Title

Skeletal evidence of craft production from the Ch'iji Jawira site in Tiwanaku, Bolivia

Author
Becker, Sara K

Publication Date
2016-10-01

DOI
10.1016/j.jasrep.2016.08.017

Peer reviewed

Journal of Archaeological Science: Reports 9 (2016) 405–415

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Skeletal evidence of craft production from the Ch'iji Jawira site in Tiwanaku, Bolivia

Sara K. Becker

Department of Anthropology, University of California, Riverside, 1334 Watkins Hall, Riverside, CA 92521, United States

ARTICLE INFO

Article history:
Received 1 May 2016
Received in revised form 18 August 2016
Accepted 18 August 2016
Available online xxxx

Keywords:
Bioarchaeology
Labor
Movement
Activity patterns
Musculoskeletal stress markers
Entheses
Osteoarthritis
Ceramics manufacture
Pottery
Weaving
Complex society formation

ABSTRACT

The Tiwanaku culture in the Bolivian highlands was comprised of neighborhoods home to various groups laboring at differing jobs. Ch'iji Jawira, one site within this community, is described archaeologically as containing both a manufacturing center for pottery and a residential area home to these ceramic manufacturers. Prior bioarchaeological research has also noted that the people buried at the Ch'iji Jawira site show statistically significant differences in labor and activity from others who lived in the Tiwanaku capital. Using a life-history approach, this study explores the idea that Ch'iji Jawira was home to ceramic specialists by describing one individual from this community, a 30–39 year old female (CJ-35250). This person has evidence of degeneration associated with osteoarthritis in her arms, wrists, hands, fingers, lumbar spine, sacroiliac, hip, and feet. The bones of her wrists, hands, fingers, and feet also have extensive skeletal changes at tendon and muscle attachment areas. The pattern on her bones suggests she worked at crafting, especially tasks involving repetitive joint movement and heavy use of arm, hand, and foot musculature. From her burial location and grave goods, it may be that CJ-35250 was one of the earliest potters at this site.

1. Introduction

The Tiwanaku culture (500–1100 CE) was one of the earliest state-level societies in the South Central Andes (Janusek, 2008; Kolata, 1993; Stanish, 2013) (Fig. 1). With its heartland in the Lake Titicaca basin *altiplano* (i.e. high-elevation Andean plateau), the main city of Tiwanaku was a dense, multi-ethnic urban center with various *barrios* (i.e. neighborhoods) home to specialists laboring at differing jobs (Albarracín-Jordán, 1996; Becker, 2013; Janusek, 2004; Janusek, 2008) (Fig. 2). Since repeated activities are inscribed onto human physical bodies (Bourdieu, 1977; Budden and Sofaer, 2009; Liimakka, 2011; Merleau-Ponty, 2013 [1945]), the observation of skeletal changes can provide insight into individuals' daily routines (Buikstra and Beck, 2006; Buikstra and Pearson, 2006; Larsen, 1997; Larsen, 2015; Sofaer, 2006). Thus, the tasks people frequently worked at throughout their lifetimes are understood as patterns of movement on their bones that address how they lived. They also provide a contextual representation, especially in cases like Tiwanaku, where we have no written record of life in a prehistoric culture.

My prior, population-centered Tiwanaku research on activity and labor has shown that people from this culture vary spatially and temporally in labor levels and workload across the state, including within the many neighborhoods of the Tiwanaku city (Becker, 2012; Becker, 2013; Becker, 2017). The *barrio* of Ch'iji Jawira (number 12 in Fig. 2) was one such area with significantly different skeletal indicators of activity (e.g. musculoskeletal stress markers and osteoarthritis). Descriptions of this site note it containing both a manufacturing center for pottery and a residential area home to these ceramic manufacturers (Janusek, 2004; Rivera, 1994; Rivera, 2003). Archaeologists uncovered ceramic firing zones, pottery production refuse, as well as evidence of floor surfaces used in the preparation and shaping of ceramics at Ch'iji Jawira (Rivera, 2003: 306). The proximity to a clay source/procurement area and an almost year-round water supply would have been beneficial reasons for settlement of this location. Residence at this site likely began during the Late Formative (300–500 CE), with it emerging as a major ceramic production area and household compound during Tiwanaku times.

In this study, I use a contextual, life-history approach to explore the lived experience of residents' connection to ceramics manufacturing by analyzing the most complete adult individual burial (i.e. CJ-35250) from this community. As noted by Rivera (2003: 297), Ch'iji Jawira provides the only significant, in situ evidence of specialized ceramic production within the city of Tiwanaku. In addition, craft specialization has a long history in the Andes of being associated with emerging civilizations, power, and identity formation (Costin, 2004; Janusek, 1999; Silverblatt, 1987; Vaughn, 2006). Thus, studying this burial provides an opportunity to observe skeletal evidence of production from a

E-mail address: sara.becker@ucr.edu.

http://dx.doi.org/10.1016/j.jasrep.2016.08.017

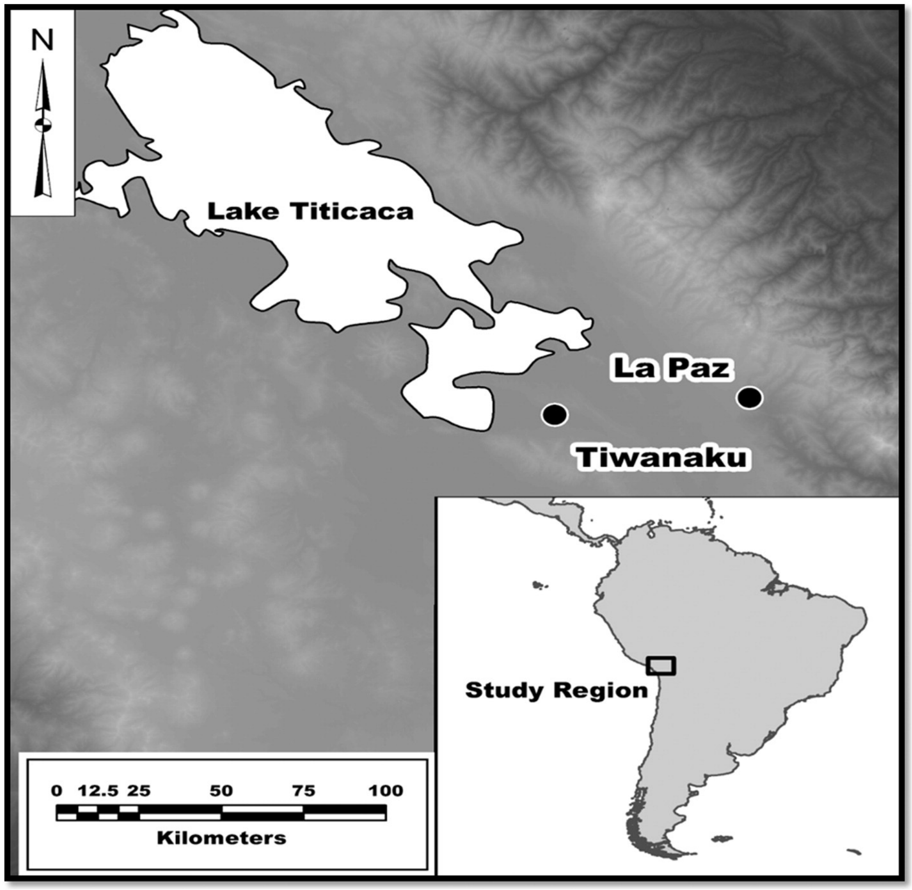

Fig. 1. Map of the study area.

known crafting site and potentially isolate a pattern of activity on skeletal remains that may be associated with ceramic manufacturing as an occupation. This research also adds a bioarchaeological perspective to the literature on Andean craft production and another possible way of assessing the importance of specialized goods producers.

2. Materials and methods

The site of Ch'iji Jawira sits on the broad, flat plain of the Andean plateau approximately 1000 m from the monumental Akapana pyramid. Excavation of Ch'iji Jawira was undertaken by the Proyecto Wila Jawira from 1990 to 1991 and proved to an area of pottery production, as noted by the evidence of a ceramic molds, broken sherds, a clay procurement source, and near to some *qochas* (i.e. rain-fed ponds). Among the many artifacts recovered, eight burials from this site are housed in the present-day town of Tiahuanaco, Bolivia under the auspices of the Centro de Investigaciones Arqueológicas, Antropológicas, y Administración de Tiwanaku (CIAAAT). For these individuals, I estimated age-at-death and sex using standard methods (Bass, 1981; Buikstra and Ubelaker, 1994; Suchey and Katz, 1998; Ubelaker, 1999). First, I evaluated dental eruption, dental wear, and epiphyseal closure. I also recorded changes in sternal rib ends, the pubic symphysis, auricular surfaces of the os coxae, as well as endocranial and ectocranial suture closure. For sex, I recorded data from various points on the os coxae, and if not present, then sex was estimated using cranial elements. Six adults (one possible male age 13–17, one possible male age 20–39, two females in their thirties, and two individuals for which sex could not be identified) and two neonatal-age subadults were noted as present.

Overall, the majority of these burials are less than 50% complete. Only burial CJ-35250, a 30–39 year-old female, had over 90% of the skeleton present with only a nasal bone and portions of the ribs missing. Hence, this individual became the focus for this life-history study. Excavation records of CJ-35250 show that the skeleton was from a flexed, individual burial context, with grave goods including an uncommon gold miniature mask in the stylized form of a human face and a camelid skull offering, along with a somewhat more common undecorated *vasija* (i.e. urn). While there are no radiocarbon dates, it is possible this burial represents some of the earliest evidence of occupation at Ch'iji Jawira as the *vasija* style, paste, and finish are akin to the Late Formative 2/Qeya style (300–500 CE) (Rivera, 2003). Of the other individuals present, the younger male age 13–17 (CJ-36995-1) had the second largest number of skeletal elements present with a left clavicle, humerus, os coxa, femur, and patella, a left and right ulnae, the proximal end of a right second metacarpal, four of the five metatarsals, three of seven metacarpals, and three lumbar vertebrae. CJ-36995-2, the other 30–39 year old female, was second most complete and comprised a left os coxa, a left humerus, a right ulna, and a left femur and tibia.

In order to understand the skeletal evidence of labor at Ch'iji Jawira, a macroscopic investigation of CJ-35250, along with data from CJ-36995-1 and CJ-36995-2 wherever possible, was undertaken and information collected on two potential indicators of skeletal activity, musculoskeletal stress markers (MSM) and osteoarthritis (OA). This first indicator of activity, MSM (alternatively called entheses), was used because muscles work like bony levers for the underlying skeleton, where a person builds muscle, so can attachment points on bones grow and strengthen. Prior medical and bioarchaeological research (Benjamin et al., 2006; Bridges, 1991b; Bridges, 1995; Emslander et al., 1998; Larsen, 1995; Larsen, 2001; Larsen, 2015; Larsen et al., 2001; Milella et al., 2015; Ruff, 2000; Villotte et al., 2010) has determined that certain tasks, like farming, show an increase in muscle mass over an individual's lifetime. MSM can also help identify directional movement in the kinds

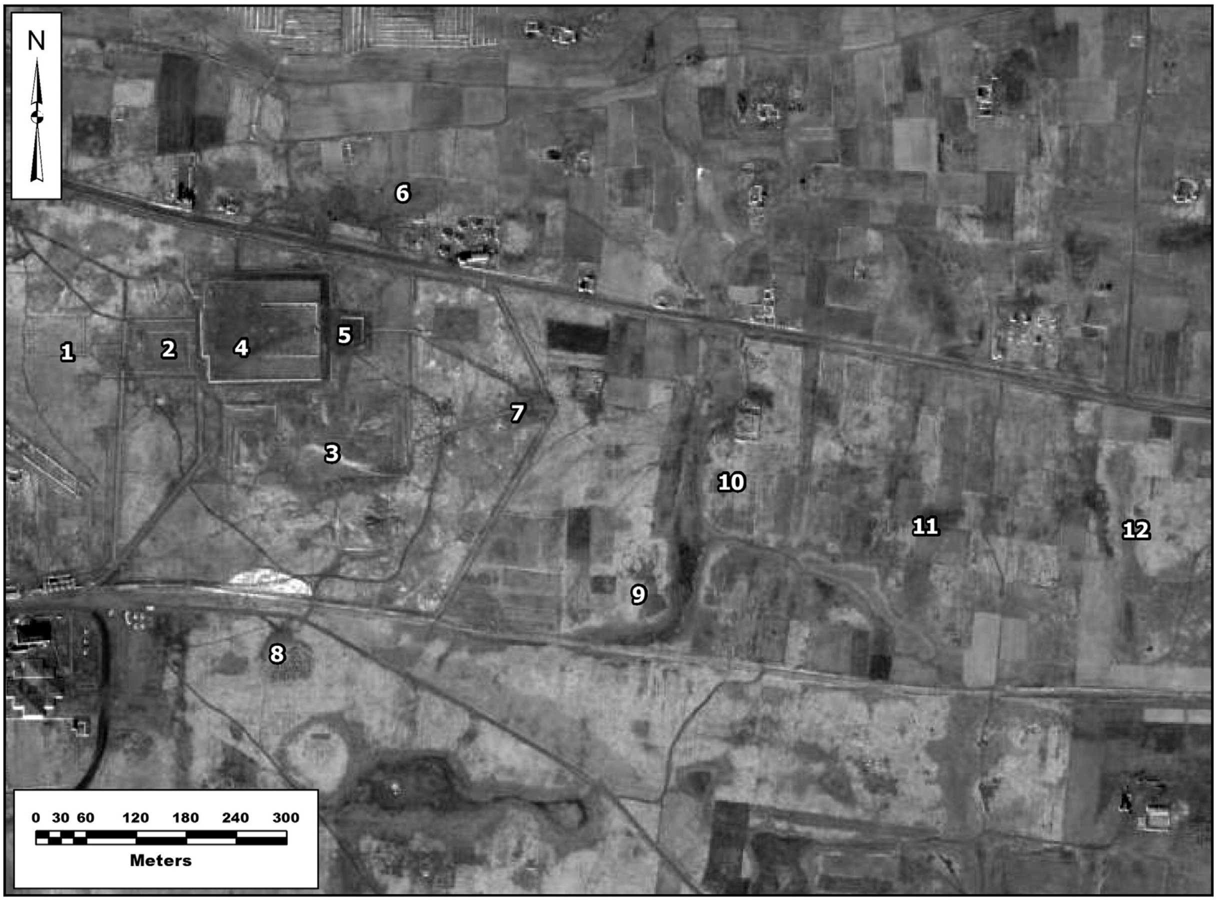

Fig. 2. Differing areas within the city of Tiwanaku on the Andean Plateau: (1) Kerikala, (2) Putuni, (3) Akapana, (4) Kalasasaya, (5) Subterranean Temple, (6) La Karaña, (7) Kantatallita, (8) Mollo Kontu, (9) Akapana East 1, (10) Akapana East 2, (11) Marka Pata, and (12) Ch'iji Jawira.

of activities performed, as well as levels of physical labor, such as workload (Becker, 2013; Benjamin et al., 2006; Chapman, 1997; Emslander et al., 1998; Eshed et al., 2004; Hawkey, 1998; Hawkey and Merbs, 1995; Thomas, 2014; Weiss, 2003). MSM data were recorded for 37 different attachment points, noting presence or absence, and when present, taking an ordinal score (i.e. 1 to 3) each for robusticity, stress, and ossification following methods by Hawkey and Merbs (1995). In addition to the original 37 MSM, additional observations were performed on the bones of the wrists, hands, ankles, and feet, and data were collected to look for evidence of MSM using the same scoring system.

The second type of data collected, OA, is part of the family of degenerative joint diseases (DJD) indicating damaging joint wear. While the exact etiology of OA is unknown, it has been associated with non-bilateral recurring motion injuries on joint surfaces (Bridges, 1992; Bridges, 1995; Cope et al., 2005; Felson, 2004; Felson et al., 1991; Felson and Zhang, 1998; Gramstad and Galatz, 2006; Huiskes, 1982; Jurmain, 1999; Larsen, 2000; Schrader, 2012; Weiss and Jurmain, 2007). OA has been used in prior bioarchaeological research to discuss task-based repetitive motion injuries within joints, estimating motions used over and over again, such as grinding grain or weaving textiles (Bridges, 1989; Bridges, 1991a; Bridges, 1992; Cope et al., 2005; Jurmain, 1999; Kennedy, 1989; Klaus et al., 2009; Larsen, 2000: 107, Pearson and Buikstra, 2006; Roberts and Manchester, 1995: 150 and others). Data were recorded bilaterally for each surface in the shoulder, elbow, wrist, sacroiliac, hip, knee, ankle, spine, hand, foot, and temporomandibular joint, totaling over 100 different joint-areas throughout the skeleton. Data for each joint surface were recorded as present or absent for OA, and if present, type or types of skeletal involvement was noted (i.e. lipping, porosity, osteophytes, eburnation) and an ordinal score was also taken along with percentage of involvement following methodology from Standards (Buikstra and Ubelaker, 1994: 121–123).

3. Results

When evaluating CJ-35250's skeleton, a 30–39 year-old female, for potential markers of activity and labor, there were MSM present on both the left and right sides of her upper and lower body, but her left side has more MSM present with stronger overall ordinal scale markers (Table 1). Fig. 3 shows the skeletal elements involved indicated in black. Many of the MSM present in both the left and right arm musculature (i.e., *brachialis*, *biceps brachii*, *supinator*, *pronator quadratus*, and *brachioradialis*) are often active in tasks that involve locking the elbow in place, along with pronating and supinating forearm musculature. In modern humans, these areas may be involved in steady and precise tasks of the upper arm and forearm musculature (Buchanan et al., 1989; Johanson et al., 1998; Sergio and Ostry, 1994; Visser et al., 2003). In addition, rugosity was documented in the metacarpals (Fig. 4), as well as medial and lateral finger phalanges (Fig. 5), which may show precision gripping or precision handling of objects (Johnston et al., 2010; Landsmeer, 1962; Long et al., 1970).

In evaluating the mid- to lower body anatomy, MSM present on left and right sides (i.e., *gluteus maximus* and *piriformes*) are often active with medium to high levels of hip and upper leg flexion. In the feet (Fig. 6), the metatarsals had similar types of bone apposition at muscle attachment points as recorded in the metacarpals. For example, a close up of the fourth right metatarsal have these bony changes (Fig. 7). However, there is little clinical literature focused on humans gripping with the feet, and only a general comparison can be made to the metacarpal musculature.

Areas with evidence of OA on CJ-35250 are noted with red circles in Fig. 3. The right temporomandibular joint had flattening on the mandibular condyle, which may be activity related to or as a result of the

Table 1
MSMs present for CJ-35250. Right three columns represent ordinal scores where 0 indicates no presence and 3 is the maximum recorded for the condition.

Side	General movement area	Present on skeletal element	MSM	Robusticity	Stress	Ossification
Left	Upper arm & forearm	Clavicle	Conoid ligament	2	0	1
		Clavicle	Subclavious	0	2	0
		Humerus	Pectoralis major	3	1	3
		Humerus	Teres major	1	0	0
		Humerus	Deltoideus	3	2	3
		Ulna	Brachialis	2	3	3
		Radius	Biceps brachii	2	0	0
		Radius	Supinator	1	0	0
		Radius	Pronator quadratus	2	0	1
		Radius	Brachioradialis	1	0	0
Right	Upper arm & forearm	Humerus	Pectoralis major	3	1	3
		Humerus	Teres major	1	0	0
		Humerus	Deltoideus	2	1	3
		Ulna	Brachialis	1	3	2
		Radius	Pronator quadratus	2	0	1
		Radius	Brachioradialis	1	0	0
Left	Mid-body/hip	Femur	Piriformes	1	0	1
		Femur	Gluteus medius	1	0	1
		Femur	Gluteus minimus	2	1	2
		Femur	Psoas major/iliacus	1	0	1
		Femur	Gluteus maximus	3	2	3
Right	Mid-body/hip & lower body/knee	Femur	Psoas major/iliacus	2	0	1
		Femur	Gluteus maximus	3	2	3
		Tibia	Patellar ligament	1	0	1

artificial cranial modification of CJ-35250. In the joints of the arms and legs, minor levels of non-bilateral degenerative lipping was seen in the left elbow joint on the coronoid process of the ulna and in the wrist at the distal articulation of the radius. On the right side, mild lipping was recorded on the coronoid process and radial notch of the right ulna in the elbow. Medium levels of lipping were also noted on the scaphoid carpal bone at the radial articulation. Degeneration in the wrist and hand joints were also seen in a non-bilateral pattern of involvement, primarily noted with evidence of mild to moderate lipping (Fig. 8). There was also mild porosity in both distal ends of the left and right first metacarpals.

CJ-35250's spine also has evidence of skeletal degeneration. Moderate lipping with spicule formation on the inferior margin of the body of the eighth thoracic vertebrae was recorded, but no other evidence in the thoracic or cervical vertebrae was found. In the lumbar vertebrae (Fig. 9), there was a small osteophyte on the superior margin of the first lumbar body and mild lipping on the inferior margin of the second. The third lumbar vertebra also has inferior lipping with spicule formation and a large growth on the right, inferior margin. The most visible evidence of degenerative change are on the fourth (L4) and fifth (L5) lumbar vertebrae, with moderate to severe lipping and new bone growth on L4 (both superior and inferior surfaces) and L5 (superior surface). There was also a sharp ridge of mild to moderate lipping on the sacral promontory.

In the mid-body joint areas of individual CJ-35250, there were medium to high levels of both pinpoint and coalesced porosity on the right acetabular surface of the os coxa in the hip joint. The right sacroiliac joint has evidence of lipping with bony growths on the auricular surface of the sacrum. In the left sacroiliac joint, the auricular surface of the sacrum has pinpoint porosity with osteophyte formation, while the auricular surface of the os coxa has mild lipping and the formation of an osteophyte.

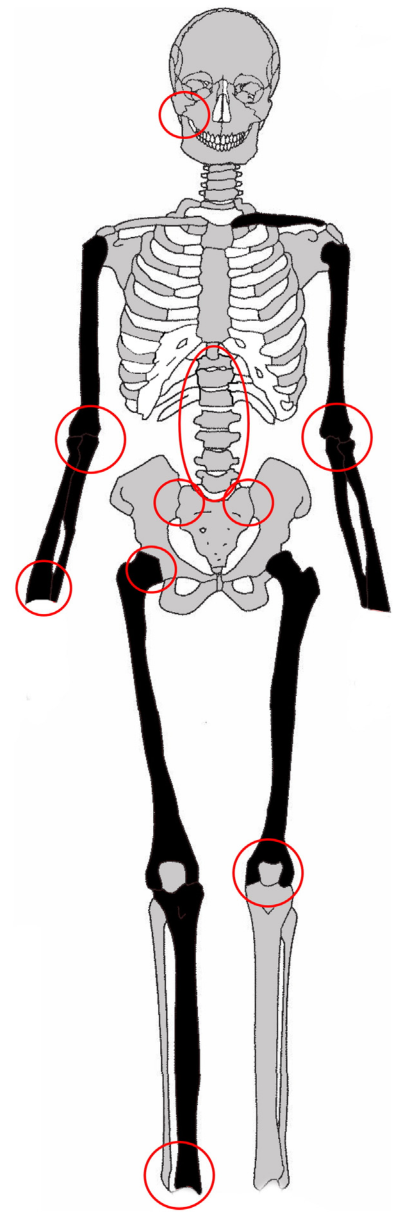

Fig. 3. Areas with evidence of MSM (bones involved in black) and OA (red circles around joints). Detailed evidence of in hands and feet are included in later figures. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

In the lower body joints of the knee and ankle, there was very mild evidence of lipping on the lateral condyle of the left tibia in the knee joint and on the right talus at the articulation with the medial malleolus in the ankle. In the tarsals and metatarsals (Fig. 10), evidence was documented for lipping in the left proximal and distal first metatarsal, proximal second metatarsal, and mild evidence on the calcaneus at the articulation with the talus. Moderate evidence of lipping was noted on the left navicular and third cuneiform at their articulation, along with evidence of pinpoint porosity on the navicular. The left cuboid also had lipping at all articular facets. The right side had moderate lipping on the proximal first metatarsal as well as on the calcaneus at the articulation with the talus. There was also pinpoint porosity and moderate lipping on the navicular at the articulation with the second and third cuneiforms, which both had mild to moderate evidence of lipping respectively on CJ-35250.

Fig. 4. Metacarpals of the left (a) and right (b) hand with some evidence of bony MSM growths noted with arrows.

Of the other two Ch'iji Jawira individuals for which data could be collected, the younger male, CJ-36995-1, age 13–17, has similar evidence to CJ-35250 of degenerative lipping with spicule formation on the proximal end of the second metacarpal, as well as in the proximal first metatarsals. However, the pattern of MSM only overlaps with CJ-35250 in *pectoralis major* and *brachialis*, and other present MSM (i.e. *supraspinatus*, *latissimus dorsi*, and *coracobrachialis*) do not. CJ-36995-1 also shows evidence of lipping in the spine at the second cervical vertebra, but no evidence in the lumbar vertebrae. There was also porosity and lipping in the acetabular surface of the left os coxa. From the skeletal elements present in CJ-36995-2, a 30–39 year-old female, there were MSM in the *supraspinatus*, *pectoralis major*, *coracobrachialis*, and *gluteus maximus*, with the pattern more similar to the male individual than to CJ-35250, the female of the same age. In addition, there was no evidence of OA in joint surfaces of bones present (os coxa, a left humerus, a right ulna, left femur, and left tibia) of CJ-36995-2. Unfortunately, the incompleteness of the CJ-36995-1 and CJ-36995-2 burials makes it hard to determine a complete comparison of activity.

Fig. 5. Finger phalanges with some MSM bony growths noted by arrows.

Fig. 6. Metatarsals of the left (a) and right (b) foot with some evidence of MSM bony growths noted by arrows.

4. Discussion

The city of Tiwanaku was home to differing neighborhoods where people labored at various tasks (Albarracín-Jordán, 1996; Becker, 2013; Janusek, 2004; Janusek, 2008). One such area, Ch'iji Jawira, was a manufacturing center for ceramics due to its location near a source of clay and a nearly year-round water supply (Rivera, 2003). Population-based statistical analyses show that skeletal evidence of OA and MSM from Ch'iji Jawira is dissimilar other sites observed from the city of Tiwanaku, meaning they were working at different tasks than others in the region (Becker, 2013). As Sharratt (2016: 408) notes, "pottery and woven cloth were both economically and ideologically significant media in the Tiwanaku realm, and in the Prehispanic Andes more generally." Consequently, ceramic manufacture and weaving were the two likeliest types of craft specialists in the Tiwanaku culture, moving these tasks beyond a household level and into realms of power, ideology, and identity formation (Berryman, 2011; Blom, 1999; Costin, 2004; Costin and Earle, 1989; Janusek, 1999; Janusek, 2003; Janusek, 2004; Janusek, 2005; Janusek and Blom, 2006; Plunger, 2009; Silverblatt, 1987; Vaughn, 2004; Vaughn, 2006).

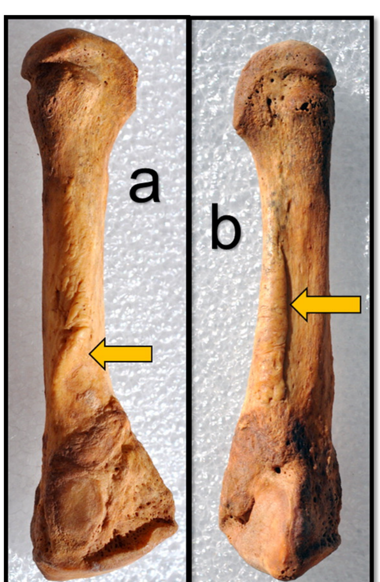

Fig. 7. Fourth metatarsal of right foot with some evidence of MSM bony growths from (a) medial view and (b) lateral view noted by arrows.

Thus, an examination from a life-history approach was undertaken on the most complete individual from the Ch'iji Jawira site, a 30–39 year-old female (CJ-35250). Overall, the MSM and OA data from her carpals, metacarpals, humeri, radii, and ulnae could indicate a lifetime of working at tasks that require good upper body strength and manual dexterity in the upper arms, forearms, wrists, and hands, as would be seen in craft specialists (Arnold and Espejo, 2015; Banerjee and Gangopadhyay, 2003; Budden and Sofaer, 2009; Druc, 2016; Eerkens and Lipo, 2005; Hartomo and Amalia Azka, 2016). The strong MSM in the upper arm, forearm, carpals, and metacarpals, along with evidence of OA in the wrist and fingers of CJ-35250, further support heavy, repetitive work in forearms, wrists, hands, and fingers that would be expected in ceramics production. However, this does not explain the MSM and OA with high levels in the mid-body, tarsals, and metatarsals until we look at the modern ethnographic record. Andean potters may use both hands and feet while manufacturing and shaping ceramics (e.g. feet holding pot in place while shaping ceramic or adding

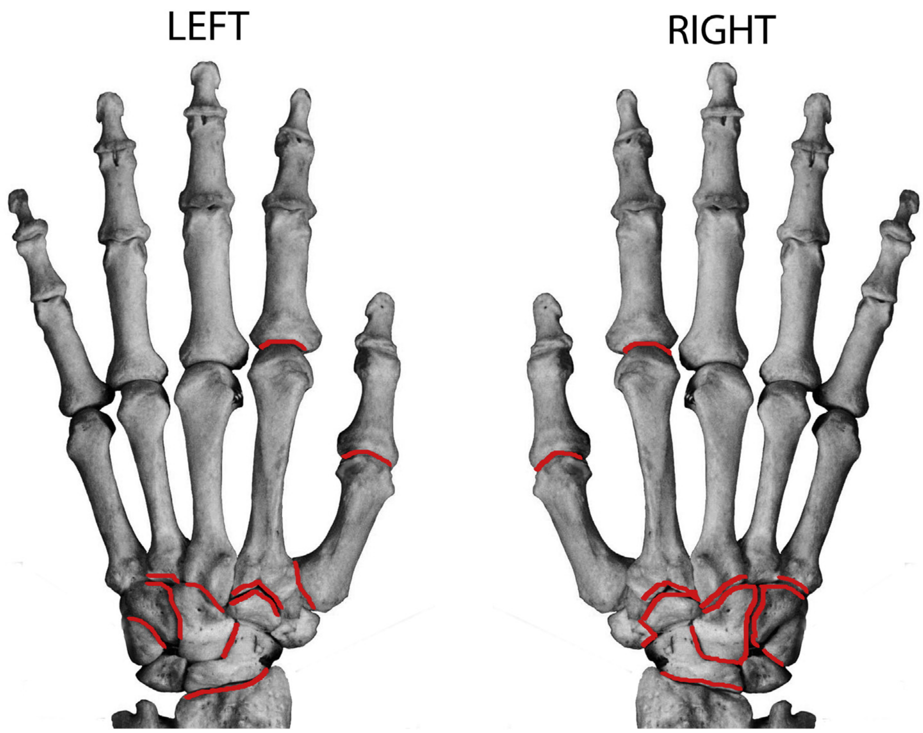

Fig. 8. Pattern of OA in the wrist and hands of CJ-35250, as noted in red. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

texture) (Fig. 11) (Druc, 2016). Individuals would be seated with the distal femur moved away from the midline, the medial surface of the knee joint facing somewhat superior, and the feet turned plantar-facing. Hence, this modern method of ceramics manufacture, likely similar to prehistoric Andean methods, could fit the skeletal evidence noted in CJ-35250. For example, the MSM evident in the gluteal muscles would likely be active when sitting cross-legged (Lee et al., 2011; Lee and Yoo, 2011), and with weight resting on the fifth metatarsal, fifth foot phalanx, cuboid, and calcaneus in this position, this could cause OA-style repetitive motion degeneration in the ankles and feet. As modern clinical studies show sitting in awkward positions while laboring can have negative effects on the lower back and pelvis (e.g. Choobineh et al., 2007; Ghosh et al., 2010; Lis et al., 2007; Snijders et al., 1995; Watanabe et al., 2010 and others), being sedentary with the feet facing each other while working may also explain some of the OA in the lumbar spine, right acetabular surface, and in both of the sacroiliac joints. In addition to the lower back, CJ-35250 also has a pattern of strong MSM on the lateral metatarsals, which may indicate active gripping in the feet and toes as part of controlling the ceramics process. The non-bilateral foot OA evidence, especially at the articulation of the talus and calcaneus, could be part of repeated motions of turning feet plantar-facing to help hold ceramics during manufacture.

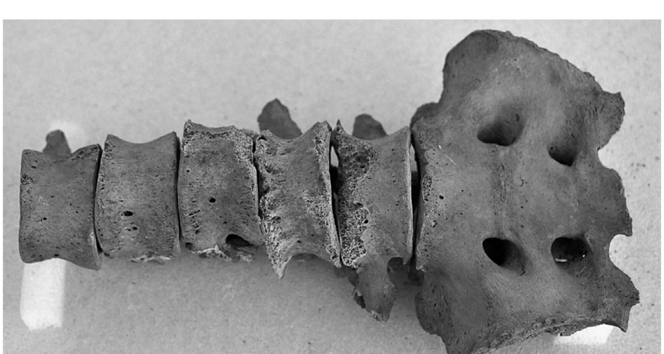

Fig. 9. Lumbar vertebrae and sacrum of CJ-35250.

Factoring in the contextual, archaeological record, CJ-35250's burial lacks radiocarbon dates, so we cannot say definitively she lived during a time of high ceramic production at Ch'iji Jawira (ca. 500–1100 CE) (Janusek, 2004; Janusek, 2008; Rivera, 2003). Grave goods from that time period were pottery molds and broken sherds (Rivera, 2003). The CJ-35250 burial, instead, contains only one ceramic element, a complete *vasija* in the Qeya form, which stylistically dates to the Late Formative 2 (300–500 CE). This could put her interment before the site's use as a major ceramic production center. However, if her burial does date to prior the Tiwanaku state, the location would still have been an area with a semi-permanent water source where clay could have been procured (Rivera, 2003: 306). Thus, CJ-35250 could still be a potter, just one who may predate the high ceramic production period. Unfortunately, other Ch'iji Jawira burials with pottery molds and sherds are less than 50% complete and no obvious skeletal pattern of activity could be discerned from CJ-35250 to CJ-36995-1 and to CJ-36995-2 in order to find a shared MSM and OA pattern.

As an alternative to pottery and because weaving was another major Andean craft specialty, the idea was explored that CJ-35250 could have been a weaver. Weaving during Tiwanaku times would have been using a backstrap loom, where tension for the warp (i.e. yarn perpendicular to the weaver's body) is held with a strap that goes across the lower back (Fig. 12). The spinal evidence of OA in CJ-35250, especially the extensive changes to the fourth lumbar and fifth lumbar vertebrae, where a strap would put pressure on the lower back, could support weaving as a task-based physical change (Chaman et al., 2015; Durlov

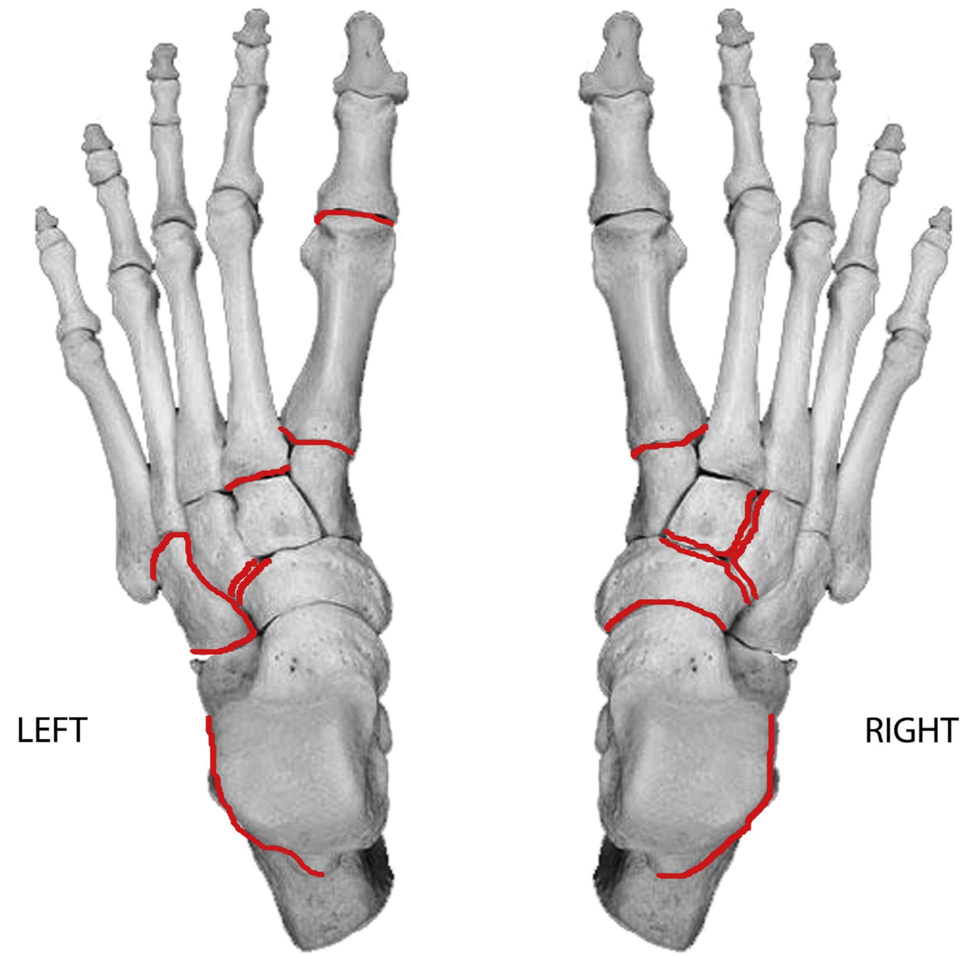

Fig. 10. Pattern of OA in the ankles and feet of CJ-35250, as noted in red. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Fig. 11. Potting using feet.
(From Druc, 2016: 31)

et al., 2014). In addition, akin to potters, weavers use both hands and feet while manufacturing cloth and designs in cloth (e.g. yarn tied around toes/feet and used as an anchor while weaving) (Fig. 13). The pattern of forearm MSM involvement, carpal and metacarpal OA, MSM likely showing gripping in the finger phalanges and metatarsals, and OA in the tarsals and metatarsals likely from plantar facing movements, could be body changes associated not only with pottery manufacture, but also with weaving. Gluteal muscle MSM could be active in sitting somewhat with legs crossed or in anchoring and adjusting the mid-body while using the backstrap loom. Thus, the skeletal activity pattern evidence in the upper and lower body could fit weaving, but unfortunately the climate of this highland Tiwanaku area does have cloth preservation. Any textiles or typical Andean weaving tools made out of wood, as found elsewhere in Tiwanaku-controlled regions with better preservation (Plunger, 2009), buried with CJ-35250 would have long since decayed. Initial research does show individuals in Moquegua, Peru, a colony of the Tiwanaku state with near-perfect textile and wood preservation, as having a pattern of heavy upper arm and forearm MSM and some OA in the wrists that can be correlated with elaborate textiles as grave goods (Becker and Goldstein, 2015). Further research will evaluate skeletal remains from this colony region, including MSM and OA in hands and feet, in order to test for skeletal patterns associated with weaving and ceramics manufacture.

Fig. 12. Woman weaving with arrow pointing to the "backstrap" portion of the loom.

5. Conclusion

The Tiwanaku culture (500–1100 CE) was an important early state-level society in the South Central Andes *altiplano*, with its capital city as home to a varied population of laborers (Albarracín-Jordán, 1996; Becker, 2013; Berryman, 2011; Blom, 1999; Blom, 2005; Janusek, 2003; Janusek, 2004; Janusek, 2005; Janusek, 2008; Knudson and Blom, 2011). By examining the skeletal remains of the Tiwanaku workforce, a contextual idea of how people lived and what tasks they performed in ancient times can be elucidated. As my prior research has described differences in workload across neighborhoods within Tiwanaku (Becker, 2012; Becker, 2013; Becker, 2017), I examined one very complete burial, a 30–39 year-old woman (CJ-35250), from the likely pottery production *barrio* of Ch'iji Jawira. The skeletal evidence of labor and activity from a life history perspective of CJ-35250's interment indicates she was involved in the production of crafts. She has a strong pattern of MSM in her carpals, metacarpals, finger phalanges, tarsals, and metatarsals that could denote she used her hands and feet, along with the musculature of her arms, heavily in her daily activities. CJ-35250 also has degenerative evidence of OA in her elbows, wrists, and hands, which could be caused by repetitive upper body movement of the same style as is noted in her robust muscle markers. The evidence of OA in the spine, hip, and sacroiliac joints could be part of tasks that involve sitting with active use of plantar-facing feet. From her skeletal activity pattern evidence, and because she was buried in an area that became a major pottery production neighborhood, it is likely her craft was ceramics manufacture, possibly some of the earliest at the Ch'iji Jawira location.

Fig. 13. Weaving using feet.
(From Arnold and Espejo, 2015: 127)

As craft production, especially ceramics manufacture and weaving, has a long history of importance in the Andes and specifically within the Tiwanaku culture (Becker, 2013; Becker, 2017; Becker and Goldstein, 2015; Costin, 2004; Costin and Earle, 1989; D'Altroy, 1992; Earle and D'Altroy, 1989; Goldstein, 1989; Goldstein, 2005; Goldstein and Rivera, 2004; Janusek, 1999; Janusek, 2004; Janusek, 2005; Janusek, 2008; Kolata, 1993; Plunger, 2009; Portugal Ortíz, 1988; Sharratt, 2011; Sharratt, 2016; Vaughn, 2006; Young-Sánchez, 2004), the grave goods of CJ-35250, a gold mask and a camelid skull offering (Rivera, 2003), also support the idea that she was an important individual during her lifetime. Alternatively, and considering this burial may predate the use of the site as a ceramics production center, it could be that CJ-35250 practiced another form of crafting, possibly weaving, as the skeletal evidence would support that interpretation. Future research will explore the skeletal pattern of OA and MSM involvement in areas with actual preservation of Tiwanaku textiles and tools associated with weaving (e.g. Moquegua, Peru) (Plunger, 2009), as well as work toward finding a pattern of skeletal involvement, which may help distinguish differing groups involved in craft production within the Tiwanaku culture.

Acknowledgements

The Bolivian Ministry of Culture, the town of Tiwanaku, CIAAAT, Deborah Blom, Kelly Knudson, John Janusek, Corey Bowen, Sara Juengst, UCR, and my anonymous reviewers. Grant funding provided by the National Science Foundation (Grant No. 0925866).

References

Albarracín-Jordán, J., 1996. Tiwanaku settlement system: the integration of nested hierarchies in the lower Tiwanaku Valley. American Antiquity]–>Lat. Am. Antiq. 7, 183–210.

Arnold, D.Y., Espejo, E., 2015. The Andean Science of Weaving: Structures and Techniques for Warp-faced Weaves. Thames & Hudson, New York.

Banerjee, P., Gangopadhyay, S., 2003. A study on the prevalence of upper extremity repetitive strain injuries among the handloom weavers of West Bengal. J. Hum. Ergol. 32, 17–22.

Bass, W., 1981. Human Osteology: A Laboratory and Field Manual of the Human Skeleton. Missouri Archaeological Society, Columbia, MO.

Becker, S.K., 2012. Labor, Gender, and Identity: Bioarchaeological Activity Patterns in Individuals from the Tiwanaku State (AD 500–1100). Society for American Archaeology, Memphis, TN.

Becker, S.K., 2013. Labor and the Rise of the Tiwanaku State (AD 500–1100): A Bioarchaeological Study of Activity Patterns. Department of Anthropology, University of North Carolina, Chapel Hill, Chapel Hill, NC.

Becker, S.K., 2017. Community labor and laboring communities within the Tiwanaku State (AD 500–1100), in: Juengst, S.L., Becker, S.K. (Eds.), The Bioarchaeology of

Community, for Archaeology Papers of the American Anthropological Association (AD3A), vol. 28 (in press).
Becker, S.K., Goldstein, P., 2015. Laboring in Tiwanaku's Moquegua colony: a bioarchaeological activity indicator comparison using population-based and life course approaches. Society for American Archaeology Meeting, San Francisco, CA.
Benjamin, M., Toumi, H., Ralphs, J., Bydder, G., Best, T., Milz, S., 2006. Where tendons and ligaments meet bone: attachment sites ("entheses") in relation to exercise and/or mechanical load. J. Anat. 208, 471–490.
Berryman, C.A., 2011. Food, Feasts, and the Construction of Identity and Power in Ancient Tiwanaku: A Bioarchaeological Perspective. Department of Anthropology, Vanderbilt University, Nashville.
Blom, D.E., 1999. Tiwanaku Regional Interaction and Social Identity: A Bioarchaeological Approach. Department of Anthropology, University of Chicago, Chicago.
Blom, D.E., 2005. Embodying borders: human body modification and diversity in Tiwanaku society. J. Anthropol. Archaeol. 24, 1–24.
Bourdieu, P., 1977. Outline of a Theory of Practice. Cambridge University Press, Cambridge.
Bridges, P.S., 1989. Changes in activities with the shift to agriculture in the southeastern United States. Curr. Anthropol. 30, 385–394.
Bridges, P.S., 1991a. Degenerative joint disease in hunter-gatherers and agriculturalists from the southeastern United States. Am. J. Phys. Anthropol. 85, 379–391.
Bridges, P.S., 1991b. Skeletal evidence of changes in subsistence activities between the Archaic and Mississippian time periods in northwestern Alabama. In: Powell, M., Bridges, P., Mires, A. (Eds.), What Mean these Bones? Studies in Southeastern Bioarchaeology. The University of Alabama Press, Tuscaloosa, AL, pp. 89–101.
Bridges, P.S., 1992. Prehistoric arthritis in the Americas. Annu. Rev. Anthropol. 21, 67–91.
Bridges, P.S., 1995. Skeletal biology and behavior in ancient humans. Evol. Anthropol. Issues News Rev. 4, 112–120.
Buchanan, T.S., Rovai, G.P., Rymer, W.Z., 1989. Strategies for muscle activation during isometric torque generation at the human elbow. J. Neurophysiol. 62, 1201–1212.
Budden, S., Sofaer, J., 2009. Non-discursive knowledge and the construction of identity: potters, potting and performance at the Bronze Age tell of Százhalombatta, Hungary. Camb. Archaeol. J. 19, 203–220.
Buikstra, J.E., Beck, L.A., 2006. Bioarchaeology: The Contextual Analysis of Human Remains Academic Press. Burlington, MA.
Buikstra, J.E., Pearson, O., 2006. Behavior and the bones. In: Buikstra, J., Beck, L. (Eds.), Bioarchaeology: The Contextual Analysis of Human Remains. Elsevier, Amsterdam, pp. 207–225.
Buikstra, J.E., Ubelaker, D.H., 1994. Standards for data collection from human skeletal remains. Research Series 44. Arkansas Archaeological Survey, Fayetteville, AK.
Chaman, R., Aliyari, R., Sadeghian, F., Vatani Shoaa, J., Masoudi, M., Zahedi, S., Bakhshi, M.A., 2015. Psychosocial factors and musculoskeletal pain among rural hand-woven carpet weavers in Iran. Saf. Health Work 6, 120–127.
Chapman, N., 1997. Evidence for Spanish influence on activity induced musculoskeletal stress markers at Pecos Pueblo. Int. J. Osteoarchaeol. 7, 497–506.
Choobineh, A., Hosseini, M., Lahmi, M., Khani Jazani, R., Shahnavaz, H., 2007. Musculoskeletal problems in Iranian hand-woven carpet industry: guidelines for workstation design. Appl. Ergon. 38, 617–624.
Cope, J., Berryman, A., Martin, D., Potts, D., 2005. Robusticity and osteoarthritis at the trapezoimetacarpal joint in a bronze age population from Tell Abraq, United Arab Emirates. Am. J. Phys. Anthropol. 126, 391–400.
Costin, C.L., 2004. Craft economies of ancient Andean states. In: Feinman, G., Nicholas, M. (Eds.), Archaeological Perspectives on Political Economies. University of Utah Press, Salt Lake City, pp. 189–221.
Costin, C.L., Earle, T., 1989. Status distinction and legitimation of power as reflected in changing patterns of consumption in late prehispanic Peru. Am. Antiq. 54, 691–714.
D'Altroy, T.N., 1992. Provincial Power in the Inka Empire. Smithsonian Institution Press, Washington.
Druc, I.C., 2016. Traditional Potters: From the Andes to Vietnam. Deep University Press, Madison, WI.
Durlov, S., Chakrabarty, S., Chatterjee, A., Das, T., Dev, S., Gangopadhyay, S., Haldar, P., Maity, S.G., Sarkar, K., Sahu, S., 2014. Prevalence of low back pain among handloom weavers in West Bengal, India. Int. J. Occup. Environ. Health 20, 333–339.
Earle, T., D'Altroy, T.N., 1989. The political economy of the Inka empire: the archaeology of power and finance. In: Lamberg-Karlovsky, C. (Ed.), Archaeological Thought in America. Cambridge University Press, Cambridge, pp. 183–204.
Eerkens, J.W., Lipo, C.P., 2005. Cultural transmission, copying errors, and the generation of variation in material culture and the archaeological record. J. Anthropol. Archaeol. 24, 316–334.
Emslander, H.C., Sinaki, M., Muhs, J.M., Chao, E.Y.S., Wahner, H.W., Bryant, S.C., Riggs, B.L., Eastell, R., 1998. Bone mass and muscle strength in female college athletes (runners and swimmers). Mayo Clin. Proc. 73, 1151–1160.
Eshed, V., Gopher, A., Galili, E., Hershkovitz, I., 2004. Musculoskeletal stress markers in Natufian hunter-gatherers and Neolithic farmers in the Levant: the upper limb. American Journal of Physical Anthropology]–>Am. J. Phys. Anthropol. 123, 303–315.
Felson, D., 2004. Risk factors for osteoarthritis. Clin. Orthop. Relat. Res. 427S, S16–S21.
Felson, D., Zhang, Y., 1998. An update on the epidemiology of knee and hip osteoarthritis with a view to prevention. Arthritis Rheum. 41, 1343–1355.
Felson, D., Hannan, M., Naimark, A., Berkeley, J., Gordan, G., Wilson, P., Anderson, J., 1991. Occupational physical demands, knee bending, and knee osteoarthritis: results from the Framingham study. J. Rheumatol. 18, 1587–1592.
Ghosh, T., Das, B., Gangopadhyay, S., 2010. Work-related musculoskeletal disorder: an occupational disorder of the goldsmiths in India. Indian Journal of Community Medicine]–>Indian J. Community Med. 35, 321–325.
Goldstein, P.S., 1989. The Tiwanaku occupation of Moquegua. In: Rice, D., Stanish, C., Scarr, P. (Eds.), Ecology, Settlement, and History in the Osmore Drainage, Peru. British Archaeological Reports, Oxford, pp. 219–255.
Goldstein, P.S., 2005. Andean Diaspora: The Tiwanaku Colonies and the Origins of the South American Empire. University of Florida Press, Gainesville.
Goldstein, P.S., Rivera, M.D., 2004. Arts of greater Tiwanaku: an expansive culture in historical context. In: Young-Sánchez, M. (Ed.), Tiwanaku: Ancestors of the Inca. University of Nebraska, Lincoln, NE, pp. 150–185.
Gramstad, G.D., Galatz, L.M., 2006. Management of elbow osteoarthritis. J. Bone Joint Surg. 88, 421–430.
Hartomo, S., Amalia Azka, R., 2016. Analysis of muscle contraction on pottery manufacturing process using electromyography (EMG). IOP Conf. Ser.: Mater. Sci. Eng. 105, 1–6.
Hawkey, D.E., 1998. Disability, compassion and the skeletal record: using musculoskeletal stress markers (MSM) to construct an osteobiography from early New Mexico. Int. J. Osteoarchaeol. 8, 326–340.
Hawkey, D.E., Merbs, C.F., 1995. Activity-induced musculoskeletal stress markers (MSM) and subsistence strategy changes among ancient Hudson Bay Eskimos. Int. J. Osteoarchaeol. 14, 7–17.
Huiskes, R., 1982. On the modeling of long bones in structural analyses. J. Biomech. 15, 65–69.
Janusek, J.W., 1999. Craft and local power: embedded specialization within Tiwanaku cities. Lat. Am. Antiq. 10, 107–131.
Janusek, J.W., 2003. The changing face of Tiwanaku residential life: state and local identity in an Andean city. In: Kolata, A. (Ed.), Tiwanaku and Its Hinterland: Archaeology and Paleoecology of an Andean Civilization. Smithsonian Institution Press, Washington, pp. 264–295.
Janusek, J.W., 2004. Identity and Power in the Ancient Andes: Tiwanaku Cities Through Time. Routledge, New York.
Janusek, J.W., 2005. Of pots and people: ceramic style and social identity in the Tiwanaku State. In: Reycraft, R. (Ed.), Us and Them: Archaeology and Ethnicity in the Andes. University of California, Los Angeles, Cotsen Institute, pp. 34–53.
Janusek, J.W., 2008. Ancient Tiwanaku. Cambridge University Press, New York.
Janusek, J.W., Blom, D.E., 2006. Identifying Tiwanaku urban populations: style, identity, and ceremony in Andean cities. In: Storey, G. (Ed.), Urbanism in the Preindustrial World: Cross-cultural Approaches. University of Alabama Press, Tuscaloosa, pp. 233–251.
Johanson, M.E., James, M.A., Skinner, S.R., 1998. Forearm muscle activation during power grip and release. J. Hand Surg. [Am.] 23, 938–944.
Johnston, J.A., Bobich, L.R., Santello, M., 2010. Coordination of intrinsic and extrinsic hand muscle activity as a function of wrist joint angle during two-digit grasping. Neurosci. Lett. 474, 104–108.
Jurmain, R., 1999. Stories from the Skeleton: Behavioral Reconstruction in Human Osteology. Gordon and Breach, Amsterdam.
Kennedy, K.A.R., 1989. Skeletal markers of occupational stress. In: Iscan, Y., Kennedy, K. (Eds.), Reconstruction of Life from the Skeleton. Alan R. Liss, Inc., New York, pp. 129–160.
Klaus, H.D., Spencer Larsen, C., Tam, M.E., 2009. Economic intensification and degenerative joint disease: life and labor on the postcontact north coast of Peru. American Journal of Physical Anthropology]–>Am. J. Phys. Anthropol. 139, 204–221.
Knudson, K.J., Blom, D.E., 2011. The complex relationship between Tiwanaku mortuary identity and geographic origin in the south central Andes. In: Knudson, K.J., Stojanowski, C.M. (Eds.), Bioarchaeology and Identity in the Americas. University Press of Florida, Gainesville, FL, pp. 194–211.
Kolata, A.L., 1993. The Tiwanaku: Portrait of an Andean Civilization. Blackwell, Oxford.
Landsmeer, J.M.F., 1962. Power grip and precision handling. Ann. Rheum. Dis. 21, 164–170.
Larsen, C.S., 1995. Biological changes in human populations with agriculture. Annu. Rev. Anthropol. 24, 185–213.
Larsen, C.S., 1997. Bioarchaeology: Interpreting Behavior from the Human Skeleton. Cambridge University Press, Cambridge.
Larsen, C.S., 2000. Skeletons in Our Closet: Revealing Our Past Through Bioarchaeology. Princeton University Press, Princeton.
Larsen, C.S., 2001. Bioarchaeology of Spanish Florida: The Impact of Colonialism. University of Florida Press, Gainesville.
Larsen, C.S., 2015. Bioarchaeology: Interpreting Behavior from the Human Skeleton. second edition. Cambridge University Press, Cambridge.
Larsen, C.S., Griffin, M., Hutchinson, D., Noble, V., Norr, L., Pastor, R., Ruff, C., Russell, K., Schoeninger, M., Schultz, M., Simpson, S., Teaford, M., 2001. Frontiers of contact: bioarchaeology of Spanish Florida. J. World Prehist. 15, 69–123.
Lee, J.-H., Yoo, W.-G., 2011. Changes in gluteal pressure and pelvic inclination angles after continuous cross-legged sitting. Work 20, 247–252.
Lee, J.-H., Park, S.-Y., Yoo, W.-G., 2011. Changes in craniocervical and trunk flexion angles and gluteal pressure during VDT work with continuous cross-legged sitting. J. Occup. Health 53, 350–355.
Liimakka, S., 2011. I am my body: objectification, empowering embodiment, and physical activity in women's studies students' accounts. Sociol. Sport J. 28.
Lis, A.M., Black, K.M., Korn, H., Nordin, M., 2007. Association between sitting and occupational LBP. European Spine Journal]–>Eur. Spine J. 16, 283–298.
Long, C., Hall, E.A., Furler, S.L., 1970. Intrinsic-extrinsic muscle control of the hand in power grip and precision handling. J. Bone Joint Surg. 52, 853–867.
Merleau-Ponty, M., 2013 [1945]. Phenomenology of Perception (Original Phénoménologie de la perception, translated by Donald Landes). Routledge, New York.
Milella, M., Cardoso, F.A., Assis, S., Lopreno, G.P., Speith, N., 2015. Exploring the relationship between entheseal changes and physical activity: a multivariate study. American Journal of Physical Anthropology]–>Am. J. Phys. Anthropol. 156, 215–223.
Pearson, O., Buikstra, J., 2006. Behavior and the bones. In: Buikstra, J., Beck, L. (Eds.), Bioarchaeology: The Contextual Analysis of Human Remains. Academic Press, Burlington, MA, pp. 207–225.

Plunger, E.M., 2009. Woven Connections: Group Identity, Style, and the Textiles of the "A" and "B" Cemeteries at the Site of Río Muerto (M43), Moquegua Valley, Southern Peru. Department of Anthropology, University of California, San Diego, San Diego.
Portugal Ortíz, M., 1988. Descubrimiento de pinturas murales en Tiwanaku. Revista Domingo de Hoy, pp. 16–17.
Rivera, C., 1994. Chiji Jawira: Evidencias Sobre La Producción De Cerámica En Tiwanaku. Carreras de Antropología-Arqueología, Universidad Mayor de San Andrés, La Paz.
Rivera, C., 2003. Ch'iji Jawira: a case of ceramic specialization in the Tiwanaku urban periphery. In: Kolata, A. (Ed.), Tiwanaku and Its Hinterland: Archaeology and Paleoecology of an Andean Civilization, Vol. 2: Urban and Rural Archaeology. Smithsonian Institution Press, Washington, DC, pp. 296–315.
Roberts, C., Manchester, K., 1995. The Archaeology of Disease. Cornell University Press, Ithaca, NY.
Ruff, C.B., 2000. Biomechanical analyses of archaeological human skeletons. In: Katzenberg, M., Saunders, S. (Eds.), Biological Anthropology of the Human Skeleton. Wiley-Liss, New York, pp. 71–102.
Schrader, S.A., 2012. Activity patterns in New Kingdom Nubia: an examination of entheseal remodeling and osteoarthritis at Tombos. American Journal of Physical Anthropology]–>Am. J. Phys. Anthropol. 149, 60–70.
Sergio, L.E., Ostry, D.J., 1994. Coordination of mono- and bi-articular muscles in multi-degree of freedom elbow movements. Exp. Brain Res. 97, 551–555.
Sharratt, N., 2011. Social Identities and State Collapse: A Diachronic Study of Tiwanaku Burials in the Moquegua Valley, Peru, Department of Anthropology. University of Illinois at Chicago, Chicago.
Sharratt, N., 2016. Beyond collapse: archaeological perspectives on resilience, revitalization, and transformation in complex societies. In: Faulseit, R.K., Anderson, J.H. (Eds.), Beyond Collapse: Archaeological Perspectives on Resilience, Revitalization, and Transformation in Complex Societies. Southern Illinois University Press, Carbondale, IL, pp. 407–430.
Silverblatt, I., 1987. Moon, Sun, and Witches: Gender Ideologies and Class in Inca and Colonial Peru. Princeton University Press, Princeton, NJ.
Snijders, C.J., Slagter, A.H.E., van Strik, R., Vleeming, A., Stoeckart, R., Stam, H.J., 1995. Why leg crossing?: the influence of common postures on abdominal muscle activity. Spine 20, 1989–1993.
Sofaer, J.R., 2006. The Body as Material Culture: A Theoretical Osteoarchaeology. Cambridge University Press, Cambridge.
Stanish, C., 2013. What was Tiwanaku? In: Vranich, A., Stanish, C. (Eds.), Visions of Tiwanaku. Cotsen Institute of Archaeology Press, Los Angeles, pp. 151–166
Suchey, J.M., Katz, D., 1998. Applications of pubic age determination in a forensic setting. In: Reichs, K. (Ed.), Forensic Osteology, 2nd ed. Charles C. Thomas, Springfield.
Thomas, A., 2014. Bioarchaeology of the middle Neolithic: evidence for archery among early European farmers. American Journal of Physical Anthropology]–>Am. J. Phys. Anthropol. 154, 279–290.
Ubelaker, D.H., 1999. Human Skeletal Remains: Excavation, Analysis, Interpretation. Taraxacum, Washington, D.C.
Vaughn, K.J., 2004. Households, crafts, and feasting in the ancient Andes: the village context of early Nasca craft consumption. Lat. Am. Antiq. 15, 61–88.
Vaughn, K.J., 2006. Craft production, exchange, and political power in the pre-Incaic Andes. J. Archaeol. Res. 14, 313–344.
Villotte, S., Castex, D., Couallier, V., Dutour, O., Knüsel, C.J., Henry-Gambier, D., 2010. Enthesopathies as occupational stress markers: evidence from the upper limb. American Journal of Physical Anthropology]–>Am. J. Phys. Anthropol. 142, 224–234.
Visser, B., de Looze, M.P., Veeger, D., Douwes, M., Groenesteijn, L., de Korte, E., van Dieën, J.H., 2003. The effects of precision demands during a low intensity pinching task on muscle activation and load sharing of the fingers. J. Electromyogr. Kinesiol. 13, 149–157.
Watanabe, S., Kobara, K., Ishida, H., Eguchi, A., 2010. Influence of trunk muscle co-contraction on spinal curvature during sitting cross-legged. Electromyogr. Clin. Neurophysiol. 50, 187–192.
Weiss, E., 2003. Understanding muscle markers: aggregation and construct validity. American Journal of Physical Anthropology]–>Am. J. Phys. Anthropol. 121, 230–240.
Weiss, E., Jurmain, R., 2007. Osteoarthritis revisited: a contemporary review of aetiology. Int. J. Osteoarchaeol. 17, 437–450.
Young-Sánchez, M., 2004. Tiwanaku: Ancestors of the Inca. University of Nebraska Press, Lincoln.