the left, and HSRI-2 index is referenced to an estimated maximum length. Data from Shackelford (unpublished) is for right side measurements exclusively, while that reported by Woo (1943), Baba and Endo (1982), Pietrusewsky and Douglas (1990, 2002), Ishida (1993 and unpublished), and Sava and Pietrusewsky (1995 and unpublished) represents right side measurements, unless only the left side was present. Data from Pietrusewsky (1989) and Trinkaus and Holliday (2000) represent left side measurements. van Dongen’s (1963) Rhodes’ (2004 and unpublished), and Nelson’s (unpublished) values represent left and right sides combined. Dittrick and Suchey (1986), Buck and Freedman (1991), and Pearson (2000) did not state which side was measured.

[2] Two additional (smaller) samples of late pre-Colonial Chamorros from Guam, from the Hyatt Hotel (valid n=12) and Apurguan (valid n=5) sites yielded mean HSRI-2 indexes of 14.4 and 14.0, respectively. Data were reported in Trembly with Tucker (1999) and Pietrusewsky et al. (1992), respectively.

In comparison with fellow Chamorros, *Taotao Tagga'* is distinguished by a value greater than one standard deviation from the mean (14.6 ± 1.1) of his peers. Of these other roughly contemporaneous male Chamorro "strong men", only one (BPBM 892) that we have measured has a stouter humerus (with a staggering HSRI-2 of 17.8), while four (viz. BPBM 694A, 696, 705 and 912) have humeri nearly as stout as *Taotao Tagga'*'s, with HSRI-2 indices of 16.0, 16.0, 15.9 and 15.9, respectively (Ishida, unpublished data). Individuals BPBM 892 and 912 were likely societal compatriots of *Taotao Tagga'* from Taga, Tinian, while the other three hyperrobust individuals were recovered from latte sites within the locality of Ypao Beach, Guam (Heathcote et al. 2012).

Beyond comparisons to other modern humans, *Taotao Tagga'* and a number of his peers had upper arm bones that were also much stouter than those of more ancient fossilized human ancestors (Table 5). *Taotao Tagga'*'s HSRI-2 index of 16.1 far exceeds the group mean for the two most robust "fossil groups", viz. European and Middle Eastern Neandertals (13.7 ± 1.3) and Epigravettian-associated "early moderns" from Italy (13.7 ± 0.8). Cold-adapted Neandertals and their warmer-climate contemporaries in the Middle East (Skhūl/Qafzeh) had Middle Paleolithic technologies and lived as hunters and gatherers roughly 30,000 to 120,000 years ago. Samples of Upper Paleolithic groups (Aurignacian, Gravettian, Magdalenian, and Epigravettian) represent big game hunting specialists who lived from around 40,000 to 11,000 years ago (Klein 1999). All individuals represented within these fossil groups would necessarily have led very active and strenuous lifestyles, and yet all of their mean HSRI-2 robusticity indexes pale in comparison to *Taotao Tagga'*'s. Since the most robust among them, the Neandertals, are characterized as having massive limb bones and being more heavily muscled than anatomically-modern humans (Klein 1999; Pearson 2000), our findings demand a qualification to that generalization. The mean and standard deviation HSRI-2 values for Neandertals indicate that only the most broad-boned and muscular Neandertals thus far measured approached *Taotao Tagga'* (and some of his Chamorro peers) in upper arm robusticity and inferred upper arm strength.

What could account for the extreme robusticity of *Taotao Tagga'*'s humeri? In a very general sense, it is apparent that the developmental pathway leading to his hyperrobust humeri was advantaged by a genetic platform well primed for interaction with work activities, probably beginning at a young age. A number of researchers have recently suggested that chronic mechanical loading before maturity has a differentially greater effect on bone strength than forces applied after conclusion of the growth period (Cowgill 2010). We consider it likely that the robust structure of *Taotao Tagga'*'s upper limb bones was achieved through the interaction of his genetic background, systemic nutritional factors—possibly related to marine foods (see Eggen et al. 1994)—and demanding motor activities during his growth years, and continuing into his adult years (cf. Lovejoy et al. 2003).

As shown in Figure 11, extreme stoutness – quantified by the minimum and maximum midshaft diameters used in calculating HSRI-2 - is manifested both at and below the levels where the deltoid muscle attaches. This muscle assists in the flexion, extension and rotation of the upper arm, but primarily serves in moving

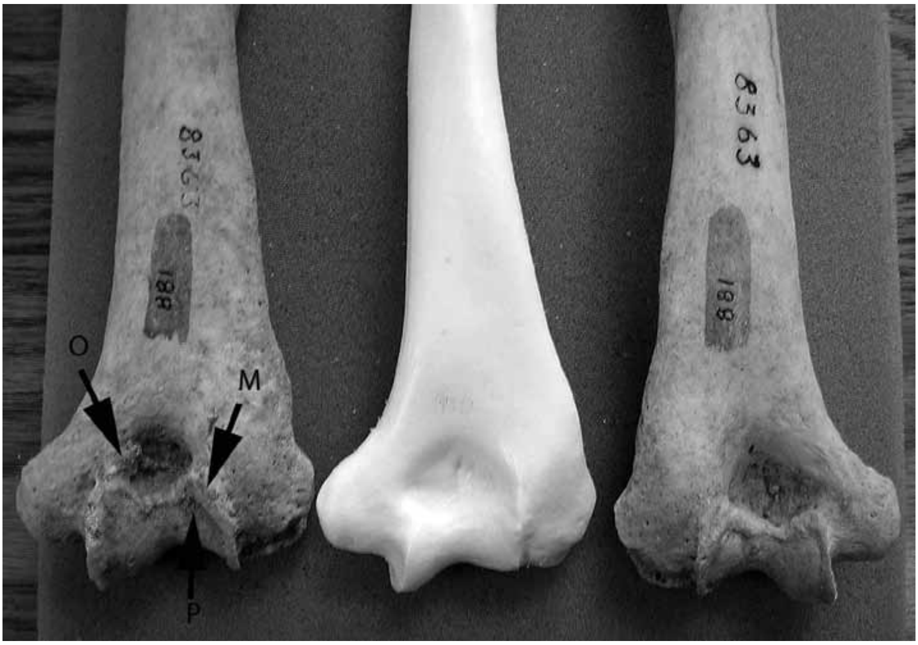

Figure 12. Posterior views of distal ends of *Taotao Tagga*''s right and left humeri, with plastic model of right humerus in center, for reference. Note greater osteoarthritic change to the right humerus, viz. marginal hypertrophy (M) and porosity (P) of the trochlea, as well as development of an osteophyte (O) on the medial aspect of the olecranon fossa.

the upper arm away from the body (Crouch 1985). The overdevelopment of his deltoid muscles could relate in part to pounding activities involved in quarrying and dressing latte stones. This surmise is supported by expressions of osteoarthritis, the commonest form of joint disease in both ancient and modern populations (Rogers and Waldron 1995), at the distal ends of his humeri. Anteriorly, the joint surfaces for the radius (capitulum) and ulna (trochlea) display marginal hypertrophy and porosity. These changes are more severe on the posterior surface of the trochlea, especially for the right humerus (Figure 12), suggesting that *Taotao Tagga*' did more pounding with his right hand.

Radii and Ulnae: The radii and ulnae of *Taotao Tagga*' bear strongly expressed robusticity changes at 5 of the 6 and 7 of the 7 muscle-bone enthesis sites which could be scored, respectively, and these MSMs are more pronounced on the right side for 3 of 4 and 2 of 3 sites, respectively (Table 4). Strongly expressed insertion sites on both forearm bones are associated with muscles responsible for virtually all arm movements, viz. flexion (biceps brachii) and extension of the arm (triceps brachii), flexion (biceps brachii and brachialis) and extension of the forearm (triceps brachii and anconeus), supination of the forearm (biceps brachii), supination of the hand (supinator), and pronation of the forearm and hand (pronator teres). Strongly marked muscle origin sites on both bones are involved in flexion of the thumb (flexor pollicis longus), abduction of the first finger and hand (abductor pollicis longus), pronation of the hand (pronator teres and pronator quadratus), supination of hand (spinator), flexion of the hand and fingers (flexor digitorus profundis) and rotation of the hand (pronator quadratus) (Steen 2003).

One of the most extreme of the activity-related changes to *Taotao Tagga*'s forearm bones is the massive spur on the back of the olecranon process of the ulna that represents hyperostosis of bone into the insertion site of the tendon of the triceps muscle (Figure 13). The long head of this muscle courses above the posterior surface of the humerus, and its main action is to extend the forearm, as well as draw the arm toward the body (Crouch 1985). Such spurring has been observed in modern wood cutters (Dutour 1986), and is sometimes referred to as "woodcutter's lesion." This lesion has also been observed at very high frequency in an Iron Age group from Central Italy, and was attributed to quarrying and other forms of hard labor (Capasso et al. 1999:78), suggesting that such enthesopathies are associated with repetitive pounding motions, regardless of the material being worked upon. Dutour (1986) has also noted its presence in habitual throwers, such as baseball players and presumptive Neolithic net casters.

In *Taotao Tagga*'s case, the massive bony spurs at his triceps insertion site may have developed in response to repetitive stone cutting activities over a long period. It is curious, however, that the spurring on the left side is much more developed than on the right. This left-right difference is the reverse of the arthritic changes at the distal end of the humerus, and metric differentials that "favored" the right humerus. A plausible explanation is that gradual worsening of activity-related arthritic pain emanating from his right elbow eventually caused him to switch to using his left arm more in stone working activities that involved pounding.

On the radii, the most extreme enthesopathies are located at the tuberosity, where the biceps brachii attached by way of a tendon. The biceps functions in flex-

Figure 13. Lateral view of proximal end of *Taotao Tagga*'s left ulna, showing a massive spur of bone at the triceps brachii insertion site (arrow).

ing the arm, flexing and supinating the forearm and pronating the hand (Crouch 1985; Steen 2003). *Taotao Tagga*'s radii show signs of habitual overuse of the biceps muscles, as there is bony spurring at, and pit-like changes near, its attachment site on both left and right sides, with the right side only somewhat more reactive (Figure 14). Such significant (and nearly) bilateral changes are rare today, but are known to occur in masons and bakers "who habitually load their extended forearms while the upper arm is held straight against the body (Capasso et al. 1999:58)." These changes indicate that he carried heavy loads with his elbows bent, and this would be consistent with stone working activities. Similar changes were also found to be common in the abovementioned group of Medieval Spanish agriculturalists, and have been attributed to lifting and carrying heavy loads, probably for long distances (Galera & Garralda 1993).

THE LOWER LIMBS

As mentioned, *Taotao Tagga*'s hip bones were not available for study, but his femora and tibiae were. While generally robust and showing activity-related changes, the lower limb bones are not remodeled as dramatically as the bones of the upper limb, either in terms of geometry *(sensu lato)* or "activity scars" at soft tissue attachment sites. This finding recalls a remark made by Noel Quitugua, former Displays Curator at the CNMI Museum of History and Culture, who suggested that *Taotao Tagga'* and other robustly built and well-muscled ancient Chamorros would not have looked like today's body builders, who strive for symmetry and propor-

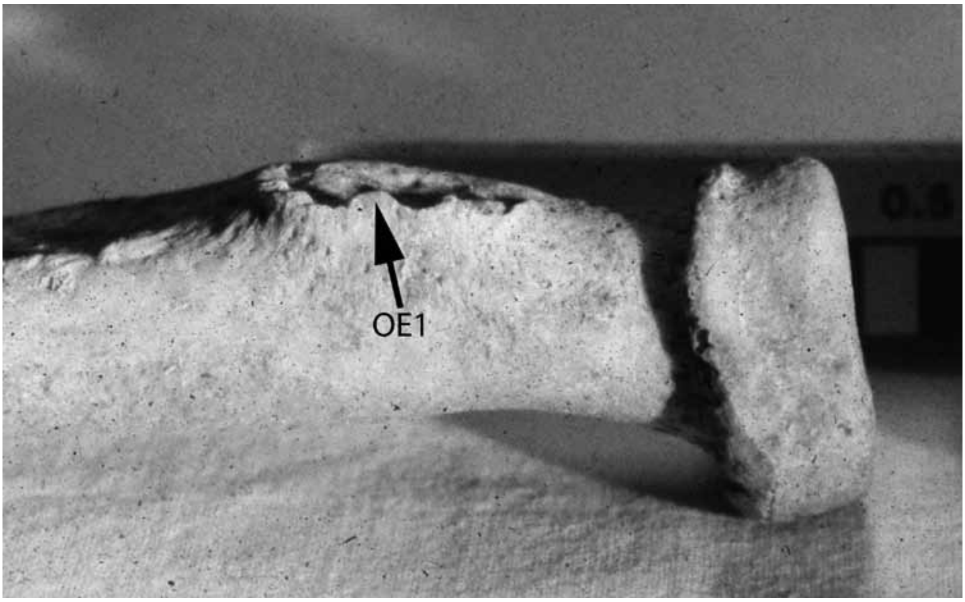

Figure 14. Medial view of proximal end of *Taotao Tagga*'s right radius, showing deep indentation (strong robusticity change) at the biceps brachii insertion site, the floor of which has a pitted, lytic appearance. Also note first stage ossification exostoses (OE1) at the margin of the insertion site.

tionality in the development of virtually all muscle groups. Indeed, as surmised by Quitugua, *Taotao Tagga*'s muscle development was uneven; his bones testifying that muscle groups related to the suite of chronic activities that he engaged in over time were well-developed and sometimes massive, while muscle groups not directly involved in these activities were less developed.

Femora: *Taotao Tagga*'s femora show arthritic changes at their distal ends, viz. marginal hypertrophy along the articular surfaces, especially the patellar, with changes to the right femur being more pronounced (Figure 15). Proximally, on the femoral heads and at the site of the *fovea capitis,* where the *ligamentum capitis* inserts, unusual changes are found. Normally, the *fovea capitis* is a shallow depression, but at this location the fovea appears to have been filled in with built-up layers of reactive new bone, more pronounced on the left side (Figure 16). Anchored to the floor of the acetabular fossa (Crouch 1985), the ligament that inserts there is normally loose, but when the thigh is semi-flexed and adducted, it is made tense (Williams et al. 1989). It is possible that this change may relate to extreme load bearing at the hip joints (acetabula), with knees bent (in a half squat position) and legs close together, in preparation for lifting loads with hands at the sides. The left-right differential in proximal vs. distal end changes could relate to placing the right foot forward to the left, when lifting the load. We further suggest that the build up of bone at the *fovea capitis* represents incremental responses that bear witness to repeated compression and trauma to the *ligamentum capitis*.

As arthritis at the knee and unusual changes on the femoral head are suggestive of an overuse syndrome and extreme load bearing, muscle markings on the femur were examined for concordant changes, but did not reveal anything unusual. The posterior surfaces of both femoral shafts have rough, thickened ridges *(linea aspera),* where three muscles from the adductor group and one muscle from the

Figure 15. Antero-distal views of distal ends of *Taotao Tagga*'s right and left femora. Note greater osteoarthritic change to the right femur, particularly the marginal hypertrophy, extending the proximal boundary of the patellar surface (arrow).

Figure 16. Medial views of *Taotao Tagga*'s right and left femoral heads. Fovea capitis, normally a shallow depression, is "filled in" on the right femur and built up further, with reactive new bone, on the left femur (arrow).

hamstring group attach. The former move the thigh towards the middle and flex the leg, while the latter extend the thigh and rotate it during knee flexion (Crouch 1985). While rugged in appearance, it is our impression that *Taotao Tagga*'s *linea aspera* are within the range of normal anatomical variation encountered in adult males in many other skeletal series we have examined.

To examine the robusticity of *Taotao Tagga*'s femora, three conventional external measurements were used to calculate a femur shaft robusticity index (FSRI), which expresses the sum of two midshaft diameters (anterior-posterior and medial-lateral) in relation to the physiological length (Table 6). While his FSRI of 13.2 is at the high (more robust) end of a range of recent and subfossil groups who have been so measured, two Inuit groups and a Jomon series from Japan have femora of greater additive midshaft breadths to length. When compared with "fossil groups", *Taotao Tagga*'s femoral shaft robusticity drops into a middle range, being far exceeded by Neandertals (14.3), two groups of Upper Paleolithic Europeans (14.0), and an Upper Pleistocene Okinawan (13.5). His moderate FSRI, together with the appearance of his *linea aspera,* indicates that *Taotao Tagga'* had a well-muscled thigh, but not massively so, in contrast to his upper arms.

For *Taotao Tagga*'s FSRI to fall short of some groups listed in Table 6 is not surprising, for he probably lived a relatively settled life in and near his village, when not at sea. While it is evident that he led an extremely vigorous life, and that work activities placed great demands on his body, his degree of terrestrial mobility was likely not great, in comparison with nomadic and semi-nomadic hunter-gatherer and herding groups. Some of the comparative samples with mean FSRI values that exceed the Chamorro mean (12.9) represent societies whose food getting strategies demanded comparatively greater mobility, viz. Sami reindeer herders, Mesolithic broad spectrum hunter-gatherers, Inuit hunters and Jomon hunter-fisher-gatherer folk. It may seem reasonable to predict that most groups surpassing *Taotao Tagga'*

Table 6. Comparative Data and Metric Derivatives for Femoral Shaft Robusticity Index (FSRI): Males

Individual or Population Sampled[1] (Valid n)	Femur Physiological Length (F2) Value or Mean / S.D.	Midshaft Ant.-Post. Diameter (F6) Value or Mean / S.D.	Midshaft Medio-Lat. Diameter (F7) Value or Mean / S.D.	FSRI Index 100 X ((F6+F7) F2)) Value or Mean / S.D.	Reference
RECENT (AND SUBFOSSIL) GROUPS					
Jomon series, western and central Japan; 4-2.5 ky BP (23)	409. 1 / 18.1	30.2 / 3.9	26.0 / 2.1	13.6 / 1.4	Shackelford (unpublished); see Shackelford (2005)
Point Hope series, combined Ipiutak and Tigara horizons, Alaska; 1619 – 300 BP (27)	425.7 / 27.9	30.0 / 2.4	27.0 / 1.6	13.4 / 0.8	Shackelford (unpublished); see Shackelford (2005)
Inuit, region(s) unspecified (25)				13.3 / 0.7	Pearson (2000)
Neolithic Tsukumo, Japan (13)	414.2 / 20.1	29.3 / 1.6	25.5 / 1.5	13.2 / -	Baba and Endo (1982)
Mesolithic, France and Denmark (6)				13.2 / 0.7	Pearson (2000)
Taotao Tagga' BPBM 881	454.0	33.0	27.0	13.2	Ishida (unpublished)
Hawaiians, WARC site, Wai'anae, O'ahu (4)	421. 0 / 24.1	29.4 / 1.9	25.6 / 1.5	13.1 / -	Pietrusewsky and Douglas (1990)
Sami, Lapland, region(s) unspecified (33)				13.0 / 0.6	Pearson (2000)
Chamorros[2], Latte to Early Historic periods, Mariana Islands (32)	446.9 / 14.5	31.0 / 1.7	27.1 / 1.0	12.9 / 0.6	Ishida (unpublished)

Individual or Population Sampled[1] (Valid n)	Femur Physiological Length (F2) Value or Mean / S.D.	Midshaft Ant.-Post. Diameter (F6) Value or Mean / S.D.	Midshaft Medio-Lat. Diameter (F7) Value or Mean / S.D.	FSRI Index 100 X ((F6+F7) F2)) Value or Mean / S.D.	Reference
		RECENT (AND SUBFOSSIL) GROUPS			
Neolithic Yang Shao Tsun, China (4)	453.7 / -	31.2 / -	28.0 / -	13.0 / -	Baba and Endo (1982)
Recent Kinai Japanese (30)	409.9 / 24.2	27.2 / 2.3	25.3 / 2.1	12.8 / -	Baba and Endo (1982)
Central California Native Americans, Early Horizon (25)	454.6 / 20.4	30.4 / 2.3	27.9 / 2.4	12.8 / -	Dittrick and Suchey (1986)
Central California Native Americans, Middle and Late Horizon (120)	443.5 / 18.7	29.8 / 2.6	26.4 / 1.7	12.7 / -	Dittrick and Suchey (1986)
Early Palauans, Orrak cemetery (3)	402.0 / 9.5	27.7 / 1.3	23.5 / 1.7	12.7 / -	Nelson (unpublished); see Nelson and Fitzpatrick (2006)
U.S. “Whites”, collection(s) unspecified (25)				12.6 / 0.8	Pearson (2000)
Ban Chiang, Thailand, 2100 B.C. – A.D. 200 (8)	436.9 / 11.4	29.5 / 1.9	25.7 / 1.8	12.6 / -	Pietrusewsky and Douglas (2002)
Zulus, region(s) unspecified (31)				12.5 / 0.6	Pearson (2000)
Hawaiians, Mokapu site, Oahu (68)	440.6 / 19.2	29.6 / 2.0	25.6 / 1.8	12.5 / -	Ishida (1993)
Khoisan, region of SW Africa unspecified (30)				12.5 / 0.7	Pearson (2000)

Tongans, pre-European contact (5)	458.0 / 3.7	29.8 / 1.5	27.2 / 1.0	12.4 / -	Sava and Pietrusewsky (1995 and unpublished)
African Americans, collection(s) unspecified (41)				12.3 / 0.8	Pearson (2000)
Chinese, region(s) unspecified (28)				12.3 / 0.8	Pearson (2000)
Aboriginal Australians, region(s) unspecified (18)				12.2 / 0.7	Pearson (2000)
Recent Fukien Formosans (148)	432.0 / 18.7	27.0 / 2.1	25.6 / 2.1	12.2 / -	Baba and Endo (1982)
Libyan Sahara series, 7 – 1.6 ky BP (16)	470.2 / 35.2	29.8 / 3.1	26.4 / 2.1	12.1 / 0.6	Shackelford (unpublished); see Shackelford (2005)
Egyptian series, Sheik Fanag site, Pre-Dynastic (>5050BP) to Middle Kingdom (3941-3736 BP) (19)	443.6 / 20.7	27.5 / 2.5	25.5 / 2.0	12.0 / 0.8	Shackelford (unpublished); see Shackelford (2005)
Negritos, Luzon, Philippines (11)	380.5 / -	25.2 / -	20.3 / -	12.0 / -	Baba and Endo (1982)
FOSSIL GROUPS					
Neandertals, Europe and Middle Eastern (6)				14.3 / 0.9	Pearson (2000)
Epigravettian-associated, Italy (5)				14.0 / 0.7	Pearson (2000)
Magdalenian-associated, Europe (3)				14.0 / 0.8	Pearson (2000)

Individual or Population Sampled[1] (Valid n)	Femur Physiological Length (F2) Value or Mean / S.D.	Midshaft Ant.-Post. Diameter (F6) Value or Mean / S.D.	Midshaft Medio-Lat. Diameter (F7) Value or Mean / S.D.	FSRI Index 100 X ((F6+F7) F2)) Value or Mean / S.D.	Reference
			FOSSIL GROUPS		
Minatogawa I, Upper Pleistocene, Okinawa	393.0	26.5	26.5	13.5	Baba and Endo (1982)
Upper Paleolithic, European and Non-European, pooled (29)	456.0 / 28.6	30.7 / 2.6	27.1 / 2.0	12.7 / 0.8	Shackelford (unpublished); see Shackelford (2007)
Paviland 1, 476.0 Aurignacian-associated	32.3	27.4	12.5	Trinkaus and Holliday	(2000)
Skhūl/Qafzeh "Early moderns", Israel (2)				12.5 / -	Pearson (2000)
Jebel Sahaba, Upper Paleolithic, Sudan (2)				12.4 / -	Pearson (2000)
Gravettian-associated, Europe (8)				12.3 / -	Pearson (2000)

[1] Taotao Tagga"s values are for the right femur. Shackelford's (unpublished) values are for left and right sides combined.

Data from Baba and Endo (1982), Ishida (1993 and unpublished), Pietrusewsky and Douglas (2002), and Sava and Pietrusewsky (1995 and unpublished) represent right side measurements, unless only left side was present. Left side data from Pietrusewsky and Douglas (1990) was used. Only the left femur of Paviland 1 was available for measuring (Trinkaus and Holliday, 2000). Pearson (2000) and Dittrick and Suchey (1986) do not state which side was measured.

[2] Two additional (smaller) samples of late prehistoric Chamorros from Guam, from the Hyatt Hotel (valid n=13) and Apurguan (valid n=3) sites yielded mean FSRI indexes of 12.9 and 12.5, respectively. Data were reported in Trembly with Tucker (1999) and Pietrusewsky et al. (1992), respectively.

in FSRI values would have been nomadic or semi-nomadic, more constantly using their legs for transportation, often on long-distance treks and carrying substantial loads, but Table 6 reveals that categorical mobility reductionism does not hold for (at least) this particular index of robusticity. While other studies have reported that terrestrial mobility correlates strongly with lower limb robusticity (Stock and Pfeiffer 2004 and references), this may only be the case for populations sharing broad ecogeographic similarities, for long bone robusticity is clearly not a simple function of habitual activity levels. Climatic adaptations may be as, if not more, important in determining robusticity of long bone shafts, as suggested by a study of postcranial robusticity which partititioned variation according to cold vs. warm climate populations and found that cold climate groups had proportionately thicker long bone shafts (Pearson 2000). In this regard, it is interesting that all of the groups that surpassed *Taotao Tagga'* in FSRI inhabited Arctic lands or, in the case of the Japanese Jomon foragers, appear to have retained the cold adapted morphology of their Pleistocene ancestors from Northeast Asia (Temple & Matsumura 2011).

Tibiae and Fibulae: The most extreme of the activity-related modifications to *Taotao Tagga'*'s lower leg bones is, more accurately, a bilateral set of trauma-related changes occurring at the tibial tuberosities. This is the site of insertion for the patellar tendon, which originates on the inferior surface of the patella and is continuous with the tendon of the quadriceps group of thigh muscles, attached to the superior surface of the patella (Crouch 1985). *Taotao Tagga'*'s tibial tuberosities bear jagged spurs (Figure 17), which are more pronounced on the right side. The spurring is interpreted as the result of partial separation of the patellar liga-

Figure 17. Supero-anterior view of the proximal ends of *Taotao Tagga'*'s left and right tibiae. Note the jagged spurs where the patellar tendon inserts at the tibial tuberosity site. The spurring is more pronounced on the right side (arrow).

ment from its attachment site, resulting from a powerful pull of the quadriceps muscles, which are involved in extending the thigh and lower leg.

Such changes to the tibial tuberosities appear consistent with what orthopedic surgeons refer to as Osgood-Schlatter's Disease (OSD) (Ortner & Putschar 1981). OSD is essentially of traumatic origin, is frequently bilateral (Blankstein et al. 2001), and is more common in boys than girls, usually occurring between the ages of 10 and 14 in boys (Jaffe 1972). It is common among young athletes who engage in sports involving sudden changes of motion, as occurs when playing soccer or basketball (Aufderheide & Rodríguez-Martin, 1998). Such a clinical profile makes it likely that *Taotao Tagga'* sustained such an injury as a youth, and the fact that there is completely healed reactive new bone, above the spurring, suggests that he was not much affected as an adult. Such an injury, as a youth, may have been the result of some reckless recreational activity, though an occupational injury cannot be ruled out, given the supporting evidence that *Taotao Tagga'* may have commenced rigorous stone working activities as a youth.

We were able to compile only limited comparative data bearing on the robusticity of his tibiae. The derived expression we calculated, the tibial shaft robusticity index (TSRI), expresses the minimum circumference of the shaft as a proportion of its total length. While *Taotao Tagga'* did not have extremely robust femora, his tibiae appear to be quite robust, at least within the confines of our very limited comparative data (Table 7). Compared to other (mostly) Latte Period Mariana Islander males, for instance, his minimum tibial circumference measurement (89mm) exceeds the Chamorro mean (81.3 ± 3.9mm) by nearly two standard deviation units. When expressing that circumference relative to total length, *Taotao Tagga'*'s TSRI of 23.9 exceeds the Chamorro mean (22.4 ±1.2) and Neolithic Japanese mean (22.4 ± 1.0) by over one standard deviation unit, while samples of recent Japanese (21.9), prehistoric Hawaiians (21.4), recent Fukien Formosans (21.3), 17th-19th century Russian hunters (20.1) and recent Negritos from Luzon, Philippines (19.8) were found to be somewhat to considerably more gracile in this measure of tibial stoutness.

Concluding Remarks

Given the detailed narrative structure of the osteobiographic constructions above, we will neither summarize nor recapitulate in this section; rather, we consider *Taotao Tagga'* and his hyperrobust peers within two broad frameworks. In the first, matters of nutrition, lifestyle and evolutionary ecology are considered and an explanation of "the Chamorro advantage", regarding body size and strength is developed. In the second, skeletal morphology and patterning of skeletal changes is discussed vis-à-vis Latte Period demographic, cultural and societal changes in the Marianas, especially in his presumed home district of Taga, Tinian.

Table 7. Comparative Data and Metric Derivatives for Tibial Shaft Robusticity Index (TSRI)

Male Individual or Population Sampled[1] (and sample size)	Tibia Total Length (T1) Value or Mean/ S.D.	Minimum Circum. Shaft (T10B) Value or Mean/S.D.	TSRI Index (T10B X 100 T1) Value or Mean/ S.D.	Reference
Taotao Tagga' , BPBM 881	373.0	89.0	23.9	Ishida (unpublished)
Chamorros, Latte to early Historic periods, Mariana Islands (26)	362.2 / 13.4	81.3 / 3.9	22.4 / 1.2	Ishida (unpublished)
Neolithic Tsukumo, Japan (7)	345.9 / 18.5	77.4 / 4.0	22.4 / 1.0	Baba and Endo (1982)
Recent Kinai Japanese (30)	326.7 / 20.3	71.8 / 4.8	21.9 / 1.2	Baba and Endo (1982)
Hawaiians, Mokapu site, Oahu (59)	365.5 / 15.3	78.9 / 4.5	21.4 / 1.2	Ishida (1993)
Recent Fukien Formosans (65)	348.1 / 17.5	74.3 / 4.5	21.3 / 1.1	Baba and Endo (1982)
Russian hunters, 17th-19th century, West Spitsbergen (19)	364.8 / 23.9	73.3 / 3.3	20.1 / -	Christiansson et al. (1967)
Negritos, Luzon, Philippines (9)	322.6 / -	64.2 / -	19.8 / -	Baba and Endo (1982)

[1] *Taotao Tagga'*'s values are for the right tibia. Other values reported by Ishida (1993 and unpublished) are for the right side, unless it was not present, in which case left side measures were substituted. Data from Baba and Endo (1982), Christiansson et al. (1967), and Pietrusewsky and Douglas (1990) represent right side measurements.

THE CHAMORRO ADVANTAGE: MULTIPLE MEANINGS OF LARGER BODY SIZE AND GREATER STRENGTH OF *TAOTAO TAGGA'* AND HIS PEERS

A large body of research has demonstrated a strong relationship between mean adult stature and a population's environmental conditions (Fogel et al. 1982). Anthropometric historians and biological anthropologists have established that adult height is an indicator of relative nutritional conditions, health and well-being at the population level (Floud 1983; Fogel 1994; Harris 1994; Steckel 1995, 1998; Steckel et al. 2002; Komlos & Baten 2004). Indeed, the relative probabilities of poor health and mortality are effectively predicted by stature (Fogel 1994; Gage & Zansky 1995). These findings for living populations have been matched in a recent bioarchaeological inquiry into the coincidental relationship between longevity and stature. Based on a large pooled sample of over 48,000 skeletons from various time periods in Europe, Kemkes-Grottenthaler (2005) reported a significant inverse relationship between estimated adult height and estimated age at death in both males and females.

Looked at this way, the relatively tall stature of *Taotao Tagga'* and his Chamorro peers reflects a quality of life advantage that they enjoyed over near-contemporary representatives of European "civilization" (Table 2). But the size and shape of Chamorro bodies are surely multifactorial in origin and development. It is our contention that the generally large and well-muscled bodies of Chamorros that contemporary Europeans beheld were the product of inter-digitated cultural, environmental and genetic factors. There is good reason to think that the Chamorro gene pool was restructured by microevolutionary processes related to the settlement history of the Marianas. Indeed, we think it likely that the "Chamorro advantage" (over European contemporaries) in body size and strength represents an adaptive phenotype, shaped by natural selection in ways that parallel the evolution of Polynesian body form (Houghton 1990, 1991, 1996; cf. van Dijk 1991).

Houghton (1990) theorized that the frequently-encountered massively muscled and tall phenotype of Polynesians is a product of the rigors involved in their settlement of Remote Oceania (see Green 1991). More particularly, he argued that contemporary Polynesians are the descendents of naturally-selected subsets of pioneers and colonizers, viz. those who were constitutionally suited to endure long voyages in frequently wet and cold conditions. Such a selective milieu, in the absence of technology and garb to buffer bodies from the elements, meant that large well-muscled bodies were at an advantage in maintaining critical body temperature and effective use of limbs.

Similarly, settlement of the Marianas involved long non-stop ocean crossings, and attendant severe stressing of the migrants' physiologies. Archaeological evidence and linguistic reconstructions (Bellwood et al. 2011) are supportive of an Island Southeast Asian (ISEA) origin of the first visitors to the Marianas (~ 3,500 BP), and subsequent immigrant populations who founded permanent settlements there, ~2,000 BP (Moore & Hunter-Anderson 1999). Within ISEA, the Philippine archipelago is the closest large land mass to the Marianas and, according to Craib (1999), was likely the proximate homeland of Chamorro ancestors, who would have navigated across more than 2,600 kilometers of open waters to reach the islands. The distance would be even greater if the proximate ISEA homeland proves to be Sulawesi or elsewhere in Indonesia, a scenario permitted by comparative studies of early pottery (Kirch 2010) and mitochondrial DNA (Vilar et al. 2012).

Post-settlement selective pressures may have further shaped the collective physiologies of Chamorros. McGarvey (1994) has suggested (for Polynesian settlers) that after explorers reached new islands, considerable time may have passed before sustainable levels of agricultural crop production was reached. Thus, under conditions of extended food shortages, interspersed with opportunities for feasting, individuals with "efficient metabolic mechanisms" would have been better able to survive and reproduce. Here, "efficient metabolic mechanisms" refer to the ability to store fat under during occasional or periodic periods of plenty to get by on during periods of food shortage.

The selection arguments of McGarvey (differential adiposity) and Houghton (differential musculature) were examined in an unpublished study on the body composition of University of Guam (UOG) students. Preliminary results show that male UOG students of Chamorro ancestry (with two or more Chamorro grandparents) have both greater mean skeletal musculature (viz. estimated for both the upper arm and total body) and adiposity (viz. estimated by both summed skinfold thicknesses and bioelectrical impedance analysis) when compared to UOG students of European or Filipino ancestry. While the "fat advantage" is not statistically significant, the Chamorro upper arm musculature advantage is enormous and highly significant (Heathcote unpublished data).

MUSCLE OVERUSE AND HEAVY WEIGHT-BEARING SYNDROME: CHANGES TO *TAOTAO TAGGA*''S SKELETON IN SOCIO-CULTURAL CONTEXT

Arthritic changes at *Taotao Tagga*''s joints, and bone overgrowth and remodeling changes at various tendon and ligament attachment sites (especially at the elbow and hip) appear to be part of a muscle overuse and heavy weight-bearing syndrome. These changes, taken together with the pronounced development of two of his occipital superstructures and the extraordinary robusticity of especially his upper limb, bespeak a life history that involved bearing, pushing, pulling, and lifting heavy weights, as well as engagement in repetitive pounding movements. These activities, repetitive and of long duration, would have been involved in the quarrying, dressing, transport and emplacement of megaliths, as well as in the construction of *guma' latte*. For these activities to have had such an influence on his skeleton, he likely engaged in such work over a long duration, likely starting at a fairly young age (see Woo et al. 1981; Weiss 2009). At this point, we can only say with confidence that his documented skeletal changes are consistent with chronic engagement in reconstructed motor activities involved in such mining, masonry and building work. Further, we think it plausible that *Taotao Tagga'* lived and worked during a Latte period "building boom" that was underway during times leading up to Spanish contact. To appreciate the demographic pressures that led to the need for such sustained development, a brief discussion of Marianas population history, from the onset of the Latte Period, is in order. This discussion includes inferences about sociocultural change and social and political organization.

At the beginning of the Latte Period (ca. AD 1000), there appeared a striking change in the material culture of the Chamorros, which is taken by local experts to reflect a significant period of sociocultural change (Hunter-Anderson and Butler 1995; Hunter-Anderson et al. 1995; Hanson and Butler 1997). Latte stones appear for the first time throughout the Southern Marianas, hence the Period's namesake. The Marianas population was generally increasing throughout the Latte Period. There are a number of estimates of prehistoric Marianas population size available in the literature, and these vary greatly. Archaeologists specializing in the Marianas have estimated prehistoric Marianas population size to be between 30,000-40,000 individuals (Hunter-Anderson and Butler 1995), and 50,000 individuals (Spoehr 1954, 1957). Demographic anthropologist Jane Underwood, a leading authority on Western Pacific population biology and history, reported an estimate of 56,000 individuals (Underwood 1973) and, more recently, of 70,000 to 80,000 individuals (J.H. Underwood unpublished). The historian Shell (2002) has estimated the Latte Period maximum population as 65,000 individuals.

Regardless of the approximate population size, there is consensus that Chamorros were under high levels of population pressure during the Latte Period. This inference is supported by the change in settlement pattern exhibited across the Pre-Latte and Latte Periods. It is important to note that Chamorros, like many other Pacific Islanders, tended to prefer settling the coastal areas as opposed to the interior regions, presumably to be closer to oceanic/coastal resources (Hunter-Anderson & Butler 1995). Around the beginning of the Latte Period, however, more and more settlements are found inland, which is believed to be a response to increasing population pressure in the coastal areas (Reinman 1977; H. Kurashina unpublished; Hunter-Anderson & Butler 1995), as well as an adaptive response to climatic oscillation (Hunter-Anderson 2010). The covariation of increasing population size, increasing number of latte structures, and changing settlement pattern supports the theory that there would have been competition between kin groups over limited resources during the Latte Period, as land area for expansion would have become more and more scarce (Graves 1986; Hunter-Anderson & Butler 1995; Hunter-Anderson et al. 1995).

Regarding sociopolitical organization, it is generally thought that local groups lacked much vertical stratification (Cordy 1986; Craib 1986), and that the salient point about the geographic domain of Chamorro leadership is that "there were no people recognized as chiefs over a region composed of more than one village (Knudson 1987:177)." While such organization may have typified local and regional polities in the Marianas generally, a higher level of stratification has been suggested for *Taotao Tagga*'s village of burial. Graves noted that the House of Taga is at once positioned between two clusters of smaller latte sets at the Taga site, and centrally located between two other latte site settlements in Tinian. He suggests that that such intra- and inter-community house patterning reflects a late (protohistoric) emergence of "inter-village unity and integration" (Graves 1986:152), i.e. the existence of a paramount chief and local chiefs, with the former being situated at the House of Taga.

The above considerations have relevance to expectations concerning the patterning of *Taotao Tagga*'s activity-induced skeletal changes. Recall that (economic role) "generalists" are expected to have less within-skeleton variation in the expression of MSMs than "specialists" (Robb 1998; Peterson 2000). While full time craft specialists are absent in societies of foragers with informal political leadership, they may sometimes be encountered in semi-sedentary, horticultural societies (Ember et al. 2007:286). Among the local and regional societies of farmer-fisher folk in the Marianas, during *Taotao Tagga*'s time, the presence of more people with less range of economic activities might reasonably be expected in polities that have two or more decision-making levels (possibly the case at Taga) vs. those with one (generally elsewhere in the Marianas). While we can document that *Taotao Tagga*'s intra-skeleton patterning of occipital superstructures, long bone MSM expressions and measures of limb bone robusticity displays "unevenness", we have not as yet quantified this precisely for his entire skeleton, nor placed his differential expressions of robusticity into group context with like data from his peers. Neither do we know how much "unevenness" is consistent or inconsistent with, say, his being primarily a quarryman, mason, and builder of *guma' latte*, and secondarily a warrior, a farmer and a fisherman/sailor. All we can say is that his geographic situation at Taga, as opposed to other hamlets and villages in the Marianas, makes it more feasible that he may have been a semi-specialist involved in a restricted range of economic behaviors throughout much of his lifetime.

It is instructional, here, to look outside the Marianas to places in Micronesia where traditional culture has been better recorded, ethnographically. In the northern islands of Kiribati, for instance, each residential kin group is known to have had a least one specialist builder of dwelling houses, and giant meeting houses. The latter feature corner and central stone pillars *(boua),* and were constructed by a specialist clan of builders within each district (Hockings 1989). By analogy, such specialists (or semi-specialists) could have existed in the Marianas, especially in places comparable to northern Kiribati, where the level of social and political organization equates with classifications of "simultaneous hierarchy", or "political superstructure" (Sahlins 1961; Johnson 1982). Such a polity, with at least two levels of decision making, corresponds to the level of political organization posited by Graves (1986) for *Taotao Tagga*''s home district.

Regardless of the degree of *Taotao Tagga*''s economic role specializations, his involvement in building latte structures should be viewed as an endeavor that was likely entangled in hostilities typical of inter-kin group competition. Since *Taotao Tagga*''s skeletal remains are not as yet dated chronometrically, it is possible that he incurred his facial wound in a skirmish between kin (or village) groups, rather than during the Spanish-Chamorro Wars. As discussed, if he was injured by a fellow Chamorro prior to the Spanish-Chamorro Wars, the nature of the facial wound suggests that his attack took place after the Chamorros had acquired metal. Notwithstanding the multiple lines of evidence for semi-specialist economic roles within his society, he was probably more than a megalithic stone quarryman, builder and warrior. That *Taotao Tagga'* may well have engaged in significant maritime activities, as well, is suggested by studies that have found enhanced humeral robusticity in ocean-rowing populations (Cybulski 2010; cf. Weiss 2003a). That he may have engaged in not only fishing and other navigational pursuits, but also in farming is supported by early contact chronicles which note that even the highest class (matua) members of Chamorro society did much of their own farming and fishing (Knudson 1987:173-4).

Acknowledgements

It has been a privilege and an honor to study the remains of *Taotao Tagga'*. We hope that this limited construction of his life history may inspire some of his descendants to study, with care and respect, the physical remains of their ancestors

with enhanced methods, analytic capabilities, and an augmented wisdom that will make our present contribution seem feeble.

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APPENDIX (Tables A1a – A7)

Table A1a. *Taotao Tagga'*'s Dental Inventory[a] and Wear[b]

Maxillary Teeth						**Mandibular Teeth**					
Side	Tooth	Inventory Category	Quadrant Wear		Total Wear	Side	Tooth	Inventory Category	Quadrant Wear		Total Wear
Right	1 M^3	(6)				Left	17 M_3	(8)			
	2 M^2	2	2	5	11		18 M_2	4			
			2	2							
	3 M^1	4					19 M_1	4			
	4 P^2	4					20 P_2	4			
	5 P^1	4					21 P_1	2			5
	6 C	2			4		22 C	2			5
	7 I^2	5					23 I_2	5			
	8 I^1	5					24 I_1	4			
Left	9 I^1	5				Right	25 I_1	4			
	10 I^2	5					26 I_2	4			
	11 C	2			4		27 C	2			5
	12 P^1	4					28 P_1	5			
	13 P^2	4					29 P_2	4			
	14 M^1	2	1	8	21		30 M_1	4			
			8	4							
	15 M^2	2	5	2	11		31 M_2	4			
			2	2							
	16 M^3	(6)					32 M_3	8			

Codes in parentheses are estimates.

[a] Inventory Category codes (Buikstra and Ubelaker 1994: 49): 2 = present, *in situ*; 4 = missing, premortem loss; 5 = missing, postmortem loss; 6 = missing, congenital absence; 8 = present, but unobservable (impacted, in crypt; portion of crown visible on left side only). X-ray verification is needed for the coding of teeth numbered 1, 16 and 17.

[b] For meaning of dental wear codes, see Buikstra and Ubelaker (1994: 52-53).

Table A1b. *Taotao Tagga*"s Dental Pathology, Part 1

Maxillary Teeth						Mandibular Teeth					
Side	Tooth	Caries[a]	Periapical cavity[b] location	Calculus score[c]/ location		Side	Tooth	Caries[a]	Periapical cavity[b] location	Calculus score[c]/ location	
Right	1 M^3					Left	17 M_3				
	2 M^2	none		1	distal		18 M_2				
	3 M^1						19 M_1				
	4 P^2						20 P_2		buccal		
	5 P^1						21 P_1	none		0	
	6 C	none		0			22 C	none		0	
	7 I^2						23 I_2				
	8 I^1						24 I_1				
Left	9 I^1					Right	25 I_1				
	10 I^2						26 I_2				
	11 C	none		0			27 C	none		0	
	12 P^1		buccal				28 P_1				
	13 P^2		buccal				29 P_2				
	14 M^1	none		1	buccal-crown; distal-roots, below CEJ		30 M_1				
	15 M^2	none		1	buccal-crown; distal-roots, below CEJ		31 M_2				
	16 M^3						32 M_3				

[a] No carious lesions were observed on any surface of any of the extant teeth. However, some zones of dentin exposure are filled in with calcareous deposits, making this judgment problematic, viz. for tooth numbers 2, 6, 11, 14, and 15.

[b] The three periapical cavities are different in significant ways. The cavity for tooth 12 has slightly roughened walls, and is >8mm, measured across the buccal surface. The cavity for tooth 13 has roughened walls, and was small (3mm); there is a small area of necrotic bone in the apical region of the alveolus (Figure 8). The walls of the cavity for tooth 20 are smooth and the cavity's diameter is >6mm across the buccal surface.

[c] Scoring scheme for dental calculus is illustrated in Buikstra and Ubelaker (1994: 56).

Table A1c. *Taotao Tagga*''s Dental Pathology, Part 2

Maxillary Teeth					Mandibular Teeth				
Side	Tooth	Alveolar bone loss[a]	Alveolar resorption rating (molars)[b]	CEJ to hypoplastic line distance[c]	Side	Tooth	Alveolar bone loss[a]	Rating of alveolar resorption (molars)[b]	CEJ to hypoplastic line distance[c]
Right	1 M^3				Left	17 M_3			
	2 M^2	>2mm of bone loss above buccal roots furcation	medium	4.8mm; max. ht. of rt. linear defect= 2.1mm		18 M_2			
	3 M^1					19 M_1			
	4 P^2					20 P_2			
	5 P^1					21 P_1	>6mm of bone loss below CEJ		
	6 C	>5mm of bone loss above CEJ				22 C	>8mm of bone loss below CEJ		
	7 I^2					23 I_2			
	8 I^1					24 I_1			
Left	9 I^1				Right	25 I_1			
	10 I^2					26 I_2			
	11 C	>5mm of bone loss above CEJ				27 C	>8mm of bone loss below CEJ		
	12 P^1					28 P_1			
	13 P^2					29 P_2			
	14 M^1	>4.5mm of bone loss above buccal roots furcation	considerable			30 M_1			
	15 M^2	>2mm of bone loss above buccal roots furcation	medium	4.3mm; max. ht. of left linear defect= 1.4mm		31 M_2			
	16 M^3					32 M_3			

[a] Post-mortem damage made measurements of bone loss relative to CEJ or root furcations approximate for tooth numbers 2, 11, 21, 22, and 27.

[b] Following visual scoring scheme in Brothwell (1981:155).

[c] First listed distance is from the CEJ to the most occlusal portion of thick linear defects on the buccal surfaces, following Buikstra and Ubelaker (1994). The second metric expresses maximum thicknesses of the defects, wherever found on the buccal surface. Other than the affected M^2s, macroscopic examination revealed no other clearly defined hypoplastic defects.

All distances were measured with a Helios Needle Point Dial Caliper, GPM No. 105A.

Table A1d. ***Taotao Tagga*'s Dental Measurements[a] (in mm.)**

Maxillary Teeth						Mandibular Teeth					
Side	Tooth	Mesio-distal dia.	Bucco-lingual dia.	Crown ht.	Root ht.	Side	Tooth	Mesio-distal dia.	Bucco-lingual dia.	Crown ht.	Root ht.
Right	1 M^3					Left	17 M_3				
	2 M^2	10.0	12.5	7.2			18 M_2				
	3 M^1						19 M_1				
	4 P^2						20 P_2				
	5 P^1						21 P_1	7.2	9.1	7.3	
	6 C	8.8	8.9	10.2			22 C	6.9	8.2	10.0	
	7 I^2						23 I_2				
	8 I^1						24 I_1				
Left	9 I^1					Right	25 I_1				
	10 I^2						26 I_2				
	11 C	8.7	8.8	9.1	(14.3)		27 C	7.0	8.1	9.6	
	12 P^1						28 P_1				
	13 P^2						29 P_2				
	14 M^1	12.3	12.3	6.1	(10.5)		30 M_1				
	15 M^2	10.0	11.9	6.4			31 M_2				
	16 M^3						32 M_3				

Measurements in parentheses are estimates.

[a]Mesiodistal diameter, buccolingual diameter and crown height measurements follow Buikstra and Ubelaker 1994:62). Root heights, when estimated from in situ teeth, are vertical distances from the midpoint of the most distant apical part of the root, visualized on the labial/buccal surface.

Table A2. Ectocranial Suture Closure for *Taotao Tagga'*, using Lateral-Anterior Sites (Meindl and Lovejoy 1985)	
Lateral-Anterior System	**Codes for Closure Stage/ Estimated Age at Death**
Midcoronal, L	0
Midcoronal, R	1
Pterion, L	1
Pterion, R	1
Sphenofrontal, L	2
Sphenofrontal, R	2
Inferior sphenotemporal, L	1
Inferior sphenotemporal, R	1
Superior sphenotemporal, L	0
Superior sphenotemporal, R	0
Composite score for 5 lateral-anterior sites	**5**
Mean age estimate (Meindl and Lovejoy 1985: Table 6)	**41.1 (S.D. = 10.0)**

Table A3. *Taotao Tagga*”s Upper Limb Measurements[a]

Measurement No. (and Measurer)[b]	Measurement Name	Measurement, Left side (mm)	Measurement, Rt. side (mm)
Humerus			
M-1 (GH)	Maximum length	322	(322)
M-2 (HI)	Total length	317	(317)
M-3 (GH)	Proximal transverse diameter of head	(53)	-
M-5 (GH)	Maximum diameter at shaft midpoint	29	29[c]
M-6 (GH)	Minimum diameter at shaft midpoint	23	24[c]
K-6A (GH)	Greatest diameter, where it occurs, at deltoid tuberosity	29	30
M-7 (GH)	Minimum circumference, just distal to the deltoid tuberosity	80	84
R-HDC (GH)	Deltoid tuberosity circumference	90	99
M-9 (GH)	Transverse diameter of head	(45)	-
M-10 (GH)	Vertical diameter of head	(41)	-
R-HDT (GH)	Distal diaphyseal breadth	20	20
R-HSB (GH)	Supracondylar breadth	33	36
R-HEB (GH)	Epicondylar breadth	63	67
R-HDAB (GH)	Distal articular breadth	(49)	52
Radius			
M-1 (HI & GH)	Maximum length	259	258
M-2 (HI)	Physiological length	243	-
M-3 (HI)	Minimum circumference	50	-
S-46 (GH)	Anterior-posterior diameter at midshaft	16	17
S-47 (GH)	Medial-lateral diameter at midshaft	18	19
Ulna			
M-1 (HI & GH)	Maximum length	276	278
M-2 (HI)	Physiological Length	240	-
M-3 (GH)	Minimum circumference	42	44
S-49 (GH)	Maximum anterior-posterior diameter of diaphysis	20	20
S-50 (GH)	Medial-lateral diameter of diaphysis, taken perpendicular to S-49	20	20

Measurements in parentheses are estimates.

[a] Measurements by Hajime Ishida (HI) and Gary Heathcote (GH). Clavicles were not measured by HI and were not available for direct study at the time of GH’s work.

[b] Measurement prefixes: K = Knüsel (2000); M = “Martin measurements” (Martin and Saller 1957); R = Rhodes (2004); and S = measurements in “Standards” (Buikstra and Ubelaker (1994).

Measurement suffixes are measurement numbers or acronyms from source cited.

[c] Using same midpoint as on the left side.

Table A4. Comparative Data[1] and Metric Derivatives for Humeral Shaft Robusticity Index No. 1 (HSRI-1): Males				
Male Individual or Population Sampled[2] (Valid n)	**Maximum Humerus Length (H1) Value or Mean/ S.D.**	**Minimum Circum. Shaft (H7) Value or Mean/S.D.**	**HSRI-1 Index (H7 X 100 H1) Value or Mean/ S.D.**	**Reference**
Taotao Tagga' , BPBM 881	**L: 322.0** **R: (322.0)**	**L: 80.0** **R: 84.0**	**L: 24.8** **R: (26.1)**	Heathcote (unpublished)
Chamorros[3], Mariana Islands (32)	320.8 / 9.7	74.6 / 4.7	23.3 / 1.7	Ishida (unpublished)[4]
Recent Fukien Formosans (102)	313.4 / 14.4	62.0 / 3.3	23.1 / 1.2	Baba and Endo (1982)
Neolithic Tsukumo, Japan (15)	291.5 / 12.4	65.2 / 3.7	22.8 / 1.3	Baba and Endo (1982)
Chichester, medieval leprosarium and later almshouse, West Sussex, England (190)	321.1 / 17.0	71.8 / 5.7	22.4 / -	Rhodes (2004 and unpublished)
Wharram Percy, medieval rural village, Yorkshire, England (156)	327.6 / 16.6	72.9 / 4.4	22.3 / -	Rhodes (2004 and unpublished)
Hickleton, medieval rural village, Yorkshire, England (15)	318.6 / 14.9	70.6 / 5.1	22.2 / -	Rhodes (2004 and unpublished)
Mary Rose crew, sunken Tudor warship, Portsmouth Harbour, England, AD 1545 (165)	332.5 / 17.4	73.5 / 4.9	22.1 / -	Rhodes (2004 and unpublished)
Towton, battlefield casualities, North Yorkshire, England AD 1455-1487 (45)	337.5 / 17.4	74.2 / 4.9	22.0 / -	Rhodes (2004 and unpublished)
Recent Kinai Japanese (30)	294.2 / 15.6	66.3 / 4.3	21.9 / 1.3	Baba and Endo (1982)
Terry Collection "Whites", largely indigent group, St. Louis, Missouri, USA, born between AD 1841-1943 (358)	331.9 / 17.5	72.7 / 5.7	21.9 / -	Rhodes (2004 and unpublished)
Fishergate, medieval urban priory, York, England, southern cemetery: low status workers and craftsmen (34)	329.2 / 11.5	71.5 / 4.5	21.9 / -	Rhodes (2004 and unpublished)
Tongans, pre-European contact (7)	332.6 / 12.3	72.6 / 3.8	21.8 / -	Sava and Pietrusewsky (1995 and unpublished)

Hawaiians, WARC site, Wai'anae, O'ahu (4)	314.0 / 17.9	68.6 / 2.3	21.8 / -	Pietrusewsky and Douglas (1990)
Fishergate, medieval urban priory, York, England, intramural cemetery: high status townspeople (90)	327.5 / 14.4	71.0 / 4.6	21.7 / -	Rhodes (2004 and unpublished)
Fishergate, medieval urban priory, York, England, eastern cemetery: ecclesiastical community (55)	328.8 / 18.1	71.3 / 5.1	21.7 / -	Rhodes (2004 and unpublished)
Fishergate, medieval urban priory, York, England, blade-injured, presumed weapon-trained cohort (26)	341.4 / 16.3	73.6 / 4.4	21.6 / -	Rhodes (2004 and unpublished)
North Alaskan Coast Whaling Inuit (39)	310.6 / 13.3	67.1 / 4.1	21.5 / 1.0	Collier (1993)
Neolithic Ukrainians (34)	342.0 / 13.4	73.5 / 4.6	21.5 / 1.3	Jacobs (1993)
Lapps (Sami), regions(s) unspecified (148)	308.0 / -	64.4 / -	20.9 / -	Schreiner (1931, 1935) in Woo (1943)
Modern Southern Chinese, Hong Kong (*)			20.8 / -	King (1997) in Pietrusewsky and Douglas (2002)
American "Whites", Terry Collection (49)	334.4 / 18.9	68.9 / 4.1	20.7 / 1.3	Collier (1989)
Hsiao T'un, Sui-T'ang Dynasties, Anyang, China (11)	312.9 / -	64.8 / -	20.7 / -	Woo (1943)
Romano-Britons, Dorset (50)	329.1 / 17.5	68.1 /4.7	20.6 / 1.4	Collier (1989)
Hsiu Chiu Shan, modern Chinese, poorer classes, E. China (61)	310.3 / 14.5	64.0 / 4.76	20.6 / -	Woo (1943)
Fuégiens, South America (12)		62.5 / -	20.6 / -	Vallois (1932)
Southwest Alaskan Riverine Yuit (45)	309.1 / 13.2	63.2 / 3.6	20.5 / 1.3	Collier (1993)
Modern Thai, Chiang Mai (*)			20.4 / -	King (1997) in Pietrusewsky and Douglas (2002)
Minatogawa I, Upper Pleistocene, Okinawa	287.0	58.0	20.2	Baba and Endo (1982)
Hawaiians, Mokapu site, Oahu (72)	319.2 / 13.0	64.8 / 3.6	20.2 / 1.3	Ishida (1993)
Russian hunters, 17th-19th century, West Spitsbergen (19)	322.7 / 18.2	64.9 / 5.1	20.1 / -	Christiansson et al. (1967)

Mesolithic Ukrainians (13)	344.0 / 16.9	68.5 / 4.6	20.0 / 1.3	Jacobs (1993)
Norwegians, region(s) unspecified (162)	337.3 / -	67.6 / -	20.0 / -	Wagner (1927) in Woo (1943)
Ban Chiang, Thailand, 2100 B.C. – A.D. 200 (11)	307.4 / 9.9	61.5 / 2.9	20.0 / -	Pietrusewsky and Douglas (2002)
Non Nok Tha, Thailand, 2800 – 200 B.C. (*)			19.8 / -	Pietrusewsky and Douglas (2002)
Central California Native Americans, Early Horizon (27)	325.0 / 17.1	64.1 / 6.6	19.7 / -	Dittrick and Suchey (1986)
Old Socorro Mission, El Paso del Norte, Texas, Spanish period Piro, from New Mexico (7)	314.6 / 11.9	61.6 / 1.9	19.6 / -	Raisor (1993)
Non Pa Kluay, Thailand, 2000 – 200 B.C. (*)			19.4 / -	Pietrusewsky and Douglas (2002)
Arikara, South Dakota (48)	327.9 / 10.6	63.0 / 2.4	19.2 / 0.9	Collier (1989)
Central California Native Americans, Middle and Late Horizon (123)	323.9 / 14.0	62.2 / 4.7	19.2 / -	Dittrick and Suchey (1986)
Watom Island, Papua New Guinea, Lapita complex (2)	337.5 / 17.5	64.5 / 3.5	19.1 / -	Pietrusewsky (1989)
Aboriginal Australians (40)	333.3 / 16.9	62.7 / 3.3	18.9 / 1.2	Collier (1989)
Aboriginal Australians, southeastern Australia (106)	320.3 / 16.4	59.3 / 5.4	18.5 / -	van Dongen (1963)

(Values in parentheses are estimates)

[*] Valid n not provided for these series.

[1] All measurements done in accordance with Martin's method (Brauer, 1988). Parenthetic acronyms for measurements (e.g. H1 humerus measurement No. 1) identify each measurement by "Martin number."

[2] *Taotao Tagga*"s left side H1 was directly measured; the right side H1 was estimated. Data from Woo (1943), Christiansson et al. (1967), Baba and Endo (1982), Pietrusewsky and Douglas (1990), Ishida (1993 and unpublished), and Sava and Pietrusewsky (1995 and unpublished) represent right side measurements, unless only left side was present. Data from Pietrusewsky (1989) and Pietrusewsky and Douglas (2002) represent left side measurements. van Dongen's (1963) and Rhodes' (2004 and unpublished) values are for left and right sides combined. Collier (1989, 1993), Dittrick and Suchey (1986), and Vallois (1932) do not specify side measured.

[3] Two additional (smaller) samples of late prehistoric Chamorros from Guam, from the Hyatt Hotel (valid n = 12) and Apurguan (valid n = 5) sites yielded mean HSRI-1 indexes of 21.9 and 21.4, respectively. Data were reported in Trembly with Tucker (1999) and Pietrusewsky et al. (1992), respectively.

[4] Summary statistics for Mariana Islander Chamorros published by Ishida (1993) included *Taotao Tagga*"s values. Here, and in Tables 5-7, group means and standard deviations have been recalculated, removing *Taotao Tagga*"s measurements.

Table A5. Taotao Tagga''s Lower Limb Measurements[a]

Measurement No.[b]	**Measurement Name**	**Measurement, Left side (mm)**	**Measurement, Rt. side (mm)**
Femur			
M-1	Maximum length	-	462
M-2	Physiological (Bicondylar) length	-	454
M-6	Sagittal (anterior-posterior midshaft) diameter	-	33
M-7	Transverse (medial-lateral midshaft) diameter	-	27
M-8	Circumference at midshaft	-	98
M-9	Maximum subtrochanteric diameter	-	32
M-10	Minimum subtrochanteric diameter	-	27
M-18	Vertical diameter of head	-	49
M-19	Transverse diameter of head	-	48
Tibia			
M-1	Total length	-	373
M-1A	Maximum length	-	377
M-8	Sagittal diameter at midshaft	-	37
M-8A	Sagittal diameter at nutrient foramen	-	42
M-9	Transverse diameter at midshaft	-	26
M-9A	Transverse diameter at nutrient foramen	-	30
M-10	Circumference at midshaft	-	103
M-10A	Circumference at nutrient foramen	-	111
M-10B	Minimum circumference of shaft	-	89
Fibula			
M-1	Maximum length	-	359
M-2	Maximum diameter at midshaft	-	21
M-3	Minimum diameter at midshaft	-	14

[a] All measurements by Hajime Ishida.

[b] All measurements follow Martin (Martin and Saller 1957).

Table A6. *Taotao Tagga*"s Skull Measurements[a]

Acronym[a]	Reference[b]	Measurement Name	Left (mm)	Midline or bi-lateral (mm)	Right (mm)
Cranial Vault					
GOL	Ho73	Glabello-occipital length		175	
NOL	Ho73	Nasion-opisthion length		169	
WFB	Ol69	Minimum frontal breadth		102	
XFB	Ho73	Maximum frontal breadth		119	
XCB	Ho73	Maximum cranial breadth		144	
WCB	Ho73	Minimum cranial breadth		77	
GWH	He86	Greater wing of the sphenoid height	57		
GWL2	He90	Greater wing of the sphenoid length, no. 2	17		
SLL	He86	Sphenion-lambda length	138		
BAC	He86	Bregma-asterion chord	136		
ASB	Ho73	Biasterionic breadth		111	
LAC	He86	Lambda-asterion chord	84		
TSL	He86	Temporal squamous length	(74)		
ZPL2	He90	Zygomatic process of the temporal length, no. 2	50		
TSH	He86	Temporal squamous height	51		
FRC	Ho73	Nasion-bregma chord		112	
FRK	BM33	Nasion-bregma arc		130	
FRP1	He86	Frontal perpendicular at ¼ point		23	
FRP2	He86	Frontal perpendicular at ½ point		27	
FRP3	He86	Frontal perpendicular at ¾ point		20	
PAC	Ho73	Bregma-lambda chord		110	
PAK	BM33	Bregma-lambda arc		125	
PAP1	He86	Parietal perpendicular at ¼ point		17	
PAP2	He86	Parietal perpendicular at ½ point		26	
PAP3	He86	Parietal perpendicular at ¾ point		20	
OCC	Ho73	Lambda-opisthion chord		96	
OCK	BM33	Lambda-opisthion arc		114	
OCP1	He86	Occipital perpendicular at ¼ point		18	
OCP2	He86	Occipital perpendicular at ½ point		25	
OCP3	He86	Occipital perpendicular at ¾ point		19	
BTC	He90	Bregma-highest temporal line chord	(54)		(67)
TLB	He90	Breadth between highest temporal lines		(104)	
Cranial Base					
OVB	He86	Minimum bi-foramen ovale breadth		53	
AUB	He86	Biauricular breadth		132	

SMB	OT76	Bi-stylomastoid foraminal breadth		87	
PLB	He86	Pars lateralis breadth	31		
PBL	He86	Pars basilaris length	(26)		
PBB	He86	Pars basilaris breadth		(25)	
PPG	He86	Inferior petrous portion diagonal	32		
FOL	Ho73	Foramen magnum length		36	
FOB	MS57	Foramen magnum breadth		28	
OCL	He86	Occipital condyle length	24		
CPR	He86	Condylar point radius		32	
OSR	Ze71	Opisthion radius		44	
BAR	Ze71	Basion radius		25	
MSR	He86	Mastoidale radius	32		
MDB2	He90	Mastoid breadth, no. 2	25		
Cranial Base to Cranial Vault					
BNL	Ho73	Basion-nasion length		101	
LAR	He86	Lambda radius		103	
BRR	Ze71	Bregma radius		121	
VRR	Ho73	Vertex radius		123	
NAR	Ho73	Nasion radius		91	
TLR	He90	Highest temporal line radius	(101)		(93)
AMG	He86	Asterion-mastoidale diagonal	50		
Cranial Base to Facial Skeleton					
BBL	He86	Basion-subnasal border length		86	
BPL	Ho73	Basion-prosthion length		93	
ZOR	Ho73	Zygoorbitale radius	78		
ZMR	Ho73	Zygomaxillare radius	70		(70)
FMR	Ho73	Frontomalare radius	73		
MFR	He86	Maxillofrontale radius	86		
PRR	Ho73	Prosthion radius		(100)	
SSR	Ho73	Subspinale radius		93	
EKR	Ho73	Ectoconchion radius	68		
AVR	Ho73	Molar (M1) alveolus radius	(78)		
Facial Skeleton					
WZH	He86	Minimum height of the zygomatic process of the temporal	8		
FPB	En70	Frontal process of the maxilla breadth	(10)		10
NPH	Ho73	Nasion-prosthion height		(71)	
NLH	Ho73	Nasal height		54	
ZFH	He86	Zygomaxillare anterior-frontomalare anterior height	46		
TFH	He86	Zygomaxillary tuberosity to frontomalare anterior height	52		
ZZG	He86	Zygoorbitale to zygomaxillare anterior diagonal	34		
WMH	Ho73	Cheek height	26		
ZYB	Ho73	Bizygomatic breadth		145	
PMB	He86	Internal premaxillary breadth		27	

ZFL	He86	Frontal process of zygomatic length	14		
ZTL	He86	Zygoorbitale to zygomatico-temporal suture length	46		
IFB	La82	Infratemporal fossa breadth	25		
JUB	Ho73	Bijugal breadth		(127)	
EKB	Ho73	Biorbital breadth		(103)	
FNB	En70	Frontonasal breadth		12	
OBH	Ho73	Orbital height	37		
OBB2	Ol69	Orbital breadth, using maxillofrontale	45		
PFB	OT76	Bi-palatine foramina breadth		32	
PPL	He86	Palatine process maximum length		(30)	
NLB	Ho73	Nasal breadth		25	
MAB	Ho73	Maximum alveolar breadth		68	
MAL	Ba71	Maximum alveolar (maxillo-alveolar) length		53	
FMB	Ho73	Fronto-malar breadth	(104)		
NAS	Ho73	Nasio-frontal subtense		20	
NBS	He86	Nasal bone subtense	16		
ZMB	Ho73	Zygomaxillare breadth		(104)	
SSS	Ho73	Zygomaxillare subtense		22	
AOL	He90	Masseter origin length	36		
WNB	Ho73	Least nasal breadth		7	
SIS	Ho73	Simotic subtense		1	
BFB	Gi88	Bimaxillofrontale breadth		18	
NMS	Gi88	Naso-maxillofrontale subtense		5	
Mandible					
GOA	Am51	Gonial angle	119°		
ADH	Am51	Mandibular height	74		
WRL	Am51	Minimum ramus length	36		
ORL	Wr87	Molar to posterior ramus length	(69)		
ADB	Am51	Mandibular arch breadth		(58)	
GOB	Am51	Bigonial breadth		110	
COB	Am51	Bicondylar breadth		138	

Measurements in parentheses are estimates.

[a] Skull measurements by Gary Heathcote. Specific techniques of measurements and acronyms follow Howells (1973), unless indicated otherwise. All measurements are in mm, except for gonial angle, which is expressed in degrees.

[b] References: Am51 = Ashley Montagu (1951); Ba71 = Bass (1971); BM33 = Buxton and Morant 1933 (British Biometric technique); En70 = Endo (1970); Gi88 = Gill et al. (1988); He86 = Heathcote (1986); He90 = Heathcote (unpublished); Ho73 = Howells (1973); La82 = Larsen (1982); MS57 = Martin and Saller (1957); Ol69 = Olivier (1969); OT76 = Olivier and Tissier (1976); Wr87 = Wright (1987); Ze71 = Zegura (1971)

Table A7. Non-metric traits recorded for *Taotao Tagga*"s skull[a]

Trait	Observation		
	Left	**Midline**	**Right**
Hypostotic Variation			
Os japonicum	Absent		Absent
Infraorbital suture	Present		Present
Metopism or metopic trace		Trace?[b]	
Os Inca or Mendosal suture trace	Absent		Absent
Pars lateralis suture trace	Absent		Absent
Tympanic dehiscence	Pin-hole sized		Pin-hole sized
Pseudo-mastoid suture	Trace		Trace
Foramen spinosum open	Absent		Absent
F. ovale and f. spinosum confluent	Absent		Absent
Hyperostotic Variation			
Marginal foramen of tympanic plate	Absent		Absent
Spino-basal bridge	Absent		Absent
Pterygobasal bridge	Absent		Absent
Pterygospinous bridge	Present		Present
Clino-clinoid bridge	Absent		Absent
Carotico-clinoid bridge	Absent		Absent
Trochlear spur	Absent		Absent
Squamo-parietal synostosis	Absent		Absent
Jugular foramen bridge	Absent		Absent
Mylohyoid bridge	Absent		Absent
Exostoses			
Auditory exostoses			
Torus palatinus size[c]		Small	
Torus palatinus shape[c]		Ridge	
Torus maxillaris[d]	Absent		Absent
Torus mandibularis[e]	Slight		Slight
Variation in Foramina, Canals and Grooves for Blood Vessels and Nerves			
Parietal foramen	Present		Absent
Frontal grooves	Absent		Absent
Supraorbital foramen	Deep notch		Absent
Supratrochlear foramen	Absent		Absent
Zygomatico-facial foramen	Count = 3		Count = 4
Parietal process of the temporal	Absent		Absent
Accessory optic canal	Absent		Absent
Vesalian foramen	?		Absent
Mastoid foramen	Present		Present
Anterior ethmoid foramen exsutural	Present		?

Supernumerary or Accessory Bones of the Cranial Vault			
Lambdic ossicle		Absent	
Lambdoidal ossicles	Absent		Absent
Asterionic ossicles	Absent		Absent
Occipito-mastoid suture ossicles	Absent		Absent
Parietal notch ossicles	Absent		Absent
Pterionic ossicles	Absent		Absent
Coronal suture ossicles	Absent		Absent
Sagittal suture ossicles		Absent	
Craniovertebral Region Variation			
Pharangeal fossa		Absent	
Odonto-occipital articulation		Absent	
Double condylar facet	Absent		Absent
Divided hypoglossal canal	Absent		Absent
Ossified apical ligament		Absent	
Intermediate condylar canal	Present		Present
Precondylar tubercle	Absent		Absent
Posterior condylar canal	Present		Present
Occipital Superstructures[f]			
Tubercles on Occipital Torus (TOT)	3		3
Retromastoid Process (PR)	4		4
Posterior Supramastoid Tubercle (TSP)	2		2
Other Traits			
Pterionic form[g]	H-shaped		H-shaped
Widest diameter of zygomaxillary suture[h]	Curved		Cannot observe, due to injury
Oval window visible?[i]	Yes		Yes
Palatine suture[j]		Curved	
Rocker jaw		Semi-rocker[k]	

[a] Scored by Gary Heathcote, following Molto (1983), after Ossenberg (1969), unless footnoted otherwise.

[b] May have been a lengthy trace, but appearance of late obliteration confuses the issue.

[c] Following Woo (1950)

[d] Following Brothwell (1981)

[e] Following Ossenberg (1981)

[f] Following Heathcote et al. (1996)

[g] Following Olivier (1969)

[h] Following Martindale in Gill (1998)

[i] Following Napoli and Birkby (1990)

[j] Following Gill (1998)

[k] Slight rocking of mandibular body can be produced by applying downward pressure above the symphysis menti (see Snow 1974)