LABOR AND THE RISE OF THE TIWANAKU STATE (AD 500-1100): A BIOARCHAEOLOGICAL STUDY OF ACTIVITY PATTERNS

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ABSTRACT

SARA KATHRYN BECKER: Labor and the Rise of the Tiwanaku State (AD 500-1100): A Bioarchaeological Study of Activity Patterns
(Under the direction of Dale Hutchinson)

This dissertation focused on understanding labor during the development of Tiwanaku (AD 500-1100), one of the earliest Andean states. Prior archaeological research (Kolata 1991, 1993a, b; Stanish 1994, 2003) argued that Tiwanaku labor was centralized under a corvée *mit'a* system. Labor was controlled and distributed by elites living within the city of Tiwanaku under a hierarchical political organization (Kolata 2003a). Other research (e.g. Albarracín-Jordán 2003; Erickson 2006) argued that local and decentralized control of labor, with workforce cooperation and collaboration under a heterarchical political system, was an important factor to the state's emergence, formation, and expansion. The author interpreted bioarchaeological research on Tiwanaku skeletal remains in order to answer questions about the Tiwanaku workforce, possible agriculture or craft-based activities performed, workload levels, gendered division of labor, as well as the political structure of the state. Skeletal samples from 1,235 adult burials were examined from previously excavated archaeological sites in the core region in the Titicaca Basin, Bolivia and a colony in the Moquegua Valley, Peru. Evidence from musculoskeletal stress markers (MSM) and osteoarthritis (OA) were used to understand activity distribution and types of labor present within different areas of

Tiwanaku society. This evidence was compared geographically between the core and colony, between different areas within the core, and between individual archaeological sites. Chronological change in labor was also compared during the Tiwanaku state (Tiwanaku phase, AD 500-1100) to labor from prior to polity formation (Late Formative phase, 250 BC – AD 500) and labor after the collapse of the Tiwanaku state (Post-Tiwanaku phase, AD 1100-1300). In addition, osteological age-at-death and sex were correlated with group composition in order to develop a more nuanced understanding of the individuals who comprised the Tiwanaku state. These findings revealed that labor was locally controlled around a decentralized and cooperative network. Activity levels in the core were also higher prior to the Tiwanaku state, indicating that highland people who formed this state may have worked less heavily and repetitively than people who lived in this region prior to the Tiwanaku state. Labor reciprocity may have been one reason to embrace becoming a member of this polity.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1
Introduction

1.1 Introduction to the Research Problem

The control and distribution of labor is essential for the development of prehistoric states. Studies of state development worldwide show a range of labor distribution from specialized craft and agricultural production (Costin 2004; D'Altroy 1992; D'Altroy and Earle 1985; Earle 1997) to dispersed labor systems (Crumley 1987, 1995; Kunen and Hughbanks 2003; Levy 2006; Lozada 1998). My research focuses on understanding labor during the development of Tiwanaku (AD 500-1100), one of the earliest Andean states. While prior Tiwanaku labor studies have considered settlement distribution (e.g. Albarracín-Jordán 1996, 1999, 2003; Albarracín-Jordán and Mathews 1990; Couture 2003; Goldstein 2005; Janusek 2003a, 2004a, b, 2005b, 2008; Janusek and Blom 2006; Kolata 1993a, b, 1997, 2003c), site types (e.g. Bandy 2001; Couture and Sampeck 2003; Goldstein 1989, 1993a; Janusek 2004a; Janusek and Blom 2006; Kolata 1996b), and material culture (e.g. Geisso 2000; Geisso 2003, 2011; Janusek 1994, 1999, 2003b, 2005a; Plunger 2009; Rivera 1994, 2003; Roddick 2009), my research is the first to analyze Tiwanaku skeletal remains for evidence of labor and activity. Because repeated daily activities are inscribed onto human physical bodies, they provide insight into individuals' routines as well as their contributions to the social groups in which they live (Sofaer 2006a following Bourdieu 1977). Thus, I provide new information to answer questions about the Tiwanaku workforce, possible activities performed, workload levels, division of labor, as well as the political structure of the state.

Prior archaeological excavations have shown that the Tiwanaku state emerged approximately AD 500 in the Bolivian highlands of the Lake Titicaca Basin, becoming a major influence in the south-central Andean region. Expansion took place throughout the Bolivian and Peruvian Andes before the state collapsed around AD 1100. Some archaeologists (Kolata 1991, 1993a, b; Stanish 1994, 2003) argue that Tiwanaku state organization was politically centralized and hierarchical, with the city of Tiwanaku as the core settlement. Labor was part of the larger political economy, controlled and distributed by elites in the city of Tiwanaku (Kolata 2003a). However, other studies (e.g. Albarracín-Jordán 2003; Erickson 2006; Goldstein 2005; Janusek 2004a, 2008; Owen 2001) describe the Tiwanaku state as heterarchical, with a federation or alliance of settlements. These allied settlements locally controlled labor, with workforce cooperation and collaboration as an important factor to the state's emergence, formation, and expansion.

Whatever the overarching dynamic, prior Tiwanaku archaeological research indicates dedicated production areas within the state. For example, within the Tiwanaku core, the Ch'iji Jawira site contains evidence that this area was dedicated to ceramic manufacturing (Janusek 1999; Rivera 1994). Other Tiwanaku areas with evidence of raised agricultural fields may have been communities dedicated to farming (Janusek 2004a; Kolata 1991, 1992, 1993a). In addition, colonies in Peru may have been home to farmers growing specialty crops, like maize and coca, or llama caravan traders (Allen 1988; Goldstein 1989, 2005; Stanish et al. 2010; Vallières 2010, 2012).

My research considers what impact state organization, as assessed through labor, would have had on the human body. A wide range of labor, whether agricultural, pastoral, or craft-based, would have left distinct signatures on the bodies of people working within the Tiwanaku state. Skeletal activity studies carried out elsewhere have shown certain agricultural tasks cause an intensification in skeletal strength through increases in levels of muscle mass and bone strength over the lifetime of an individual (Larsen et al. 2001; Ruff 2000). In addition, specific precision tasks, such as grinding grain or weaving textiles, can be seen on areas of the body involved in their performance (Merbs and Euler 1985; Miller 1985).

I examined skeletal samples from previously excavated archaeological sites in the core region in the Titicaca Basin, Bolivia and a colony in the Moquegua Valley, Peru for the bioarchaeological evidence of activity through musculoskeletal stress markers (MSM) and osteoarthritis (OA). The burials represent a minimum of 1,235 adults. To understand activity distribution and types of labor present within different areas of Tiwanaku society, I compared skeletal evidence of labor geographically during the Tiwanaku state (1) by region (between the core and colony), (2) by inter-highland area (between areas within the core), and (3) by intra-area (between archaeological sites). I also looked at chronological change and compared labor during the Tiwanaku state (Tiwanaku phase, AD 500-1100) to labor from prior to polity formation (Late Formative phase, 250 BC – AD 500) and labor after the collapse of the Tiwanaku state (Post-Tiwanaku phase, AD 1100-1300). Finally, I correlated osteological age-at-death and sex with group composition in order to develop a more nuanced understanding of the individuals who comprised Tiwanaku during the formation and advancement of this polity.

1.2 Organization of the Dissertation

I begin this dissertation by providing background on the Tiwanaku state (Chapter 2) and the environmental context for the core and colony regions. I also cover the chronology, culture history, and proposed models for Tiwanaku political organization, including further information on state typology. In Chapter 3, I provide expectations for the skeletal evidence of labor within this early state's emerging political complexity. I also address the theoretical construction of age and gender, essential to understand group composition within anthropological studies, from the bioarchaeological estimates of age-at-death and sex. In Chapter 4, I further describe the methods for reconstructing sample profiles of individuals in this study and include a description of the archaeological sites located within each of these regions. I provide information on the distribution of the study sample, including detailed information of sex estimates, age-at-death, and temporal composition of the skeletal populations. In Chapter 5, I describe the osteological and statistical methods used to evaluate prehistoric labor. The results of the activity studies are presented in the latter chapters, with Chapter 6 containing the results for musculoskeletal stress markers (MSM) and Chapter 7 for osteoarthritis (OA). In Chapter 8, I provide a discussion and summary of the results for these two lines of activity data. In Chapter 9, I explain the relation of the activity data to the original research questions and offer conclusions. By understanding labor patterns throughout the Tiwanaku state, as well as chronological comparisons of labor changes, my dissertation provides insight on the social, economic, and political lives of individuals from one of the earliest Andean expansive states.

Chapter 2
Background on the Tiwanaku State

2.1 Introduction

Tiwanaku was “discovered” in the sixteenth century by Spanish explorers, and first documented by Pedro Cieza de Léon (Cieza de Léon 1998 [1553]). However, the ruins in this area were no new discovery to the native people living in their vicinity. Instead, when questioned about who built these impressive stone structures, the locals had no memory of the civilization, but a legend had been passed down from Inca times about these ruins in the form of an origin myth – Viracocha, a creator deity who labored and sculpted the Andean peoples, plants, and animals at the site of Tiwanaku. This story had early scholars creating fanciful tales about the Tiwanaku civilization; most were not based on any factual evidence.

Early archaeological research at the city of Tiwanaku was based upon more reasonable ideas of how and where civilizations form – that these ruins were the remnants of a ceremonial center with no residences (Squier 1973 [1877]). The high plains near Lake Titicaca were deemed too harsh of a climate to support a large population, so instead, researchers only focused on the stone structures and were not looking for evidence of occupation. Modern archaeologists now know that the Tiwanaku site was a dense urban center and capital of an expansionist state, with colonies and influence on various regions within the south-central Andes (Goldstein 2005; Goldstein and Owen 2001; Janusek 2003a, 2008; Kolata 1993a, b).

In this chapter, I first give the chronology of the Central Andean region, as well as explain the environmental context of the two regions discussed in this study, the southern Lake Titicaca Basin, Bolivia and the Middle Moquegua Valley of Peru. I then describe the culture history of the Tiwanaku civilization using the archaeological record. I also discuss zonal complementarity and the Inca forced labor system of the *mit'a* as historic paradigms of Andean labor. Finally, I provide information about competing models of Tiwanaku's development into statehood in order to understand the emergence of this polity and how labor would have been controlled and organized.

2.2 Chronology of the Study Area

Tiwanaku developed over 1300 years, from its early antecedents (ca. 250 BC – AD 500) into a powerful state (ca. AD 500-1100). During this time, Tiwanaku controlled, or at least influenced, much of the southern Andes and lowlands, including present-day southern Peru, northern Chile, western Bolivia, and western Argentina (Fig. 2.1) (Berenguer and Dauelsberg 1989; Kolata 1992; Rivera 1985; Stanish 2003; Thomas et al. 1985). The two main areas in this study are (1) the highland Andean region in the Southern Titicaca Basin of Bolivia – the 'core' of the Tiwanaku state, and (2) the lower elevation Osmore Drainage in the Middle Moquegua Valley, Peru – a 'colony' of the state (Fig 2.2). The archaeological sites in these two regions span the antecedents to the state (250 BC – AD 500), through the height of the Tiwanaku polity (AD 500-1100), to the collapse of Tiwanaku's influence in each region (after ca. AD 1100 in the highlands of Bolivia, and after ca. AD 1000 in Moquegua).

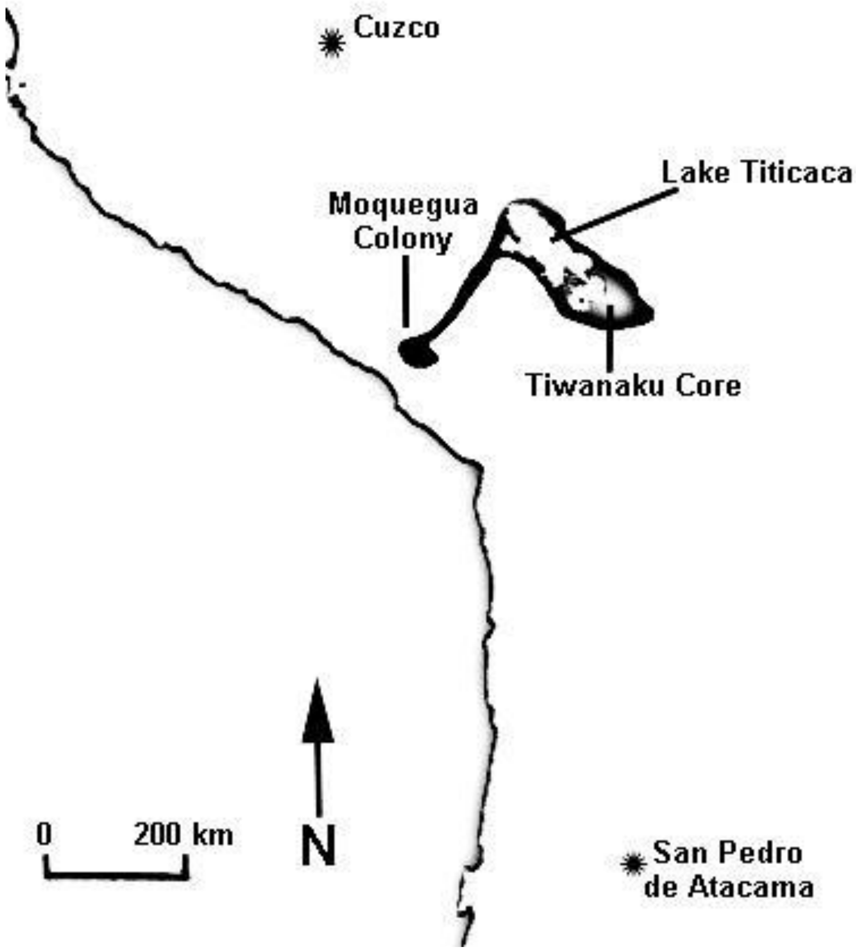

Figure 2.1 Area Controlled by the Tiwanaku State Noted in Black (modeled after Stanish 2003:10)

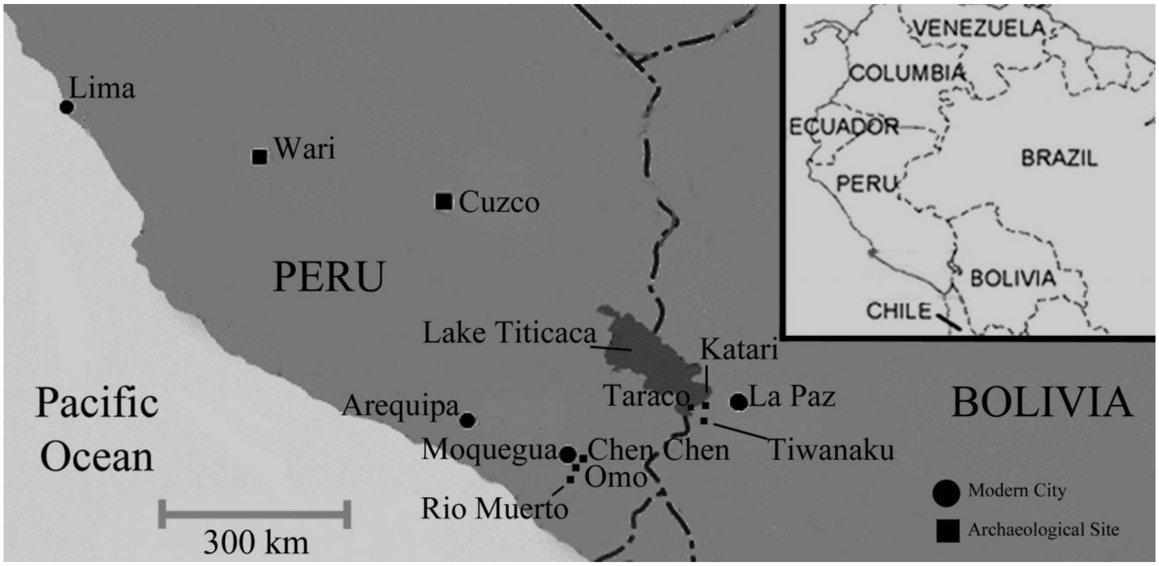

Figure 2.2 Map of Region and Sites in this Study (adapted from Blom 1999)

Because the social and cultural development of Andean South American varies by location, Figure 2.3 provides the chronology for the Central Andes, the Southern Titicaca Basin, and Middle Moquegua regions. Time period designations from the Central Andes (Fig. 2.3, column one) are the most widely used in scholarly literature about prehistoric Andean peoples. Using this chronology, the archaeological sites discussed in this study date from the Early Intermediate Period through the Middle Horizon to the Late Intermediate Period. However, regional chronology for the Southern Titicaca Basin, Bolivia (Fig. 2.3, column two) and the Middle Moquegua Valley, Peru (Fig. 2.3, column three) differ somewhat from the Central Andean chronology. For this study, Southern Titicaca Basin and Middle Moquegua Valley chronological designations are the most appropriate choice and will be used to discuss the Tiwanaku state throughout this manuscript.

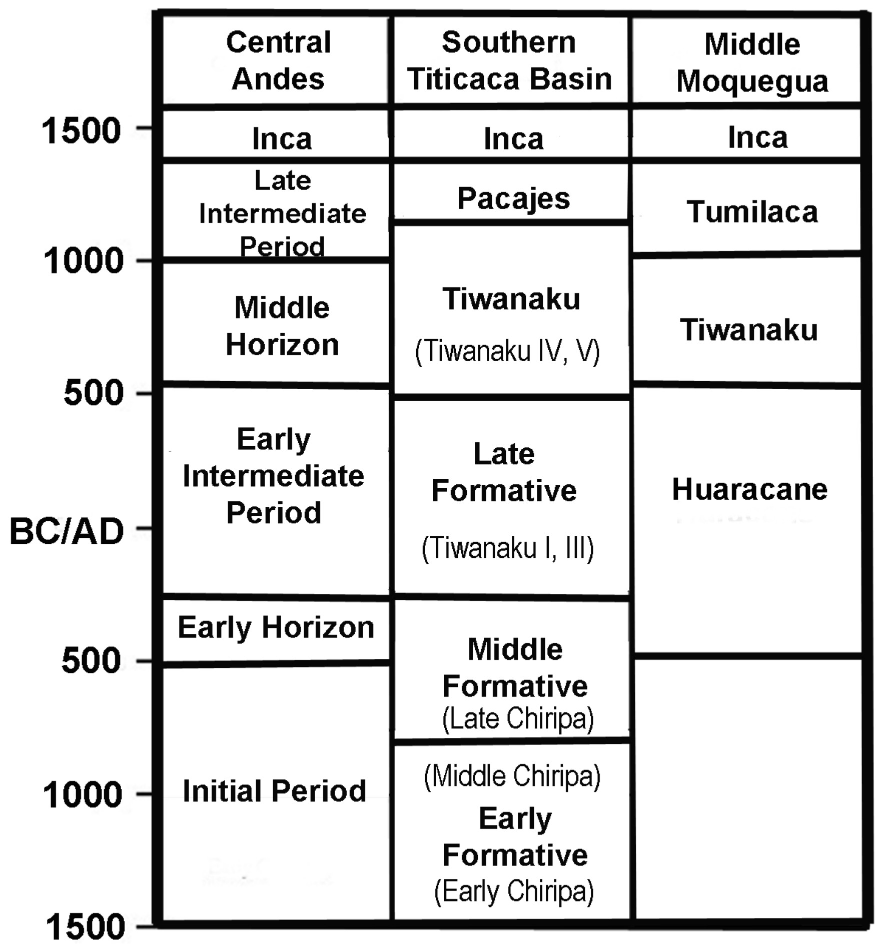

Figure 2.3 Chronology for the Study Area (after Bandy 2001; Goldstein 2005; Janusek 2008; Stanish 2003)

The temporal context of the archaeological sites used in my study fall within the Late Formative, Tiwanaku, and Pacajes periods; sites in the Middle Moquegua region fall within the Huaracane, Tiwanaku, and Tumilaca phases. For clarity, I discuss the chronology in three stages: Late Formative, Tiwanaku, and post-Tiwanaku. The “Late Formative,” which covers the Late Formative in Bolivia and Huaracane in Peru, is the earliest period in this study. “Tiwanaku,” also called Tiwanaku in both Bolivia and Peru, represents the height of the Tiwanaku polity. "Post-Tiwanaku" encompasses the Pacajes period in highland Bolivia and Tumilaca in the Middle Moquegua, Peru region.

2.3 The Environment of the Study Area

The environment of the study area varies greatly in elevation, with the Lake Titicaca Basin, Bolivia core region at approximately 3800m and the colony area in middle Moquegua Valley, Peru at approximately 2000m. The core area is located approximately 80km west of modern-day La Paz, Bolivia, and consists of the Taraco Peninsula, the Katari Valley, and the Tiwanaku Valley, on the southeastern edge of Late Titicaca (Figure 2.4). These areas are situated between the Cordillera Oriental and the Cordillera Occidental Andes Mountain ranges. Average high temperatures range between 50º F and 60ºF and low temperatures range between 40º F and 25º F in this region due to the high elevation and proximity to the equator. This region also has a dual climate with a dry and rainy season. The dry season has cold temperatures in the fall and winter months, and the wet season has warmer, monsoon-style downpours during spring and summer months. Despite these conditions, people have been able to thrive in this region from Archaic through modern times, with the local Aymara people as one of the present-day native populations.

The Moquegua Valley, Peru, is approximately 300km from the Tiwanaku core region (Fig. 2.5). This area comprises a system of rivers and underground aquifers that make up the Osmore Drainage[1] into the Pacific Ocean. Local temperatures are generally warm with average temperatures around 70º F and very little seasonal change. Tiwanaku

[1] The Osmore River is also known as the Moquegua River.

settlements in the Moquegua Valley are centered in the middle valley zone (1000-2000m in elevation). This zone has the most arable farmland in the drainage, as anything above 2000m must be terraced, and below 1000m is a coastal desert.

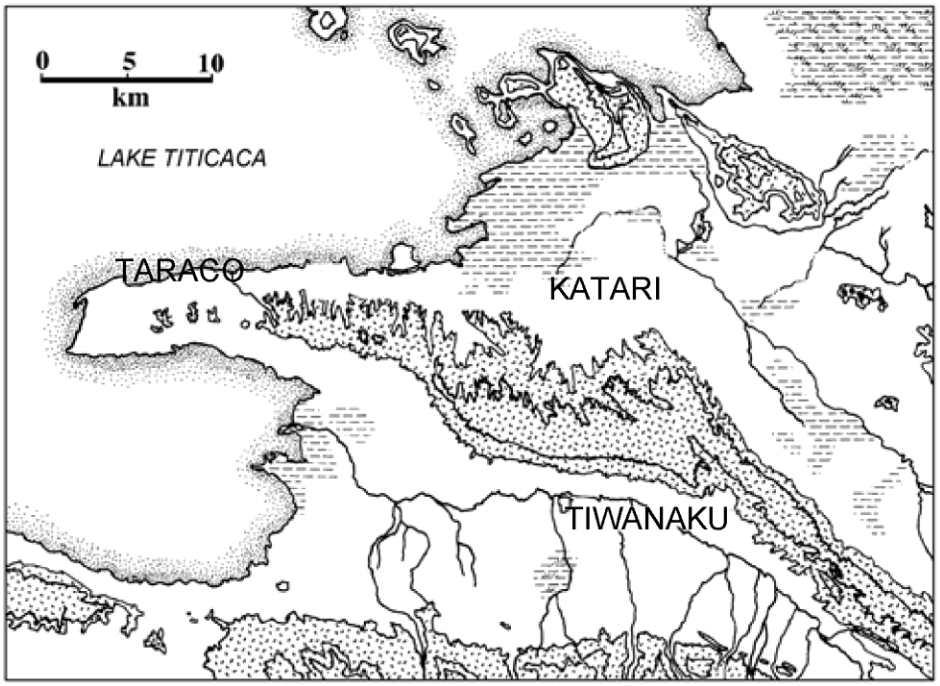

Figure 2.4 Highland Bolivia Study Area with Taraco Peninsula, Katari Valley, and Tiwanaku Valley Noted (modeled after Kolata 1986).

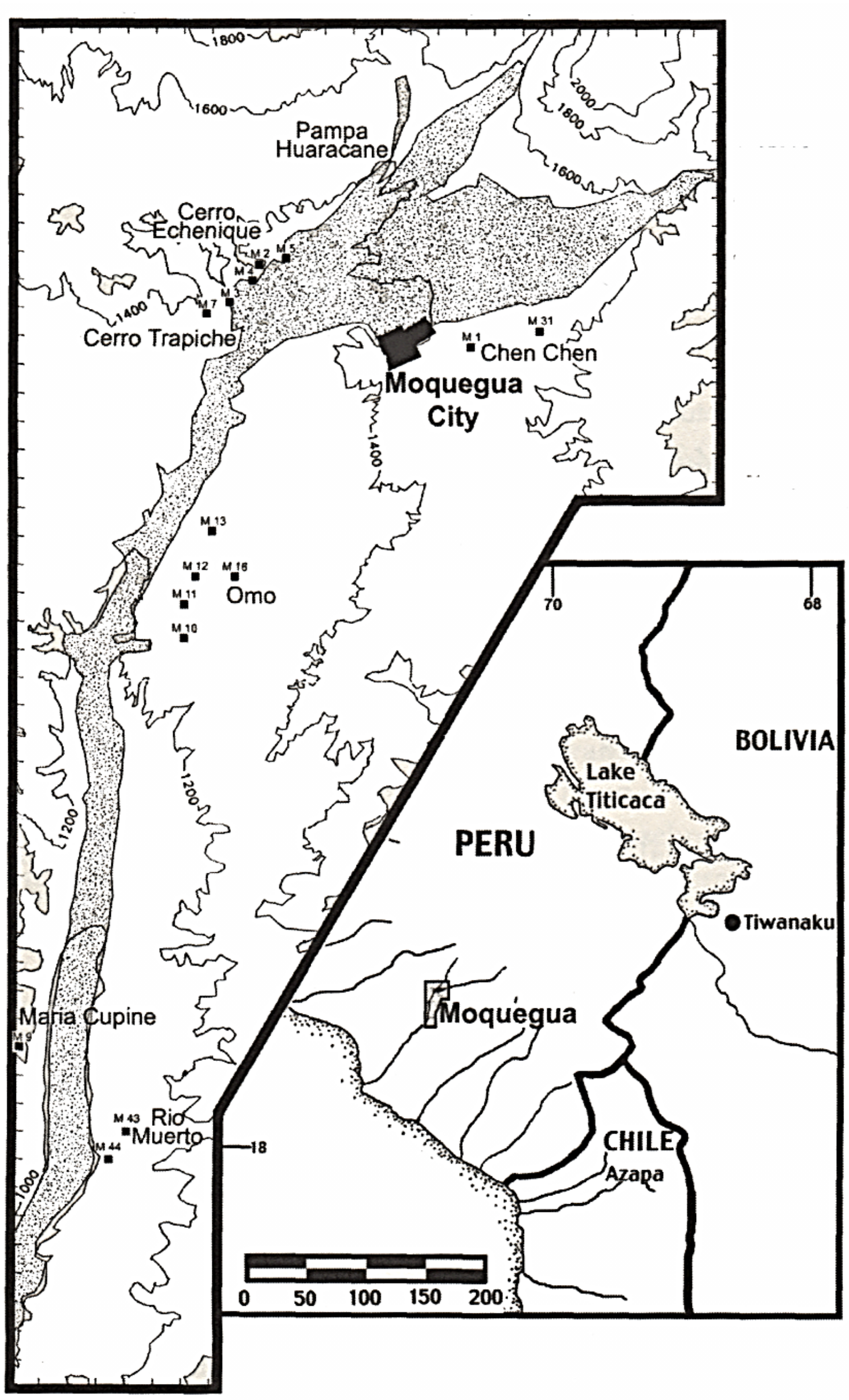

Figure 2.5 Middle Moquegua Valley Study Areas with Archaeological Sites of Rio Muerto, Omo, and Chen Chen Noted (modeled after Goldstein 2005)

2.4 Culture History

During the Early (1500-800 BC) and Middle (800-250 BC) Formative periods, the southern Titicaca Basin area underwent a transition visible in the archaeological record as the use of ceramics, new architectural techniques, and dependence on domesticated plants was noted (Browman 1984; Pearsall 1989, 1992; Pickersgill and Heiser 1978; Wright et al. 2003). During this time, people farmed and lived in small settlements of approximately 10 households per village (Bandy 2001). By 800 BC, increases in village size, production of ceremonial artifacts, such as decorated serving ceramics or ceramic trumpets, and the appearance of public architecture indicated expanding cultural and ideological complexity. Archaeologists (Bandy 2001; Chávez 1988; Steadman 1999) have attributed this to the emergence of the "Yaya-Mama" religious tradition, as evidenced by newly built temple structures. These structures were accompanied by stone carvings with unique iconography and ritual paraphernalia in various areas like the Taraco Peninsula and Copacabana Peninsula. Also during this time, trade networks spanned the Titicaca Basin area and farther into the lowlands, with exotic goods, such as lapis lazuli beads, originating from areas as far as 300km away (Browman 1981). Bandy (2001) noted that with the appearance of exotic goods in some Taraco Peninsula graves and not others, could translate as a greater disparity of social status and power. He (2001:160) describes this new dynamic as a way for,

> "groups and individuals to lay claim to the reciprocal labor services of their neighbors…[with] surplus labor harnessed back into the system via the construction of increasingly elaborate ceremonial facilities and related items of material culture."

As such, by the end of the Middle Formative, goods exchange along with cultural changes may have led to an intensification in asymmetrical relationships accompanied by the beginnings of complex labor relationships.

In the Late Formative (250 BC – 500 AD), highland Bolivia saw the movement of individuals from more rural to urban settings with multi-polity communities emerging throughout the lake basin (Bandy 2001; Bermann 1994; Couture and Sampeck 2003; Janusek 2004a; Janusek and Alconini Müjica 1998; Kolata 1986, 1991, 1993a; Stanish 1994, 2003). The increases in population growth and settlement at the site of Tiwanaku in the Tiwanaku Valley suggest this area's growing cultural and political influence among the Titicaca Basin's residents (Kolata 1986, 1993a). Archaeologically, the use of special ceremonial vessels continued from earlier periods and special purpose ceramic vessels decorated with zoomorphic, geometric, or anthropomorphic designs were also found in what have been called "elite" contexts (Bandy 2001; Janusek 2008; Kolata 1993a). These vessels have been interpreted as increasing ideological complexity among Tiwanaku people (Bandy 2001; Bermann 1994). This increasing complexity was also observed in Tiwanaku architecture through specialized areas consistent with ceremonial centers for ritual activities (Couture and Sampeck 2003; Hastorf 2005; Kolata 1993a; Manzanilla 1992). The development of public architecture persisted during the transition from the Late Formative to the Tiwanaku period, indicating a continuing transformation in public divisions of space and place, and likely in the way the Titicaca Basin people viewed each other.

Communities located outside of the Tiwanaku Valley, such as Kala Uyuni on the Taraco Peninsula, had a local coalescence of control over agricultural production and trade (Janusek 2004a, 2008; Kolata 1986, 1991, 1992, 2003c; Stanish 1994). However, by the latter half of the Late Formative (300-500 AD), Tiwanaku had begun to establish itself as a population center that controlled local trade routes and had an increased emphasis on food production in an agro-pastoral lifeway (Janusek 2008:20). Bandy (2001) interpreted these changes as a new and successful political strategy involving a system of labor management. This system increased political and ideological control with greater levels of ceremonialism and large-scale feasting during the Late Formative, so that by AD 500, "Tiwanaku was a city [that] had become capable of dominating the entire Titicaca Basin politically, economically, and militarily" (Bandy, 2001:204).

In the Tiwanaku phase (AD 500 – 1100), the state reached its height of control in the highland Bolivia region, as well as throughout the southern Andes Mountains. The city of Tiwanaku and surrounding neighborhoods emerged as the major regional urban center. Monumental structures, like Akapana and Pumapunku, were built using precise methods such as mortise and tenon construction. These platforms, with interior sunken courts and decorated with carved iconographic images (e.g. pumas, humans), served as ceremonial centers during the Tiwanaku state. Additionally, within the city, various distinct neighborhoods (*barrios*) developed around the city's center and were likely home to various groups, such as specialized producers like metalworkers, potters, weavers, or herders (Berryman 2011; Blom 1999, 2005; Janusek 1999, 2003a; Janusek and Kolata 2004; Rivera 1994).

Kolata (1993a; 2003c) explained that this layout was about concentric gradients of status in that society was organized as a "concentric cline of the sacred that diminished in intensity from the city core to its far peripheries… inhabitants of the Tiwanaku occupied physical space in accordance with their relative social and ritual status" (Kolata 1993a:93-94). Neighborhoods near the core were elites connected to the Tiwanaku ritual and ceremony through feasting and corn beer (*chicha*) production (Berryman 2011). These elites could have used feasting to create reciprocal obligations to create "productive obligations among communities" (Janusek and Kolata 2004:416). *Barrio* communities could have produced to service the core, and many of their goods may have ended up as part of the feasting cycle. Kolata (1997:253) suggested that the whole purpose of the city of Tiwanaku was for servicing elites and their aristocratic lineages; Tiwanaku urbanites and craftspeople enjoyed high status living, however, only if they served the aristocracy.

In contrast, other researchers (Bermann 1994; Goldstein 2005; Janusek 1999; Rivera 1994) suggest that craft production was performed by independent households or larger artisan collectives, autonomous in their social and exchange relationships. Bermann (1994) and Janusek (1999) note that regular household activities and their associated artifacts, food processing lithics, ordinary textiles, and utilitarian hoes occurred in craft production households. Goldstein (2005:77) concluded, "urban residence and craft production were embedded in Tiwanaku's diverse and segmentary social substructure and not dictated by the demands of patrician sponsors." In association with the urban environment, pastoral and agricultural production increased during the Tiwanaku phase, likely to support the growing population (~20,000 people). These production increases were also a major component of the state's emergence. Specialized agricultural production, in the form of raised field agriculture, occurred within the Katari Valley. At its peak, raised fields covered as much as 70km^2 during the latter portion of the Tiwanaku period (Kolata 1986:759). The largest settlement in the Katari Valley, Lukurmata, also increased in population during the Tiwanaku period. This community may have been home to administrators and an administrative center involved in overseeing the farming, as well as organization and movement of the agricultural products (Bermann 1994, 2003). However, Bermann (1994) also noted various areas within Lukurmata for producing craft goods.

In addition, during the Tiwanaku phase, Tiwanaku-style material culture was found increasingly farther away from the core area in the warmer lowland region. Prior to this expansion, there is very little evidence for control over lowland areas, just trade exchanges (Goldstein 1989; Goldstein and Owen 2001). Archaeologists (Albarracín-Jordán 1999; Goldstein 1989, 2005; Janusek 2004a, 2008; Kolata 1993a, b) generally agree that this expansion to lower elevation areas was a political one. The Tiwanaku peoples had a wish for luxury items, such as maize or coca, which can only be abundantly grown at lower elevations and in warmer climes. Goldstein (1989:251) believed that sometime within AD 500-650, Tiwanaku peoples arrived in lowland valleys "suddenly and in force." He noted that in the Moquegua Valley, one of these locations, colonization was peaceful and there is very little evidence of violence[2] or warfare in the archaeological and bioarchaeological record (Blom 1999; Blom et al. 1998; Goldstein 1989, 1993b, 2005; Isla et al. 1998). Agro-pastoral production would have been a major impetus for

[2] There is little direct evidence of sustained warfare or violence present throughout the growth and expansion of the Tiwanaku state (Isla et al. 1998). Exceptions to this are skeletal remains from the Akapana and Akapana East area, which show evidence of ritual, not interpersonal, violence (Blom and Janusek 2004; Blom et al. 2003) and three trophy heads from a Tiwanaku site on the east side of Lake Titicaca (Alconini and Becker 2011). Research on interpersonal violence within this region and reasons for it associated with these trophy heads is currently ongoing.

movement to this lower elevation region. Maize production was probably of primary importance to both core and colonists alike (Berryman 2011; Blom 1999). Blom (1999:99) noted that “whoever was controlling Moquegua might have held a powerful bureaucratic tool that could be used to gain prestige and power in [highland] Tiwanaku society.” With the movement of Tiwanaku people to the Moquegua Valley, there was a local standardization of ceramics, clothing worn was similar to Tiwanaku highlander styles, and similar monumental architecture built. Goldstein (1989, 1993) argued that this could have been part of an increasing centralized government, with state control over goods production and trade networks. However, Blom (1999:98) noted that the standardization of goods may have been a byproduct of the migration to help identify Tiwanaku highlanders in a local, visually perceptible way, as they were only one group of people living in the Moquegua Valley[3].

After AD 800, an economic and ideological shift in the state occurred, as noted through Tiwanaku-style ceramics looking more mass produced (Janusek and Kolata 2004). Along with increased construction around the ceremonial core of the city of Tiwanaku, agricultural production increased to its greatest levels in the Katari Valley. However, this was concurrent with the abandonment of the city of Lukurmata in the Katari Valley. Settlements in this valley shifted to impermanent ‘field-stations’ focused on crop protection. These changes may be indicative of growing elite control and consolidation of resources (Bermann 1994; Janusek 2004a, 2008; Janusek and Kolata 2004). Janusek (2008:192-193) noted that “raised-field farming became the signature

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[3] There was a contemporaneous Wari settlement on Cerro Baúl within the Moquegua Valley, Peru

productive regime of the Lake Titicaca Basin." Other agro-pastoral activities (e.g. herding, fishing, and rain-fed farming) would have been lower status tasks as the main push was on raised-field crops. These agricultural goods funded the cyclical feasting that helped Tiwanaku's residents negotiate power relations (Janusek 2008:193).

In addition, this change in agriculture intensification may have had a direct impact on lower elevation colonies. After AD 900, a destruction and rejection of Tiwanaku-style material culture in the Moquegua Valley coincided with the Tiwanaku state losing control of this region (Goldstein, 1993:42). In the Moquegua Valley, the post-Tiwanaku Tumilaca phase included changes to dress, textile manufacture, and ceramics that showed the waning influence of the Tiwanaku state. Goldstein (2005:171) noted that there was still some local influence, however only as a style in transition. The change in settlement, with smaller, dispersed, and more defensible sites, along with ceramics and dress were distinct enough to be identified in the archaeological record as a transition to the Tumilaca phase in the Moquegua Valley.

A focus on agricultural intensification in the highlands had eventual negative consequences in the Titicaca Basin. The region underwent a long-term drought that started around AD 1000 and could have been a factor in the collapse of Tiwanaku about 100 years later (Binford et al. 1997; Erickson 1999, 2006; Kolata et al. 2000; Moseley 1997; Ortloff and Kolata 1992). Any major construction projects were discontinued by AD 1000, and around this time, monuments associated with elites and elite ancestors were ritualistically defaced and buried. After AD 1100, populations shifted from large, urban centers to small, hilltop fortress settlements (*pukaras*) (Albarracín-Jordán 1992; Stanish 2003). Akin to Tumilaca sites in the Moquegua Valley, these *pukara* settlements in the Pacajes phase (AD 1100-1400) were generally dispersed and easily defensible, reaching into upper sectors of the mountains. Janusek and Kolata (2003:157) suggested that a lack of agricultural artifacts in Katari Valley post-Tiwanaku Pacajes sites coincided with lowered agricultural production and abandonment of the raised-field system. In addition, Albarracín-Jordán (1999:85) noted that these fortified *pukara* settlements marked a period of conflict with neighboring groups over economic resources as a result of the collapse of the Tiwanaku state. Whatever the cause or causes, Tiwanaku state collapse triggered striking changes in settlement, labor, and food procurement throughout the south-central Andes. The state, as a controlling component, did not return to this region until Inca elites arrived hundreds of years later to claim heritage and mythical ancestry with Tiwanaku peoples.

2.5 Labor in the Andes

From this culture history, a general understanding of labor paradigms in the Andes is required to provide a thorough interpretation of how people could have lived and worked within the Tiwanaku state. As the Andean environment is highly variable on a short-distance scale due to dramatic changes in elevation, the landscape in this region can be envisioned as a series of tiers with differential environmental resource availability in each area depending upon the elevation. Access to prestige goods or luxury items not available locally and only able to be grown at certain elevations, like maize and coca, would have been an important consideration in this region (Allen 1988). Because of this, the production, as well as the traffic of these items, would have been an important component of the state.

As the precontact Andes lacked a public market system, goods were moved using either direct or indirect zonal complementarity, where indirect is trade or exchange between people while direct would be direct control of another zone to procure goods (Murra 1995). This zonal complementarity, first described by Murra (1965; 1972; 1980; 1981; 1985), is a model for resource procurement and labor movement in the Andes. While indirect zonal complementarity is understood as trade or exchange between zones, Murra based direct zonal complementarity on ideas of risk aversion as well as the traditional Andean value of self-sufficiency. The more access to various areas of land, the less likely one is to starve if a crop fails or all crops fail at a certain elevation. With direct complementarity, control ranged from familial management within a short distance (i.e. within a day's walk) to permanent colonization in disparate regions depending on the type of society and how it was organized (Murra 1968, 1972, 1985, 1995).

Murra also discussed that differences in control of resource tiers could be further developed depending on proximity. The closer the area, the more continuous (i.e. compressed) the resources, the farther the area between tiers, the more they became discontinuous (i.e. vertical archipelagos). Thus, several satellite communities within a varying distance may support one main community. As the population increased and the system developed into a large settlement or city, the more likely they were to control a greater number of areas over a longer distance, thus adding more resource archipelagos (i.e. more than a 10 day walk away) to the network (Murra 1968, 1981, 1985). In the south-central Titicaca Basin, long distance trade networks (i.e. indirect zonal complementarity) were established prior to the Tiwanaku state and likely continued up to the collapse of the state (Bandy 2001; Browman 1984; Goldstein 2005; Janusek 2004a, 2008; Sharratt 2011). However, major direct zonal complementarity with the movement of people to the Moquegua Valley and other regions as possible resource archipelagos did not take place until after the state had established itself in the highlands.

Murra (1985) also suggested that archipelago communities remained in close contact, could see each other as similar ethnic groups, and worked reciprocally for each other. However, Van Buren (1996) challenged this idea by suggesting a more “for profit” reason for settling in these archipelagos. She believed that people participating in this system were not ethnically related groups that worked in reciprocal trade networks. Instead, the exchange network would have been “established by internally differentiated societies [that] probably never functioned to provision whole populations, but to produce goods that were critical to the maintenance of political power” (Van Buren 1996:348). Specifically, this was a political and economic relationship as she notes that these lower elevation colonies were different groups of people that supported themselves through particular goods production (e.g. maize, coca). Some of these goods were subsequently given as tribute or tax to certain political leaders in the Andes to whom they owed allegiance. While a critique of one portion of the zonal complementarity system, Van Buren’s study provides another component to Andean labor organization and maintenance by broadening the idea of colonial archipelagos to include various cultural groups as multiethnic communities.

Along these same lines, the movement of groups or colonies in a labor system also has a basis in historic and ethnohistoric studies of Andean labor records from the Inca Empire. During Inca times, laborers were exploited through a ‘*mit’a*’ system, a temporary labor service involving a kind of conscripted, corvée labor. In general, both men and women between the ages of 15 to 50 were required to perform yearly service to the state, averaging around 300 days a year. This system of labor, defined as "he who works when his time comes" (Murra 1980:192-193), was noted during colonial times as groups of people moved to work lowland crops for the Inca elite. As lowland agriculture often requires more work than highland production, especially to create surplus, these areas would have required a constant supply of workers to both farm and guard the storage areas (Wachtel 1982:214). In return, the *mit'a* groups may have received rewards, such as land or goods, as well as the right to sell some of their lowland product in the highland markets (Murra 1995). To be clear, this was not a voluntary system. Those who worked were promised support from the state for themselves and their families, and those who did not were put to death (Cieza de Léon 1998 [1553]). In addition, besides agricultural production, under a *mit'a* system people may have served in Inca military functions or trained as specialists in the production of certain goods, like textiles or ceramics. In a few cases, these specialists were removed from society, elevated in status, and employed in special production locations, as is the case with the *acllas*. These *acllas* were groups of women who were weavers, *chicha* producers, and ritual specialists (Silverblatt 1987). Thus, the mandatory workforce in the Inca Empire was comprised of general agriculturalists to specialized producers who shaped ritual within the state.

2.6 Explanations of Tiwanaku Political Organization

The Tiwanaku state's control over labor and its workforce distribution is essential in understanding the development of this prehistoric Andean state. From early research in and around this area, a model of state formation was developed broadly based around prior traditional ideas of complex society formation (Carneiro 1970; Earle 1997; Haas et al. 1987; Service 1975; Sinopoli and Morrison 1995; Wright and Johnson 1975; Yoffee 1988), where in order to have a state-level society, a centralized and hierarchical core is required (Fig. 2.6). Historic and ethnohistoric accounts of the Inca Empire, along with archaeological evidence, have often been used as a political and cultural example of how states formed in the Andes (e.g. D'Altroy 1992, 2005; D'Altroy and Bishop 1990; D'Altroy and Earle 1985; Demarest and Conrad 1984; Earle 1997; Earle and D'Altroy 1989; Murra 1980; Rowe 1982 and others). For example, state run labor with craft production, movement of individuals throughout the Inca Empire for agricultural production, and the building of monumental architecture under a centralized and ordered authority were noted as part of the formation and maintenance of this state.

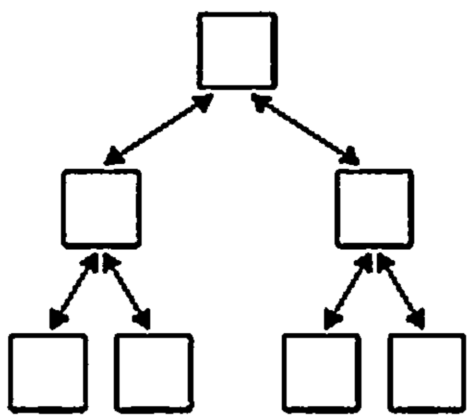

Figure 2.6 Model of Hierarchical and Centralized Organization.

While Tiwanaku predates the Inca, much of the early research in the Titicaca Basin asserted that a developing Tiwanaku state would have required a centralizing and hierarchical core of elite managers who maintained and oversaw goods production (Bandy 2001; Janusek and Alconini Mújica 1998; Kolata 1986, 1991, 1993a; Ponce 1972; Stanish 1994). As described by Kolata (1993a:223), "labor was most likely extracted by the centralized authorities of the Tiwanaku state in the form of corvée through a mechanism similar to the Inca *mit'a* tax system." Elite managers, located in the city of Tiwanaku, would have been necessary to organize and maintain the state, establish authority over the various communities, claim resources in and around the Titicaca Basin, and control and organize agricultural production raised-field farming[4] areas (Kolata 1986, 1993a, b, 1997; Ponce 1972). From this high-status center outwards, decreasing in status and power, were other areas home to craft or production specialists in service to this elite core (Kolata 1993a, b, 2003c).

In addition, Tiwanaku controlled various local areas outside of the urban core, such as Lukurmata in the Katari Valley, as administration centers that reported to Tiwanaku elites (Kolata 1986, 1991, 1992, 2003c; Stanish 1994). Farther-reaching settlements, such as colonies in Moquegua, Peru or Cochabamba, Bolivia could have been extractive colonies – state controlled production centers where highlanders worked in the lowlands. The degree of control to which Tiwanaku elites controlled these highlanders is not known, but if modeled on examples from the Inca Empire, it may have resembled the mandatory corvée labor tax of the *mit'a* (Costin 1998; D'Altroy 1992, 2005; D'Altroy and Bishop 1990; D'Altroy and Earle 1985; Earle and D'Altroy 1989; Murra 1980; Silverblatt 1987). Kolata (1993a:213-214) does note that the relationship between core and colony would likely have struck some kind of balance of reciprocal exchange between commoners and elites. As such, colonists would have produced goods

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[44] This farming system was 'rediscovered' by the archaeological research of Proyecto Wila Jawira in the 1980s (Kolata 1986, 1991, 1993a, 1996a, b, 2003b; Kolata and Ortloff 1989, 1996; Ortloff and Kolata 1992).

and crops, thus providing the elite center with luxury items such as textiles, coca, and maize, that could not be procured at higher elevations (Kolata 1986, 1991, 1992, 2003c; Stanish 1994). Overall, this model of Tiwanaku statehood with agricultural intensification, urban growth, centralization, and elites in-charge in the core city fits well with centralized and hierarchical states noted in other parts of the world (Carneiro 1970; Haas et al. 1987; Kolata 1997; Service 1975; Sinopoli and Morrison 1995; Wright and Johnson 1975; Yoffee 1988).

As Crumley (1995:3) noted, coming out of a dissatisfaction with the band-tribe-chiefdom-state model in systems theory, archaeologists (e.g. Crumley 1974; Crumley and Marquardt 1987; Crumley et al. 1987) began to explore an alternative to this concept of the 'traditional' or 'classic' centralized hierarchical model of state. Known as heterarchy (Fig. 2.7) and based on a study by McCulloch (1945) of human neural networks, the term 'heterarchy' was used to explain diallels in brain organization. McCulloch noted that the brain cannot only function linearly and hierarchically, but instead must work in more of a netlike association of orderly with occasional logical contradictions in the decision making process[5].

Understanding these concepts from an archaeological perspective, a heterarchy is the "relation of elements to one another when they are unranked, or when they possess the potential for being ranked in a number of different ways" (Crumley 1987:158). Crumley (2003:41) noted that concepts of power relations in systems theory can conflate hierarchy with order, and that heterarchy is suited as a corrective to this way of thinking

[5] Crumley (2003, 2005) used the example of people who are both pro-life/against abortion rights and for the death penalty (or vice versa) as a good example of this in modern human thinking.

as there can still be order or hierarchy within heterarchy (Crumley 2003:40-41). Additionally, heterarchy does not need elements of complex systems to be permanently ranked as it is an approach to identifying ranked and unranked values, behaviors, and organization with shifts in time and space (Crumley 1995:3; 2005:45).

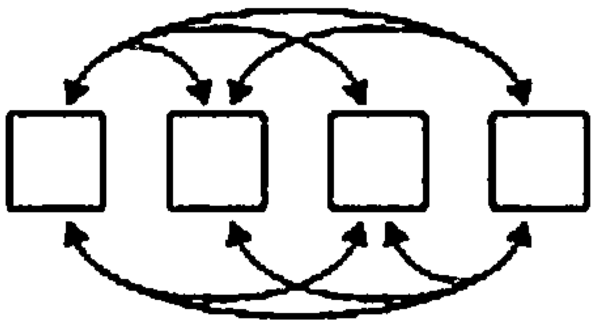


Figure 2.7 Model of Heterarchical and Decentralized Organization.

While the term heterarchy was not originally used by archaeologists who rejected the idea that a forming and expanding Tiwanaku state required a centralizing and hierarchical core of elite managers (e.g. Albarracín-Jordán 1992, 1996; Bandy 2001; Erickson 1985, 1993, 1999, 2006; Erickson and Candler 1989 and others), recently it has been appropriately applied to studies of the landscape, material culture, and power relations within this area (Arnold and Hastorf 2008; Goldstein 2000, 2005; Janusek 2004a, 2005b, 2008). Albarracín-Jordán (1996) introduced the concept of "nested hierarchies"[6] in the Lake Titicaca Basin using ethnohistorical and ethnographic

[6] Albarracín-Jordán used Netherly's (1984) north coast Peru research on the Chimu as the basis for his concepts, hence why they were not initially labeled "heterarchical".

examples of modern Andean community *ayllu*[7] organization to explain Tiwanaku statehood. From his model, the local family is the *haatha*, while an *ayllu* means the local community within the larger region (*marka*) and territory (*suyu*). These levels are used to explain the state's emergence at an *ayllu* level. These *ayllus* function as "nested hierarchies," which combined a kin-based (real and fictive) household group that considers itself linked to the land.

Albarracín-Jordán (1996) noted that control would have been organized and maintained by those elected or appointed from certain *ayllus*, such as *mallkus*[8] who each head their own *ayllu*. These leaders shared common ideology and would have organized and labored within a reciprocal network, as is the case in modern Aymara groups (Abercrombie 1986; Albarracín-Jordán 1996, 1999, 2003; Browman 1981, 1984). Experimental reconstructions of raised-field agriculture suggest that rural groups could have controlled Tiwanaku agriculture under a local leader who also worked the land in the *ayllu* system (Erickson 1985, 1993, 2006; Erickson and Candler 1989; Janusek 2004a). Craft production within the urban city of Tiwanaku is explained by Janusek (1999) as families (*haatha*) of embedded craft producers, instead of specialists attached to elite households. Multiple neighborhoods practicing different crafts in the city of Tiwanaku, many of which had associated household contexts, could be an example of a heterarchical and *ayllu*-oriented organization. In addition, colonies of the state could be

[7] The world *ayllu* has multiple meanings and varying levels of complexity. Albarracín-Jordán (1996:185-186) noted some of various ways this word is used. Abercrombie (1986:97-100) also discussed the varying scale (i.e. macro-, micro-*ayllu*) to which local Aymara people apply the word and in what context.

[8] From the Aymara language, meaning leader.

explained as the migration of individuals or families who voluntarily moved to other regions and had personal or familial motivation, such as a better climate or relatives in an *ayllu* network (Blom 1999; Blom et al. 1998; Janusek 1999, 2004a; Mujica 1985).

In summary, a major difference between these competing models, centralized and hierarchical or decentralized and heterarchical with nested hierarchies, would have been in labor organization and production. In this centralized and hierarchical model, the labor force could have been mobilized to work more homogenously at the behest of the state. For example, the Katari Valley's residents would have been called upon to work the "proprietary agricultural estates [i.e. state-owned and operated fields] in which ownership and usufruct rights were… in the hands of the elite, dominant classes" (Kolata 1991:120) and that labor organization management was "beyond that of locally autonomous village or *ayllu* groupings" (Kolata 1993a:223). While decentralized labor control in a heterarchical model, local areas would have controlled and supervised their own labor under someone such as a *mallku*, not under "an urban elite and their hydraulic engineers" (Albarracín-Jordán 1996:205). This localized labor force worked reciprocally and benefited numerous settlements in the area, as well as had the potential for local negotiation into larger labor groups to tackle monumental projects as part of a reciprocal exchange, such as labors for occasional feasting in the form of *chicha* or future promises of aid. Albarracín-Jordán (1996:186) noted that this reciprocity would have integrated political authority at different levels and contrasted Kolata's ideas of centralized and hierarchical labor. However, Kolata (1993a) also noted that reciprocity and redistribution would have occurred in a managed and centralized state. The difference is in the level of reciprocity and redistribution. A Tiwanaku heterarchy with decentralized labor control would have had more localized reciprocal labors and exchanges, with fewer large-scale events like feasting, while a Tiwanaku centralized hierarchy would have had larger-scale redistribution and reciprocity between elites of disparate areas, with more *mit'a*-like events of feasting for most labor projects.

In theory, these two models of Tiwanaku state formation are diametric contrasts in political and social organization. However, it is possible that the Tiwanaku state was not radically one or the other as this polity was not static or monolithic. Instead, political control could have changed over time during the state from decentralized and local heterarchical labor control to more hierarchical and centralized labor arrangements as Tiwanaku elites consolidated power and ideology. The state could also have been centralized near the city of Tiwanaku, but left rural households farther out to their own devices, as is shown in Figure 2.8. For example, Hassan (1994:178) noted that Pharaonic Egypt, with its well-known hierarchy and elite society, survived for such a lengthy period of time because of "weak connections between central administration and production." Farmers, who were generally left alone to produce their goods, helped the centralized core flourish with food surplus; labor was local, but still with a centralized core. Although this case is a world away from the Andes, it does present a cautionary example that must be considered when evaluating labor and activity patterns within the Tiwanaku state.

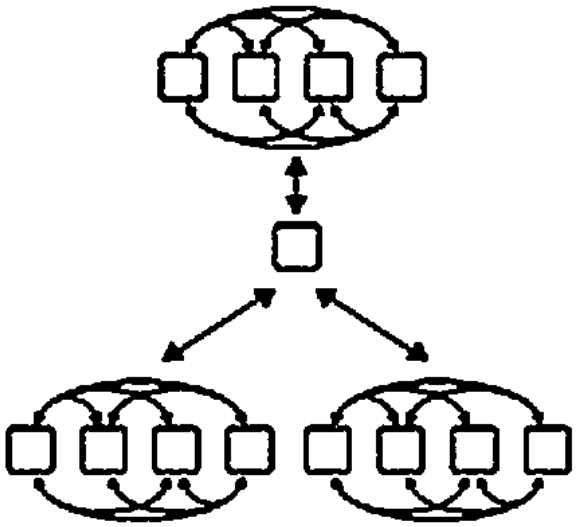


Figure 2.8 Hybrid Model with a Combination of both Centralized Hierarchy and Heterarchy.

In addition, recent work by Angelbeck and Grier (2012) provided an interesting example adding to the political complexity discussion of a hierarchy and heterarchy. In working to understand their Pacific Northwest Coastal Salish material culture evidence and human skeletal remains, the authors took an anarchistic approach with decentralization and self-governance as the main components to complex society formation in this group. This anarchistic approach also allowed for the “development of power, privilege, and influence while retaining consensual, decentralized properties of non-hierarchical systems” (Angelbeck and Grier 2012:4). Although the case study in this paper was technically from an ‘egalitarian chiefdom,’ many of the organizational properties the authors put forth, such as individual and local autonomy, network organization, decentralization, and justified authority seem comparable to ideas presented within the Tiwanaku “nested hierarchy” heterarchy approach. Under a justified authority example, modern Aymara *mallkus* can be elected community leaders in charge of reciprocal obligations (Abercrombie 1986; Platt 1982), similar to the Coastal Salish chiefs in charge of potlatch goods redistribution. In both areas, these autonomous local corporate groups voluntarily link into bigger networks that are structured according to the needs of the people. While I am not trying to reduce these cultures to a one-to-one comparison, I do want to point out that the article presents some interesting associations, and at the very least, the anarchist perspective on political and social complexity is one that should be studied and considered in future research on Andean states.

2.7 Summary

This chapter contained information on some of the earliest accounts of Tiwanaku as a social and political polity. I have also given information on the chronology of the various areas in this study along with the disparate environments in which the Titicaca Basin core and Moquegua Valley colony were established. Information on the culture history of the study area was also provided in order to explain competing theories on how the state formed, and specifically, how labor was controlled and organized. Additionally, traditional types of labor organization were discussed in both a corvée *mit'a* system as well as the well-known zonal complementarity examples from Murra. In the next chapter, I discuss more about labor from a bioarchaeological and theoretical perspective.

Chapter 3
The Bioarchaeology of Labor

3.1 Introduction

In this chapter, I focus on labor organization and its effects on people within the Tiwanaku state. I first present the labor-related differences one might expect to find on the skeletal remains of individuals who worked within the study area for both models of Tiwanaku state formation, with centralized and hierarchical labor organization at one end of a spectrum and decentralized and heterarchical labor organization at the opposite end. I also discuss caveats to these models because the skeletal evidence of labor may suggest a hybrid of both models, falling somewhere within the range of expectations. Second, because there is a cultural legacy of division of labor by gender or age in the Andes (Abercrombie 1986:115; Bolin 2006:72; Carter 1967; Hardman 1976; Lucy 2005:43; Mitchell 2003:276), I describe my contextual approach to reconcile these cultural categories with biological divisions of sex and age-at-death to discuss group membership within the Tiwanaku workforce. The third section includes prior bioarchaeological research pertinent to Tiwanaku statehood because these studies provide important information about group composition, genetic relatedness, and the movement of labor groups within the Tiwanaku state.

3.2 Expectations of Labor in the Tiwanaku State

Geographic Differences

The control of labor during Tiwanaku state formation was described in Chapter 2 as centralized and hierarchical or more decentralized and heterarchical with nested hierarchies. To assess which of these models is more appropriate, I looked at labor during the Tiwanaku time period (AD 500-1100) from three geographic perspectives: (1) regional (i.e. between the highland core and the Moquegua colony), (2) inter-highland area within the highland core (i.e. between the Tiwanaku Valley and the Katari Valley), and (3) intra-area (i.e. between archaeological sites within each valley).

Kolata (1991:100) described labor organization in the Tiwanaku state as,

> "structured hierarchical interaction between urban and rural settlements characterized by a substantial degree of political centralization and the mobilization of labor by social principles that reached beyond simple kinship relations… Tiwanaku urban elites had a compelling interest in establishing a dedicated landscape of intensive agricultural production in the core territory and that the organizational principles they instituted to manage this landscape were of regional, rather than local scope."

Kolata (1991:115) also noted that "labor was most likely extracted by the centralized authorities of the Tiwanaku state in the form of a corvée through mechanisms similar to the Inca *mit'a* labor-tax system… and points to a managerial hand beyond that of locally autonomous village or *ayllu* groupings." Kolata (1991:117) further noted "repeated and consistent occurrence of major Tiwanaku hydraulic structures in both rural and urban zones vitiates application of the laissez-faire hypothesis to the Tiwanaku system." Thus, Kolata believed that labor would have been more constant, as opposed to the idea that the state rarely invested in capital- and labor-intensive projects (i.e. laissez-faire hypothesis). In addition, this labor was also managed by a regional authority with at least a "rudimentary bureaucratic system to track the extraction of labor service from subject communities and the subsequent flow of produce from state-operated fields" (Kolata 1991:120).

Thus, in a centralized model of the Tiwanaku state, as described by Kolata (1991; 1992; 1993a; 1993b; 2003c), if labor were organized around servicing the elites, then I would expect to see significant differences in both the regional and inter-highland area comparisons (Fig. 3.1). I would argue that the farther one was from the urban center of Tiwanaku, the greater the demand on labor of non-elites would have been. For example, there would have been a greater labor demand on the workforce in the Katari Valley when compared to individuals from the Tiwanaku Valley. In addition, as lowland agriculture often requires more work and a constant supply of workers than highland production (Wachtel 1982:201), I argue that colonists would have likely worked in some form of an extractive colony under a *mit'a*-style leadership to grow luxury crops like maize and coca for the state's elites (Kolata 1991, 1992, 1993a, b, 2003c).

In contrast, research by Erickson (1988a; 1985; 1988b; 1992; 1993; 2006) asserted that raised-field agriculture in the Titicaca Basin did not require a centralized and hierarchical core of elite managers. Instead, Erickson (1988a:348) noted that

> "the raised fields were associated with relatively small cooperative groups, while the dominant political organization in the basin was at the level of a state. It is unlikely that this highly productive system which functioned efficiently under local management would have been tampered with by the state."

These small corporate groups could have been more locally organized around the community and the Andean *ayllu* in what Albarracín-Jordán (1996) called "nested hierarchies," rather than in a *mit'a* system with a centralized authority.

Thus, if the labor force in the Tiwanaku state were decentralized and more heterarchical, then I would expect that the greatest differences in labor organization would be in the intra-area comparisons (i.e. between archaeological sites within each valley) which were under the control of local people within a family or *ayllu* network (Fig. 3.2). The differences in activity would have been within neighborhoods, as labor would have likely been controlled under a *mallku* (i.e. local leader) and more evenly dispersed across the larger region or territory. In essence, the variation between regions or within the core (i.e. core vs. colony or inter-highland area) was the same or similar because there was no *mit'a* obligatory service to an elite core. The expectation is that neighbors, friends, and families worked more reciprocally and equally for each other in a heterarchical local arrangement like would be found in nested hierarchy (Albarracín-Jordán 1996, 2003).

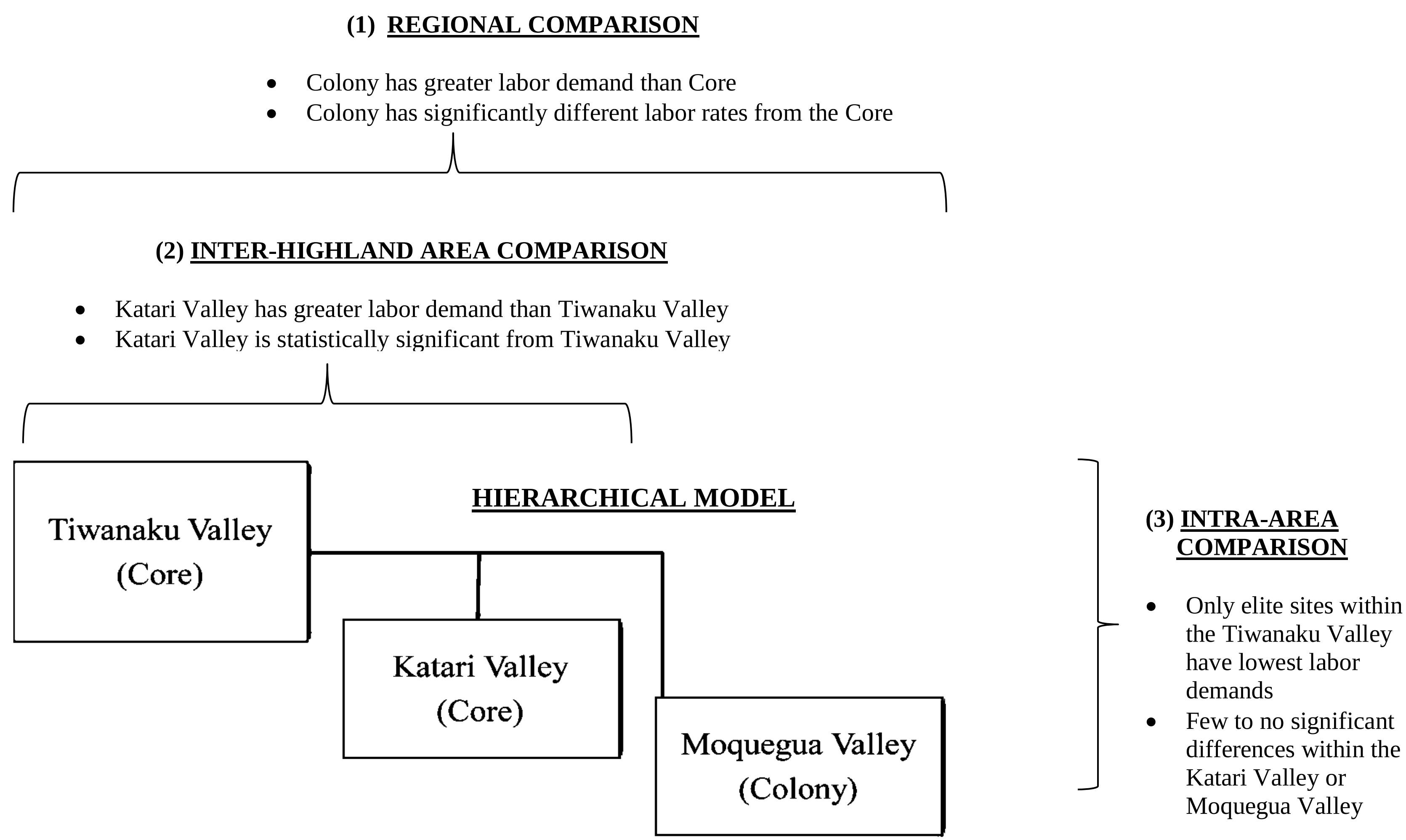


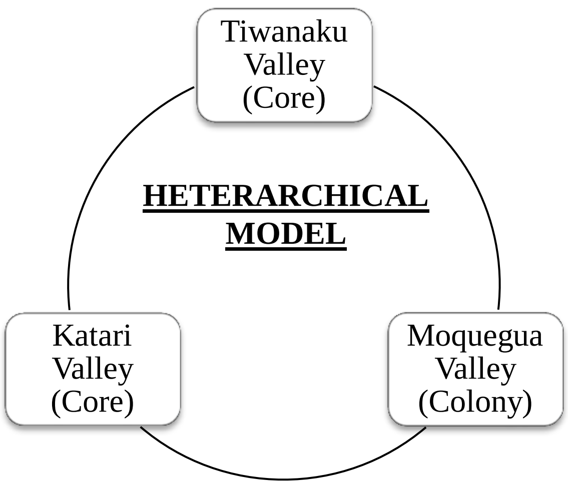
Figure 3.1 Geographical Changes Expected in a Centralized Labor Model of the Tiwanaku State

(1) REGIONAL COMPARISON

- Labor demand is equal in both Core and Colony
- There are no statistically significant differences between Core and Colony

(2) INTER-HIGHLAND AREA COMPARISON

- Labor demand is equal between Tiwanaku Valley and Katari Valley
- There are no statistically significant differences between Katari Valley and Tiwanaku Valley



(3) INTRA-AREA COMPARISON

- Local Labor Control with more significant differences between sites:
    - Within the Tiwanaku Valley
    - Within the Katari Valley
    - Within the Moquegua Valley

Figure 3.2 Geographical Changes Expected in a Decentralized Labor Model of the Tiwanaku State

In order to assess activity levels and labor intensity, I use two bioarchaeological indicators of activity, musculoskeletal stress markers (MSM) and osteoarthritis (OA). In measuring labor within both the centralized and decentralized labor models, I conduct comparisons over the three geographic areas during the Tiwanaku state: (1) regional core vs. regional colony, (2) inter-highland area between the Tiwanaku Valley and the Katari Valley, and (3) intra-area within the Katari, within the Tiwanaku, and within the Moquegua Valleys (Table 3.1).

For the centralized labor model, I would expect to see that the prevalence and muscle-use intensity of MSM and percentage of area affected in OA would be statistically significantly different in the regional comparison between core and colony. Rates would also be highest with greatest workload intensity for both indicators of activity from the colony in the Moquegua Valley, Peru area. I argue that the reason for this is that colonists would have been subject to the heaviest of the state's labor demands for the core under a *mit'a* system.

When looking at differences within the highland core comparisons, the Katari Valley should have the heaviest labor demand, the highest rates of bioarchaeological markers of activity, and be significantly different from the Tiwanaku Valley. As agriculture would have been a primary focus among Katari Valley residents, the expectation is that MSM and OA would have a greater prevalence for each indicator of activity, especially in the arm and shoulder joint and in the foot musculature and ankle joint in the lower body. I argue higher use in these areas of the body because activity reconstruction in modern studies using traditional Andean tools such as the *rawkana* (hoe), *chakitaqllaa* (foot plow), and *waqtana* (clod-breaker) (Erickson 1985:36; 1988b:14,16) could have especially effected these joints and musculature.

Finally, the intra-area comparisons within the Katari Valley and Moquegua Valley should show few to no significant activity differences between sites. Katari Valley and Moquegua Valley residents likely labored more homogenously at agriculture for the core. In this model, everyone within the Katari Valley or the Moquegua Valley worked just as hard as his or her neighbors at nearby sites did. In addition, areas with differences would be within the Tiwanaku Valley in the city of Tiwanaku where burials from elite areas should show the lowest rates and evidence of activity indicators as this "ceremonial core of Tiwanaku were… the palatial residences of the elite" (Kolata 1993a:91-92).

In contrast, a decentralized labor model within the Tiwanaku state would show fewer labor differences in within the core or in core and colony area comparisons because the majority of differences should be within each region. Bioarchaeological evidence should show similar prevalence and muscle-use intensity of MSM and percentage of area affected in OA in regional comparisons between the core and colony. Any differences in patterns of activity between core and colony would be more indicative of differences in activities, such as raised-field farming in the highlands and canal/riverine irrigation farming in the colony, but should not be statistically significant.

The geographic comparison between highland Tiwanaku Valley and Katari Valley areas (i.e. inter-highland area) during the Tiwanaku state in the decentralized model would show few to no significant labor differences. Between these two highland valleys, there should be no significant differences and similar activity levels of MSM and OA. The reason for this is that I believe activity and labor would have been organized at a local level and the people working in either valley should have similar levels of activity.

The primary activity differences would be between archaeological sites within the Tiwanaku Valley, within the Katari Valley, and within the Moquegua Valley (i.e. intra-area) because a decentralized and heterarchical model calls for neighborhood labor that is more locally controlled. As people labored within their *ayllu*, they would have worked as groups, possibly with certain labor specializations, but not as districts in more uniform production areas for elites or as corvée laborers. The bioarchaeological evidence should show significantly higher rates and muscle-use intensity of MSM and percentage of area affected in OA between people from these sites. For example, the expectation within the Katari Valley would be that people from the Lukurmata site worked less intensely than their rural counterparts because tasks would have been distributed more reciprocally over a larger population. Within the Tiwanaku Valley, if labor was controlled locally, the archaeologically distinct areas of craft specialization within the city of Tiwanaku should reflect what scholars have described as embedded producers – family groups working at production (Browman 1978, 1981; Janusek 1999; 2004a; Rivera 1994, 2003). Thus, the many sites within the city of Tiwanaku would reflect significantly different levels of labor and activity that have less to do with their being elites or working for elites, and more to do with embedded family guilds or *barrios* that grew up as the city evolved.

In addition, the Moquegua Valley colony area during the Tiwanaku state's occupation contained settlements suggesting both pastoral and agricultural areas (Goldstein 1993b, 2005), and the expectation is that there should be major differences between each of these areas in the activity patterns suggested by MSM and OA. Hence, some residents who lived as pastoralists could show evidence of mobility in lower body musculature, joints, and bone strength when compared to areas that were home to people dedicated to farming. In addition, these farmers likely ground grain and this should show higher levels of OA in shoulder, elbow, and wrist joint, as well as arm musculature in association with MSM as has been noted in activity studies in other parts of the world (Eshed et al. 2004; Eshed et al. 2010; Hawkey and Merbs 1995; Larsen 1997; Molleson 1994).

Table 3.1 Bioarchaeological Expectations of Labor

Geographic Comparisons:	Centralized Labor Expectations:	Decentralized Labor Expectations:
Regional	• Colony > Core • Colony ↑ rates	• Colony = Core • No significant differences
Inter-highland area	• Katari Valley > Tiwanaku Valley • Katari Valley ↑ rates	• Katari Valley = Tiwanaku Valley • No significant differences
Intra-area 1. Within Katari Valley	1. All sites =	1. All sites ≠ a. Lukurmata ↓ rates
2. Within Tiwanaku Valley	2. All sites almost = a. Non-elite > elite sites	2. All sites ≠ a. Evidence of household embedded craft production
3. Within Moquegua Valley	3. All sites =	3. All sites ≠ a. Rates vary due to mobility, grinding, farming

Chronological Differences

In addition to the geographic expectations, there could be chronological differences in labor throughout Tiwanaku influence. Within both core and colony regions, labor rates were compared during the formation and expansion of Tiwanaku state in the Tiwanaku phase (AD 500-110) to labor rates prior to the state in the Late Formative phase (250 BC – AD 500). I also compared the Tiwanaku phase to labor after the collapse of the Tiwanaku state in the Post-Tiwanaku phase (AD 1100-1300).

If Tiwanaku labor was organized under a centralized and hierarchical model, I would argue that chronological labor changes would present as a shift from heterogeneity of tasks from prior to the Tiwanaku state, to homogenous and repetitive activity in service to the state's elites with heterogeneity in tasks again after state collapse (Fig. 3.3). These should be statistically significant from Late Formative to Tiwanaku phases and Tiwanaku to post-Tiwanaku chronological time periods. This is due to the expectation of a homogeneity of tasks during the state under a hierarchical and centralized elite core as opposed to heterogeneity before and after.

If Tiwanaku labor was organized in more of a decentralized way with local control in a heterarchy, I would expect to see few, if any, changes in activity from the Late Formative to Tiwanaku phases, and the Tiwanaku phase to post-Tiwanaku phase. The reason for this is that local families would have controlled and organized labor before, during, and after the state. As such, they would have mitigated labor organization and physical stressors on average better as *ayllu* groups, with no need to overwork the family within the nested hierarchy.

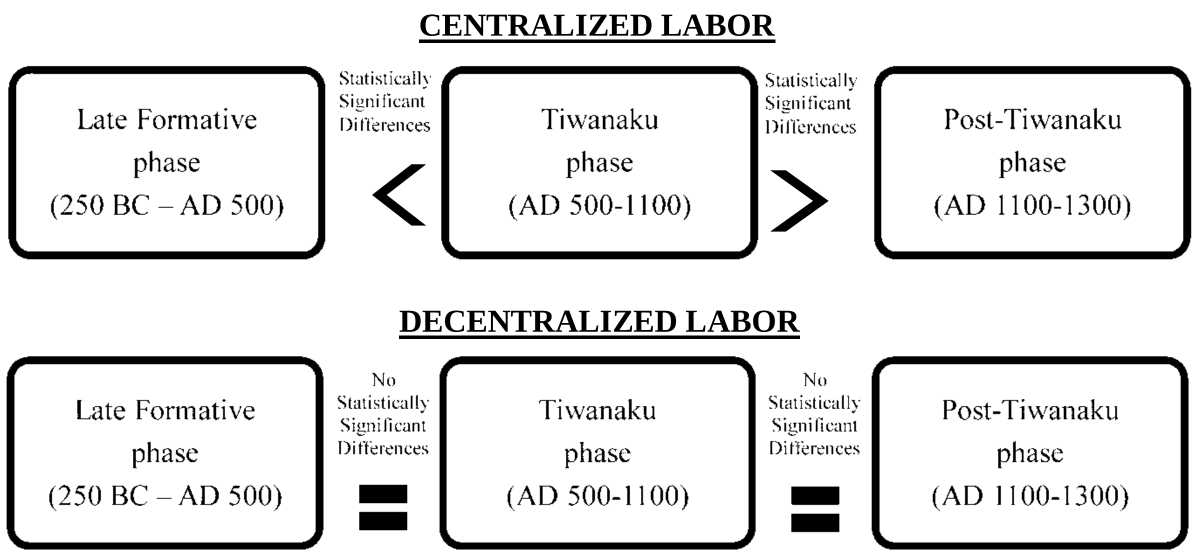


Figure 3.3 Chronological Changes Expected in Centralized or Decentralized Labor Models of the Tiwanaku State

Caveats to Testing the Models

The caveat to these models is that the stated expectations are not met in the results sections for either centralized or decentralized models of Tiwanaku labor organization. It is possible that expected bioarchaeological labor results with the development and control of labor I have detailed in this chapter do not fall within the boundaries outlined by Kolata for a centralized, hierarchical, and elite controlled state or Erickson and Albarracín-Jordán for a decentralized and nested hierarchy based in *ayllu* heterarchical organization. However, the expectations I have described are what I would anticipate if the skeletal evidence strictly tests the boundaries of these two models of state formation. Even in a case where there is no conclusive proof for either model, my data and interpretations still provide necessary information on the Tiwanaku state's labor and its workforce in order to better understand the development of this prehistoric Andean state.

3.3 Bioarchaeological Approach to Labor in Subgroups

I am interested in subgroup composition and the role of individuals who worked during the Tiwanaku state in order to understand divisions of labor, especially those of differing ages and genders. In order to recognize these subgroups as more than just their bones, I examine gender from the biological concept of sex, and age from the estimated age-at-death. I also discuss modern Andean labor divisions by gender and age because a contextual understanding of Tiwanaku labor is a main component to my bioarchaeological approach. My focus on these as important divisions in Tiwanaku labor, especially when combined with archaeological evidence within the Andean cultural context, constitute a stronger and more complete understanding of Tiwanaku daily life, labor, and habitual activity.

Sex and Gender

Bioarchaeologists use skeletal remains from areas of the body like the cranium or pelvic bones to classify the sex of individuals they study into categories such as male or female. In comparison, gender or gendering bodies is a social construct and understood as the culture's perception and distinction of an individual as a man, woman, or a third (fourth or fifth) gender. Any assumed complementarity of sex and gender can become awkward when used in social interpretations as recent research has suggested that bioarchaeologists have problems engaging gender as a sociocultural construct that may or may not be contingent upon anatomical differences or physiological processes (Agarwal and Glencross 2011; Baxter 2005; Blackless et al. 2000; Geller 2005, 2008, 2009; Hollimon 2011; Perry and Joyce 2001; Powell et al. 2006; Sofaer Derevenski 1997; Sofaer 2006a, b). For example, the sex of skeletal remains is discussed biologically as male or female. Once this is established, a researcher may directly link the male sex to gender identity concepts of manhood or masculinity. The danger with this is that biologically "male" has been equated to the gender of "man" (Fausto-Sterling 2000; Geller 2005, 2008).

While important, this hazard brings up issues about how to understand bioarchaeological research. The first concern is making sure that any person who studies skeletal remains or tries to interpret sex from a skeleton realizes that sex is an estimate. Although it is based in biological understandings of how the human body develops secondary sex characteristics, this information is always an estimate. Second, the bioarchaeological categorization of an individual being 'female', 'male', 'possibly male', 'possibly female', or even 'undetermined' is a range and based solely on how certain a researcher is with the actual observation and analysis of the skeletal remains present, and not about how people would have been a 'possible woman' or 'a possible man' in their culture. Third, while DNA categorizations can be done, knowing the actual genetics (e.g. XX, XY, or XXY) of the skeletal remains studied still does not explain the gender of the individual.

These potential problems have resulted in a bioarchaeology that focuses on an integrated, context-based, and macroscopic examination of the individuals within a population (Buikstra 2006; Buikstra and Pearson 2006; Larsen 1997, 2000). Archaeologists and bioarchaeologists continue to contextualize information from both burials and material culture evidence in a concerted effort to understand a holistic picture of a society. For example, a study on the skeletal evidence of activity could establish that people of a particular sex have certain musculoskeletal stress markers (MSM) with a greater frequency than others. Then, a researcher could go on to demonstrate that both male and female skeletons have MSM associated with key activities, including tasks that had previously thought of as men’s tasks as these jobs may have been ethnohistorically more in the purview of men. In context, the research provides information on possible understandings of gendered labor within this particular group and could go on to explore if certain activities were more frequent among certain groups of people. Thus, this bioarchaeological approach can be used to discuss patterns of activity and identify subgroups within the larger population, but does not make assumptions that this was the only way it was or that all people participated. As such, the focus in my study is to use a holistic perspective to understand differences and contextualize, wherever possible, with other known data to create the macroscopic picture of activity and labor within the Tiwanaku state.

From this larger theoretical picture, a contextual understanding is required to address labor in the Andes. Many studies in this region have included gender research on various societal differences with the division of labor (e.g. Allen 1988; Arnold and Hastorf 2008; Berryman 2011; Berryman et al. 2009; Blom

2005; Carter 1967; Cook 2004; Costin 2004; Dean 2001; Ebert and Patterson 2006; Hardman 1976; Harris 1978, 1980; Hastorf 1991; Isbell 1977, 1978; Levy 2006; Mitchell 2003; Silverblatt 1987; Weismantel 1988; 2004 and others). This division of labor in the past may have included the Andean concept of male/female duality and complementarity, where each individual holds a portion of the means of production. For example, a married couple could be described as *chachawarmi* (in Aymara, *chacha*=man, *warmi*=woman, wife), or a complementary unit that reflects a change in their combined status as a community member and a full 'person' within the group with land rights and obligations (Hardman 1981; Harris 1978, 1980). In the public sphere, this may translate to groups performing gendered labors, such as a married couple sponsoring a celebration with the wife calling on her relatives and *comadres* (godmothers to her children) to help her in gender-specific tasks and the husband doing the same with his male friends and *compadres* (Widmark 1992, 2000).

Work in the Andes may also have been further divided in ways like social standing in the community, age-based jobs, or even whether the person was married or single (Conkey and Gero 1991; Costin 1998, 2004; Ebert and Patterson 2006; Hastorf 1991). It is also important to note that while there are modern and historic accounts of traditional work for "men" or work for "women," occasionally within the community, women do men's jobs and men do women's jobs as necessary for the family (Allen 1988; Dean 2001; Hardman 1976; Isbell 1977). In addition, the value placed on men's and women's labor may have been equal prior to both Inca and Spanish times. Inequality, described in historic and ethnographic examples, could have become amplified within the context of empire as large groups of ethnically unrelated people were conquered and assimilated during the Inca Empire, or with the Spanish view of women and their means of production as less than those of men (Hardman 1976; Harris 1978, 1980; Hastorf 1991; Silverblatt 1987).

The idea of men being “in-charge” could also be a misunderstanding in interpretation. As noted by Widmark (1992; 2000), in modern highland Bolivia Aymara culture, decisions made are verbalized at community meetings by the male head of the family (i.e. father or husband). However prior to that decision, private discussion and consensus took place within the family by both men and women. Widmark suggested that it is seen as irresponsible for a man to make a decision that affects his family without consulting them, and that while the father or husband may have given the decision, the community understands that the whole family was behind it. Thus, she notes, these are not men’s decisions or women’s decisions, but family decisions. From these examples, multiple divisions of labor and the value placed on work by different groups within the community varies within the Andes and may have as well during the Tiwanaku state.

Age-at-Death and Age

Bioarchaeology also has somewhat of an advantage when addressing age in the archaeological record because it looks at the actual skeletal remains of individuals present and uses age as part of studies of past populations. Various skeletal indicators, such as epiphyseal closure during bone growth, dental eruption, or dental wear, are evaluated from prior biological and physiological research on how human bones should grow and form. Thus, an osteological researcher can estimate from physiological age and translate these data into a chronological age to provide a comparative estimate of age-at-death (Bass 1981; Buikstra and Ubelaker 1994; Scheuer and Black 2000; Steele and Bramblett 1988; White 1991).

Chronological and physiological categorizations of age-at-death can still lack understanding age as a social construct. Social expectations of a person's life may have been directly converted from named age intervals, such as child, juvenile, or elderly. Problems with interpretations can arise when assumptions about behavioral expectations are made from these modern and culturally loaded age-group terms (Gowland 2006; Lucy 2005:58; Sofaer 2006a, 2011). In many cases, a bioarchaeologist likely used these categories for ease of description. However, in interpretation, they can be misunderstood to represent cultural changes that may or may not actually have been going on in the society.

Additionally, these named categories can also turn age into a synchronic "snapshot" in the archaeological record, when it is really a diachronic picture of the life of a person or groups of people (Sofaer 2011). Therefore, the focus in both archaeological and bioarchaeological studies needs to move from age groups (i.e. child, juvenile, or elderly) towards more of a "life history" perspective, where age is treated less as a fixed point and more as a component to a person's lived experiences. In practice, this approach is the same as recommended for bioarchaeological studies of sex and gender – a contextual and holistic analysis of bodies to the material record.

Age in the Andes must be contextualized in order to understand age and age-related labors within the Tiwanaku state. Within this area, age is an important part of a person's lived experience, sometimes more so than the gender of an individual. For example, Hardman (1976:11) describes a scene where an older Aymara man asks two young people, a boy and a girl, sitting at a well to move aside so he can get water. She describes that it is their youth, and not gender, that permits the man talk to the children in a brusque tone. Additionally, the Aymara language makes many allowances for various age-grades, including a non-gendered distinction between someone who would be considered around 50 years of age (i.e. *chuymani*) versus someone around 70 years of age (*sinti chuyami*) (Hardman 1981:42).

Work also begins at a young age for many modern native people in the Andes. For example, Aymara and Quechua children begin to care for and watch after younger toddler siblings as early as five or six years old (Bolin 2006; Hardman 1976). They are responsible for pasturing animals, making *chuño* (i.e. freeze-dried potatoes), getting water and firewood, helping spin, and breaking up dirt clods in farming fields (Bolin 2006; Hardman 1976:2). While many of these are not unsupervised tasks, the level of responsibility is rather young when compared to Western cultures where these age groups would just be beginning formal education. Hardman (1976:2) noted, "Maria Marasa, who is only about eight years of age, is entrusted with a flock that represents approximately one-fifth of the family's wealth." This idea of responsibility from a young age is one of the major components to many native Andean cultures (Bolin 1998, 2006;

Hardman 1976). In part, this may be because life in this region can be tough in rural areas, and the whole family must work and contribute in order to survive (Bolin 2006). As Hardman (1976:3) noted, the concept of "laziness" can be likened to the Catholic concept of a sin and that "no one sits and does nothing… each does what needs to be done" and "real Aymara cultural ideals [are] hard work, responsibility, and cooperation."

From these ideas, there would likely have been hard work for younger people in the Tiwanaku state. Additionally, beginning work at a young age, while not a direct focus of this research, does build a pattern of muscle and bone use intensity that could show up on the skeletons of older individuals, who are the focus of this dissertation research. Thus, people performing different types of labors in youth, growing in experience and expertise along with years, may provide a good indicator of their life history, identity, and lived experience.

3.4 Prior Tiwanaku Bioarchaeological Research

Because archaeologists have been working and publishing for approximately 10 to 15 years longer than bioarchaeologists in the Titicaca Basin, Bolivia, and information from the Moquegua Valley, Peru had focused more on cultures other than the Tiwanaku (e.g. Inca, Chiribaya, etc.), the bioarchaeological record for the Tiwanaku peoples is less extensive than the archaeological one. However in the last few decades, bioarchaeologists have focused on questions of Tiwanaku state formation and the composition of the state through concepts of ethnicity, relatedness (i.e. genetic, dental, or nonmetric traits), migration, and diet, which, albeit indirectly, address labor and workforce organization.

Blom's (1999; 2005) research on the practice of artificial cranial modification and epigenetic traits (Blom et al. 1998) is one example. She evaluated skeletal remains for these changes, both selected (artificial cranial modification) and familial (nonmetric traits), as a way of identifying distinct, possibly ethnic, groups of people in Tiwanaku core and colony sites. Along with Blom's work, another study (Hoshower et al. 1995) of cranial modification within the Moquegua Valley suggested there were discrete groups and these were members of distinct *ayllus*. These results suggest that groups of people with permanent physical modifications, possibly related to their ethnic identities, lived in different areas of the Tiwanaku state. For example, annular shaped artificial cranial modification was practiced in the Katari Valley, while the fronto-occipital form modification was found in the Moquegua Valley (Blom 1999).

In addition to ethnic identity, there have been questions of the expansionist nature of Tiwanaku and if all forms of material culture found outside of the core represent actual highland people settling in other various regions. Prior bioarchaeological studies have looked at the mitochondrial DNA (mtDNA) and dental biodistance of peoples in the southern Andes. The study by Lewis et al. (2007) suggests that the movement of people, as assessed through genes (mtDNA), was common throughout Andean prehistory and not exclusive to Tiwanaku colonization. However, the sample was small and there was no direct proof that Moquegua Valley residents were not descendants or settlers from the highland Titicaca Basin area. Additionally, dental relatedness studies (Sutter 1997, 2006a, b; Sutter and Mertz 2004; Torres-Rouff 2002) have shown that while the Moquegua Valley may have been directly settled and controlled by Tiwanaku peoples, they only influenced settlements in northern Chile. Thus, not all settlements with Tiwanaku-style ceramics or textiles were actual Tiwanaku highlanders or their descendants.

Continuing to study the relatedness of Tiwanaku individuals, scholars working in the area (Blom et al. 1998; Knudson 2004; Knudson and Blom 2011; Knudson and Price 2007; Knudson et al. 2004) showed chemical evidence of isotopic strontium for the colonization of the Moquegua Valley by groups of highlanders from the Titicaca Basin. Isotopic strontium is incorporated into bone as individuals grow, as it is found in groundwater with slight, but identifiable, chemical variations in different regions. Measuring this variation can help identify the origin of individuals. This is because not all human bones develop at the same time and bones grown as a child may have different chemical signatures if the individual moved as a teen or adult. Hence, research by Knudson and her various coauthors showed direct evidence of people who lived in the south-central Titicaca Basin as young persons and then migrated to the Moquegua Valley as adults.

In addition to looking at the relatedness of individuals who comprised the Tiwanaku state, other bioarchaeological studies have focused on rituals associated with state formation. Burials within the Akapana area in the city of Tiwanaku show two distinct types of burial practices. The first of these appear to be a form of ancestor veneration (i.e. Akapana East), and the second are those who were likely ritual sacrifices or bodies left as offerings (i.e. Akapana) (Blom and Janusek

2004; Blom et al. 2003). Blom and her co-authors suggested these burials represent “shared ideas and practices regarding the transcendence of social, natural and supernatural worlds [that] culturally united the diverse groups” (Blom and Janusek 2004:138). Ritual feasting has also been the focus of Berryman’s (2011; Berryman et al. 2009) work in the highland Tiwanaku area. Her research on skeletal evidence of food consumption covered evidence of dentition pathology (e.g. dental caries) and carbon-nitrogen isotope changes (i.e. isotopic indicators of types of foods consumed). Overall, Berryman’s (2011:306) research showed the importance of ritual feasting, *chicha* production and consumption, and the existence of institutionalized asymmetries of social power. She suggested that the Tiwanaku state was intensely politically stratified and possibly a centralized state.

These prior bioarchaeological studies provide evidence important for my research on labor organization within the state. First, these studies show definitive proof of the movement of highland people to the Moquegua Valley. The people in both the core and colony had a common cultural and genetic history. This is crucial for understanding shared worldview prioritizations in labor organization and physiological impacts labor would have had on their bodies, which cannot dismissed as separate genetic groups. Second, these data show distinct, possibly ethnic, groups of people who lived and worked during the Tiwanaku state. Third, they demonstrate that ritual was important during the Tiwanaku state. As prior studies emphasize the importance of burials near-to monumental architecture, there may be implications about the workforce that constructed and maintained these visual and ceremonial symbols. Fourth, data support the movement of laborers associated with ritual and ritual-use of products like *chicha* and coca. *Chicha*, with its long history of use in the Andes as part of labor reciprocity, hospitality, and ritual (e.g. Allen 1988; Arnold and Hastorf 2008; D'Altroy 2005; Hastorf 1993; Rowe 1946), would have been important because maize cannot be farmed in great quantities in the highlands. As such, the migration of people to a growing region at a lower elevation (i.e. Moquegua Valley) has direct implications on labor organization with the movement of people between these regions to provide ritual or prestige items for use in the highlands. Hence, these prior bioarchaeological studies show that people who lived in both the highland core and the Moquegua-area colony had a shared ritual and cultural background with differences in subgroup, possibly ethnic, composition. These people valued certain goods, like maize, migrated to these lower elevations as possible farmers, and participated in a complex trade network from colony to highland core as components of the emerging Tiwanaku political and economic complexity.

3.5 Summary

This chapter has addressed the expectations where labor was organized in a centralized system or a decentralized system within the Tiwanaku state. As a main component of this research is a thorough contextual interpretation, prior archaeological, bioarchaeological, and ethnographic studies, especially analyses of labor and activity were provided. From these ideas, social group composition with gender and age from bioarchaeological origins were discussed. The next two chapters move towards further explaining the materials present and context of the populations in this study, as well as the methodology I used to collect bioarchaeological evidence on labor.

Chapter 4
Context of the Populations

4.1 Introduction

My project entailed detailed bioarchaeological analysis of previously excavated human skeletal remains from two regions in Andean South America – the ‘core’ of the Tiwanaku state in highland Lake Titicaca Basin, Bolivia (~3800m) and the lower elevation ‘colony’ located in the Osmore Drainage (Moquegua River) of the Moquegua Valley, Peru (~2000m). The collections from Bolivia consisted of skeletal remains from 18 archaeological sites spread across three separate areas (i.e. Taraco Peninsula, Katari Valley, and Tiwanaku Valley) in the core region of the Tiwanaku state. The Peruvian sample consists of five sites located in the colony region of the Moquegua Valley.

In this chapter, I present methods for reconstructing the sample population from archaeological skeletal remains. I provide information on the locations from which the sample populations were taken. Minimum number of individuals (MNI), sex estimates, age-at-death estimates, and relative chronology for these areas is also provided from the core area. After this data, I next describe the contextual information for the colony in the Moquegua Valley, Peru region, the archaeological sites located within this valley, the MNI, age-at-death, sex estimates, and relative chronology.

4.2 Reconstructing Sample Profiles with Skeletal Populations

Reconstruction of vital statistics, such as age-at-death and sex, is essential to understanding the population of prior civilizations. However, population profiles of excavated human remains are not exact representations of the groups of people who lived and died in the study area (Milner et al. 2000; Wood et al. 1992). Choices the culture made in who was buried, differences in burial practices, as well as where people were interred can all complicate the mortuary record. Additionally, those who die and are buried must also be preserved in the local environment long enough to be found and excavated (Milner et al. 2000:473). An example of this is differences in environmental preservation, and the samples in this study can serve as one case study. The annual dry-rainy season in highland Bolivia can speed up the decomposition process, while the desert conditions in the Moquegua Valley, where rain is an infrequent occurrence, can make for near-perfect preservation of human remains, such as fully mummified individuals. While this is one local example, environmental preservation biases affect the ease of recovery of skeletal remains throughout the world.

In addition to environmental differences, bone preservation and recovery rates may have varied due to age-at-death of the individuals buried. For example, infant bone does not often preserve as well as adult bone, due both to bone mineral composition differences, as well as the size of skeletal elements able to be recovered (i.e. multiple smaller bones in children than adults). Bone preservation and recovery also could have been dependent on bone health. An individual with fragile bones, due to a condition such as osteoporosis, does not sustain as long as an individual with good bone health does, and thus, not have been recoverable by archaeologists and bioarchaeologists.

One final idea to consider in making a population profile from prehistoric human skeletal remains is the ‘human factor’ involved in the archaeological process. Choices made by scholars about where to excavate, what to retain, and how to preserve these artifacts could change the demographic profile (Milner et al. 2000). The skeletal samples in this study can be used as an example of this process, as they represent collections from noncontiguous archaeological excavations that span three decades. The excavations were run by various archaeologists from Bolivia, Canada, Peru, and the United States, and each project had their own excavation area, research plan, and strategy. Thus, when analyzing any previously excavated archaeological skeletal collection, it is important to remember that prior decisions made by researchers may arise that could hinder a skeletal analysis.

Even considering these problems, the contextual profile of a skeletal sample is important in order to understand the past population. By focusing on individuals from a population level, many of the aforementioned challenges can be reduced, and skeletal samples used for analyses (Hoppa and Vaupel 2002; Larsen 1997; Milner et al. 2000; Wood et al. 1992). The MNI present in the sample can be clarified, along with estimated age-at-death and estimated sex of individuals present (Hoppa and Vaupel 2002; Milner et al. 2000). In addition, I realize that these Tiwanaku skeletal collections do not represent the actual population of the Titicaca Basin or the Moquegua Valley. Rather, they represent the various skeletal samples of multiple excavation projects, all with well-regarded archaeological excavation methods that made them good samples for this dissertation on labor and activity in the Tiwanaku civilization.

Calculating the Minimum Number of Individuals (MNI)

As preservation of these samples varied from fair to excellent, the majority of individuals were allotted a unique specimen number at the time of excavation, as they were discrete, single individual burials. Skeletal remains were then rechecked to determine if there were any duplicate skeletal elements present. If I noted any duplicate skeletal elements, an additional letter was added (i.e. -a, -b, -c, and so on) to sort individuals and reach an accurate MNI. All excavation data present (e.g. site number, level, excavator) for each specimen was noted for the purposes of this study. After data were collected per each site, I established the MNI and developed further population profiles.

Age Estimation

I estimated the age-at-death of each individual using established diacritical methods: dental eruption, dental wear, cranial suture closure, epiphyseal suture closure, degeneration of the pubic symphysis, auricular surface, and sternal rib ends (Bass 1981; Brothwell 1989; Buikstra and Ubelaker 1994; Işcan and Miller-Shaivitz 1983; Krogman and Işcan 1986; Suchey and Katz 1998; Ubelaker 1999). Age estimates were first performed for dental eruption and epiphyseal closure data, which have high degrees of reliability for aging skeletons, especially when combined (Krogman and Işcan 1986; Stewart 1979; Ubelaker 1999). Secondary information consisting of dental wear, pubic symphysis surface aging, cranial suture closure, and sternal rib end data were also collected wherever possible to obtain as much age information as possible about each individual (Brothwell 1989; Krogman and Işcan 1986; Suchey and Katz 1998).

The age-at-death of individuals was first divided into two subcategories: subadult or SA (individuals under the age of 15) and adult or A (all individuals age 15 and over).

While important to understand the demographic profile of the population, subadults were not scored for osteological markers of activity and labor. As previous analyses have shown that bone remodeling in subadults is relatively rapid and does not adequately represent potential skeletal changes associated with activity (Jurmain 1999; Pearson and Buikstra 2006; Weiss and Jurmain 2007). If there was a question as to subadult or adult status of an individual near age 15, I used fusion or partial fusion of the os coxae pelvic bones to consider the individual in the adult category.

After each of the above age estimates were scored, a combined age was estimated using these multiple methods for each individual. Of the individuals determined to be in the Adult (A) category, they were categorized into five specific age ranges: 15-19, 20-29, 30-39, 40-49, and individuals over 50 years old at the time of death. It is important to note that the groups used to create these age-standards models are from outside of South America, and thus represent a potential bias. However, while these methods for estimating age are not an exact science, they do however provide the best age estimates when working with osteological populations, as well as a standard measure comparable to other studies.

Sex Estimation

Sex estimation of adults was primarily determined through examination of the pelvis, and secondarily from the cranium. I estimated individuals, whenever possible, as female (F), male (M), possible female (PF), and possible male (PM). Seven pelvic elements (ventral arc, subpubic concavity, ischiopubic ramus/ridge, greater sciatic notch, preauricular sulcus, sacrum curvature, and the pelvic basin) were noted as male or female using standard visual methods (Bass 1981; Buikstra and Ubelaker 1994; Steele and Bramblett 1988). If sex could be estimated from the pelvic bones, no cranial analysis was performed. However, if sex observation was conflicting, or there were no pelvic elements (i.e. os coxae and sacrum) present, then the cranium was used to estimate sex. Cranial observations were also entered as male, female, possibly male or female from six areas of the cranium and mandible – nuchal crest, mastoid process, supraorbital margin, supraorbital ridge/glabella, mental eminence, and ascending ramus. In general, each of these cranial elements was compared to prior visual cranial morphology and scored as male if more robust (larger), and if gracile (smaller), it was scored as female (Bass 1981; Buikstra and Ubelaker 1994).

4.3 The Sample

There were a minimum of 2,232 individuals from the core and the colony samples within this study (Table 4.1). The majority fell within the Tiwanaku period, with comparatively sized samples from prior to (Late Formative) and after (Post-Tiwanaku) the state (Table 4.2). Overall, the sample distribution showed more adults than subadults, and this is consistent with other bioarchaeological projects in other parts of the world (e.g. Goodman et al. 1984; Larsen 1997; Milner et al. 2000; Steckel and Rose 2002; Wood et al. 1992). The reason for this, as described above in Section 4.2, is that subadults are likely underrepresented due to problems recovering these smaller skeletal elements, as well as preservation problems due to the mineral composition of juvenile bone (i.e. younger individuals have more cartilaginous skeletons) (Larsen 1997; Lewis 2006; Scheuer and Black 2000; Wood et al. 1992).

When I evaluated the core and colony region adults by sex (Table 4.3), females comprise the largest portion, males make up the next largest, followed by possible males, and possible females. The majority of this sample being female was not surprising, as prior to modern medicine childbirth represents a higher mortality risk (Van Lerberghe and De Brouwere 2001). Table 4.4 contains the age-at-death for the sample populations. The majority of individuals died in their thirties, with fewer dying in their twenties and forties, and even fewer dying early in life (late teens) or surviving to reach an 'old' age (50+). This age-at-death curve is also consistent with a population prior to modern medicine (Goodman et al. 1984; Larsen 1997; Steckel and Rose 2002; Verano and Ubelaker 1992; Wood et al. 1992).

Table 4.1 Sample of Subadults and Adults Divided by Region (n=2232)

	Subadults	Adults	MNI
Core	230	452	682
Colony	767	783	1550
Sample Total (n=):	997	1235	2232

Table 4.2 Time Period Distribution of All Individuals Sampled in this Study Divided by Region (n=2212)

Region	Late Formative Period (250 BC- AD 500)	Tiwanaku Period (AD 500-1100)	Post-Tiwanaku Period (AD 1100-1300)
Core	226	386	50
Colony	14	1422	114
Sample Total (n=):	240	1808	164

Table 4.3 Sex Distribution of All Adults Sampled in this Study Divided by Region (n=640)

	Females	Males	Possible Females	Possible Males
Core	46	61	21	34
Colony	222	165	41	50
Sample Total (n=):	268	226	62	84

Table 4.4 Age-at-Death Distribution of All Adults Sampled in this Study Divided by Region (n=706)

	15-19	20-29	30-39	40-49	50+
Core	21	42	64	48	26
Colony	50	125	205	81	44
Sample Total (n=):	71	167	269	129	70

<u>Archaeological Sites - Bolivia</u>

The highland core region comprised a minimum of 682 individuals from the Taraco Peninsula, the Katari Valley, and the Tiwanaku Valley (Table 4.5). Five sites from the Taraco Peninsula dated to the Late Formative period (250 BC – AD 500). The Katari Valley, which also contains five sites, had occupations from the Late Formative through the collapse of the Tiwanaku state, and the Tiwanaku Valley, with seven archaeological sites, also spanned the chronology. The sites varied in size and usage (e.g. domestic or ritual) and what follows below is a description including prior archaeological research about site-use, including possible labors and activities performed by the residents.

Table 4.5 Study Sample from the Titicaca Basin, Bolivia by Area

Area	Subadults	Adults	MNI	Time Period
Taraco Peninsula	72	154	226	Late Formative (250 BC – AD 500)
Katari Valley	74	108	182	Late Formative (250 BC – AD 500), Tiwanaku (AD 500 – 1100), and Post-Tiwanaku (AD 1100 – 1300)
Tiwanaku Valley	84	190	274	Late Formative (250 BC – AD 500), Tiwanaku (AD 500 – 1100), and Post-Tiwanaku (AD 1100 – 1300)
Core Sample Total (n=):	230	452	682	

Taraco Peninsula

The Taraco Peninsula extends into Lake Titicaca and is approximately 20km from the main Tiwanaku city. Burials used in this study were excavated by various researchers from the Taraco Archaeological Project (TAP) under the direction of Dr. Christine Hastorf. The Taraco Peninsula burials I used in my study date to the Late Formative period (Hastorf 2005; Machicado 2009) and are from one of the five Taraco archaeological sites: Chiripa, Quispe, Kala Uyuni, Kumi Kipa, or Sonaji (Fig. 4.1). Taraco Peninsula skeletal remains were housed in two locations, Chiripa or Santa Rosa, Bolivia, and were in fair to good states of skeletal preservation, with this range affecting percentage of skeletal elements present in each individual burial. The individuals who comprised the Taraco Peninsula sample (Table 4.6) would have participated in labors that ranged from food procurement, to pottery and stone tool manufacturing, to the building of both domestic and ceremonial structures during the Late Formative. The Taraco sites provided a foil to later Tiwanaku time period sites in order to understand the chronological progression of labor in the core region of the Tiwanaku polity. In addition, a site-by-site description is provided below.

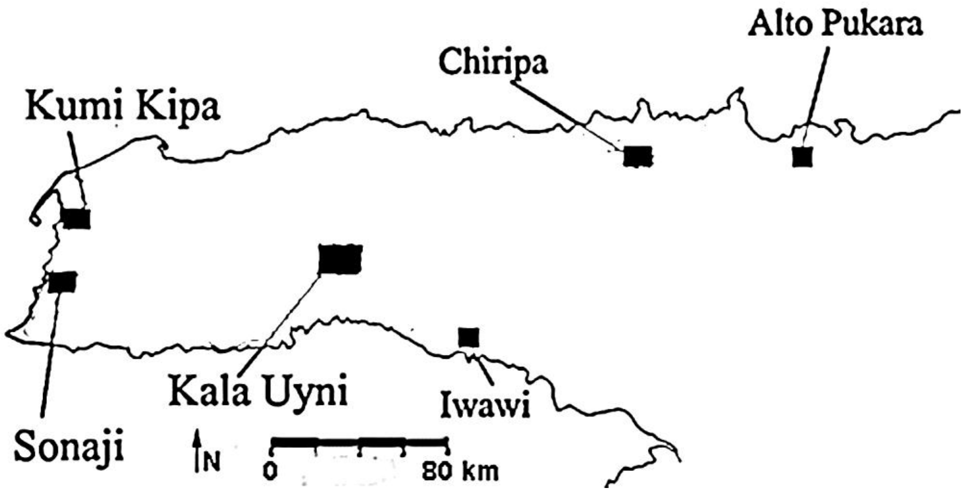


Figure 4.1 Study Sites Located on the Taraco Peninsula (after Roddick 2009:100)

Settlement at Chiripa spanned the Formative periods in the Southern Titicaca Basin chronology. Chiripa contained evidence of public, possibly monumental, architecture. There were also domestic settlements surrounding the mound (Hastorf 2005). Near to Chiripa was the small, terraced, and slightly higher in elevation Quispe site. This site may have been home to agricultural producers, as maize starch grains may have been found on ground stone in this area (Logan 2006:102). Additionally, people participated in the local labor economy with some kind of farming or horticulture, fishing, pastoralism, and ceramic production (Whitehead 2007). Whitehead (2007:280) argued that people did not work at intensive agriculture. Instead, they farmed moderately and participated in other activities, like pottery and stone carving.

Kala Uyuni is located on the southern side of the Taraco Peninsula. This site was settled during the Formative, and contains two sunken courts (Roddick 2009). Bandy (2001:176) believes that by the Late Formative, this site was the "center of a multi-community polity encompassing all of the Taraco Peninsula settlements" and could have been in competition with other regional centers, such as Tiwanaku. In addition, to the evidence of public architecture, this site has evidence of domestic use as noted in the evidence of quinoa, fish bone, as well as ceramic production areas (Bruno 2008).

Kumi Kipa and Sonaji are both located at the end of Taraco Peninsula, about 150 meters from the lakeshore and date to the Formative. It was possible they were a single community, with Kumi Kipa as the residential area and Sonaji, which contained a large platform area, as the more public or ceremonial area. Bandy (2001:182) suggested that Sonaji may have been home to the local elite at the "principal public architectural complex on the Taraco Peninsula." Of the Sonaji burials, one had two grinding stones associated with it (Roddick 2009:134), and another had items such as gold, ceramics, and lithic tools (Bruno et al. 2006:56). A Kumi Kipa burial had similar grave goods with a grindstone, turquoise, ceramics, and some gold fragments (Fernandez Murillo et al. 2004). Other burials excavated had few to no grave goods, which suggest status differences among the people who lived on the Taraco Peninsula.

Table 4.6 Taraco Peninsula Sample Population by Archaeological Site and Divided by Subadult and Adult (n=226)

Site	Subadults	Adults	MNI
Chiripa	23	39	62
Quispe	2	1	3
Kala Uyuni	25	55	80
Kumi Kipa	15	41	56
Sonaji	7	18	25
Taraco Peninsula Total Sample (n=):	72	154	226

Katari Valley

The Katari Valley is on the northern side of the Taraco Mountains and named for the Katari River that drains into Lake Titicaca. Sites from this region span the chronology of Tiwanaku state formation and collapse. There are five sites within the Katari Valley: Kirawi, Lukurmata, Pokachi Kontu, Qeya Kontu, and UriKatu Kontu (Fig. 4.2). Of the five archaeological sites in the Katari Valley, Lukurmata contains the highest number of burials (Table 4.7). Lukurmata also has archaeological evidence for a range of agriculture production and craft specialization, with the other areas primarily dedicated to raised-field farming. In addition, the Katari Valley sample has individuals from all three time periods, although the majority date to the Tiwanaku time period (Table 4.8). These Tiwanaku time period individuals were used to understand the composition of the state's workforce in the core as well as the composition of the workforce. As such, age-at-death estimates are provided in Table 4.9 and sex estimates by archaeological site are noted in Table 4.10. Site descriptions and site-use for the skeletal series from these areas are provided below.

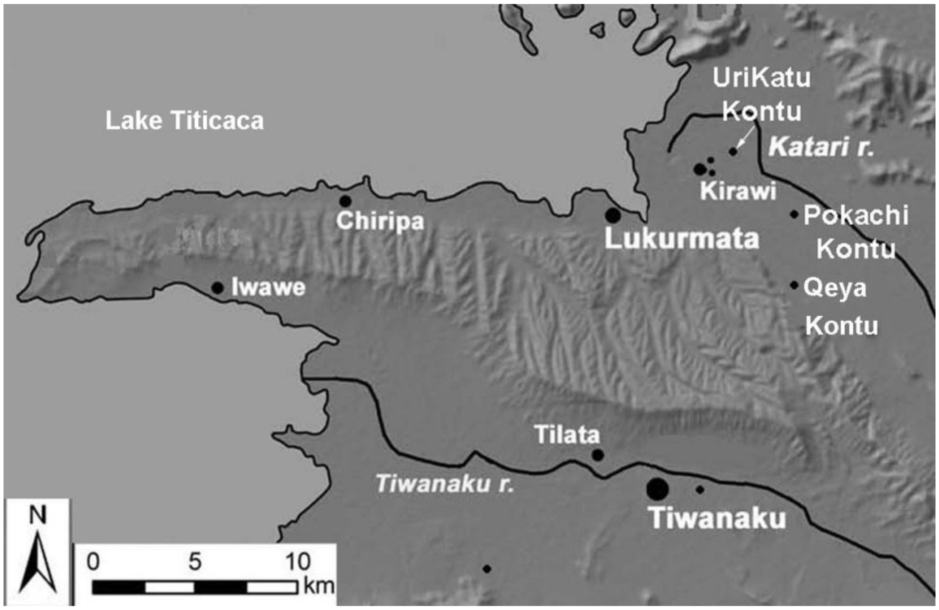


Figure 4.2 Study Sites Located in the Katari Valley (modeled after Janusek 2008:73)

Kirawi, also noted as CK65, is a rural altiplano site located in the Katari Valley dating to the Late Formative through Tiwanaku time period. This site is approximately 2km west of the Katari River and is composed of two large platform mounds, the eastern of which had domestic occupation during the Late Formative (Janusek and Kolata 2003:140). Evidence from faunal remains, ceramics, lithics, along with stone tool production indicated these people were agriculturalists. These stone tools were present in both male and female burials (Janusek 2008:93), and may indicate a lack of gendered labor differences at Kirawi during the Late Formative (Janusek and Kolata 2003:145-146).

During the Tiwanaku time period, occupation at this site was reduced with little evidence of permanent habitation. However, burials from this period were found at Kirawi with grave goods that included decorated pottery and grindstone. As Kirawi was located in the raised-field growing region, this could have been a field station where individuals stayed to oversee the crops (Janusek and Kolata 2003:150).

The site of Lukurmata near the shores of Lake Titicaca is 14km from the city of Tiwanaku. The earliest archaeological evidence from Lukurmata (approximately 250 BC) showed a small settlement roughly contemporaneous in size with the city of Tiwanaku at that time. Up until AD 300, Lukurmata was a small self-sufficient community (Bermann 1994). During the Late Formative, Lukurmata participated in a regional exchange network as evidenced by exotic trade items like marine shell and obsidian. Burials had few grave goods, which Bermann (1994:81) interpreted as an egalitarian lifeway that involved fishing, farming, and herding.

By the end of the Late Formative, either Lukurmata was under Tiwanaku control or Tiwanaku was a major influence. Bermann (1994:142, 146) argued that an increase in pottery imported from Tiwanaku, a lack of transitional-style pottery, a change in storage patterns associated with domestic activities, and an increased dependence on agricultural products support this. Lukurmata also participated in Tiwanaku ceremonialism as noted by the building of a temple complex, along with evidence of ritual paraphernalia and feasting with *chicha* (Bermann 1994:185; 2003; Berryman 2011). However, unlike Tiwanaku's ceremonialism, Janusek (2004a:188) argued that feasting was less public at Lukurmata because "residential compounds [located near the temple] were precisely where many feasts were located." This localizing of ritual also seemed to follow for burials. While cemetery burial still occurred, there was a transition in mortuary ritual with burial nearer to domestic structures.

During the Tiwanaku time period, Lukurmata could have been an important regional or ceremonial administrative center, a "second city" due to its geographic location within a few hours walk of Tiwanaku and proximity to raised-field agriculture Tiwanaku (Janusek 2004:56). Archaeologists (Bermann 1994:159, 177; Janusek and Kolata 2003) maintain that an increase in both population (approximately 5,000-10,000 individuals) and farmland control (120 hectares) support this idea. People who worked at Lukurmata may have had certain occupations, like assisting in the movement of goods or participating in communication to and from Tiwanaku (Janusek 2004a:197). By the latter half of the Tiwanaku period, Lukurmata went from urban city to field camp and burial area (Bermann 1994, 2003). Bermann (1994:223) and others (Albarracín-Jordán and Mathews 1990; Browman 1981; Janusek and Kolata 2004) noted that these changes were part of the increased agricultural production in the Katari Valley.

Lukurmata also contained residential areas and burials from the post-Tiwanaku times. Bermann (1994:235) noted that this did not represent a reinvigoration of Lukurmata as a major residential center. Instead, the post-Tiwanaku peoples at this site were akin to families and social organization during the Late Formative, small, egalitarian households with few grave goods, but different in that there was no long distance trade. The reduction in the movement of goods and change to fortified *pukara*[9] settlements were earmarks of the post-polity decline.

[9] In the Quechua language meaning fortress.

Pokachi Kontu (CK104) is 4km southeast of Kirawi on the west side of the Katari River. Settlement at this site began in the Late Formative near the *pampas*[10]. However, the most conclusive evidence for settlement at Pokachi Kontu was during the Tiwanaku period with an extensive midden and evidence of floor surfaces. By AD 800, this habitation area was converted into a probable field guardian site, and finally into a burial area during the latter portion of the Tiwanaku period (Janusek and Kolata 2003:153).

Qeya Kontu (CK152) is located 11km from Lukurmata on the west side of the Katari River in the alluvial zone of the Taraco Mountains. This site was settled initially during the Late Formative and ceramics, including a modeled ceramic trumpet as part of the Yaya-Mama religious complex, were found at this site (Janusek and Kolata 2003:134-135). In addition, lithic tools, stone hoes, and a variety of faunal remains and worked animal bone were recovered that indicated the importance of this area in the agro-pastoral lifeway (Janusek and Kolata 2003:137). During the latter part of the Formative, Tiwanaku style pottery was excavated at Qeya Kontu. Partially disarticulated burials have also been noted, including one child with artificial cranial modification.

During the Tiwanaku period, Qeya Kontu increased in size and monumental architecture in the form of cut-stones and platforms were found. Researchers (Janusek and Kolata 2003; Ortloff and Kolata 1992) noted that Qeya Kontu was a residential compound that helped direct water from the alluvial flows down the Taraco range during the rainy season. Janusek and Kolata (2003:149) suggested that this site was to provide two key functions, "to provide needed water to fields and to slow the processes of erosion

[10] Quechua for fertile plain and in this usage are considered agricultural production areas.

and sedimentation caused by… [the] rainy season”. They also supported the idea that portions of this site were lithics processing centers during the Tiwanaku time period (Janusek and Kolata 2003:150). However, burials at Qeya Kontu from this time contain only ceramic, and not lithic, offerings.

UriKatu Kontu (CK70) is 1km fom Kirawi on the west side of the Katari River. This group of mound sites has been designated the Quiripujo cluster (Janusek and Kolata 2003:133). The site is comprised of a large platform mound that was first settled in the Late Formative. Janusek and Kolata (2003:144) noted that this was likely an impermanent field guardian settlement. Use of this site as a field camp likely continued through the Tiwanaku time period, however, some burials from UriKatu Kontu date to the post-Tiwanaku period.

Table 4.7 Katari Valley Sample Population by Archaeological Site and Divided by Subadult and Adult (n=182)

Site	Subadults	Adults	MNI
Kirawi	6	15	21
Lukurmata	62	60	122
Pokachi Kontu	2	18	20
Qeya Kontu	3	5	8
UriKatu Kontu	1	10	11
Katari Valley Total Sample (n=):	74	108	182

Table 4.8 Time Period Distribution within the Sample Population of the Katari Valley, Bolivia (n=172)

Area	Late Formative Period (250 BC- AD 500)	Tiwanaku Period (AD 500-1100)	Post-Tiwanaku Period (AD 1100-1300)
Katari Valley	15	121	36

Table 4.9 Age-at-Death Distribution of the Sample Population within the Katari Valley, Bolivia (n=65)

Site	15-19	20-29	30-39	40-49	50+
Kirawi	1	2	-	3	2
Lukurmata	4	6	14	12	7
Pokachi Kontu	1	2	3	1	-
Qeya Kontu	-	-	1	-	-
UriKatu Kontu	-	3	2	1	-
Katari Valley Total Sample (n=):	6	13	20	17	9

Table 4.10 Sex Distribution of Adults within the Sample Population of the Katari Valley, Bolivia (n=52)

Site	Females	Males	Possible Females	Possible Males
Kirawi	2	3	1	1
Lukurmata	13	12	4	5
Pokachi Kontu	1	2	1	2
Qeya Kontu	-	-	-	-
UriKatu Kontu	-	4	-	1
Katari Valley Total Sample (n=):	16	21	6	9

<u>Tiwanaku Valley</u>

The Tiwanaku Valley is on the southern side of the Taraco Mountains and named for the Tiwanaku River that drains into Lake Titicaca (Fig 4.3). The sites in this study span the chronology from prior to Tiwanaku state formation, through state formation to the collapse of the Tiwanaku state. Settlements within the Tiwanaku Valley fall into two categories, the urban sites around the ceremonial core of the city, and the rural sites farther removed from the this city.

The city of Tiwanaku, with both monumental and residential architecture, is approximately 20 km from Late Titicaca and covered approximately 6.5km^2 at its zenith. Six monumental structures are considered the ceremonial center of the city of Tiwanaku:

Akapana pyramid, Putuni palace, Kalasasaya, Kantatayita, Chunchukala, Kherikala, and the Semi-Subterranean Temple. This center was laid out on a grid pattern and oriented to the cardinal directions. It also contained middens, an extensive drainage system, and a moat/canal that may separate elites from commoners or ritual specialists from non-specialists (Kolata 1993b). Outside of the moat, there were various residential areas, cemeteries, fields, and one small monumental structure (Mollo Kontu) (Couture 2003). Unlike the rural sites in the Tiwanaku Valley, many areas within the city of Tiwanaku lack agricultural implements, suggesting farming and agricultural production was not part of living in this urban center (Geisso 2000, 2011). Instead, craft production and llama trade caravans may have been more important to move manufactured goods and foodstuffs (Stanish et al. 2010; Vallières 2010; Webster and Janusek 2003).

For this study, skeletal samples from seven sites located within the city of Tiwanaku were examined: Akapana, Akapana East, Ch'iji Jawira, La K'araña, Marka Pata, Mollo Kontu, and Putuni (Fig. 4.4). In addition to these sites in the urban area, there are a set of rural sites, Tilata, Pukara, and Guaqui, from the Tiwanaku Valley. These eight sites comprised the largest sample population from the core region. As with the other highland samples, there are more adults than subadults (Table 4.11). The chronological range for the Tiwanaku Valley is similar to the Katari Valley in that the majority of the sample dates to the Tiwanaku time period, but there are individuals from the Late Formative and the Post-Tiwanaku phases (Table 4.12). The age distribution within the Tiwanaku Valley area has individuals in every age category, with the majority of adults' deaths occurring during the 30-39 year decade (Table 4.13). Most Tiwanaku Valley adults died in their twenties or thirties, and the four most populous sites (i.e. Akapana,

Akapana East, Marka Pata, and Mollo Kontu) show a majority of people who died in the 30-39 age category. When I estimated sex for the Tiwanaku Valley adults, there were more males and possible males than females and possible females (Table 4.14). A site-by-site description for each of these sites in the urban core of the city of Tiwanaku as well as the rural areas in the Tiwanaku Valley is provided below.

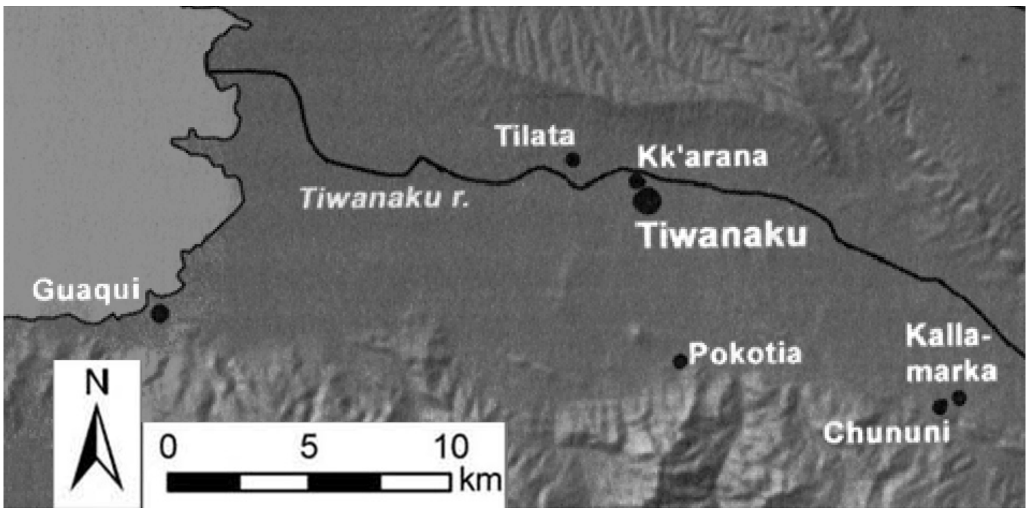


Figure 4.3 Study Sites Located in the Tiwanaku Valley (modeled after Janusek 2008:73)

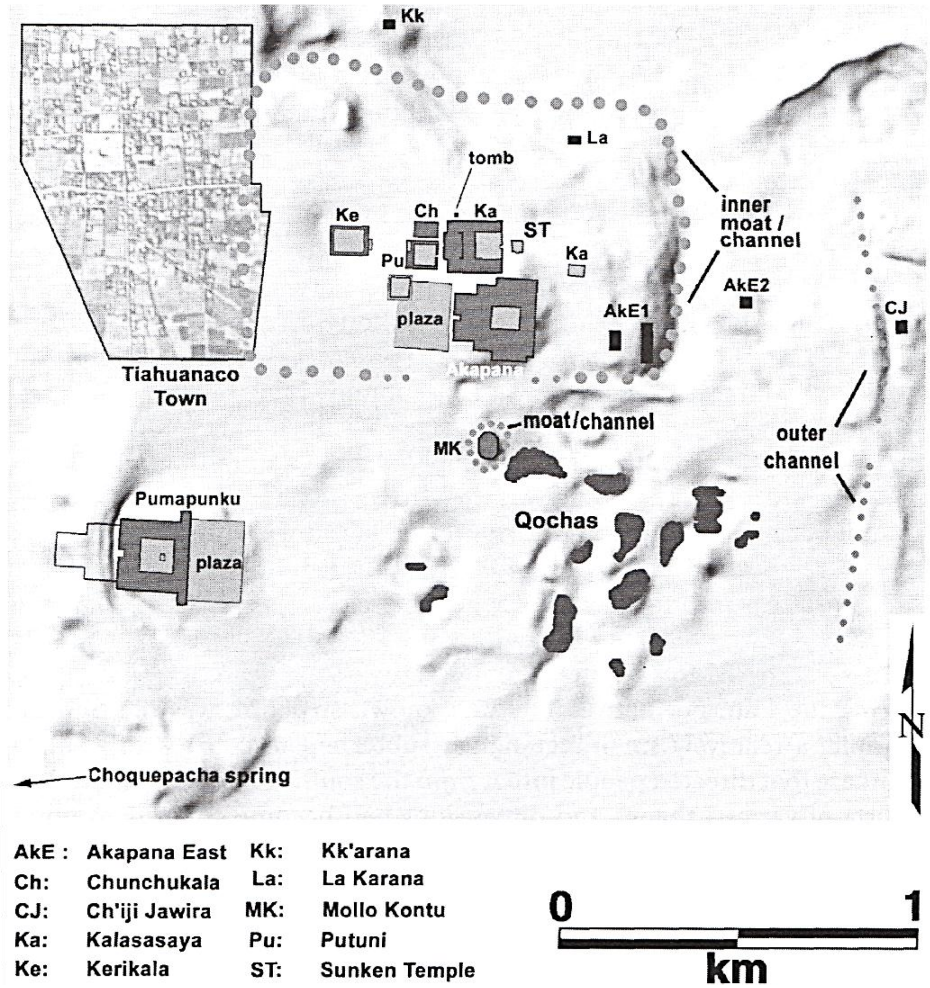


Figure 4.4 City of Tiwanaku with Archaeological Sites (after Janusek 2008:109)

The Akapana (AK) site is a platform mound with a sunken court and various stone structures. Construction of the pyramid structure began in the Late Formative and continued throughout the Tiwanaku phase, with a major construction event that began around AD 800. The Akapana (204 x 192m base, 17m high) is a massive structure and would have required much manpower for construction and maintenance (Kolata 2003c:183). In addition, the Akapana area served primarily as a ceremonial center with feasting, and contained both animal and human dedications (Blom 1999; Blom and Janusek 2004; Janusek 2008; Manzanilla 1992; Manzanilla and Woodard 1990). Burials from this site could have been ritual offerings or people captured as sacrifices. However, these skeletal remains have no signs of interpersonal trauma, which would indicate violent capture. Instead, they show cut mark damages, which could indicate perimortem processing of the bodies (Blom and Janusek 2004).

Akapana East (AKE) is located approximately 200m from the Akapana mound. During AD 500-800, a population increase occurred in the urban city of Tiwanaku. To accommodate this population, urban development grew as multiple areas, including AKE, which emerged with planned and walled residential architecture. Because grave goods buried with people from AKE included ritual paraphernalia (i.e. a snuff spoon and an *incensario*), AKE was possibly home to elites or ritual practitioners, and Janusek (2008:148) suggested that these people were ritual specialists involved with caste-like groups of specialized occupations, such as priests, rulers, and bureaucrats. Berryman (2011:39, 290-291) noted that during the latter half of the Tiwanaku period, AKE was fully devoted to large-scale *chicha* production, likely as a main component to feasting rituals. Individuals buried in AKE may have been in charge of political or religious rituals, and employed with the important task of *chicha* brewing for the ongoing feasts (Berryman 2011; Janusek 2008). This emphasis on ritual also coincided with numerous small stone rooms built near the summit of the Akapana mound, possibly dormitory style housing for local elites, priests, or ritual practitioners (Kolata 1993a).

Ch'iji Jawira is located outside and to the east of the city of Tiwanaku. Settlement at this site began during the Late Formative, and increased during the Tiwanaku period (Rivera 1994). During the Late Formative, this area was used as a burial location. However, during the growth experienced at the start of the Tiwanaku time period, Ch'iji

Jawira emerged as a dual residential compound and ceramic production area. Archaeologically, it contained evidence of floor surfaces appropriate for preparation and shaping of ceramics, ceramic firing zones, and refuse areas. This site was also close to a clay source/procurement area and semipermanent water supply (Rivera 2003:306).

It had been suggested that Ch'iji Jawira people were of lower status primarily based on the model of concentric gradients of status, as it was located far from the ceremonial core (Kolata 1993a). Additionally, when compared archaeologically to other Tiwanaku city sectors, Ch'iji Jawira had high levels of refuse, lacked sewage canals, and contained ceramic wares, which indicated an origin or connection to people from outside of the highland Bolivia region (Janusek 2004a, 2008; Rivera 2003). As opposed to being a low status location, this site may have been purposefully chosen because of the proximity to a local source of clay.

Analogous to this, Janusek (2004a:147) argued that the Ch'iji Jawira people were semiautonomous "embedded" craft specialists, something like the Western concept of a craft guild, and not elite-sponsored "attached" crafters. Ch'iji Jawira residents were embedded ceramic manufacturers who were "not directly controlled by or conducted [production] for ruling elites… rather conducted and managed in a local residential context" (Janusek 2004a:158) and ceramics produced at this site were likely for the Tiwanaku public (Janusek 2004a, 2008). In addition, stone cores at the site support Janusek's theory as they indicate that these people maintained and reconstructed their own lithic tools instead of obtaining them from lithic production specialists, as would be expected for specialists attached to elites (Geisso 2011; Janusek 1999).

La K'araña (LK) is a small mound site located directly north of Tiwanaku's ceremonial core. It was a walled residential compound that may have been home to local elites (Escalante 2003; Portugal Ortíz 1988). However, these elites may not have been as high in status as in other regions, such as at Putuni (discussed below). Both lower quality canals and fewer ceramic assemblages than Putuni were present at La K'araña, indicating that if these people were elite, they might have been of a lower rank (Janusek 2004a:153, 156). In addition, Escalante (2003:323) argued that La K'araña peoples controlled and distributed agricultural products, and organized local religious activities. He pointed to evidence from a circular structure found within this site that could have been a storeroom for agricultural products and canals that may have been used to transport freshwater to the area for rituals (Escalante 2003:326). While it is unclear the status level of these individuals, burials at La K'araña did not have extensive grave goods, rather small assemblages of lithics, ceramics, and animal bone.

Marka Pata (MP) is located 200m west of Ch'iji Jawira and was a mortuary area. In addition to being a burial location, Marka Pata contained raw materials, and could have been a location of stone tool manufacture (Geisso 2000, 2003, 2011). Geisso (2003:373; 2011:166) also noted that this site contained few exotic raw lithic materials, and for that reason he argued that it is more akin to rural sites than urban ones. Burials from this site, some of which contained decorated ceramics and obsidian, date from the Late Formative through the Tiwanaku phase (Berryman 2011; Geisso 2003). In addition, individuals buried in the Marka Pata region had diets relatively high in maize (40-60%) (Berryman 2011; Berryman et al. 2009).

Mollo Kontu (MK) is located outside of the moat of the city of Tiwanaku and south of the Akapana pyramid. The site was inhabited from the Late Formative through the Tiwanaku period. Mollo Kontu consists of a small monumental structure, likely for ritual use, as well as various walled, residential structures (Couture 2003; Couture et al. 2008). Ceramics from the Tiwanaku period associated with *chicha* preparation and ritual feasting were excavated at Mollo Kontu. In addition, a variety of lithics comprised of obsidian and quartz, some of which were fashioned into points, were also excavated from Mollo Kontu. However, Geisso (2011:165) notes that due to a lack of microartifacts from Mollo Kontu, the manufacture of these lithics took place in other sectors. Additionally, he notes that like Marka Pata, the southern portion of Mollo Kontu's lithic assemblage is more consistent with rural sites than urban ones. However, this southern portion is in contrast to the mound area where exotic lithic points, especially obsidian quarried from a variety of distant locations, were purposefully added to the fill (Couture 2003).

In contrast to other sectors, people from the residential area of Mollo Kontu ate little maize, large quantities of meat, and practiced annular cranial modification (Berryman 2011; Berryman et al. 2007; Blom 1999). A recent zooarchaeological study by Vallières (2010) supports these dietary results. Vallières' data also suggest that people from the residential area were involved in the pastoral economy, possibly as camelid herders and butchering specialists, because of the zooarchaeological evidence that the animals arrived alive and were then butchered onsite.

In contrast to the residential burials, mound burials were more like those recovered from other Tiwanaku sectors. Diets consisted of large quantities of maize (probably consumed as *chicha*), less meat consumption than in the residential area, and fronto-occipital artificial cranial modification. It has been suggested that these individuals were human offerings at the Mollo Kontu mound (Couture 2003). However, skeletal analyses of these mound burials show no overt signs of trauma, but do show odd burial positions (Couture et al. 2008). For example, one individual (excavated by this researcher in 2007) was buried face down, and another adult individual was buried face up in a flexed position with the legs beneath the torso. It is possible that individuals were sacrifices or dedications that died through nonviolent methods, and then were buried in unusual positions. It is also possible, especially with the range of ages and burial positions, that this represents some kind of disease epidemic where individuals were buried hurriedly (Couture et al. 2008).

Putuni (PUT) is located within the core of the city of Tiwanaku and represents one of the “longest and most complete records of human occupation” in this area (Couture and Sampeck 2003:226). Putuni has been described as a ritual and residential area palace with decorated adobe walls and elaborate drainage canals that removed waste from the compound and was home to elites of the Tiwanaku state. Couture and Sampeck (2003:231-232) suggest that Putuni was home to ritual specialists working at the palace or pilgrims from other communities there to visit the local temples. Ceramic evidence supports this idea as the local plaza area, likely a ritual center, was used for both domestic and ceremonial activities (Couture and Sampeck 2003:231). In addition, within the residential area, there was a “kitchen complex” that contained hearths and ash pits indicating a portion of the site was used as an area of food preparation. To the south of the kitchen was a mortuary complex that contained a large concentration of high quality ceramics and prestige goods (e.g. lapis lazuli, obsidian), which have been interpreted as elite burials (Couture and Sampeck 2003:240-241). Also, in this burial area were foreign-style ceramics that could indicate elites or ritual specialists may have maintained ties with groups outside of the Tiwanaku highlands.

Tilata**,** Pukara**,** and Guaqui are rural sites located in the Middle or Lower Tiwanaku Valley. Due to the small sample of burials from these sites and their rural location, they have been combined into one rural Tiwanaku Valley group for this study. Tilata is located approximately 4km northwest of the city of Tiwanaku on the eastern alluvial plain of the Taraco Mountains. Scholars (Albarracín-Jordán and Mathews 1990; Mathews 1992, 2003) suggested that this site was originally settled to make use of the alluvial soil and floodplain. They note, however, that agricultural production would not have been as high as in the raised-fields in the Katari Valley. Artifacts recovered from this site, such as stone hoes and camelid faunal remains, support the idea that this site was the largest agricultural and pastoral area in the Tiwanaku Valley. Mathews (2003:117) noted that during the Tiwanaku time period, sites in the middle Tiwanaku Valley were regularly spaced and he interprets this as Tilata managing crops for the state.

Guaqui and Pukara are located in the lower Tiwanaku Valley. Akin to Tilata, Pukara is located in the alluvial zone of the Taraco Mountains and was likely a settlement for local agriculturalists as it would have overlooked nearby raised-field agricultural production areas (Albarracín-Jordán 1992:103; 1996). Ceramic and lithic artifacts have also been recovered from this site. Guaqui is closer to the shores of Lake Titicaca in the lower Tiwanaku Valley. Along with evidence of agricultural production of quinoa, people who lived at Guaqui were likely utilizing local lacustrine resources and camelids for dietary resources (Albarracín-Jordán 1992).

Table 4.11 Sample Tiwanaku Valley, Bolivia Population Divided by Subadult and Adult Divided by Archaeological Site (n=274)

Site	Subadults	Adults	MNI
Akapana	19	27	46
Akapana East	10	20	30
Ch'iji Jawira	3	5	8
La K'araña	0	2	2
Marka Pata	11	57	68
Mollo Kontu	29	50	79
Putuni	11	21	32
Tilata/Pukara/Guaqui	1	5	6
Tiwanaku Valley Sample Total (n=):	84	190	274

Table 4.12 Time Period Distribution within the Sample Population of the Tiwanaku Valley, Bolivia (n=274)

Area	Late Formative Period (250 BC- AD 500)	Tiwanaku Period (AD 500-1100)	Post-Tiwanaku Period (AD 1100-1300)
Tiwanaku Valley	4	255	15

Table 4.13 Age-at-Death Distribution of the Sample Population within the Tiwanaku Valley, Bolivia (n=100)

Site	15-19	20-29	30-39	40-49	50+
Akapana	-	7	8	6	2
Akapana East	5	3	2	1	1
Ch'iji Jawira	-	1	1	1	-
La K'araña	-	1	1	-	-
Marka Pata	4	5	10	6	-
Mollo Kontu	2	2	6	4	5
Putuni	3	5	1	2	1
Tilata/Pukara/Guaqui	1	1	-	2	-
Tiwanaku Valley Sample Total (n=):	15	25	29	22	9

Table 4.14 Sex Distribution of Adults within the Sample Population of the Tiwanaku Valley, Bolivia (n=84)

Region	Females	Males	Possible Females	Possible Males
Akapana	4	8	2	4
Akapana East	1	1	1	3
Ch'iji Jawira	1	-	-	1
La K'araña	-	2	-	-
Marka Pata	5	9	5	5
Mollo Kontu	6	6	3	4
Putuni	2	4	2	2
Tilata/Pukara/Guaqui	1	2	-	-
Tiwanaku Valley Sample Total (n=):	20	32	13	19

Archaeological Sites – Peru

I analyzed collections from five archaeological skeletal series[11] comprised of 1,550 individuals in the Middle Moquegua Valley area. The first sites, Tres Quebradas and Los Joyeros, date to the Late Formative period and represent individuals of the Huaracane tradition living in this area prior to direct colonization by the Tiwanaku state (Fig. 4.7). Huaracane peoples participated in an agricultural economy, primarily based in canal irrigation farming (Goldstein 2000).

The sites of Chen Chen, Omo, and Rio Muerto represent the Tiwanaku state's colonies in the Middle Moquegua Valley during the Tiwanaku time period (Fig. 4.8). With their arrival, settlers participated in a pastoral and more agriculturally intensive lifeway than did prior residents of the area. Individuals worked at farming, herding,

[11] Multiple sites were examined, however for the purposes of this study these sites were combined into five skeletal series categories.

pottery production, and lithic manufacture, with labors varying depending upon location within the valley (Goldstein 2000, 2005).

The last site, Tumilaca la Chimba, dates to the collapse of Tiwanaku's influence and loss of direct control in this region (Fig. 4.9). After Tiwanaku's loss of influence in this valley, the agricultural intensity in the region diminished as evidenced by location and population changes during the post-Tiwanaku phase (Sharratt 2011; Williams 2006).

What follows is a detailed description of skeletal samples from these areas, including MNI, age-at-death, and sex estimates. A discussion of each archaeological site is also provided with information on prior research about site-use and possible labors and activities performed by the residents. All skeletal samples from these archaeological collections are currently housed in the Museo Contisuyo, Moquegua, Peru and are in good condition with excellent preservation, including mummified tissue remaining on some individuals.

Within the Moquegua Valley, all of the skeletal series show a high number of subadults when compared to many other bioarchaeological studies (Table 4.15). As previously noted, skeletal preservation in this very dry region is near-perfect in that it includes mummies, mummified tissue on the skeletal remains, as well as the textiles people were wrapped in for burial (Plunger 2009). Under environmental conditions like these, it is unsurprising that there are high, and in some sites, higher numbers of subadults buried in this area as this would be the expected 'actual' pattern for infant mortality rates prior to modern medicine and without burial recovery complications (as discussed in Section 4.2) (Milner et al. 2000; Wood et al. 1992). Additionally, similar to the samples from the core region in the highlands of Bolivia, the majority of the sample from Peru is from the Tiwanaku time period (Table 4.16). When comparing the age-at-death estimates from the Moquegua Valley, the majority of individuals fall within the 30-39 age range, with comparatively lower numbers in the 20-29 and 40-49 range, and the lowest numbers for people who died in their late teens and those over 50 years of age (Table 4.17). Of the adults in the Moquegua Valley samples, females comprised the largest portion of the adult population for whom sex could be estimated (Table 4.18).

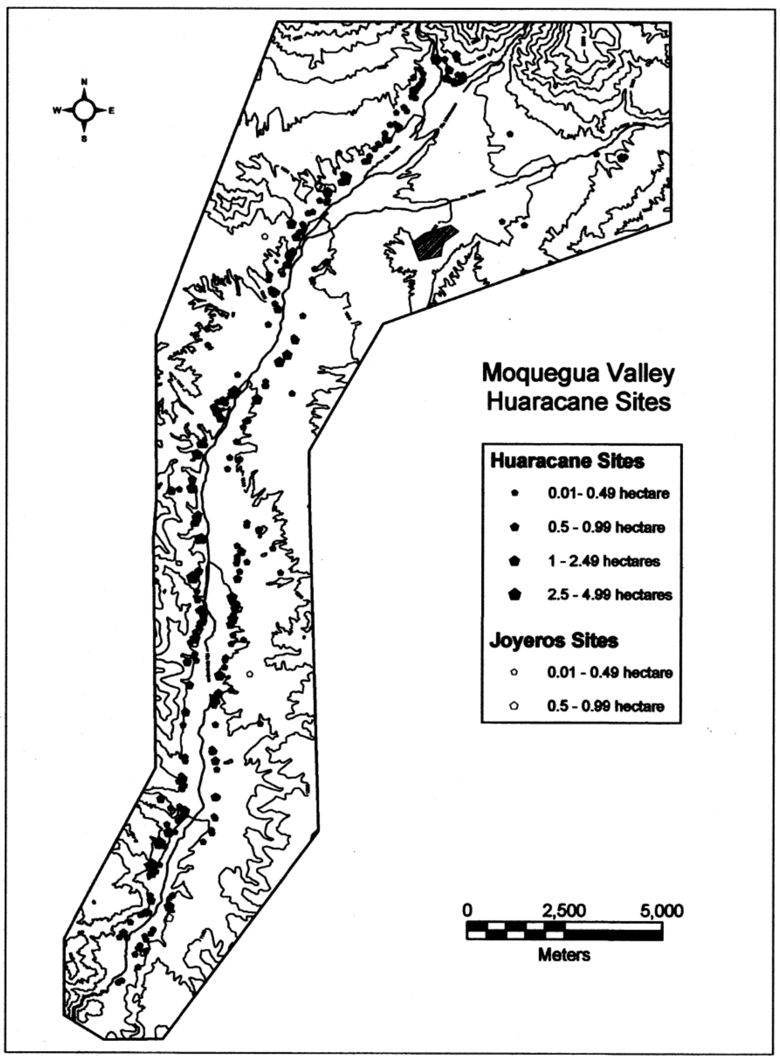


Figure 4.5 Late Formative Study Sites (after Goldstein 2005:124)

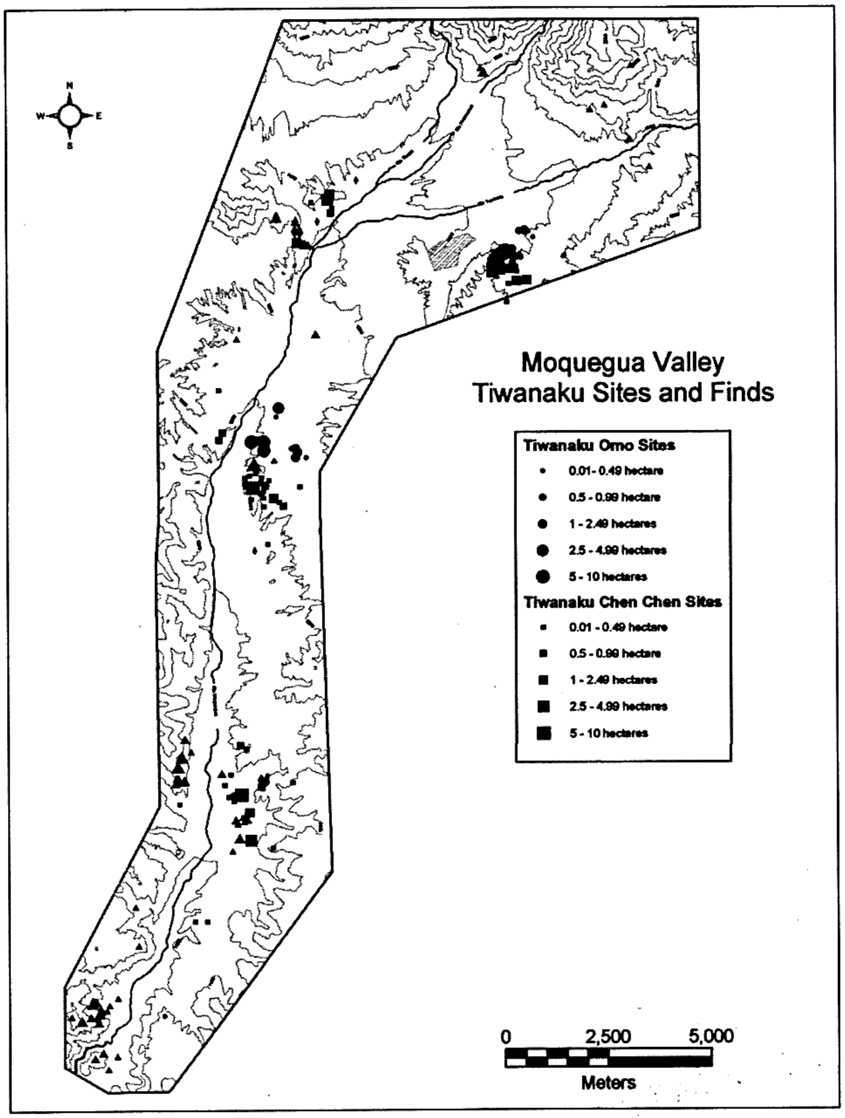


Figure 4.6 Tiwanaku Time Period Study Sites (after Goldstein 2005:135)

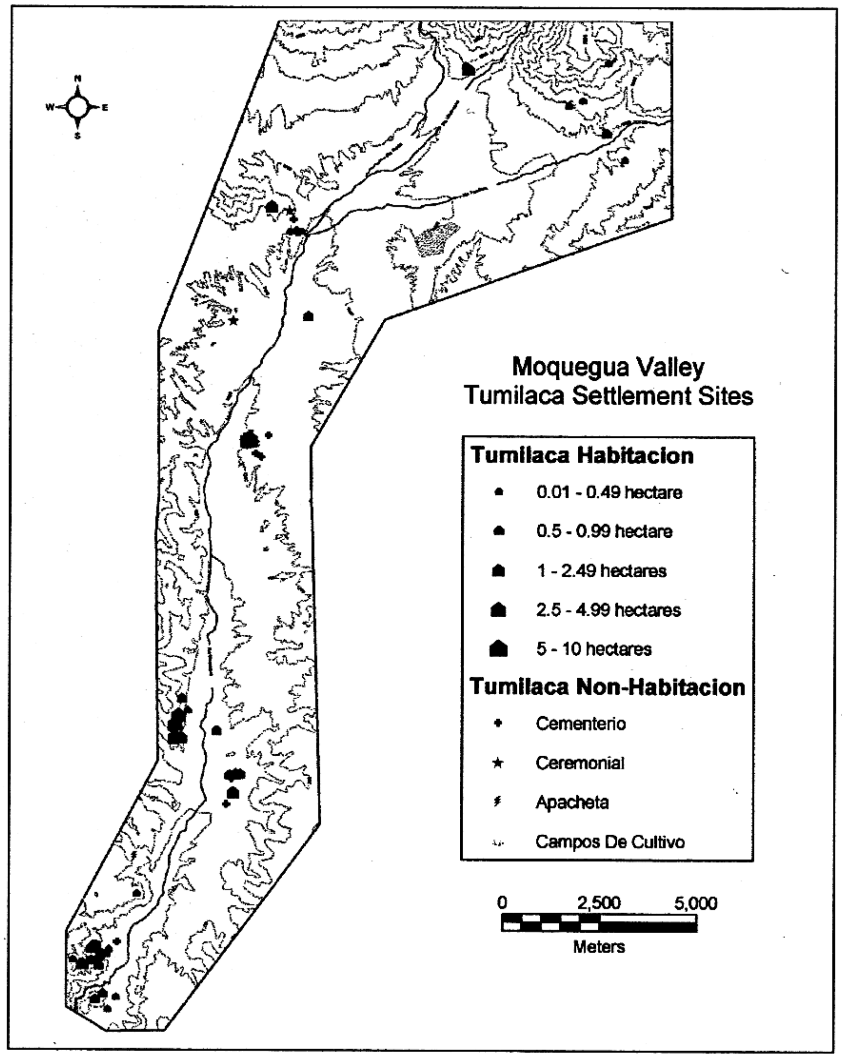


Figure 4.7 Post-Tiwanaku Time Period Study Sites (after Goldstein 2005:172)

Tres Quebradas (M73) and **Los Joyeros** (M76) are sites of the early and late Huaracane phase respectively (Goldstein 2005; Goldstein and Owen 2001). The Huaracane occupation was a series of small, agrarian sites that existed prior to Tiwanaku colonization in the Middle Moquegua Valley. Huaracane settlements were located near to the floodplain of the local Osmore (Moquegua) River, indicating floodplain agriculture with a reliance on simple canal irrigation (Goldstein 2005:123). Burials from this culture generally had shell or bone beads, with few ceramic offerings.

Chen Chen (M1) is one of four sites[12] in the Middle Moquegua Valley that were Tiwanaku-affiliated settlements (Cardona and de la Varga 1996; Goldstein 2005; Owen 1997; Pari 1997; Vargas 1998; Williams 1997). Chen Chen is on the southern side of the Moquegua River and farthest upriver of the Tiwanaku settlements. This site contained household settlements, agricultural fields, canal systems, and cemeteries. Specialization among individuals at Chen Chen would have involved agricultural production and cultivation, with working fields, maintaining a complex irrigation system, and processing of the agricultural resources (Blom 1999:92; Goldstein 2000; Williams 1997:90; 2006). Agricultural equipment, such as stone hoes and extensive grinding stones, were found throughout residential sectors at Chen Chen. Additionally, below-ground storage areas likely used to hold grain, possible maize, to be sent to the Tiwanaku state in the highlands were found (Bandy et al. 1996). This area was an important maize producing region for the Tiwanaku state, and likely provided much of the corn used for *chicha* production and consumption in the core (Goldstein 2000; 2005:320; Goldstein and Owen 2001).

Household excavations at Chen Chen show permanent residential architecture as well a lighter zone of occupation, explained as residences for temporary visitors (Blom 1999; Blom et al. 1998; Goldstein 1989, 1993b, 2005). These residences could have been for laborers who were moved to the region in a corvée labor system, as noted during the Inca Empire with the *m'ita* labor tax (Bandy et al. 1996). Mortuary analyses of the Chen

[12] The sites are Chen Chen, Omo, Rio Muerto, and Cerro Echenique. Cerro Echenique was not included in this study as it lacked associated human burials housed at the Museo Contisuyo in Moquegua, Peru.

Chen cemeteries showed patterns similar to highland Tiwanaku traditions, with everyday items, such as ceramic bowls, jars, and wooden spoons, as grave goods.

Omo (M10, M11, M12, M13, and M16) is located on the southern side of the Moquegua River, approximately 10km downriver from the Chen Chen site. These sites are situated on bluffs above the river, a natural overlook on agricultural lands below. This settlement contained both agrarian, “Chen Chen-style” and pastoral, “Omo-style” occupation. Evidence from prehistoric trade routes make Omo a likely stopping point for llama caravans heading to the highlands or to Chen Chen (Goldstein 1993a:34; 2005:145, 147). Goldstein (2005:153) hypothesized that many of the early residents in the Omo-style settlements were pastoralists as it is the type of place a llama herder might have chosen because it avoided farmland, farmers, and floodplains. House structures in the Omo-style areas showed more tent-like domiciles and contained few permanent features, furniture, or grindstones, which contrasts with Chen Chen’s more permanent style of settlements (Goldstein 2005:155).

While all of the Omo areas contained domestic residences, the M10 bluff contained both residential areas and a temple associated with that sector’s Chen Chen-style occupation. Akin to the Tiwanaku core city, Omo’s ritual area included altiplano-style architecture, with a typical Tiwanaku change between secular and sacred space toward the inner sunken court area (Goldstein 1993b:42). Both Omo-style and Chen Chen-style ceramics recovered show a direct connection to highland styles of domestic-use pottery. Goldstein (2005:151) concluded that these ceramics indicated the movement of Tiwanaku-trained potters to the region or importation of highland ceramics. In addition to potters, Omo may have been home to other craft specialists, such as those who worked marine shell in the M12 area. M12 was also home to areas for *chicha* production and consumption (*chicherias*), and evidence at M12 of face painting ochre and coca leaves indicated its importance as a ritual and ceremonial location (Goldstein 1993a:36).

Rio Muerto (M43 and M70) is located on the south side of the Osmore River and farthest downriver of all the Tiwanaku colony settlements. This area is the third largest Tiwanaku settlement in the Middle Moquegua Valley and consists of both Chen Chen- and Omo-style contexts as well as a possible ritual temple structure (Baitzel 2008; Goldstein 2005). Goldstein (2005:149) noted that Rio Muerto, like Omo, is located near natural springs, but that these springs would have been inadequate to irrigate agriculture except for years in which there were major floods. He stated that “two such floods, dated to AD 700 and AD 1300, bracket the Tiwanaku occupation at Rio Muerto” (Goldstein 2005; Magilliagan and Goldstein 2001). Hence, it is possible that Rio Muerto’s residents were agriculturalists.

Tumilaca la Chimba (CB06, CB07) is located 15km upriver from the site of Chen Chen on a bluff overlooking the Tumilaca River and associated floodplain farmlands below. This site is smaller than its prior Tiwanaku counterparts (Sharratt 2011). Akin to other Tumilaca period (post-Tiwanaku) sites, the area lacks public ritual spaces, storage facilities, and any kind of central administration center (Goldstein 2005:172-173). Tumilaca la Chimba peoples continued in the farming tradition, but it was likely not intensive (Sharratt 2011). David Goldstein’s (Appendix G of Sharratt 2011:585) report on this site noted the macrobotanical data contrast with the remains recovered from both domestic and burial contexts in and around the Rio Muerto assemblage that he had studied previously. He suggested that the data indicate dietary differences in agricultural production after the collapse of the Tiwanaku state. In addition, burials from Tumilaca la Chimba contained some grave goods that were similar to individuals buried at Chen Chen, with some ceramics, wooden spoons, and weaving tools (Sharratt 2011).

Table 4.15 Age-at-Death MNI within the Moquegua Valley, Peru

Site	Subadults	Adults	MNI	Time Period
Tres Quebradas/ Los Joyeros	1	13	14	Late Formative (250 BC - AD 500)
Chen Chen	537	538	1075	Tiwanaku (AD 500-1000)
Omo	106	129	235	Tiwanaku (AD 500-1000)
Rio Muerto	63	49	112	Tiwanaku (AD 500-1000)
Tumilaca la Chimba	60	54	114	Post-Tiwanaku (AD 1000-1300)
Moquegua Valley Sample Total (n=):	767	783	1550	

Table 4.16 Time Period Distribution within the Sample Population of the Moquegua Valley, Peru (n=1550)

Area	Late Formative Period (250 BC- AD 500)	Tiwanaku Period (AD 500-1100)	Post-Tiwanaku Period (AD 1100-1300)
Tiwanaku Valley	14	1422	114

Table 4.17 Age-at-Death Distribution of the Sample Population within the Moquegua Valley, Peru (n=505)

Site	15-19	20-29	30-39	40-49	50+
Tres Quebradas/ Los Joyeros	-	-	2	-	-
Chen Chen	29	82	138	55	34
Omo	14	18	44	13	4
Rio Muerto	6	11	11	1	4
Tumilaca la Chimba	1	14	10	12	2
Moquegua Valley Sample Total (n=):	50	125	205	81	44

Table 4.18 Sex Distribution of Adults within the Sample Population of the Moquegua Valley, Peru (n=478)

Site	Females	Males	Possible Females	Possible Males
Tres Quebradas/ Los Joyeros	1	1	-	2
Chen Chen	171	98	26	30
Omo	25	39	11	11
Rio Muerto	12	16	1	4
Tumilaca la Chimba	13	11	3	3
Moquegua Valley Sample Total (n=):	222	165	41	50

4.4 Summary

In this chapter, I have discussed bioarchaeological methods used to reconstruct population profiles for this study, including calculating the MNI, age-at-death and sex estimates. The site-by-site context and population profiles for this study provide an interesting picture of the labors of people who lived and died in these regions. This information will be used to answer the research questions posed in this study over labor organization and the composition of the state's workforce. In the next chapter, I discuss the methods used to estimate labor from the two skeletal indicators of activity (MSM and OA), and the statistics that were performed to interpret significant differences in these data in order to understand labor and activity within the Tiwanaku state.

Chapter 5
Methods for Estimating Labor

5.1 Introduction

In this chapter, I explain the methods used for estimating labor from the skeletal collections in this sample. Of primary importance to this study was the pattern and level of activity for each skeletal indicator, as bones and muscles work in conjunction with each other while people perform activities. As such, I provide information over the bioarchaeological data on musculoskeletal stress markers (MSM) and osteoarthritis (OA).

Prior bioarchaeological studies of labor commonly utilized only one osteological measure, either MSM or OA, to determine activities performed. In general, the emphasis was on subsistence differences or the reconstruction of a specific activity (i.e. canoe paddling or spear throwing) (Churchill and Formicola 1997; Hawkey 1988; Hawkey and Merbs 1995; Kennedy 1989). More recently, bioarchaeological scholars (Buikstra and Pearson 2006; Jurmain 1999; Jurmain et al. 2012; Pearson and Buikstra 2006; Stirland 1998; Weiss 2003; Wilczak 1998) have questioned conclusions being drawn from these approaches. Instead, they suggest that interpretations that are more accurate arise from synthesizing multiple lines of osteological evidence and evaluating workload levels within a population. To address these concerns, I utilized both skeletal measures of labor (MSM and OA) as an integrative population-based bioarchaeological approach to study the chronological and spatial labor changes associated with Tiwanaku state formation. In avoiding what Jurmain (1999) calls "activity-only myopia", my research builds on previous studies, expands theoretical perspectives within bioarchaeology concerning the use of activity indicators, and considers the archaeological evidence of labor. This brings an integrative approach to Tiwanaku state formation and the role of groups and subgroups within this polity.

From this approach, data were collected from adults of both sexes with no signs of chronic infection in order to understand labor within the emerging and expanding Tiwanaku state. Bilateral involvement was recorded wherever possible and data were noted for each individual on both the left and right side of the body. What follows is a description of each of the skeletal indicators of labor, how data were collected and scored for each activity marker, concerns about using these methods to estimate labor within these areas, and finally a description of the statistical methods used to evaluate this information.

5.2 Musculoskeletal Stress Markers (MSM)

As humans live and work, musculature increases and decreases in relation to activities performed. In turn, the attachment of these muscles to bone are developed and strengthened. The presence of raised bony areas where these muscles attach, MSM, can be used to understand activities people did or did not engage in and how much physical labor was involved (Chapman 1997; Churchill and Morris 1998; Hawkey 1988; Kennedy 1989; Toyne 2008). These muscle, tendons, and ligaments leave distinct marks at their attachment into the periosteum and underlying bone. As these areas are subjected to repeated minor stresses, bone (osteonal) remodeling occurs and leaves a pattern of habitual muscle use (Churchill and Morris 1998; Hawkey and Merbs 1995). Such trends have been supported by many modern clinical studies (see Kennedy 1989 for review). Additionally, researchers (Chapman 1997; Churchill and Morris 1998; Toyne 2008) using MSM have also been successful at discerning levels of physical labor, such as between those who perform lighter physical activities and those involved in heavy labor.

Each individual was analyzed for 25 upper body and 12 mid- and lower body attachment points commonly used in bioarchaeology (Table 5.1), emphasizing the humerus and femur as the best preserved limb bones in the body (al-Oumaoui et al. 2004; Hawkey 1988; Hawkey and Merbs 1995; Toyne 2008). In the **upper arm**, 15 muscles comprise movements in the upper arm of the clavicle, scapula, and humerus. There are three ligaments (*conoid*, *costoclavicular*, and *trapezoid*) and one muscle (*subclavius*) insertion point on the clavicle, as shown in Figure 5.1. The remaining upper arm MSM (i.e. *trapezius*, *pectoralis minor*, *coracobrachialis*, *deltoideus*, *infraspinatus*, *latissimus dorsi*, *pectoralis major*, *subscapularis*, *supraspinatus*, *teres major*, and *teres minor*) are all insertions on the scapula and proximal humerus, as shown in Figure 5.2. Figure 5.3, shows the 10 **forearm** MSM points on the bones of the distal humerus, ulna, and radius. The first two of these on the humerus are origin points for *flexors* and *extensors* of the wrist, with another three (i.e. *anconeus*, *brachialis*, and *triceps brachii*) are muscle insertions on the ulna. The remaining five are insertions on the radius: *biceps brachii*, *brachioradialis*, *pronator quadratus, pronator teres*, and *supinator* muscles. In the lower anatomy, Figure 5.4 shows the five **mid-body** muscles that insert on the proximal femur: *gluteus maximus*, *gluteus medius*, *gluteus minimus*, *piriformes*, and *psoas major/iliacus*. The **lower body** MSM comparisons are comprised of the *linea aspera*, *quadriceps tendon*, and *patellar ligament* and are shown in Figure 5.5. In addition, there are four **foot**

MSM, *soleal* (*soleus*) muscle, *abductor hallucis*, *Achilles tendon*, and *flexor digitorum brevis* (Fig. 5.6).

These 37 MSM have been shown by Hawkey and Merbs (1995) to be good indicators of a variety of activity patterns with low inter- and intraobserver error. All of these MSM were rated first as present or absent. If present, they were judged on a 1 through 3 scale each for robusticity, stress, and ossification using previously published levels (see description in Appendix A) (Hawkey 1988; Hawkey and Merbs 1995). I then calculated a combined mean ordinal score of robusticity, stress, and ossification as this has been shown to evaluate the workload level throughout an individual's lifetime (Toyne 2004, 2008). Finally, as these MSM group into different movement areas of the body (i.e. **upper arm**, **forearm**, **mid-body**, **lower body**, and **foot**), a combined measurement was evaluated for each region of the body and, when appropriate, an ordinal score calculated to evaluate labor levels.

Table 5.1 List of Musculoskeletal Stress Markers used in this Study

Movement Area	MSN / Location
Upper Arm	• Conoid ligament / Clavicle • Costoclavicular ligament / Clavicle • Subclavious / Clavicle • Trapezoid ligament / Clavicle • Trapezius / Scapula • Pectoralis minor / Scapula • Coracobrachialis / Humerus • Deltoideus / Humerus • Infraspinatus / Humerus • Latissimus dorsi / Humerus • Pectoralis major / Humerus • Subscapularis / Humerus • Suprasinatus / Humerus • Teres major / Humerus • Teres minor / Humerus
Forearm	• Extensors, common origin / Humerus • Flexors, common origin / Humerus • Anconeus / Ulna • Brachialis / Ulna • Triceps brachii / Ulna • Biceps brachii / Radius • Brachioradialis / Radius • Pronator quadratus / Radius • Pronator teres / Radius • Supinator / Radius
Mid-Body	• Gluteas maximus / Femur • Gluteus medius / Femur • Gluteus minimus / Femur • Piriformes / Femur • Psoas major/iliacus / Femur
Lower Body	• Linea aspera (Adductor longus and Adductor magnus)/ Femur • Quadriceps tendon (Superior-anterior, Rectus femoris, and Vastus intermedius) / Patella • Patellar ligament / Tibia
Foot	• Soleus / Tibia • Abductor hallucis / Calcaneus • Achilles tendon / Calcaneus • Flexor digitorum brevis / Calcaneus

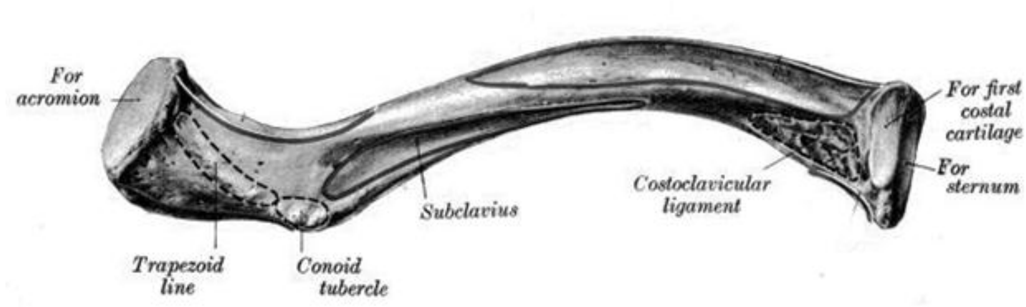
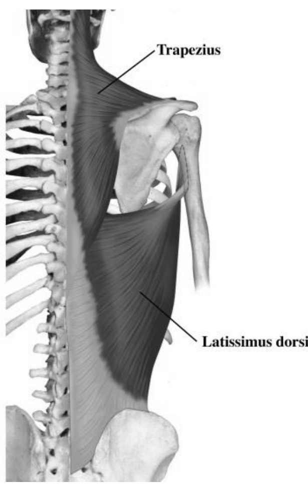


Figure 5.1 Ligament and Muscle Attachment Points on the Clavicle



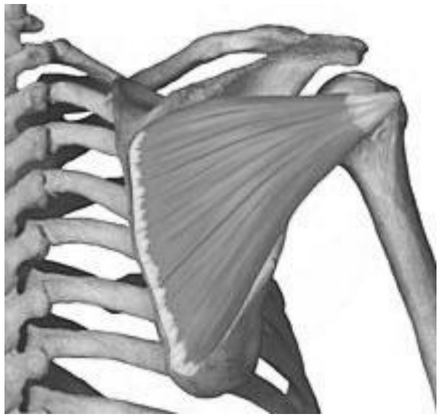
b. ***Trapezius and***

c. ***Latissimus dorsi***

d. ***Pectoralis minor***

e. ***Coracobrachialis***

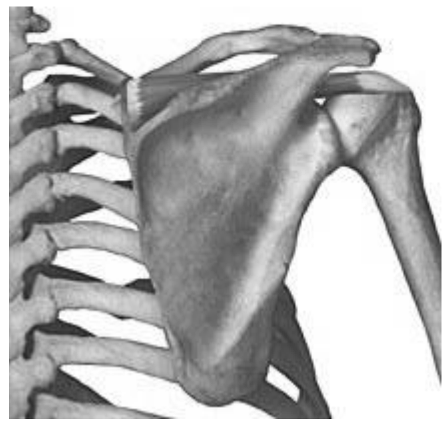
f. ***Deltoideus***



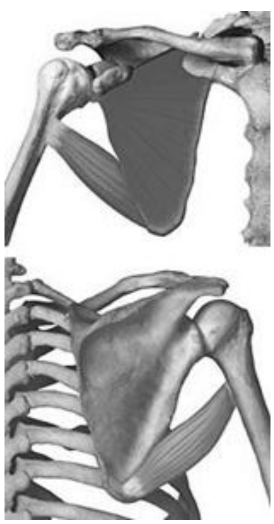
g. ***Infraspinatus***

h. ***Pectoralis major***

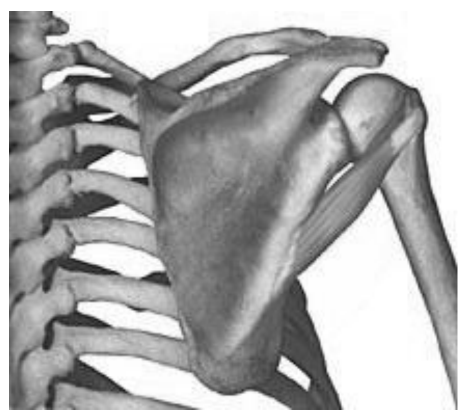
i. ***Subscapularis***



j. ***Supraspinatus***

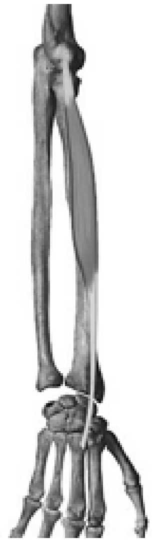


k. ***Teres major – Anterior (Top) and Posterior (Bottom) Views***

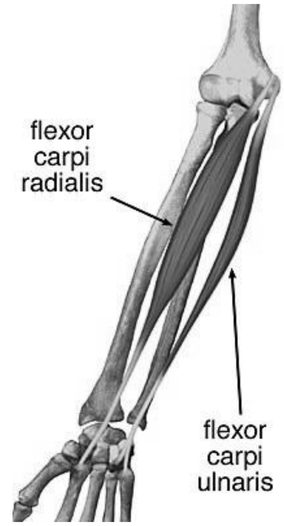


l. ***Teres minor***

Figure 5.2 Muscle Attachment Points on the Scapula and Humerus for the Upper Arm



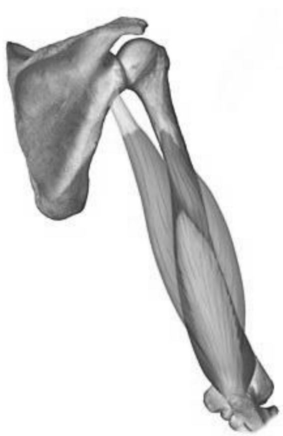
a. ***Extensors – common origin***



b. ***Flexors – common origin***

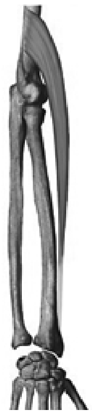
c. ***Anconeus***

d. ***Brachialis***



e. ***Triceps brachii***

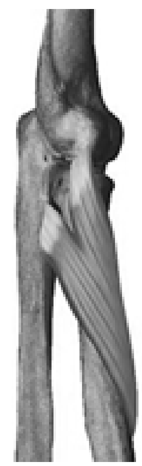
f. ***Biceps brachii***



g. ***Brachioradialis***

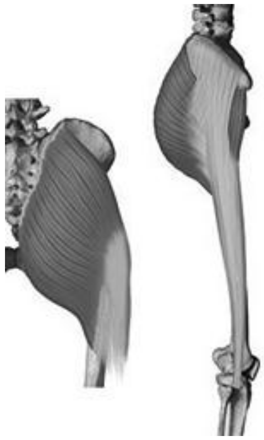
h. ***Pronator quadratus***

i. ***Pronator teres***



j. ***Supinator***

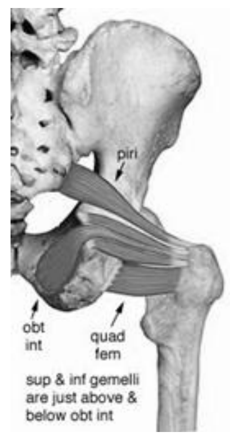
Figure 5.3 Muscle Attachment Points in the Forearm



a. *Gluteus maximus*

b. *Gluteus medius*

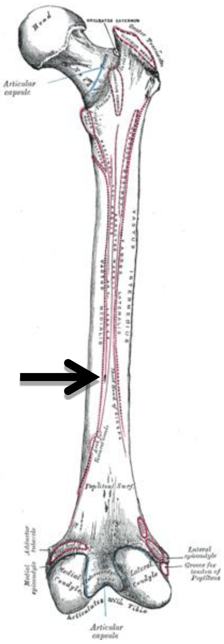
c. *Gluteus minimus*

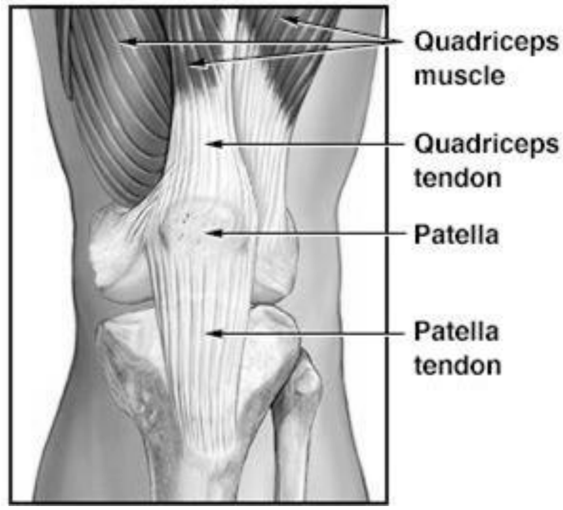


d. *Piriformes (noted by 'piri' and arrow)*

e. *Psoas / Iliacus*

Figure 5.4 Muscle Attachment Points in the Mid-Body



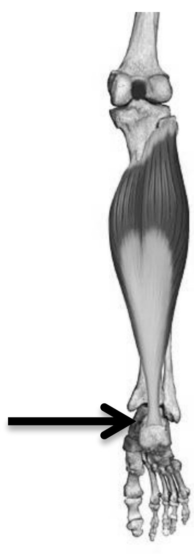


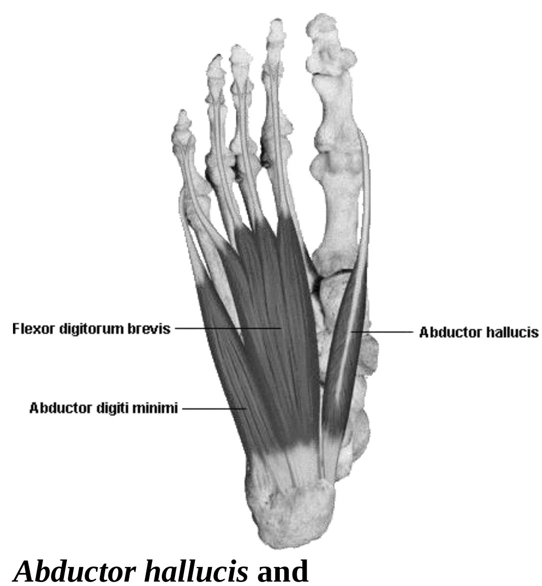
g. ***Quadriceps tendon and***

h. ***Patellar ligament (patella tendon)***

f. ***Linea Aspera (Posterior View of Femur) and Noted with Arrow***

Figure 5.5 Muscle Attachment Points in the Lower Body





a. ***Soleus* (posterior view)**

b. **Achilles tendon (noted by arrow)**

c. ***Abductor hallucis* and**
d. ***Flexor digitorum brevis* (inferior view)**

Figure 5.6 Muscle Attachment Points in the Foot

5.3 Osteoarthritis (OA)

The second measurement, OA, is part of the family of degenerative joint diseases. The presence of OA at joints indicates repetitive use of the same bone/muscle/joint groups, causing a series of recurring motion injuries that can be helpful in determining tasks that were done repeatedly (Huiskes 1982; Jurmain 1999). Of primary importance to this study is the pattern and level of OA in each joint, therefore data were collected from seven joint surfaces throughout the body – **shoulder**, **elbow**, **wrist**, **hip**, **sacroiliac**, **knee**, and **ankle**.

As there are multiple bones involved in these joint surfaces, Table 5.2 lists the specific areas for which OA information was collected. The glenoid fossa and the humeral head are the two surfaces in the **shoulder joint** and shown in Figure 5.7. The six areas of the **elbow joint** (i.e. distal end of humerus, head of radius, trochlear notch, olecranon process, coronoid process, and radial notch) are shown in Figure 5.8 and the three areas of the **wrist joint** (i.e. distal articular surfaces of the radius and ulna, ulnar surface of the radius) in Figure 5.9. Figure 5.10 and Figure 5.11 each show the two articular surfaces of the **hip joint** and **sacroiliac joint**, respectively. The six surfaces in the **knee joint** (i.e. medial and lateral condyles of the femur, medial and lateral facets of the patella, and medial and lateral condyles of the tibia) are shown in Figure 5.12. Additionally, Figure 5.13 shows the three areas within the **ankle joint** for which data were collected.

As OA can have various levels of involvement, data collected for each joint surface involved multiple observations using previously published criteria (see Appendix A) (Buikstra and Ubelaker 1994). If OA was noted as present, ordinal scores for evidence of lipping, surface porosity, osteophyte formation, and eburnation were collected along with percentage of joint surface involved. I then calculated a mean ordinal score for each type of OA evidence and a separate mean ordinal score for the percentage of joint surface affected. I performed these actions for each of the 24 individual surfaces in the joint, as well as for each of the seven joints combined. In doing so, I provide a clearer picture of the totality of OA throughout the body. In addition, I feel collecting the data in this fashion gives the best estimate for levels of OA by articular surface in the joint, along with a good overall estimate of arthritis involvement for all the joints in the body.

Table 5.2 List of Joints and Joint Surfaces Observed for Osteoarthritis

Joint	Joint Surfaces
Shoulder	• Glenoid fossa of scapula • Head of humerus
Elbow	• Distal end (capitulum & trochlea) of humerus • Head of radius • Trochlear notch of ulna • Olecranon process of ulna • Coronoid process of ulna • Radial notch of ulna
Wrist	• Distal articular surface of the radius • Distal articular surface of the ulna • Ulnar surface of radius
Hip	• Acetabulum of the os coxa • Head of femur
Sacroiliac	• Auricular surface of os coxa • Auricular surface of sacrum
Knee	• Medial condyle of femur • Lateral condyle of femur • Medial facet of patella • Lateral facet of patella • Medial condyle of tibia • Lateral condyle of tibia
Ankle	• Distal articular surface of tibia • Superior articular surface of talus • Medial malleolar surface of talus

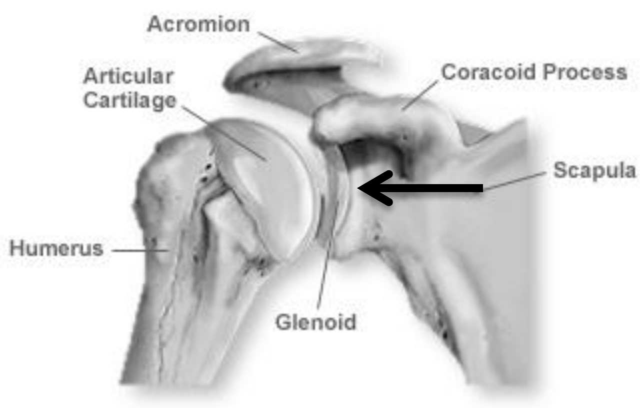


Figure 5.7 Shoulder Joint

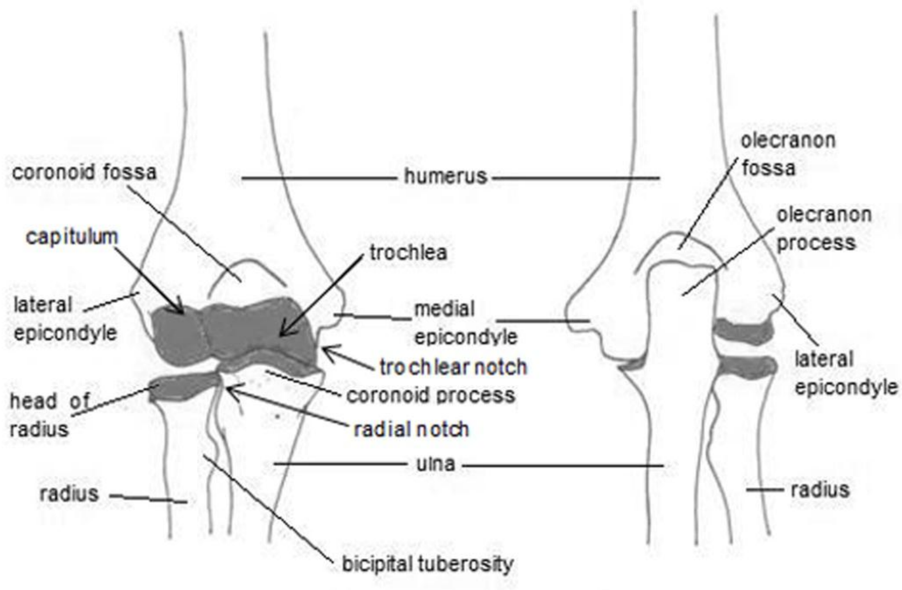


Figure 5.8 Elbow Joint

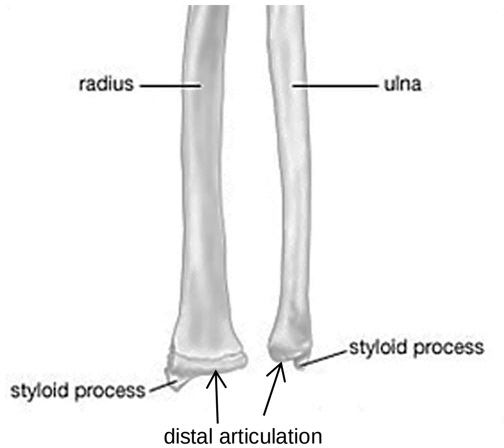


Figure 5.9 Wrist Joint (Radius Distal Articulation on Left, Ulna Distal Articulation on Right)

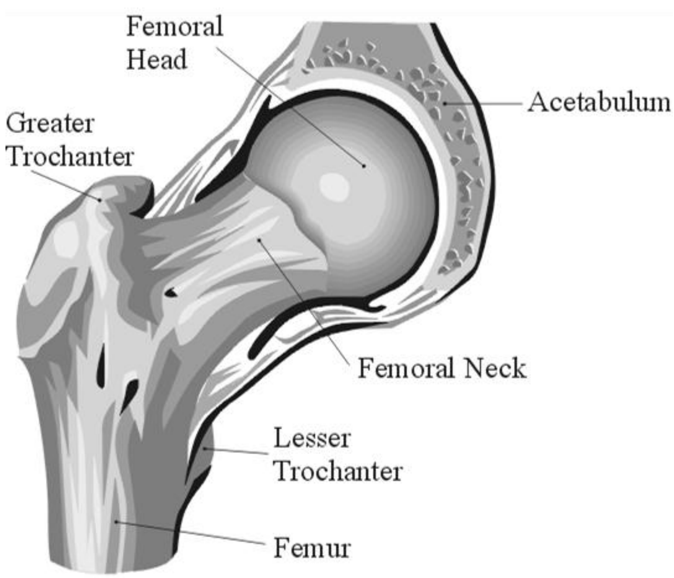


Figure 5.10 Hip Joint

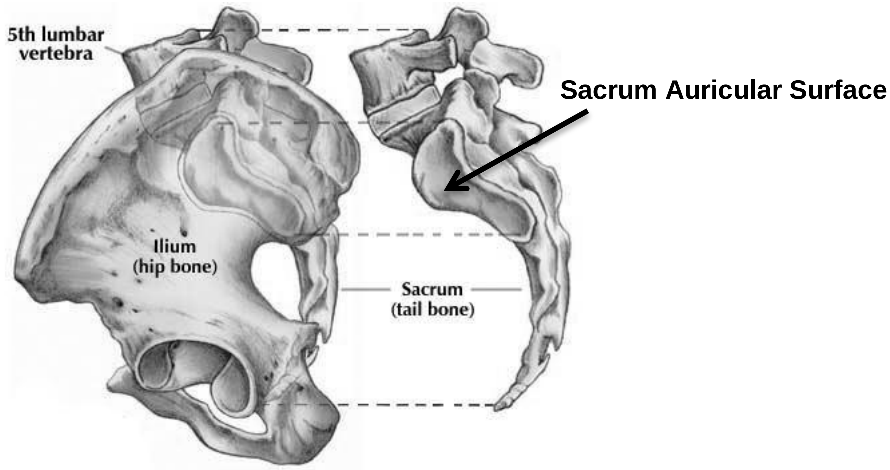


Figure 5.11 Side View of Sacroiliac Joint with Separate View of Sacrum

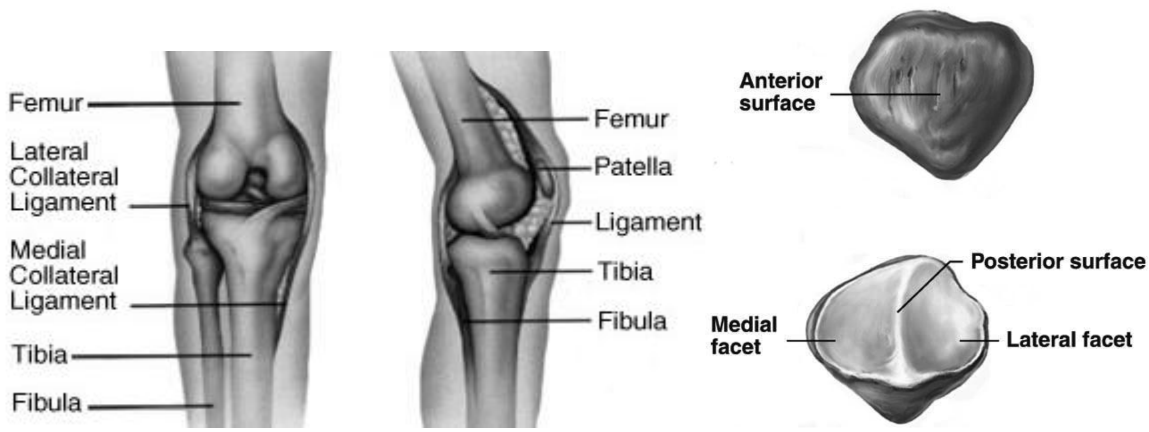


Figure 5.12 Knee Joint

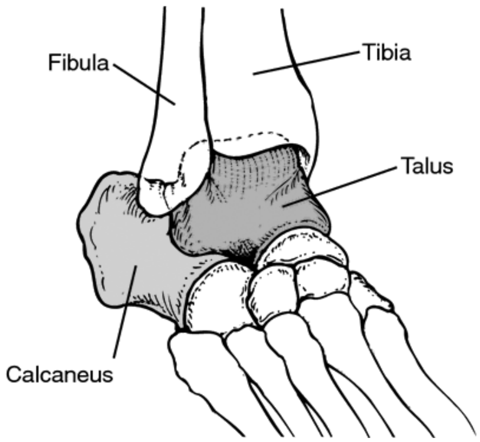


Figure 5.13 Ankle Joint

5.4 Concerns about Using MSM and OA

There is debate in the anthropological literature over the validity of using these measurements as indicators of activity. In prior MSM studies (e.g. Hawkey 1988; Kennedy 1989), researchers tried to show a direct comparison of specific actions with a certain muscle attachment point or points. Problems with these type of studies have been reported throughout anthropological literature with various cautionary examples about the misuse of these as indicators of specific activity from individual skeletal remains (e.g. spear throwing or rowing) (Jurmain 1999; Jurmain et al. 2012; Robb 1998; Stirland 1998; Stock and Shaw 2007; Weiss 2003, 2007; Weiss and Jurmain 2007 and others). A study performed by Zumwalt (2006) discounted the use of MSM altogether as an indicator of activity. However, that study focused on short-term intense activity and did not provide a conclusive rejection of the use of MSM, especially over the lifetime of a human being.

Pearson and Buikstra (2006) note more clinical studies are required to give a definitive answer about both MSM and OA as a correlate of activity. Age, sex, bone length, and possible childhood activities all seem to be important factors not only to OA

(Jurmain 1999; Jurmain et al. 2012; Weiss and Jurmain 2007), but with MSM (Jurmain et al. 2012; Robb 1998; Stirland 1998; Weiss 2007). In addition, Bridges (1989a; 1991a) noted that these osteological measures of activity may not be directly correlated, and instead each measurement could be from a possible range of causes. However, as this study utilizes both methods, I addressed issues like these and from other prior studies that only used one measurement as a specific indicator of activity. I also addressed prior problems, as noted in the literature, by collecting extensive data, from both sexes, and using as narrow as possible estimates of age-at-death from the sample populations. In addition, instead of trying to determine a specific activity performed by an individual from the Tiwanaku state, my population-centered modeling approach aimed to correlate skeletal evidence with a variety of movements and labor levels both chronologically and spatially within the archaeological record of the Tiwanaku state.

5.6 Statistical Methods

Associations made with aggregate-level measures of risk of illness and death by individual members of past populations may be incorrect, as they do not account for demographic nonstationarity, selective mortality, or hidden heterogeneity in risks (Milner et al. 2000; Wood et al. 1992). Instead, studies using skeletal remains to discuss past human populations must collect data on a population level, while taking into account these three factors (explained further in Chapter 4, Section 4.2). Because of this, significance testing was first performed for all adults as a group. However, in order to understand hidden heterogeneity better, I collected specific age-at-death estimations and categorized them in five or 10-year increments to measure the relationships between certain ages and activity. *T*-tests were first used to evaluate any significant differences among and between age-at-death groups and sex groups with no significant results found.

In order to test research questions from this study, I collected activity information from multiple data points for MSM and OA on each individual and analyzed them using the generalized estimated equations model (GEE). GEE is a population-averaged method, accounting for correlation among measures within subjects (Agresti 2007; Ghislatta and Spini 2004; Liang and Scott 1986). It is an appropriate statistical method using the data points in this study because GEE models estimates of population parameters that are calculated using individually recorded data points, allowing for the largest possible sample size. However, each of these data points remains linked to the individual, preserving individual level information (Ghislatta and Spini 2004). This procedure retains the categorical dependent variable, while keeping the data points (joints surfaces or muscle markers) of an individual linked. It also solves a common statistical issue in bioarchaeology, scalar issues of choosing between either individuals or each pathology measurement as the unit of comparison (Gagnon 2004, 2006; Gagnon and Wiesen 2011; Simon and Gagnon 2005). If activity measurement is reduced to an overall present or absent count per individual, the sample sizes may result in loss of very specific pathology data, as well as be insufficient to address research questions. However, if the condition is calculated on a per data point basis, one individual may skew statistical results when looking for patterns of activity, or could be a violation of the independence of data required for many statistical tests.

GEE works well for bioarchaeological samples as it is flexible enough to accommodate variables that are not normally distributed, small sample sizes, and most importantly, randomly missing or unobservable variables (Ballinger 2004; Liang and Scott 1986; Rochon 1998). As the collections in this study are previously excavated cemetery collections, missing or unobservable data points occur, and using a statistical procedure that permits missing data points is vital to obtain as much information as possible from the skeletal remains.

The GEE used in this study was applied to a logistic regression model (logit-linear) that simultaneously explores relationships between categorical, dependent variables, and any number of nominal or quantitative predictor variables that cannot be assessed using bivariate analysis. Interactions among predictor variables can be examined for significance of whether or not the effect of one variable outcome is conditioned on the value of another at a .05 level or greater. The algebraic equation for this is: $\text{Log}(\pi / 1 - \pi) = x\theta$, where x= an independent variable and the GEE estimates the change in θ (theta). The outcome variables for MSM and OA were rated as present or absent for each bony attachment point or articular area in each individual. I then used GEE regression analysis to look for significant differences ($p<.05$) with the independent categories of site location (e.g. core versus colony) and time period and the dependent categories of each bone-muscle attachment point (MSM), or each joint surface (OA) for each specimen or groups of specimen. Finally, the Wald test was calculated as part of the logistic regression to test the null hypothesis that groups in this study have the same rates of activity. By doing so, I was able to assess the research questions in this study in terms of answering questions over labor levels and organization, as well as address significant differences between groups of individuals (i.e. sex, age-at-death) to explain complexity with Tiwanaku state formation.

5.7 Summary

In this chapter, I have provided the osteological methods for evaluating labor within the Tiwanaku state. Each skeletal indicators, MSM and OA, were discussed as to their efficacy in developing a pattern of activity and movement. How the data were collected and scored was also discussed along with the possible problems and biases using these methods could have to understand labor. The statistical method, GEE, was also provided to explain how significance testing was performed in order to answer the research questions I posed in this dissertation. What follows in the next two chapters are the results for each indicator.

Chapter 6
Musculoskeletal Stress Markers (MSM) Results

6.1 Introduction

MSM are comprised of the points where joints, ligaments, and tendons attach to the skeleton and function almost like levers in skeletal movement. I have calculated the results for each of the 37 MSM (see Chapter 5, Table 5.1 for full list). I also combined these into five categories (**upper arm**, **forearm**, **mid-body**, **lower body**, and **foot**), which correspond to their use and movement in their respective areas of the body[13]. I focused on patterns of use, the intensity (i.e. ordinal scores from 1-3), and significant MSM differences ($p \leq .05$) as they provide distinctions about movement and how heavy the workload was between groups of Tiwanaku peoples. Data were collected bilaterally, however results in this chapter are provided as combined scores for both sides of the body[14].

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[13] The reason for grouping these is that muscles function in combination with each other on various regions of the anatomy. While each muscle marker might detail directional movement or muscle-use intensity, interpretations made of only individual MSMs can digress into problems with specific activity reconstruction, which is not the focus of my research.

[14] I did this as I believe it represents the best possible way to achieve the maximum amount of data from individuals present in this study, does not bias the potential handedness of individuals involved (i.e. choosing right over left or vice versa), as hand dominance is not directly relevant to answering the research questions, and the GEE statistical procedure used does not bias these combined results (Becker 2012; Gagnon and Wiesen 2011). Results for the core versus colony comparison are shown by right and left side of the body in Appendix B, Tables B.1-B.2. When compared with both sides of the body combined in

Using these criteria in this chapter, I present the MSM results for a MNI of 1,235 people within the study sample population. MSM data consist of geographic and time-based comparisons in order to understand labor organization within the Tiwanaku state. The geographic comparisons are divided into three components: (1) **core versus colony**, (2) within the highland core (i.e. **inter-highland area** Tiwanaku Valley versus Katari Valley), and (3) within each valley (i.e. **intra-area**) during the Tiwanaku phase. **Chronological comparisons** were also performed in order to evaluate labor change over time. In addition, I also correlated sex and age-at-death with burial location in order to understand how geographic patterns of MSM activity reflect labor distribution.

6.2 Synopsis of the MSM Results

In the **regional comparison**, I found significant spatial differences in labor between individuals from the core and individuals from the colony (Section 6.3). The modeled rates of MSM were higher for individuals within the core. These results do not support the idea that Tiwanaku labor was organized in a centralized corvée *mit'a* labor model.

Inter-highland area (Section 6.4) comparisons showed similar modeled rates of MSM, ordinal muscle-use intensity scores, and no significant MSM differences between the Katari Valley and the Tiwanaku Valley. From these results, people in and around the highland core region during the Tiwanaku state all participated in various labors and

Appendix B, Table B.3, they show more about bilateral asymmetry, possibly handedness, than actual muscles involved in activity or level of labor performed.

activities. In addition, Katari Valley peoples did not labor more than those in the Tiwanaku Valley did.

Intra-area (Section 6.5) comparisons, showed significant differences within each area. Within the Katari Valley, Lukurmata and Pokachi Kontu individuals significant MSM differences with higher modeled rates and ordinal scores from Lukurmata. These data do not suggest that Lukurmata's residents were only local administrators. Instead, Lukurmata people worked physically hard and likely were often called upon to labor for themselves and others.

Within the Tiwanaku Valley, labor rates and ordinal scores were greatest for people buried at the Akapana, Akapana East, Marka Pata, and Mollo Kontu sites. Putuni and La K'araña burials had the lowest rates and ordinal scores, and MSM evidence supports these people performing less physically demanding labor, potentially indicating elite status. MSM results, together with the archaeological evidence, indicated multiple working communities and possible groups of laborers. For example, Ch'iji Jawira's residents could have been ceramic production specialists, Mollo Kontu residents could have been *llameros* who herded and butchered their livestock, and Akapana East residents may have been *chicha* brewers.

Modeled MSM rates within the Moquegua Valley were comparable with no statistically significant differences between Omo and the other sites. However, Rio Muerto and Chen Chen peoples had **upper body** and **foot** MSM differences. It is unclear what the two groups did that was dissimilar, but Rio Muerto's residents had greater MSM **upper body** rates, while Chen Chen had higher rates in the **foot** musculature. It is possible that Chen Chen peoples used a foot plow (i.e. *chaquitaqlla*) or may have ground grain with the feet, as has been noted in the highlands among modern Aymara people (Bruno 2011). Ordinal scores were highest from people of the Omo and Rio Muerto sites, but lowest from the Chen Chen site. No matter what tasks people performed, be it *chicha* brewing, farming, or herding (Goldstein 1993a, 2005), Rio Muerto and Omo peoples worked intensely. However, Chen Chen peoples, involved in canal-irrigated agricultural production (Bandy et al. 1996; Goldstein 2000; Williams 2006), labored much less intensely than Omo's or Rio Muerto's residents.

Chronological (Section 6.6) differences in the core showed people had heavier labor demands prior to the Tiwanaku-state. This may have been a reason for people to participate in the state as an incentive - reduced activity cost. Rates did not change from the Tiwanaku phase to the post-Tiwanaku phase. In the colony, labor rates for the Tiwanaku phase to the post-Tiwanaku phase were significantly lower after the Tiwanaku state lost influence in the Moquegua region, possibly as part of reduced trade network mobility and less highland demand for maize.

Synopsis of the Composition of the State's Workforce

In order to understand the various groups of people laboring within the Tiwanaku state, I looked at geographic differences by sex (i.e. between females, between males) and by age-at-death (Section 6.7). The **regional comparison** by sex showed females in the core worked significantly different tasks than females in the colony did, with higher rates in the core. Higher OA rates and significant differences between males, with higher rates for core males was also noted in this core versus colony comparison. The age-at-death **regional comparisons** for MSM indicated age-related task differences for each age-at-death category (i.e. 15-19, 20-29, 30-39, 40-49, and 50+ years) between the core and the colony, with higher MSM results in the core.

Inter-highland area sex comparisons (Katari Valley vs. Tiwanaku Valley) showed no division of labor by sex, although the ordinal scores were greater from the Tiwanaku Valley, which may indicate greater workload intensity. Age related differences in arm musculature were greater for younger people (age 15-19) and people in their thirties in the Katari Valley and greater for older people (age 50+) in the Tiwanaku Valley.

Inter-highland area comparisons within the Katari Valley showed higher labor from Lukurmata's female residents when compared to females buried at other sites. Males from Lukurmata also had higher MSM rates compared to the sites of Kirawi and Pokachi Kontu. Katari Valley **intra-area** age-at-death showed few age-related activity differences, with Kirawi people who died in their twenties had higher rates than Lukurmata's residents, while Lukurmata people who died in their thirties had the highest MSM rates.

Within the Tiwanaku Valley divisions of labor by sex indicated that women as well as men from Mollo Kontu worked as *llameros* and men from Akapana East may have been *chicha* brewers. The results also support the idea that people within the Tiwanaku Valley began working at heavy muscle building tasks as young people (i.e. under age 20), as has been shown in many modern Andean communities (Bolin 2006; Lucy 2005).

Within the Moquegua Valley, there were few MSM differences by sex. Instead, MSM labor changes were from differences in age-at-death, with higher labor rates for people age 30 and younger from Rio Muerto and highest for Omo people in their thirties. The lowest age-at-death rates were from people buried at the Chen Chen site for all ages except 50 and over, which may say something about higher survivorship for Chen Chen individuals.

6.3 Regional Core vs. Regional Colony MSM Results

Results for the MSM comparison between individuals the core highland region and the colony are presented in Table 6.1 (Full results by each MSM are in Appendix B, Table B.3). People who lived in both the core and the colony were involved in tasks that left evidence of MSM, as shown by the modeled frequency results. The majority of these modeled results also showed that rates were occasionally the same, but usually higher in the core than in the colony. In some cases, the results were different enough to be statistically significant.

In the **upper arm**, I found six statistically significant MSM differences (shown in bold font): *subclavius, trapezoid ligament*, *coracobrachialis*, *latissimus dorsi*, *teres major*, and *teres minor*. The combined **upper arm** MSM was also statistically significant in a comparison between the core and colony peoples. In terms of movement, the *subclavius* draws the clavicle inferiorly and anteriorly, as well as depressing the shoulder in forward and downward movements. The *trapezoid ligament* helps with scapula rotation in a forward and backward motion, similar to movements with the *subclavius*. The *coracobrachialis* muscle helps to flex and adduct the arm, as well as drawing the humerus forward and towards the shoulder. The *latissimus dorsi* extends, adducts (i.e. to move or draw toward the axis of the body), and medially rotates the humerus. Additionally, as the *latissimus dorsi* runs along the back, it helps raise the body during climbing motions and has a synergistic relationship with extension and flexion of the lumbar spine. The *teres major* adducts and medially rotates the arm, assisting the *latissimus dorsi* in drawing the raised humerus down and backward, as well as stabilizing the humeral head in the glenoid cavity. The *teres minor* muscle helps hold the humeral head in the shoulder joint and works in lateral rotation of the arm.

Of these significant MSM, modern studies (Ackland and Pandy 2009; Yu et al. 2011) have shown that one possible combined muscle movement is a forward then lateral “stirring motion” (external and lateral rotation). Core residents likely participated in this type of movement more than their counterparts in the colony did due to the higher modeled frequency numbers and the higher intensity ordinal scores for these six statistically significant MSM. In summary, the overall **upper arm** MSM category was statistically significant, with higher rates and ordinal scores, indicating that there were significant movement differences and levels of muscle-use intensity between the core and colony.

Combined **forearm** musculature rates were also statistically significant with higher modeled frequencies and ordinal scores for individuals from the core than those in the colony region. Of the 10 **forearm** MSM, five were statistically significant in the core versus colony comparison: *extensors* of common origin, *triceps brachii*, *brachioradialis*, *pronator teres*, and *supinator* muscles. The *extensors* of common origin, extend, abduct, and adduct the hand at the wrist joint, extend the medial four digits, and extend the hand at the wrist joint. This one **forearm** muscle was the only significantly greater modeled MSM among the colony peoples from Moquegua. In addition, the ordinal scores between the two regions for the *extensor* muscles showed a somewhat higher intensity among colonists.

Of the remaining four significant MSM in the **forearm**, all had greater modeled frequencies and ordinal scores for the people from the core highland region. *Triceps brachii* is the chief extensor of the **forearm**, especially of the elbow joint. A modern study (Richardson 2011) has shown that *triceps brachii* can also fix the elbow joint when the **forearm** and hand are used for fine movements, such as writing, painting, and weaving. *Brachioradialis*, a **forearm** flexor at the elbow, is involved when lifting heavy items during slow flexion of the **forearm** and is an elbow stabilizer during movements like hammering (Richardson 2011). *Pronator teres* pronates the **forearm**, turning the hand posteriorly and turning the palm inferiorly when the elbow is at a right angle. The *supinator* rotates the radius to turn the palm anteriorly, performing this movement in all positions of elbow flexion and extension, and is a primary muscle of wrist and hand movement.

The significant **forearm** MSM do not present an exact picture of a series of movements that core residents participated in to a greater degree than their counterparts in the colony of Moquegua did. They do suggest that **forearm** movements were significantly different between the two regions. <u>I would also suggest that fine motion **forearm** movements (e.g. locked elbow) as the kind noted above with the *triceps brachii*, may have been something performed more by core residents, while colonists were involved in motions that required dexterity in the wrist and hands due to the statistically significant comparison of the *extensor* MSM.</u>

Overall, these **upper arm** and **forearm** results indicate that there were differential movements performed during the Tiwanaku state, with higher significant rates and muscle-use intensity scores for all MSM, except *extensors* of common origin, for core residents than their counterparts in the colony. Additionally, these upper body data do not support the idea that colonists worked excessively hard, as might be expected under a corvée labor or as part of a *mit'a* system noted during the Inca Empire. Rather, it seemed that core Tiwanaku peoples had heavier demands on their labor, but that both groups used their arm and shoulder musculature, just in different ways and at different levels.

MSM **mid-body**, **lower body**, and **foot** results are also given in Table 6.1 (Full results are in Appendix B, Table B.4). These MSM would be involved with mobility, as these are the weight bearing bones and their associated muscles. Both the **mid-body** and **lower body** combined scores were statistically significant with greater rates and ordinal scores for core Tiwanaku peoples. Of the individual **mid-body** MSM, only the *gluteus medius* was significant. It is a major abductor of the thigh, which helps rotate the hip medially and laterally. In the lower-body MSM, only the *linea aspera* was significant. Located on the posterior, medial femur above the popliteal surface, the attachment point noted in this study is for the *adductor longus* and *adductor magnus* muscles. These muscles help in adduction and lateral rotation of the thigh associated with bipedal walking. The last statistically significant MSM in the lower anatomy was the *soleal* muscle as part of the **foot** musculature, although the combined MSM for the **foot** was not significant. The *soleal* muscle is the major plantar flexor of the ankle with a vital role in movements such as walking, running, and dancing, and it also 'pulls' the body backwards to help maintain bipedal posture (Richardson 2011).

The *gluteus medius*, *adductor longus*, *adductor magnus*, and *soleal* muscles are all active during the bipedal gait cycle (Loudon et al. 2008; Schultz et al. 2005). Specifically, these muscles are activated in walking from flat **foot** through midstance as part of the loading response of balancing while only on one **foot**, as shown in Figure 6.1. With the modeled frequencies in both core and colony, all individuals were mobile. However, with the higher modeled rates and greater ordinal intensity scores for these muscles and muscle groups from the core highland region, it was possible that core people were more mobile, had different terrain considerations, or used different tools (i.e. foot plow) than their counterparts in the colony.

Table 6.1 MSM Core vs. Colony Upper Anatomy Results during Tiwanaku Phase

MSM Use-Area	n=	Core Modeled % frequency	Core Ordinal Score Mean	Colony Modeled % frequency	Colony Ordinal Score Mean	χ^2 value (df=1)	*p*-value
UPPER ARM	**5801**	**63%**	**1.62**	**47%**	**1.03**	**15.99**	**<.0001**
FOREARM	**4569**	**56%**	**1.54**	**43%**	**0.96**	**12.0**	**.0005**
MID-BODY	**1941**	**77%**	**1.81**	**58%**	**1.10**	**8.54**	**.004**
LOWER BODY	**1449**	**62%**	**1.68**	**39%**	**1.15**	**18.78**	**<.0001**
FOOT	1510	62%	1.55	48%	0.91	3.33	.07

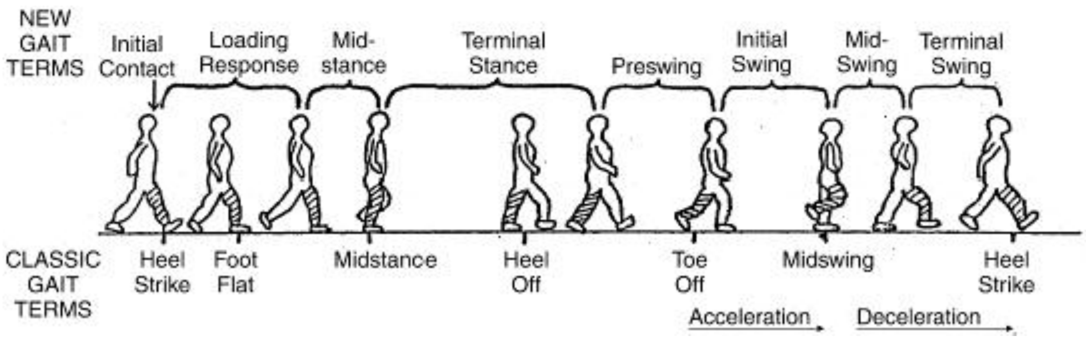

Figure 6.1 The Gait Cycle of Bipedal Walking (modeled after Cuccurullo 2010:458)

6.4 Inter-Highland Area Comparisons MSM Results

A comparison of all 37 individual MSM and the five combined areas of the body was performed between the core areas of the Katari Valley and Tiwanaku Valley. Modeled rates were approximately the same in each valley except for the *pronator teres*, which was statistically significant (Appendix B, Table B.4). This MSM could indicate some significant pronation motion in the **forearm** between the Katari and Tiwanaku Valley peoples. However, it is the only significant difference between these two areas, thus it is hard to say that there were major labor differences between those living in either valley. <u>Instead, from these inter-highland area comparisons it was much more likely that people participated in similar activities and activity levels throughout the highland core.</u>

6.5 Intra-Area Comparisons MSM Results

Results for site-by-site comparisons within the Katari Valley, within the Tiwanaku Valley, and within the Moquegua Valley during the Tiwanaku state are provided below for intra-area site comparisons. I evaluated each of the intra-area comparisons for the 37 MSM attachment points and the full results are in Appendix B.

For ease of comparison and in order to discuss general trends in movement and muscle intensity, I have included the combined five use-area MSM indicators modeled frequencies, their ordinal scores (1-3), and statistically significant results in this chapter.

Within the Katari Valley

The sites of Kirawi, Lukurmata, and Pokachi Kontu were compared to test for evidence of activity, levels of labor, and any significant differences during the Tiwanaku state within the Katari Valley[15]. Modeled frequencies for the three sites were relatively comparable, and there were one significant difference in the **lower body** MSM between Lukurmata and Pokachi Kontu, with higher rates from Lukurmata (Table 6.2, full results in Appendix B, Table B.5). The ordinal scores showed intensity differences between the three areas (Table 6.3). The sample from Lukurmata had the highest numbers and Kirawi had the lowest overall ordinal scores with all five MSM use-areas falling below a score of one. The ordinal numbers from Pokachi Kontu varied depending on region of the body, with lower scores for the **forearm**, **lower body**, and **foot**, but higher numbers for the **upper arm** and **mid-body**.

From these results, people who lived within the Katari Valley worked at similar activities that involved the use of the same muscle groups. However, intensity in activities varied among the people buried in this area. It is interesting to note that the ordinal scores were highest from the Lukurmata, with its varied population of possible farmers, crafters, and local administrators, while the more agriculturally oriented sites of Kirawi and Pokachi Kontu had relatively lower muscle-use intensity scores. The only

[15] All five sites had the potential to be included, but no results were noted for Qeya Kontu, and UriKatu Kontu peoples during the Tiwanaku time period for MSM.

significant MSM difference was in the **lower body** MSM between Lukurmata and Pokachi Kontu, which indicated some difference in knee musculature movement between the two sites. From the change in ordinal scores, I would also suggest that Lukurmata people used their muscles more intensely. Lukurmata's residents may have been a local source of labor their neighbors called upon for help.

Table 6.2 MSM Intra-Area Katari Valley GEE Chi-Square Results during the Tiwanaku Phase (df=1)

MSM Use-Area	Site / Modeled %	Lukurmata	Pokachi Kontu
UPPER ARM n=253	Kirawi / 62%	χ^2=0.32 *p*=.57	0.89 .35
	Lukurmata / 67%	-	1.31 .25
	Pokachi Kontu / 55%	-	-
FOREARM n=118	Kirawi / 50%	0.11 .74	0.00 1.00
	Lukurmata / 62%	-	0.38 .54
	Pokachi Kontu / 50%	-	-
MID-BODY n=51	Kirawi /67%	2.53 .11	0.41 .52
	Lukurmata / 84%	-	0.58 .45
	Pokachi Kontu / 75%	-	-
LOWER BODY n=66	Kirawi /43%	1.79 .18	0.04 .85
	Lukurmata / 74%	-	**11.43 .0007**
	Pokachi Kontu / 38%	-	-
FOOT n=41	Kirawi / 50%	0.27 .60	0.14 .71
	Lukurmata / 68%	-	0.00 .98
	Pokachi Kontu / 67%	-	-

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table 6.3 MSM Intra-Area Katari Valley Ordinal Mean Scores during the Tiwanaku Phase

MSM Use-Area	Kirawi	Lukurmata	Pokachi Kontu
UPPER ARM	0.72	1.66	1.08
FOREARM	0.67	1.77	0.58
MID-BODY	0.89	1.71	1.28
LOWER BODY	0.83	1.74	0.72
FOOT	0.83	1.61	0.50

<u>Within the Tiwanaku Valley</u>

The site-by-site comparisons for the Tiwanaku Valley are presented for the upper anatomy in Table 6.4 (full results in Appendix B, B.6). In the **upper arm** and **forearm**, Akapana East had one of the highest modeled frequencies and Putuni the lowest. Mollo Kontu peoples also had one of the highest rates in the **upper arm**, but more average rates in the **forearm**. Ch'iji Jawira peoples had lower rates of MSM in the **upper arm**, but the highest rates in the **forearm**. From these modeled rates, statistically significant results in the **upper arm** were noted for all seven sites located in the city of Tiwanaku[16]. In the **forearm**, the highest modeled rates from Ch'iji Jawira and Akapana East account for all of the significant differences between the sites except with each other. When looking at muscle-use intensity scores (Table 6.5), Putuni and La K'araña have the lowest ordinal scores, while Akapana East, Marka Pata, and Mollo Kontu have the highest scores throughout the body.

Table 6.6 contains the results for the **mid-body**, **lower body**, and **foot** MSM results. Modeled rates were highest from the sites of Marka Pata and Mollo Kontu, with

[16] There were no significant results for the rural sites of Tilata, Pukara, and Guaqui within the Tiwanaku Valley during the Tiwanaku time period.

lower results, wherever available, from Ch'iji Jawira and Putuni. These two sites were also responsible for the majority of lower anatomy significant differences between the seven sites. Ordinal scores (Table 6.5) also show the highest **mid-body**, **lower body**, and **foot** numbers for Akapana and Akapana East, lower results for Marka Pata and Mollo Kontu, and the lowest from Ch'iji Jawira, La K'araña, and Putuni.

From these results, I surmise that people who lived at these sites worked at a variety of tasks involving different motions in the **upper arm**. The use of these **upper arm** muscles was most intense in the sites of Akapana, Akapana East, Ch'iji Jawira, Marka Pata, and Mollo Kontu. However, results in the **upper arm** MSM were lowest for Putuni and La K'araña. These two sites, along with the Akapana site, have the lowest ordinal scores in the **forearm**.

Ch'iji Jawira residents' pattern of MSM indicated that these people performed tasks that were different from others sampled within the city of Tiwanaku, except Akapana East. However, muscle-use intensity was not that strong among the residents. As such, these data add support to the archaeological evidence that Ch'iji Jawira's residents were involved in ceramic production. The lower ordinal scores would also go along with the idea that they were embedded craft specialists who were not in service to the state's elite, but rather worked autonomously. In addition, the rates for the lower anatomy also suggest that the Ch'iji Jawira people were not highly mobile. While they may have been related to lower elevation populations in areas like modern-day Copacabana, Bolivia, it was unlikely that many of these people traveled often between there and the core city of Tiwanaku.

I would also suggest from the modeled frequencies, ordinal scores, and significant results that Akapana East's residents worked hard at tasks that involved **upper arm** and **forearm** musculature. Prior archaeological (Janusek 2004a, 2008) and bioarchaeological (Berryman 2011) research of Akapana East's residents suggests that these people were ritual specialists involved in *chicha* production, and my MSM results do not dispute this. Individuals buried here were actively working the muscles of their arms and **forearms**, especially when compared to other sites.

It is also interesting to note that La K'araña and Putuni, both sites that have been suggested as elite residences (Couture and Sampeck 2003; Escalante 2003), have significantly different chi-square results, low modeled rates of MSM throughout the body, and the lowest muscle-use intensity ordinal scores. My results support the idea these, possibly elite, people worked less than their counterparts did and were not highly mobile.

Marka Pata and Mollo Kontu were sites that contained few exotic raw lithic materials, akin to many rural sites as noted by Geisso (2011). Marka Pata peoples had diets relatively high in maize (Berryman 2011; Berryman et al. 2009). The results for Marka Pata in the **mid-body** and **foot** were relatively high and could indicate that these people were involved in the movement of maize or maize processing, as grinding with the feet is relatively common among modern highland Aymara people in Bolivia (Bruno 2011. Pers. comm). Also, while not directly noted in the diet of Marka Pata peoples, the production of freeze-dried potatoes (*chuño)* in the *altiplano* involves repeated walking on these small tubers to process into a dry-good suitable for later use. C*huño* was likely a staple crop during the Tiwanaku state, and its production may have taken hip and **foot** muscle balance in order to walk on the potatoes and produce large quantities for storage. In addition, Mollo Kontu people had high **mid-body**, **lower body**, and **foot** rates of MSM. The MSM data for Mollo Kontu indicated differences in mobility that support prior research (Couture 2003; Couture et al. 2008; Vallières 2010) of people from this site as pastoralists in charge of llama caravans.

Table 6.4 Upper Anatomy MSM Intra-Area Tiwanaku Valley GEE Chi-Square Results during the Tiwanaku Phase (df=1)

MSM Use-Area	Site / Modeled %	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
UPPER ARM n=468	Akapana / 67%	**χ^2=3.92 *p*=.048**	**11.95 .0005**	**8.70 .003**	0.63 .43	2.93 .09	**10.68 .001**
	Akapana East / 85%	-	**29.9 <.0001**	**25.4 <.0001**	**7.27 .01**	.06 .81	**24.3 <.0001**
	Ch'iji Jawira / 40%	-	-	**11.79 .0006**	**5.41 .02**	**26.03 <.0001**	1.42 .23
	La K'araña / 44%	-	-	-	3.36 .07	**21.84 <.0001**	2.70 .10
	Marka Pata / 59%	-	-	-	-	**5.89 .02**	**6.15 .01**
	Mollo Kontu / 83%	-	-	-	-	-	**21.69 <.0001**
	Putuni / 31%	-	-	-	-	-	-
FORE-ARM n=340	Akapana / 50%	**6.63 .01**	**55.13 <.0001**	1.63 .20	0.08 .78	0.65 .42	0.03 .87
	Akapana East / 83%	-	0.69 .41	2.48 .12	**5.99 .01**	3.16 .08	**7.34 .01**
	Ch'iji Jawira / 89%	-	-	**18.48 <.0001**	**59.05 <.0001**	**18.13 <.0001**	**67.47 <.0001**
	La K'araña / 64%	-	-	-	1.16 .28	0.12 .73	2.11 .15
	Marka Pata / 52%	-	-	-	-	0.37 .54	0.20 .65
	Mollo Kontu / 59%	-	-	-	-	-	0.91 .34
	Putuni / 48%	-	-	-	-	-	-

Table 6.5 MSM Intra-Area Tiwanaku Valley Ordinal Mean Scores during the Tiwanaku Phase

MSM Use-Area	Akapana	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
UPPER ARM	1.76	1.95	1.50	0.60	1.75	1.81	0.80
FOREARM	0.94	1.96	0.90	0.94	1.66	1.52	0.64
MID-BODY	2.32	2.50	1.30	0.33	1.85	1.92	0.92
LOWER BODY	2.12	2.06	0.67	0.56	1.78	1.60	-
FOOT	1.80	1.96	-	-	1.77	1.77	0.33

Table 6.6 Lower Anatomy MSM Intra-Area Tiwanaku Valley GEE Chi-Square Results during the Tiwanaku Phase (df=1)

MSM Use-Area	Site / Modeled %	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
MID-BODY n=389	Akapana / 68%	-[a]	-[a]	-[a]	χ^2=1.48 *p*=.22	0.71 .40	**7.82 .01**
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 84%	-	-	-	-	0.01 .90	**18.14 <.0001**
	Mollo Kontu / 82%	-	-	-	-	-	**7.87 .005**
	Putuni / 33%	-	-	-	-	-	-
LOWER BODY n=224	Akapana / 52%	2.69 .10	**5.03 .02**	0.32 .57	0.16 .69	**4.43 .04**	-[a]
	Akapana East / 89%	-	**9.08 .003**	2.21 .14	2.16 .14	0.04 .85	-[a]
	Ch'iji Jawira / 25%	-	-	**40.72 <.0001**	**12.97 .0003**	**14.79 .0001**	-[a]
	La K'araña / 60%	-	-	-	0.02 .90	**4.06 .04**	-[a]
	Marka Pata / 59%	-	-	-	-	3.82 .051	-[a]
	Mollo Kontu / 90%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
FOOT n=154	Akapana / 66%	-[a]	-[a]	-[a]	0.03 .87	0.03 .86	**18.52 <.0001**
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 69%	-	-	-	-	0.11 .74	**14.67 .0001**
	Mollo Kontu / 63%	-	-	-	-	-	**26.37 <.0001**
	Putuni / 13%	-	-	-	-	-	-

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Within the Moquegua Valley

Results for comparisons within the Moquegua Valley during the Tiwanaku phase are shown in Table 6.7 (full results in Appendix B, Table B.7-B.9). Of these, modeled rates were relatively comparable between Omo and sites of Chen Chen and Rio Muerto for all five use-areas of the body. The Chen Chen and Rio Muerto comparisons showed two statistically significant MSM differences in the **upper arm** and **foot**. In the **upper arm**, Rio Muerto had greater rates of MSM, while in the **foot** Chen Chen was higher. Ordinal MSM scores showed that residents of Chen Chen had the lowest intensity and Omo the highest with Rio Muerto in the middle (Table 6.8).

The results suggest that the Tiwanaku colonists buried in the Omo area performed many similar tasks to peoples from Chen Chen and Rio Muerto, but that the muscle-use intensities were distinct. Whatever activities the Omo peoples were performing, be it *chicha* brewing, farming, or herding (Goldstein 1993a, 2005), they worked hard at it. Rio Muerto peoples worked at similar tasks and nearly as intensely as those from Omo did. However, Chen Chen peoples, involved in canal-irrigated agricultural production (Bandy et al. 1996; Goldstein 2000; Williams 2006), labored much less intensely than Omo's or Rio Muerto's residents.

In addition, the statistical comparison between Chen Chen and Rio Muerto showed that **upper arm** activities were different, with Rio Muerto showing a higher modeled frequency. However, it is unclear from these data and the archaeological record exactly what types of activities the two groups did that was dissimilar. The individual MSM results showed differences in forward and backward scapula movement, which could be attributed to any number of dissimilar movements between the residents of Chen Chen and Rio Muerto. The significant **foot** results, with higher modeled rates from Chen Chen and the likelihood that these people were maize growers, could indicate something like grinding with the feet (Bruno 2011. Pers. comm). It is also interesting to note that the individual MSM, show differences in toe flexion that could be related to a controlled movement associated with using the feet to grind maize. Whatever the action or mobility, these differences were enough to show up as statistically significant in the results.

Table 6.7 MSM Intra-Area Moquegua Valley GEE Chi-Square Results during the Tiwanaku Phase (df=1)

MSM Use-Area	Site / Modeled %	Omo	Rio Muerto
UPPER ARM n=5080	Chen Chen / 45%	χ^2=1.35 *p*=.17	**5.68 .02**
	Omo / 49%	-	0.74 .39
	Rio Muerto / 53%	-	-
FORE-ARM n=4111	Chen Chen / 42%	1.89 .18	0.62 .43
	Omo / 47%	-	2.80 .09
	Rio Muerto / 40%	-	-
MID-BODY n=1743	Chen Chen / 58%	0.06 .81	0.01 .94
	Omo / 59%	-	0.06 .80
	Rio Muerto / 58%	-	-
LOWER BODY n=1011	Chen Chen / 39%	0.00 .99	0.19 .66
	Omo / 39%	-	0.13 .72
	Rio Muerto / 42%	-	-
FOOT n=1378	Chen Chen / 50%	2.44 .12	**4.16 .04**
	Omo / 43%	-	0.32 .57
	Rio Muerto / 40%	-	-

Table 6.8 MSM Intra-Area Moquegua Valley Ordinal Mean Scores during the Tiwanaku Phase

MSM Use-Area	Chen Chen	Omo	Rio Muerto
UPPER ARM	0.87	1.35	1.21
FOREARM	0.80	1.42	1.20
MID-BODY	0.91	1.67	1.38
LOWER BODY	0.98	1.55	1.42
FOOT	0.83	1.23	1.03

6.6 Chronological MSM Results

The chronological comparison between the core and the colony during the Tiwanaku phase was presented in Section 6.2, as it is also the regional comparison. The results showed differences in modeled rates, in ordinal scores, and in statistical comparisons. In summary, the modeled rates were higher and ordinal rates were greater in the core area than in the colony. There were multiple significant MSM comparisons throughout the body, with four (**upper arm**, **forearm**, **mid-body**, and **lower body**) out of the five use-areas as significantly different between the two regions. From these overall results, I suggest that people labored harder at different tasks in the core during the Tiwanaku state. What follows are the intra-core and intra-colony chronological results in which I looked for change over time within these regions.

Intra-Core

The core highland area change over time was primarily noted during the transition from the Late Formative to the Tiwanaku phase. Among residents of this area, upper body statistically significant differences were found in various MSM of the **upper arm**, as well as the **upper arm** as a combined use area (Table 6.11, full results are in Appendix B, Table B.10). These rates were higher during the Late Formative in the core area of highland Bolivia. Ordinal scores were usually higher during the Late Formative, and occasionally higher during the Tiwanaku state. This same pattern is noted in the lower anatomy results, with higher modeled rates during the Late Formative and significant differences in the **mid-body** MSM.

These results indicate that people who lived and died in the core area had heavier labor demands prior to the Tiwanaku-state and this may have been a reason for people to participate in the Tiwanaku state. This state may have included reduced activity cost and effort in that labor was shared more equally and reciprocally as a reduction to workload levels during the Tiwanaku state. This participation in a shared labor network may have also continued after the state's loss of control in the highlands, as there were similar modeled frequencies, ordinal numbers, and no statistically significant differences in the transition from the Tiwanaku to the post-Tiwanaku phase (Appendix B, Table B.11).

Table 6.9 Core Upper Anatomy MSM Results from Late Formative to the Tiwanaku Phase

MSM Use Area	n=	LF Modeled % frequency	LF Ordinal Score Mean	TW Modeled % frequency	TW Ordinal Score Mean	χ^2 value (df=1)	*p*-value
UPPER ARM	**1074**	**82%**	**1.71**	**63%**	**1.62**	**7.74**	**.01**
FOREARM	697	66%	1.20	56%	1.54	2.29	.13
MID-BODY	**310**	**90%**	**1.62**	**77%**	**1.81**	**4.11**	**.04**
LOWER BODY	269	70%	1.56	62%	1.68	0.98	.32
FOOT	227	70%	0.77	62%	1.55	0.61	.44

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Intra-Colony

The results for chronological comparisons within the Moquegua Valley were performed between the Tiwanaku and Post-Tiwanaku phase samples. Data were calculated between the Late Formative and the Tiwanaku periods, however modeled results were inconclusive due to the small sample size from prior to the state and thus not presented in this chapter.

The Tiwanaku to Post-Tiwanaku MSM comparisons are given in Table 6.10 (full results are in Appendix B, Table B.12). In general, the modeled percentages in this chronological comparison show greater rates during the Tiwanaku occupation in the

Moquegua Valley. Three individual MSM in the **upper arm** and one MSM in the **forearm** were statistically significant, with only the *trapezius* having higher rates during the post-Tiwanaku phase. Ordinal scores show a variety of differences in both periods and do not point to either time having a greater intensity of muscle-use.

In the lower anatomy, there was one difference in the combined use-area of the **lower body**, with higher rates during the Tiwanaku phase. There were also four individually significant MSM in the lower anatomy that did not represent any direct picture of changes in movement between these two groups. However, it was possible that the individual markers from the lower anatomy represent a change in mobility after the collapse of the state. It was possible that there was a reduction in mobility among Moquegua Valley peoples, possibly reduced llama trade caravans to the highlands after the collapse of the Tiwanaku polity. This lack of long distance trade has been noted archaeologically in the highlands with the change to fortified settlements and reduction in the movement of goods in highland regions such as the Katari Valley (Bermann 2003; Janusek 2004a). These MSM data from the post-Tiwanaku Tumilaca la Chimba peoples likely represented a reduction in labor and movement across the landscape with the loss of Tiwanaku control in this region. In addition, as Tumilaca la Chimba was my only post-Tiwanaku sample, it is possible that these results represent only a small group of Moquegua Valley post-Tiwanaku peoples and thus, future research is needed to see if this reduction in mobility and **upper arm** labors were common throughout the area after the state lost influence in the Moquegua Valley.

Table 6.10 Colony MSM Results from Tiwanaku to Post-Tiwanaku Phase

MSM Use-Area	n=	TW Modeled % frequency	TW Ordinal Score Mean	PT Modeled % frequency	PT Ordinal Score Mean	χ^2 value (df=1)	*p*-value
UPPER ARM	5528	47%	1.03	41%	1.27	2.23	.14
FOREARM	4471	43%	0.96	39%	1.25	1.20	.27
MID-BODY	1871	58%	1.10	48%	1.35	3.27	.07
LOWER BODY	**1098**	**39%**	**1.15**	**14%**	**1.53**	**11.82**	**.001**
FOOT	1506	48%	0.91	34%	1.17	3.38	.07

6.7 Composition of the State's Workforce Using MSM

The second research question in this study concerns the composition of the Tiwanaku state's workforce, as I am interested in how modeled rates of MSM, ordinal scores of intensity, and significant differences between subgroups reflect the social structure (e.g. gendered labor) and distribution of activity across the landscape. As such, I recorded data for individuals from the core and colony region during the Tiwanaku phase for both sex and age-at-death. Results are presented below in order to discuss age-related tasks and gendered division of labor in various areas throughout the Tiwanaku state.

Regional MSM Comparison by Sex and by Age

MSM results for females in the core and colony areas are presented in Table 6.11 (full results in Appendix B, Table B.13). In general, females from the core region have higher modeled frequencies of each MSM, as well as in the **upper arm** and **forearm** combined use-area categories. Muscle-use intensity ordinal scores were also generally greater among core females than those found in the colony. Significant differences between the two regions were found in three **upper arm** MSM, the combined **upper arm** use-area MSM, and the *brachioradialis* MSM in the **forearm**. Lower anatomy results showed most of the modeled frequencies were greater among the core females, with a few exceptions that were not statistically significant. The **lower body** combined use-area, the *linea aspera*, and *soleal* individual MSM were significant with greater frequencies and ordinal numbers from core females.

The labor comparison between males from the core and colony are presented in Table 6.12 (full results in Appendix B, Table B.14). Of the 25 upper anatomy individual MSM, 10 were significantly different between males from the core and the colony areas. In all of these cases, modeled rates and ordinal scores were higher among males from the core. In addition, these data also translated into both the **upper arm** and **forearm** combined use-areas as significantly different, with higher modeled percentages and intensity scores among core males. Lower anatomy results were similar in that any significant differences were the result of higher modeled rates among core males, with greater ordinal scores among the same group. The combined use-areas of **mid-body** and **lower body** MSM were also significantly different between these two groups.

In summary, the results in the comparison between core and colony females were similar to the regional results not divided by sex – higher rates and ordinal scores in the core. The significant differences suggest that there were differences in movement, activity, and labor among females between the two regions. In addition, combined results that showed heavier **upper arm** and **lower body** workload indicate weightier labor intensity among women in the core than in the colony.

Akin to the results noted for females, males from the core worked their muscle attachment points at greater modeled rates than their counterparts in the colony did. The overall muscle-use intensity scores were much higher among males in the core during the

Tiwanaku state. These outcomes indicate that males in and around the Titicaca Basin area of Bolivia worked much harder and more intensely than their counterparts in the Moquegua Valley colony. Both groups were working, but highland males worked at different activities than colonists, as is shown by the significant difference and modeled frequencies in the MSM results.

Overall, the regional MSM comparison by sex showed that both males and females in the core worked different tasks than did their colleagues in the colony. One possible explanation for the differences is agriculture, which was likely important in both of these regions, and would have been differently adjusted for terrain, elevation, and crops grown (Erickson 1985, 2006; Erickson and Candler 1989; Goldstein 2005; Janusek 2004a, 2008). The fact that both men and women in the core worked harder, as shown through ordinal scores and modeled frequencies of MSM, is somewhat unexpected and does not directly concur with models of Tiwanaku state formation. From the significant muscle comparisons, it also looks like both men and women within the core worked at different tasks, especially activities that used dissimilar muscles in the **upper arm** and **forearm** areas. Additionally, males from the core were more mobile than females from the same region, as was shown by the modeled frequencies.

Regional age comparisons were evaluated between groups within each of the five age-at-death categories, 15-19 years, 20-29 years, 30-39 years, 40-49 years, and 50+ years. Prior research (Chapman 1997; Jurmain 1999; Jurmain et al. 2012; Kennedy 1998; Pearson and Buikstra 2006; Toyne 2004, 2008) has shown that people build bony attachment points throughout life and that the presence and intensity can be contingent upon age. Hence, the older the individual, the greater the likelihood he or she will show

MSM. By restricting comparisons to each age-at-death category and not judging between age groups, problems with survivorship (an individual's ability to survive to an older age) are limited. Thus, the results provide information on body movement, workload levels, and significant activity differences adults were subjected to within each age-at-death category, as well as activities that may have been age-dependent tasks within the Tiwanaku state.

Age-at-death comparisons between the core and colony regions for each of the five use-area MSM results are shown in Table 6.13. Within these comparisons, the modeled rates were higher for individuals in the core than those in the colony (except for **upper arm** MSM in adults 50+ years). All ages, except for 50+ years, had significant differences for the five use-areas of the body (individual significant MSM are in Appendix B, Table B.15). The youngest people had significant MSM in all regions of the body except the **upper arm**. People in their twenties and thirties had the same pattern of significant MSM – **upper arm**, **forearm**, **mid-body**, and **lower body**. People in their forties had significant core versus colony differences in the **upper arm**, **forearm**, and **lower body**. In almost each category, MSM ordinal use-intensity scores increased with the age of individuals observed. The muscle-use intensity scores were greater for the core than the colony in almost all comparisons. However, for people who died in their twenties, these ordinal scores were occasionally lower in the core.

These age-at-death comparisons for MSM indicate age-related task differences between the core and the colony. From the pattern of significant MSM, it looks like all age groups, except the oldest individuals, worked at higher rates with greater muscle-use intensity in the core during the Tiwanaku state. The exception to this was in the **forearm** and **lower body** MSM comparisons in the 20-29 age-at-death category. Why these two MSM comparisons, with higher modeled rates in the core, have higher ordinal scores in the colony is unclear. Additionally, in the significant individual 37 MSM regional comparisons (Appendix B, Table B.15), rates were higher for all individuals from the core. The one exception to this was in the *extensors* muscles (of common origin) in the 30-39 age-at-death category. This same significant difference was noted in the overall regional comparisons (see Section 6.3), and suggests that colonists who died in their thirties worked at tasks that involved movement in the fingers and wrist involving the *extensor* muscles. In addition, many of these individual MSM from the overall regional results correspond with the findings when divided by age-at-death. For example, *brachioradialis* was significant in older individuals from the 40-49 age-at-death category, and *triceps brachii* was significant in younger individuals in their late teens and twenties. However, there were no discernible labor patterns (e.g. changes in the gait cycle for a certain age group) found when comparing the overall and age-at-death results.

Table 6.11 MSM Core vs. Colony Results during Tiwanaku Phase for FEMALES

MSM Use-Area	n=	Core Modeled % frequency	Core Ordinal Score Mean	Colony Modeled % frequency	Colony Ordinal Score Mean	χ^2 value (df=1)	*p*-value
UPPER ARM	**2933**	**62%**	**1.55**	**47%**	**1.11**	**6.01**	**.01**
FOREARM	2310	49%	1.34	43%	0.93	1.64	.20
MID-BODY	1025	75%	1.61	58%	1.06	3.48	.06
LOWER BODY	**557**	**59%**	**1.55**	**35%**	**1.07**	**8.32**	**.004**
FOOT	739	57%	1.61	48%	0.90	0.97	.33

Table 6.12 MSM Core vs. Colony Results during Tiwanaku Phase for MALES

MSM Use-Area	n=	Core Modeled % frequency	Core Ordinal Score Mean	Colony Modeled % frequency	Colony Ordinal Score Mean	χ^2 value (df=1)	*p*-value
UPPER ARM	**2223**	**69%**	**1.75**	**47%**	**1.05**	**11.17**	**.001**
FOREARM	**1695**	**66%**	**1.63**	**16%**	**1.02**	**17.04**	**<.0001**
MID-BODY	**713**	**79%**	**1.93**	**57%**	**1.12**	**4.04**	**.04**
LOWER BODY	**467**	**67%**	**1.65**	**43%**	**1.20**	**8.03**	**.005**
FOOT	589	57%	1.64	46%	0.93	0.79	.37

Table 6.13 MSM Core vs. Colony Results, Tiwanaku Phase by AGE-AT-DEATH

MSM Use-Area	n=	Core Modeled % frequency	Core Ordinal Score Mean	Colony Modeled % frequency	Colony Ordinal Score Mean	χ^2 value (df=1)	*p*-value
15-19 years							
UPPER ARM	560	55%	1.25	37%	1.07	2.73	.10
FOREARM	**395**	**40%**	**1.29**	**26%**	**0.98**	**9.67**	**.002**
MID-BODY	**153**	**71%**	**1.33**	**39%**	**1.03**	**20.20**	**<.0001**
LOWER BODY	**106**	**63%**	**1.40**	**12%**	**0.94**	**25.4**	**<.0001**
FOOT	**126**	**80%**	**1.50**	**34%**	**1.07**	**4.79**	**.03**
20-29 years							
UPPER ARM	**2479**	**70%**	**1.31**	**51%**	**1.14**	**8.04**	**.005**
FOREARM	**1943**	**61%**	**1.01**	**48%**	**1.15**	**5.44**	**.02**
MID-BODY	**840**	**90%**	**1.50**	**66%**	**1.21**	**9.84**	**.002**
LOWER BODY	**515**	**64%**	**1.23**	**46%**	**1.34**	**6.36**	**.01**
FOOT	395	43%	1.47	33%	1.09	0.54	.46
30-39 years							
UPPER ARM	**2479**	**70%**	**1.67**	**51%**	**1.14**	**8.04**	**.005**
FOREARM	**1943**	**61%**	**1.59**	**48%**	**1.14**	**5.44**	**.02**
MID-BODY	**840**	**90%**	**1.77**	**66%**	**1.39**	**9.84**	**.002**
LOWER BODY	**515**	**64%**	**1.69**	**46%**	**1.37**	**6.36**	**.01**
FOOT	692	70%	1.32	54%	1.05	1.80	.18
40-49 years							
UPPER ARM	**648**	**82%**	**1.81**	**50%**	**1.24**	**12.82**	**.0003**
FOREARM	**559**	**73%**	**1.78**	**49%**	**1.14**	**7.96**	**.005**
MID-BODY	229	-	-	-	-	-	-[a]
LOWER BODY	**123**	**91%**	**1.87**	**47%**	**1.28**	**13.51**	**.0002**
FOOT	149	80%	1.82	65%	0.85	.62	.43
50+ years							
UPPER ARM	385	52%	1.77	58%	1.19	0.09	.76
FOREARM	294	71%	1.62	54%	1.29	2.35	.13
MID-BODY	119	-	-	-	-	-	-[a]
LOWER BODY	72	-	-	-	-	-	-[a]
FOOT	97	87%	1.99	51%	0.87	0.06	.8

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Inter-Highland Area MSM Comparisons by Sex and by Age

When contrasting the Katari Valley and Tiwanaku Valley by sex, no significant results in major modeled frequency differences for males or females were found. Ordinal results (Table 6.14) showed higher rates for both males and females in the Tiwanaku Valley. From these results, I propose that movement and activities for both males and females worked similar tasks during the Tiwanaku state in both highland areas. However, muscle-use intensity, as shown in the ordinal scores, was greater among both males and females who were buried in the Tiwanaku Valley. Thus, I believe that workload intensity was elevated in and around the city of Tiwanaku when compared to male and female residents of the Katari Valley.

Significant inter-highland area age-at-death results between the Katari Valley and the Tiwanaku Valley are shown in Table 6.15. There were only upper anatomy differences for adults in the 15-19, 30-39, and over 50 years age-at-death categories. For people in their late teens, **forearm** MSM rates were higher among the Katari Valley sample. For people who died in their thirties, **upper arm** MSM had higher rates in the Katari Valley. For the oldest people in the sample, **upper arm** and **forearm** modeled rates were higher for adults from the Tiwanaku Valley. In addition, in all of the significant comparisons, Tiwanaku had higher ordinal rates.

From these results, I suggest that there were some significant differences by age between the Katari Valley and Tiwanaku Valley. In the comparisons that were significant, all were upper body MSM. Younger individuals worked at higher rates in the Katari Valley, while those who made it to age 50 and older likely survived longer in the Tiwanaku Valley to show higher modeled rates of MSM. In addition, the ordinal scores suggest that the workload was heavier among people living in the Tiwanaku Valley for all age groups, with the highest numbers for people age 50 and older.

Table 6.14 MSM Inter-Highland Area Valley Ordinal Mean Scores during the Tiwanaku Phase for FEMALES and MALES

MSM Use-Area	FEMALES		MALES	
	Katari Valley	Tiwanaku Valley	Katari Valley	Tiwanaku Valley
UPPER ARM	0.97	1.18	1.29	1.53
FOREARM	1.04	1.20	1.87	1.51
MID-BODY	1.16	1.58	1.41	1.87
LOWER BODY	1.13	1.57	1.05	1.85
FOOT	1.06	1.33	1.32	1.77

Table 6.15 MSM Inter-Highland Area Results during Tiwanaku Phase by AGE-AT-DEATH

MSM Use-Area	n=	Katari Valley Modeled % frequency	Katari Valley Ordinal Score Mean	Tiwanaku Valley Modeled % frequency	Tiwanaku Valley Ordinal Score Mean	χ^2 value (df=1)	*p*-value
15-19 years							
FOREARM	**15**	**55%**	**1.08**	**35%**	**1.44**	**9.42**	**.002**
30-39 years							
UPPER ARM	**244**	**84%**	**1.49**	**59%**	**1.54**	**6.68**	**.001**
50+ years							
UPPER ARM	**21**	**30%**	**1.78**	**73%**	**1.90**	**15.04**	**.0001**
FOREARM	**14**	**57%**	**1.65**	**86%**	**2.02**	**4.52**	**.03**

Intra-Area MSM Comparisons by Sex and by Age

In the following sections, I present the data from the comparisons within the Katari Valley, within the Tiwanaku Valley, and within the Moquegua Valley in order to discuss the composition of the workforce within the Tiwanaku state. A brief note is needed on the presentation of data, as each MSM was not provided in this section. The results by sex are presented for the combined use-area MSM indicators (i.e. **upper arm**, **forearm**, **mid-body**, **lower body**, and **foot**), their respective modeled frequencies, and if they were or were not statistically significant. For the results by age-at-death, only the significant results and their modeled frequencies are presented. All other results are presented in Appendix B. Ordinal results for both sex and age-at-death are found in a separate table for each indicator. In addition, for the Katari and Moquegua Valley sex results, data are presented side-by-side for females and males. Due the large amount of comparative data within the Tiwanaku Valley (i.e. seven different site comparisons), data are first given for females and then for males.

Within the Katari Valley

The results for females and males in site-by-site comparisons for the Katari Valley are shown in Table 6.16. Among females, the modeled frequencies are highest from Lukurmata and lowest from Pokachi Kontu. All significant differences were between Pokachi Kontu and Kirawi or Lukurmata, with no significant results between Lukurmata and Kirawi females. The ordinal scores (Table 6.17) were greatest in females from Lukurmata, and approximately the same scores between females buried at Kirawi or Pokachi Kontu.

Males from these three Katari Valley sites had modeled rates which varied in the combined MSM areas, with only one significant difference between Lukurmata and Pokachi Kontu in the **lower body** MSM. Ordinal scores were highest for males from Lukurmata, akin to the results noted for females; however, Pokachi Kontu males also had somewhat high muscle-use intensity scores, especially when compared with Kirawi.

These results suggest differences in activities between Pokachi Kontu females and males with the other two sites in the Katari Valley. However, the small sample from which sex was estimated for Pokachi Kontu may be inflating differences. Overall, the higher muscle-use intensity scores from Lukurmata indicated that these people worked harder than those buried at the two other Katari Valley sites.

Within the Katari Valley, significant age-at-death MSM site comparisons are shown in Table 6.18. The only significant results were found in people from the 20-29 and 30-39 age-at-death categories. For people in their twenties, Kirawi had higher rates of MSM in the **upper arm** and was significantly different from Lukurmata. For people who died in their thirties, Lukurmata had significantly higher rates in the **upper arm** and **lower body** when compared with Pokachi Kontu. The ordinal scores (Table 6.19) showed that muscle-use intensity scores were higher from Lukurmata for both age groups.

From these MSM results, I suggest that there were few age-related activity differences within the Katari Valley. For the differences that were significant, Kirawi people who died in their twenties performed more **upper arm** tasks when compared to Lukurmata people of the same age. It was possible that tasks were harsher for younger people from Kirawi. However, the ordinal scores suggest that labor intensity was greater for the Lukurmata area. For people in their thirties, labor differences indicate **upper arm** and **lower body**, possibly mobility, changes between Lukurmata and Pokachi Kontu. The higher ordinal scores for the 30-39 age-at-death category show muscle-use intensity was much heavier throughout the body among the Lukurmata populations. If life was tougher during the Tiwanaku state in the rural sites, I would have expected higher ordinal scores for sites like Kirawi and Pokachi Kontu. It may also be that Kirawi people worked harder as younger individuals and did not survive to older ages. However, the size of the Katari

Valley sample population for which age could be estimated was somewhat small, and sample size is a factor to consider when evaluating these results.

Table 6.16 MSM Intra-Area Katari Valley GEE Chi-Square (df=1) Results during the Tiwanaku Phase for FEMALES and MALES

MSM Use-Area	FEMALES			MALES		
	Site / Modeled %	Lukurmata	Pokachi Kontu	Site / Modeled %	Lukurmata	Pokachi Kontu
UPPER ARM n=130 **F** n=95 **M**	Kirawi / 57%	χ^2=1.29 *p*=.26	**583.28 <.0001**	Kirawi / 67%	χ^2=0.15 *p*=.70	0.14 .71
	Lukurmata / 70%	-	**4.54 .03**	Lukurmata / 74%	-	0.36 .55
	Pokachi Kontu / 45%	-	-	Pokachi Kontu / 64%	-	-
FORE-ARM n=50 **F** n=54**M**	Kirawi / %			Kirawi / %	-[a]	-[a]
	Lukurmata / 51%	-	**16.08 <.0001**	Lukurmata / 74%	-	-[a]
	Pokachi Kontu / 25%	-	-	Pokachi Kontu / %	-	-
MID-BODY n=30 **F** n=17 **M**	Kirawi / 67%	1.41 .24	2.86 .09	Kirawi / %	-[a]	-[a]
	Lukurmata / 79%	-	1.41 .24	Lukurmata / 91%	-	-[a]
	Pokachi Kontu / 67%	-	-	Pokachi Kontu / %	-	-
LOWE R BODY n=28 **F** n=25 **M**	Kirawi / 67%	0.19 .66	**487.28 <.0001**	Kirawi / 25%	2.76 .10	0.60 .44
	Lukurmata / 73%	-	**6.35 .01**	Lukurmata / 80%	-	**8.14 .004**
	Pokachi Kontu / 33%	-	-	Pokachi Kontu / 50%	-	-
FOOT n=18 **F** n=20 **M**	Kirawi / %	-[a]	-[a]	Kirawi / %	-[a]	-[a]
	Lukurmata / %	-	-[a]	Lukurmata / 59%	-	-[a]
	Pokachi Kontu / %	-	-	Pokachi Kontu / %	-	-

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table 6.17 MSM Intra-Area Katari Valley Ordinal Mean Scores during the Tiwanaku Phase for FEMALES and MALES

MSM Use-Area	FEMALES			MALES		
	Kirawi	Lukurmata	Pokachi Kontu	Kirawi	Lukurmata	Pokachi Kontu
UPPER ARM	0.75	1.54	0.63	0.82	1.78	1.28
FOREARM	0.67	1.44	1.00	-	1.87	-
MID-BODY	1.00	1.66	0.83	-	1.78	1.44
LOWER BODY	1.00	1.72	0.67	0.67	1.73	0.75
FOOT	0.67	1.46	-	-	1.64	-

Table 6.18 MSM Intra-Area Katari Valley GEE Chi-Square (df=1) Results during the Tiwanaku Phase by AGE-AT-DEATH

MSM Use-Area	Site / Modeled %	Lukurmata	Pokachi Kontu
	20-29		
UPPER ARM n=80	Kirawi / 60%	**χ^2=5.06 *p*=.02**	-[a]
	Lukurmata / 47%	-	-[a]
	Pokachi Kontu / %	-	-
	30-39		
UPPER ARM n=105	Kirawi / %	-[a]	-[a]
	Lukurmata / 92%	-	**63.26 <.0001**
	Pokachi Kontu / 55%	-	-
LOWER BODY n=31	Kirawi / %	-[a]	-[a]
	Lukurmata / 82%	-	**13.26 .0003**
	Pokachi Kontu / 33%	-	-

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table 6.19 MSM Intra-Area Katari Valley Ordinal Mean Scores during the Tiwanaku Phase by AGE-AT-DEATH Table

MSM Use-Area	Kirawi	Lukurmata	Pokachi Kontu
		20-29	
UPPER ARM	0.79	0.98	-
FOREARM	-	0.72	-
MID-BODY	1.00	1.31	1.33
LOWER BODY	-	1.33	0.83
FOOT	-	0.89	-
		30-39	
UPPER ARM	-	1.90	1.08
FOREARM	-	1.96	0.58
MID-BODY	-	1.89	1.25
LOWER BODY	-	1.88	0.67
FOOT	-	1.34	1.37

Within the Tiwanaku Valley

Intra-area upper anatomy results for females from the Tiwanaku Valley are found in Table 6.20. Akapana, Marka Pata, and Mollo Kontu have the highest number of <u>females</u> and represent the best sites to address divisions of labor within the Tiwanaku workforce. In the **upper arm** MSM, Marka Pata's comparisons with both Akapana and Mollo Kontu were significantly different from each other, and suggest that females from Marka Pata worked at different upper anatomy tasks. From the ordinal scores (Table 6.21), Akapana, Akapana East, Marka Pata, and Mollo Kontu females worked with the most muscle-use intensity throughout the body.

Ch'iji Jawira also had many significant differences in the **upper arm** and **forearm**, which may be attributable to the smaller sample size (one female present). However as these were modeled results from multiple MSM, it is interesting to note that there were many significant differences and high **forearm** MSM rates when other sites were compared to Ch'iji Jawira. In the lower anatomy (Table 6.22), **mid-body** results among Tiwanaku Valley females were only different between Marka Pata and Putuni, with higher rates from Marka Pata. In the lower body, Mollo Kontu was significantly different from the sites of Marka Pata and Putuni. Putuni in the **foot** MSM was also significantly different from Mollo Kontu and Akapana due to the low modeled frequencies from this site.

Akin to the female sample, Akapana, Marka Pata, and Mollo Kontu had the highest number of males in the sample from the Tiwanaku Valley, with lesser numbers from Akapana East, La K'araña, and Putuni. There was no sample of males from Ch'iji Jawira. From those sampled, high modeled **upper arm** and **forearm** rates were noted for the Akapana East and Mollo Kontu areas (Table 6.23). La K'araña had the lowest modeled rates and was significantly different in the **upper arm** MSM from Akapana East and Marka Pata. Putuni was also significantly different from Akapana East and La K'araña. Ordinal scores (Table 6.24) were also highest from Akapana, Akapana East, Marka Pata, and Mollo Kontu with the lowest numbers from La K'araña and Putuni. Additionally, lower anatomy modeled rates were higher for all sites and there were no significant differences (Table 6.25).

Overall, the results by sex within the Tiwanaku Valley for females showed that Akapana, Marka Pata, and Mollo Kontu females worked the hardest with some significant movement differences in the upper body between these three sites. **Mid-body**, **lower body**, and **foot** MSM rates were high among Mollo Kontu females and these results support the idea that women may have participated in llama caravans as *llameras*. Marka Pata also had high lower anatomy modeled frequencies among females and may indicate that like Mollo Kontu females were highly mobile. It is also possible, from the upper body results and the archaeological evidence from Ch'iji Jawira (Janusek 2004a, 2005a; Rivera 1994, 2003), that the female buried there was some kind of ceramic specialist due to the lower **upper arm** MSM, but heavy **forearm** musculature and ordinal scores.

<u>The intra-area results for Tiwanaku Valley males showed upper anatomy MSM differences.</u> Mollo Kontu's significant differences from Akapana, La K'araña, and Marka Pata, and higher **forearm** MSM numbers may indicate an activity performed by males at this site that was not common among other males. One possible suggestion is that if these men were *llameros*, and assuming the alpacas required leads, they developed strong **forearm** muscles and developed great grip strength while holding caravan reins. Modern studies have shown that one *llamero* is generally responsible for about 20 animals as part of the llama caravan (Tripcevich 2008) and it may be that maintaining control over 20 camelids caused Mollo Kontu people to develop strong **forearm** gripping musculature.

Additionally, Akapana East also had significant differences from La K'araña and Putuni in the upper arm for males. Akapana East was also significantly different in the **forearm** from Putuni, but not La K'araña. As Akapana East may have been home to some kind of ritual specialists, including *chicha* brewers (Berryman 2011; Janusek 2004a), it is interesting that these modeled rates and ordinal scores for males were significantly higher than in sites which were also supposed to be home to elites and/or ritual specialists (Couture and Sampeck 2003; Escalante 2003). It was possible that these **upper arm** and **forearm** MSM results show the difference between men working in Akapana East as ritual specialists, La K'araña elite males of lower status (Escalante

2003), and the highest status males who were buried at the Putuni palace during the Tiwanaku state.

Significant results for MSM age-at-death comparisons within the Tiwanaku Valley were only found for younger individuals in the 15-19 and 20-29 categories (Table 6.26). For people who died in their late teens, **upper arm** and **forearm** MSM were significantly different between Marka Pata and Mollo Kontu, with higher modeled rates from Mollo Kontu. **Upper arm** ordinal scores were greater at Mollo Kontu, but lower in the **forearm** (Table 6.27). These results suggest some **upper arm** and **forearm** task that people in the 15-19 age-at-death category were doing at Mollo Kontu differently from Marka Pata. Mollo Kontu may have been home to llama herders and butchers (Couture et al. 2008; Vallières 2010), and it was possible that this was a job started at a younger age, as is noted in many modern Andes populations (Bolin 2006; Mitchell 2003).

For people in the 20-29 age-at-death category, the significant comparisons were in the **upper arm** MSM between Putuni and two other sites, Akapana and Mollo Kontu. Putuni was about half of the modeled frequency when compared to the other two sites - 31% versus 62% for Akapana and 64% for Mollo Kontu. Ordinal scores for Putuni were also the lowest in these significant comparisons. As previously noted, Putuni may have been home to elite individuals (Couture and Sampeck 2003). It was possible that these results for people in their twenties reflect some kind of age-related status disparity.

Overall, the age-at-death results within the Tiwanaku Valley do not suggest many age-related differences. When present, they were between younger individuals and do not represent any overarching pattern that suggested certain sites had labor differences related to age. Instead, I would suggest that the results for people in their late teens represent the idea that people began working as young individuals, younger than many Western educated scholars would expect (Bolin 2006; Lucy 2005; Sofaer 2006a). Additionally, the MSM results in the 20-29 age-at-death category represent labor differences that may be a sign of status disparities between people who were buried at different sites within the Tiwanaku Valley.

Table 6.20 Upper Body MSM Intra Area Tiwanaku Valley GEE Chi-Square (df=1) Results during the Tiwanaku Phase for FEMALES

MSM Use-Area	Site / Modeled %	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
UPPER ARM n=179	Akapana /73 %	-[a]	**χ^2=15.33 *p*=<.0001**	-[a]	**10.39 .001**	0.46 .50	**34.49 .0001**
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / 40%	-	-		0.05 .82	**22.20 .0001**	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 38%	-	-	-	-	**15.22 .0001**	**5.12 .02**
	Mollo Kontu / 79%	-	-	-	-	-	**43.49 .0001**
	Putuni / 25%	-	-	-	-	-	-
FORE-ARM n=107	Akapana / 42%	-[a]	**379.17 <.0001**	-[a]	0.08 .77	0.72 .40	0.14 .70
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / 89%	-	-	-	**28.44 <.0001**	**24.23 <.0001**	**126.15 <.0001**
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 39%	-	-	-	-	0.65 .42	0.04 .84
	Mollo Kontu / 51%	-	-	-	-	-	1.00 .32
	Putuni / 41%	-	-	-	-	-	-

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table 6.21 MSM Intra-Area Tiwanaku Valley Ordinal Mean Scores during the Tiwanaku Phase for FEMALES

MSM Use-Area	Akapana	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
UPPER ARM	1.59	-	0.75	-	1.06	1.57	0.96
FOREARM	2.06	-	0.67	-	1.36	1.31	0.58
MID-BODY	2.07	2.00	1.00	-	1.82	1.64	0.92
LOWER BODY	1.67	2.00	1.00	-	1.69	1.47	-
FOOT	1.28	2.00	0.67	-	1.78	1.90	0.33

Table 6.22 Lower Anatomy MSM Intra-Area Tiwanaku Valley GEE Chi-Square (df=1) Results during the Tiwanaku Phase for FEMALES

MSM Use-Area	Site / Modeled %	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
MID-BODY n=49	Akapana / %	-[a]	-[a]	-[a]	-[a]	-[a]	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 76%	-	-	-	-	χ^2=0.07 *p*=.79	**4.20** **.04**
	Mollo Kontu / 70%	-	-	-	-	-	3.33 .07
	Putuni / 33%	-	-	-	-	-	-
LOWER BODY n=41	Akapana / 25%	-[a]	0.0 1.00	-[a]	0.86 .35	**6.58** **.01**	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / 25%		-	-[a]	2.72 .10	**13.08** **.0003**	-[a]
	La K'araña / %			-	-[a]	-[a]	-[a]
	Marka Pata / 45%				-	**4.29** **.04**	-[a]
	Mollo Kontu / 87%					-	-[a]
	Putuni / %						-
FOOT n=36	Akapana / 71%	-[a]	-[a]	-[a]	0.11 .73	0.41 .52	**11.38** **.0007**
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %		-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %			-	-[a]	-[a]	-[a]
	Marka Pata / 60%				-	0.01 .93	3.55 .06
	Mollo Kontu / 57%					-	**21.44** **<.0001**
	Putuni / 13%						-

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table 6.23 Upper Body MSM Intra-Area Tiwanaku Valley GEE Chi-Square (df=1) Results during the Tiwanaku Phase for MALES

MSM Use-Area	Site / Modeled %	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
UPPER ARM n=195	Akapana / 68%	χ^2=1.13 *p*=.29	-[a]	2.93 .09	0.07 .79	-	0.36 .55
	Akapana East / 80%	-	-[a]	**1330.5 <.0001**	0.75 .39	-[a]	**133.24 <.0001**
	Ch'iji Jawira / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	La K'araña /44 %	-	-	-	**6.03 .01**	-[a]	**214.01 <.0001**
	Marka Pata / 72%	-	-	-	-	-[a]	1.27 .26
	Mollo Kontu / %	-	-	-	-	-	-[a]
	Putuni / 60%	-	-	-	-	-	-
FORE-ARM n=140	Akapana / 61%	1.76 .18	-[a]	0.02 .89	0.01 .94	**4.80 .03**	0.01 .94
	Akapana East / 75%	-	-[a]	2.32 .13	**4.41 .04**	0.00 1.00	**648.12 <.0001**
	Ch'iji Jawira / %	-	-	-	-[a]	-[a]	-[a]
	La K'araña / 64%	-	-	-	0.01 .93	**7.14 .008**	0.02 .89
	Marka Pata / 63%	-	-	-	-	**12.76 .0004**	0.00 .94
	Mollo Kontu / 82%	-	-	-	-	-	**98.13 <.0001**
	Putuni / 63%	-	-	-	-	-	-

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table 6.24 MSM Intra-Area Tiwanaku Valley Ordinal Mean Scores during the Tiwanaku Phase for MALES

MSM Use-Area	Akapana	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
UPPER ARM	2.16	2.04	-	0.73	1.89	1.93	0.44
FOREARM	1.81	2.56	-	0.94	1.51	1.65	0.60
MID-BODY	1.66	2.83	-	0.33	1.84	2.67	-
LOWER BODY	2.03	2.33	-	0.56	1.56	2.75	-
FOOT	1.52	1.83	-	0.73	1.83	1.89	-

Table 6.25 Lower Anatomy MSM Intra-Area Tiwanaku Valley GEE Chi-Square (df=1) Results during the Tiwanaku Phase for MALES

MSM Use-Area	Site / Modeled %	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
MID-BODY n=14	Akapana / 69%	-[a]	-[a]	-[a]	χ^2=0.60 p=.44	-[a]	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 84%	-	-	-	-	-[a]	-[a]
	Mollo Kontu / %	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
LOWER BODY n=17	Akapana / 56%	-[a]	-[a]	0.04 .85	0.73 .39	-[a]	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / 60%	-	-	-	1.07 .30	-[a]	-[a]
	Marka Pata / 75%	-	-	-	-	-[a]	-[a]
	Mollo Kontu / %	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
FOOT n=34	Akapana / 58%	-[a]	-[a]	-[a]	0.00 .95	-[a]	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 60%	-	-	-	-	-[a]	-[a]
	Mollo Kontu / %	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table 6.26 MSM Intra-Area Tiwanaku Valley GEE Chi-Square (df=1) Results during the Tiwanaku Phase by AGE-AT-DEATH

MSM Use-Area	Site / Modeled %	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
	15-19						
UPPER ARM n=47	Akapana / %	-[a]	-[a]	-[a]	-[a]	-[a]	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 33%	-	-	-	-	**χ^2=69.63 p=<.0001**	-[a]
	Mollo Kontu / 83%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
FORE-ARM n=34	Akapana / %	-[a]	-[a]	-[a]	-[a]	-[a]	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 30%	-	-	-	-	**7.16 .007**	-[a]
	Mollo Kontu / 38%	-	-	-	-	-	
	Putuni / %	-	-	-	-	-	-
	20-29						
UPPER ARM n=165	Akapana / 62%	-[a]	-[a]	2.39 .12	0.73 .39	0.02 .89	**4.21 .04**
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / 42%	-	-	-	0.52 .47	0.0 1.00	1.96 .16
	Marka Pata / 48 %	-	-	-	-	2.88 .09	2.16 .14
	Mollo Kontu / 64%	-	-	-	-	-	**16.94 <.0001**
	Putuni / 31%	-	-	-	-	-	-

Table 6.27 MSM Intra-Area Tiwanaku Valley Ordinal Mean Scores during the Tiwanaku Phase by AGE-AT-DEATH

MSM Use-Area	Akapana	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
	15-19						
UPPER ARM	-	-	-	-	1.30	1.52	-
FOREARM	-	-	-	-	1.67	1.22	-
MID-BODY	-	2.00	-	-	-	1.17	-
LOWER BODY	-	2.00	-	-	-	1.22	-
FOOT	-	2.00	-	-	0.33	1.56	-
	20-29						
UPPER ARM	1.54	-	-	0.50	1.61	1.38	0.80
FOREARM	1.57	-	-	-	1.70	1.08	0.60
MID-BODY	1.63	-	-	0.33	1.84	-	0.92
LOWER BODY	1.67	-	-	0.67	1.58	1.50	-
FOOT	1.83	-	-	-	1.78	1.33	0.33

Within the Moquegua Valley

Results within the Moquegua Valley for females and males are presented in Table 6.28. In general, rates were comparable among females and there were no significant differences between the samples from Chen Chen, Omo, and Rio Muerto. Ordinal scores (Table 6.29) show that Omo had the highest muscle-use intensity, Rio Muerto was in the middle, and Chen Chen had the lowest numbers. This same pattern for muscle-use intensity was noted for males as well. Males also had one significant difference in the **foot** MSM between Chen Chen and Omo, with higher modeled rates from Chen Chen.

Overall, the intra-Moquegua Valley results indicated that females who lived and died within this region worked at similar tasks as shown by no significant differences and similar modeled frequencies. However, from the ordinal scores, females in the Omo and Rio Muerto areas worked harder than did women from the Chen Chen site. The same pattern in ordinal scores was found among the males in the Moquegua Valley and suggests that males from Chen Chen had the lightest workload. Males also had significant differences in **foot** MSM with the highest modeled rates from Chen Chen. As Chen Chen was the largest agricultural production site in the Moquegua Valley (Bandy et al. 1996; Goldstein 2005; Williams 2006), and modern Aymaras, possible descendants of the Tiwanaku peoples, use their feet to grind (Bruno 2011: pers. comm.), it is possible that these results were the product of males who used their feet to grind. In addition, these results do not suggest a higher mobility among Chen Chen males, as there were lower rates and no significant differences in the **mid-body** and **lower body** MSM.

Age-at-death significant MSM comparisons within the Moquegua Valley during the Tiwanaku state are shown in Table 6.30. Age-related discrete MSM intra-Moquegua Valley comparisons are in Appendix B, Table B.16. All of the age categories had at least one significant difference, suggesting that there were age-related task differences between these three sites. For all age groups, except those 50 years and older at the time of death, Chen Chen had the lowest modeled rates and ordinal scores.

For adults in their late teens and early twenties, the significant comparisons were between Chen Chen and Rio Muerto in the **upper arm** MSM, with higher ordinal scores from Rio Muerto (Table 6.37). These results may reflect that labor intensity with agricultural production was greater for younger people from Rio Muerto, who may have been dry-wash farming as opposed to canal-fed farming in the Chen Chen area. In addition, Chen Chen likely had a large population (Goldstein 2005; Owen 1997), hence it is also possible that the significant results could be related to population differences. Rio Muerto peoples may have had to work harder and more frequently, while Chen Chen colonizers could spread the work out over a larger population.

In the 30-39 age-at-death category, **forearm** and **lower body** MSM differences were between Chen Chen and Omo. Omo had higher modeled rates and ordinal scores, which suggests that people in their thirties from this area worked harder than their counterparts did in Chen Chen. In addition, this pattern supports the archaeological evidence (Goldstein 1993b, 2005) of pottery and lapidary production at Omo with more fine motion type of **forearm** movements (e.g. working marine shell or pottery decoration), as well as mobility differences, as noted in the lower body.

For people in their forties, modeled **upper arm** MSM rates were highest from Rio Muerto with comparative rates from Omo and Chen Chen. As such, significant differences were noted between Rio Muerto and the other two sites. Rio Muerto ordinal scores were equal or a little higher when likened to Omo, but higher when compared to Chen Chen. These results suggest some **upper arm** task that Rio Muerto's residents performed as older individuals, but not by people in their forties at Omo or Chen Chen. However, as there was only one individual from Rio Muerto in the 40-49 age-at-death category, these results could also be a product of small sample size.

The oldest residents of the Tiwanaku Valley colony sites had lower anatomy MSM differences in the **lower body** and **foot**. Modeled frequencies were highest from Rio Muerto, lower at Chen Chen, and the lowest at Omo. In the lower body, rates were significantly different between Omo and Rio Muerto, and in the **foot**, between Omo and both of the other sites. Ordinal scores in the **lower body** had the lowest rates from Chen Chen and highest from Rio Muerto. In the **foot**, Chen Chen had the highest ordinal scores. These **lower body** and **foot** MSM results between Omo and Rio Muerto may indicate mobility differences, in that Rio Muerto adults who made it to an older age were more mobile. However, the comparison between Omo and Chen Chen from the **foot** MSM likely indicated something other than mobility. Once again, it may be with the higher ordinal scores that there was an age-related task, such as grinding with the feet, given to older individuals from Chen Chen.

Overall, the intra-Moquegua Valley age-at-death results had the most age-related task differences during the Tiwanaku state. For younger adults (29 years and under), Rio Muerto with the highest modeled rates had significantly different **upper arm** labors from residents of the same age buried at Chen Chen. From these results, I would suggest younger people worked the land, albeit differently in each location. Chen Chen was primarily canal-irrigation farming and Rio Muerto may have been dry-wash farming. If not differences in farming activity, it may have been that activities were spread out over a larger population at Chen Chen.

For people in the middle age category (30-39 years), differences were between Chen Chen and Omo in both the upper (**forearm**) and lower (**lower body**) anatomy for MSM, which may be attributed to some kind of craft specialization as well as greater mobility within the Omo population. Omo and Chen Chen peoples in their forties were significantly different from Rio Muerto, but these **upper arm** MSM results may be attributed to either actual labor differences or the small sample size from Rio Muerto in the 40-49 age-at-death category.

Finally, older individuals within the Moquegua Valley had significant lower anatomy differences. The Rio Muerto and Chen Chen **lower body** and **foot** comparisons suggest mobility differences between these two groups who survived to an older age, with higher rates from Rio Muerto. However, the Omo and Chen Chen comparison with

MSM differences in the **foot**, suggests that older people from Chen Chen worked at age-related tasks like grinding using the **foot** muscles.

Table 6.28 Upper Anatomy MSM Intra-Area Moquegua Valley GEE Chi-Square (df=1) Results during the Tiwanaku Phase for FEMALES and MALES

MSM Use-Area	**FEMALES**			**MALES**		
	Site / Modeled %	Omo	Rio Muerto	Site / Modeled %	Omo	Rio Muerto
UPPER ARM n=2624 **F** n=1933 **M**	Chen Chen / 45%	χ^2=0.58 p=.45	5.70 .02	Chen Chen / 46%	χ^2=0.23 p=.63	0.34 .58
	Omo / 49%	-	1.06 .30	Omo / 48%	-	0.01 .92
	Rio Muerto / 57%	-	-	Rio Muerto / 48%	-	-
FORE-ARM n=2153 **F** n=1501 **M**	Chen Chen / 43%	0.14 .71	0.00 .95	Chen Chen / 40%	2.66 .10	0.63 .43
	Omo / 45%	-	0.09 .77	Omo / 47%	-	3.62 .057
	Rio Muerto / 43%	-	-	Rio Muerto / 36%	-	-
MID-BODY n=946 **F** n=627 **M**	Chen Chen / 59%	0.01 .92	0.36 .55	Chen Chen / 58%	0.99 .32	0.20 .65
	Omo / 58%	-	0.13 .72	Omo / 53%	-	1.35 .25
	Rio Muerto / 55%	-	-	Rio Muerto / 61%	-	-
LOWER BODY n=488 **F** n=403 **M**	Chen Chen / 34%	0.32 .57	0.10 .75	Chen Chen / 46%	2.48 .12	0.02 .89
	Omo / 40%	-	0.06 .80	Omo / 34%	-	1.16 .28
	Rio Muerto / 37%	-	-	Rio Muerto / 45%	-	-
FOOT n=685 **F** n=535 **M**	Chen Chen / 50%	0.11 .74	2.42 .12	Chen Chen / 51%	**4.83** **.03**	2.25 .13
	Omo / 47%	-	0.82 .37	Omo / 38%	-	0.12 .73
	Rio Muerto / 37%	-	-	Rio Muerto / 40%	-	-

Table 6.29 MSM Intra-Area Moquegua Valley Ordinal Mean Scores during the Tiwanaku Phase

MSM Use-Area	**FEMALES**			**MALES**		
	Chen Chen	Omo	Rio Muerto	Chen Chen	Omo	Rio Muerto
UPPER ARM	0.87	1.44	1.24	0.86	1.29	1.25
FOREARM	0.82	1.49	1.20	0.81	1.44	1.22
MID-BODY	0.95	1.68	1.32	0.81	1.74	1.43
LOWER BODY	0.94	1.36	1.32	1.01	1.50	1.50
FOOT	0.85	1.19	1.06	0.80	1.38	1.04

Table 6.30 MSM Intra-Area Moquegua Valley GEE Chi-Square (df=1)Results during the Tiwanaku Phase by AGE-AT-DEATH

MSM Use-Area	Site / Modeled %	Omo	Rio Muerto
	15-19		
UPPER ARM n=474	Chen Chen / 31%	χ^2=0.81 *p*=.37	**8.55 .004**
	Omo / 35%	-	3.07 .08
	Rio Muerto / 45%	-	-
	20-29		
UPPER ARM n=1394	Chen Chen / 37%	0.68 .41	**4.58 .03**
	Omo / 41%	-	1.89 .17
	Rio Muerto / 51%	-	-
	30-39		
FORE-ARM n=1798	Chen Chen / 45%	**9.06 .003**	0.47 .49
	Omo / 58%	-	7.25 .007
	Rio Muerto / 47%	-	-
LOWER BODY n=451	Chen Chen / 43%	**4.06 .04**	0.23 .63
	Omo / 55%	-	0.81 .37
	Rio Muerto / 47%	-	-
	40-49		
UPPER ARM n=523	Chen Chen / 50%	0.03 .87	**108.58 <.0001**
	Omo / 51%	-	**12.89 .0003**
	Rio Muerto / 80%	-	-
	50+		
LOWER BODY n=64	Chen Chen / 59%	1.72 .19	3.77 .052
	Omo / 33%	-	**6.27 .01**
	Rio Muerto / 76%	-	-
FOOT n=90	Chen Chen / 52%	**9.28 .002**	0.17 .68
	Omo / 29%	-	**32.21 <.0001**
	Rio Muerto / 56%	-	-

Table 6.31 MSM Intra-Area Moquegua Valley Ordinal Mean Scores during the Tiwanaku Phase by AGE-AT-DEATH

MSM Use-Area	Chen Chen	Omo	Rio Muerto
		15-19	
UPPER ARM	0.90	1.13	1.18
FOREARM	0.74	1.05	1.17
MID-BODY	0.62	1.27	1.20
LOWER BODY	0.83	1.00	0.97
FOOT	0.70	1.10	1.42
		20-29	
UPPER ARM	0.99	1.17	1.26
FOREARM	0.77	1.39	1.29
MID-BODY	0.94	1.45	1.24
LOWER BODY	1.08	1.58	1.37
FOOT	0.84	1.33	1.10
		30-39	
UPPER ARM	0.85	1.36	1.19
FOREARM	0.84	1.47	1.11
MID-BODY	0.93	1.75	1.51
LOWER BODY	0.98	1.64	1.48
FOOT	0.85	1.35	0.95
		40-49	
UPPER ARM	0.89	1.42	1.42
FOREARM	0.80	1.47	-
MID-BODY	0.83	1.74	-
LOWER BODY	0.96	1.22	1.67
FOOT	0.78	0.92	-
		50+	
UPPER ARM	0.91	1.34	1.33
FOREARM	0.78	1.75	1.35
MID-BODY	0.97	1.93	1.43
LOWER BODY	0.80	1.44	1.57
FOOT	0.93	0.85	0.81

6.8 Summary

Overall, the results were presented in this chapter in Sections 6.3 through 6.7 and summarized in the above Section 6.2. Further labor data are examined in the following chapter over osteoarthritis. In addition, these results are discussed in Chapter 8 and 9, the discussion and concluding chapters of this dissertation respectively.

Chapter 7
Osteoarthritis (OA) Results

7.1 Introduction

OA, a type of degenerative joint disease, has been used in prior bioarchaeological research to discuss task-based repetitive motion injuries within joints (Bridges 1991a; Cope et al. 2005; Jurmain 1999; Kennedy 1998; Klaus et al. 2009; Larsen 1997; Pearson and Buikstra 2006 and others). Because multiple surfaces are involved in joint movement, I collected data for 24 different surfaces within seven joints in the body: (1) **shoulder**, (2) **elbow**, (3) **wrist**, (4) **sacroiliac**, (5) **hip**, (6) **knee**, and (7) **ankle** (see Chapter 5, Table 5.2 for full list of surfaces in the joints). In order to understand repetitive movement and the workload across the Tiwanaku state, I noted spatial and temporal frequency differences, OA intensity changes[17], as well as any statistically significant differences ($p \leq .05$). Data were collected bilaterally, however results in this chapter are provided as combined scores for both sides of the body[18].

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[17] Ordinal scores for evidence of lipping, surface porosity, osteophyte formation, and eburnation. See Appendix A for the scalar information on OA involvement.

[18] I believe this represents the best possible way to achieve the maximum amount of data from individuals present in this study and the GEE statistical procedure used does not bias these combined results (Becker 2012; Gagnon and Wiesen 2011). Presented in this fashion, the results also address problems with choosing one side of the body over the other to represent the amount of OA joint damage and levels of repetitive movement. Results for the core versus colony comparison are shown by right and left side of the body in Appendix C, Tables C.1-C.2 and can be compared to the OA results not divided by sex in Table C.3.

Using these criteria in this chapter, I present the OA results for a MNI of 1,235 people within the study sample population. OA data consist of geographic and temporal comparisons in order to understand labor organization within the Tiwanaku state. The geographic comparisons are divided into three components: (1) **core versus colony**, (2) **inter-highland area** (i.e. Tiwanaku Valley versus Katari Valley) and (3) within each valley (i.e. **intra-area**) during the Tiwanaku phase. **Chronological comparisons** were also performed in order to evaluate labor change over time. In addition, in order to discuss possible social relationships including gendered division of labor and age-related tasks throughout the Tiwanaku state, I correlated labor data with sex, age-at-death, and geographic burial location.

7.2 Synopsis of the OA Results

In the **regional comparison** (Section 7.3), OA rates were generally higher for the core and the data do not suggest that colony people worked as corvée workers for the Tiwanaku elite. The lack of OA **inter-highland area** (Katari Valley vs. Tiwanaku Valley) differences further support a less centralized model of labor organization (Section 7.4).

Intra-area comparisons (Section 7.5) within the Katari Valley showed people worked at repetitive tasks that varied by site. Lukurmata, Pokachi Kontu, and Kirawi all showed OA differences, with higher OA rates from Lukurmata and Pokachi Kontu and lower OA rates from Kirawi.

Within the Tiwanaku Valley, OA results differed by site and joint area in the body, suggesting various elite and non-elite communities all working at different repetitive tasks. For example, OA rates were the highest in the **knee** joint for burials from the La K'araña site suggesting some kind of damaging repetitive motion among these possible elites (Escalante 2003; Portugal Ortíz 1988). In the Mollo Kontu area, people had high OA rates throughout the body. These labor rates along with the archaeological evidence of a meat-based diet (Berryman et al. 2009; Vallières 2010, 2012) could mean that Mollo Kontu was home to repetitively working *llameros*.

Within the Moquegua Valley, OA results showed that Chen Chen residents worked at the least amount of repetitive tasks, while Rio Muerto peoples worked much more repetitively. Omo peoples within the colony showed higher OA rates in mid- and lower body joints, possibly associated with greater mobility among these people.

Chronological differences in the core showed people had heavier repetitive labor demands prior to the Tiwanaku-state (Section 7.6). In addition, **sacroiliac** joint rates in the core were significantly different in the Tiwanaku phase to the post-Tiwanaku phase comparison. An explanation for this is that while goods were likely transported on peoples' backs during the state, there was a reduction in trade after state collapse. This reduction in the movement of goods and trade routes in highland regions had been noted archaeologically as an earmark of Tiwanaku state collapse (Bermann 2003; Janusek 2004a). In addition, colony OA levels went down after the state lost influence in the Moquegua region, suggesting that Tiwanaku colonists worked more repetitively during the Tiwanaku state.

Synopsis of the Composition of the State's Workforce

In order to answer my second dissertation question concerning the various groups of people laboring within the Tiwanaku state, I looked at geographic differences between females, between males, and by age-at-death (Section 7.7). The **regional comparison** showed that females worked at similar levels of repetitive labor, with one significant difference in the **sacroiliac** joint. Males in the regional comparisons had significant differences in the **elbow** joint, with higher rates for core males when compared to colony males. The age-at-death comparisons for OA also indicated age-related task differences with higher rates for all age-at-death groups (i.e. 15-19, 20-29, 30-39, 40-49, and 50+ years) for people from the core when compared to colonists.

In the **inter-highland area comparisons** (Katari Valley vs. Tiwanaku Valley), females from both valleys had comparable OA rates. There were labor divisions by sex for males in the arm joints. Katari males had higher **elbow** OA modeled rates and Tiwanaku Valley males had higher **shoulder** OA frequencies. Females from both valleys had comparable OA rates. There were few significant OA age-related differences between core valleys, indicating that labors were less age-related in the core.

Intra-area comparisons suggested that there were few age or sex related divisions of labor within the Katari Valley and within the Tiwanaku Valley. Within the Moquegua Valley, both Omo and Rio Muerto males had higher modeled OA rates than Chen Chen males, indicating repetitive task differences between these sites. Females had few repetitive labor differences, suggesting females worked at similar levels of repetitive tasks within the Moquegua Valley. In addition, age-related divisions of labor showed that Rio Muerto people worked at more repetitive tasks in their twenties, Omo people in their thirties, and Chen Chen residents had generally low rates for all age groups (except in the sacroiliac joint) for people over age 50.

7.3 Regional Core vs. Regional Colony OA Results

Results for the OA comparisons between individuals from the core highland Lake Titicaca region and the Moquegua Valley colony are presented in Table 7.1 (Full results for each area of the joint surface are found in Appendix C, Table C.3). Ordinal scores with the different ways OA presented (i.e. lipping, porosity, osteophytes, and/or eburnation) joint surfaces are in Table 7.2.

People who lived in both the core and colony were involved in repetitive tasks that left evidence of OA, as shown by the modeled frequency results. Rates were higher in the core than the colony and in some cases, these results were different enough between the two groups to be statistically significant. For example, while none of the combined arm joint surfaces in the body were statistically significant, there was one surface in the **elbow** (i.e. ulna radial notch) and one surface in the **wrist** (i.e. ulna distal articulation), which were significantly different. Both of these surfaces are on the ulna and the modeled frequencies were greater in the core than the colony. Additionally, the OA scalar scores only showed evidence of lipping in the ulna radial notch, with a greater area of involvement in the core (33-66%) than the colony (less than 33%).

In the mid-body joints of the **hip** and **sacroiliac**, modeled rates were higher in the core than the colony, with somewhat similar levels of ordinal involvement (i.e. lipping, porosity, and osteophytes). In the **hip**, there were no significant differences between core and colony. In the **sacroiliac** joint, both the auricular surface of the sacrum and the joint overall were statistically significant. In general, the sacroiliac joint is used to help absorb shock to the upper body and helps with weight balancing over hips and to the legs. Additionally, because the sacroiliac is a less mobile synovial joint and OA in this joint is rare (Jellad et al. 2009), it was unlikely that the evidence of OA indicates direct repetitive movement of the type that would be found in hinge joints like the **elbow** and **knee**. Instead, it was much more likely that the significant **sacroiliac** joint OA was caused by pressure placed on loadbearing muscles of the back while walking or running with higher rates among individuals from the core (Eck 2012).

In the leg joints, modeled rates between core and colony were closer than in the arm joints. Modeled frequencies are 6% higher for the **knee** joint in colony populations than in the core and almost the same (1% higher in the core) in the **ankle** joint. It was possible that the higher rates in the **knee** joint for the colony indicate greater repetitive flexion and mobility among colonists. However, the similar OA rates in all leg joint areas as well as the lack of differences in the **ankle** suggests both groups were relatively mobile and did a lot of walking or running. In addition, ordinal scores of lipping, porosity, and osteophyte formation for the knee and ankle joints were slightly greater for core residents, suggesting more task repetition among residents from that area.

Overall, the arm joint results showed core residents performed some kind of repetitive task that involved significantly greater use of the two aforementioned articular surfaces on the ulna and this could have involved repeated twisting of the ulna and pressure on the distal articulation with **wrist** (i.e. carpal) bones. The actual motion or task that caused the OA in these specific areas was unclear, but it could be something akin to a forward push with a repetitive grinding-style or dough kneading motion with a bent **elbow**. Additionally, as these were only two significant surfaces out of multiple ones in the arm joints and the whole **elbow** or **wrist** joint was not affected, it was unclear if there was a specific motion that caused a greater increase of OA in these two specific areas or if it was just greater repetitive tasks in general.

For the significant **sacroiliac** OA results, one possible explanation is that during the Tiwanaku state goods were transported over long distances on the back of highlanders. Because there was no market system in the Andes prior to European contact, there is a tradition in this region of using a cloth carryall, also known as an *aguayo*, to transport goods as well as children (Fig. 7.1). Modern uses of the *aguayo* show that it is slung across the back and tied on the front of the chest near the sternum, with items in the cloth resting on the mid to lower back (Carter 1967; Mitchell 2003). I would suggest that *aguayo* goods transport, along with llama caravans, was used during the Tiwanaku state and the **sacroiliac** OA results were evidence of this repetitive damage. In addition, while not systematically studied, I noted many cases of lumbar vertebral OA, including at least one case of spondylolysis in the highland sample. These **sacroiliac** results and evidence of vertebral OA support the idea of repetitive goods transport via a backpack (i.e. compressive spinal loading), as has been shown among modern populations (Chosa et al. 2004; Whiting and Zernicke 2008:281).

In addition, another possibility could have been associated with hormonal changes in the **sacroiliac** joint that are noted for women during menstruation and pregnancy. These hormones make the ligaments around the **sacroiliac** 'fixed' joint more flexible than usual, especially during pregnancy (Gariola et al. 1989). This biological response among females could account for a few of the **sacroiliac** OA differences.

Table 7.1 OA Core vs. Colony Results during Tiwanaku Phase

JOINT AREA	n=	Core Modeled % frequency	Colony Modeled % frequency	χ^2 value (df=1)	*p*-value
SHOULDER	620	25%	20%	0.70	.40
ELBOW	2907	37%	29%	3.10	.08
WRIST	501	29%	21%	1.59	.21
SACROILIAC	**354**	**64%**	**43%**	**5.03**	**.03**
HIP	384	22%	18%	0.38	.54
KNEE	781	16%	22%	0.85	.36
ANKLE	549	16%	15%	0.00	.96

Table 7.2 Core vs. Colony OA Ordinal Mean Scores during the Tiwanaku Phase with Percentage of Joint Involvement

JOINT AREA	Core Lipping / %	Colony Lipping / %	Core Porosity / %	Colony Porosity / %	Core Osteophyte / %	Colony Osteophyte / %	Core Eburnation / %	Colony Eburnation / %
SHOULDER	1 / 33-66%	1 / 33-66%	1 / 0-33%	0	0	0	0	0
ELBOW	2 / 33-66%	1 / 33-66%	0	1/ 0-33%	1/ 33-66%	0	0	0
WRIST	2 / 33-66%	1 / 33-66%	1 / 33-66%	0	1 / 33-66%	1 / 0-33%	0	0
SACROILIAC	2 / 33-66%	1 / 33-66%	1 / 33-66%	1/ 33-66%	1 / 33-66%	1 / 0-33%	0	0
HIP	1 / 33-66%	1 / 0-33%	1 / 33-66%	1/ 0-33%	1 / 33-66%	0	0	0
KNEE	2 / 33-66%	1 / 33-66%	1 / 0-33%	0	2 / 0-33%	1 / 0-33%	1 / 0-33%	1 / 0-33%
ANKLE	2 / 33-66%	1 / 33-66%	0	0	0	0	0	0

Figure 7.1 Aymara Woman Demonstrating *Aguayo* Use and Placement

7.4 Inter-Highland Area Comparison OA Results

The comparison between the Katari Valley and Tiwanaku Valley in the highland core showed similar modeled rates for OA. The two exceptions to this were on the humerus capitulum and the head of the radius in the **elbow** joint (Appendix C, Table C.4) with higher greater modeled frequencies for Katari Valley residents. It was likely that Katari Valley people were involved in a specific labor that affected the lateral joint area (i.e. capitulum and articular surface of the radius), such as moving the hand from palmer to planar, but not the whole **elbow** joint. Modern studies of OA in this **elbow** area were noted for people who have engaged in strenuous manual activity and repetitive motion in the **elbow** near the lateral epicondyle (Gramstad and Galatz 2006). As these were the only significant differences and modeled rates were similar between these two highland valleys, it is hard to say that there were major repetitive labor differences between those living in either area. Instead, from these inter-highland area results it was much more likely that people participated in similar activities and activity levels throughout the highland core.

7.5 Intra-Area Comparison OA Results

Results for site-by-site comparisons within the Katari Valley, within the Tiwanaku Valley, and within the Moquegua Valley during the Tiwanaku state are provided below for intra-area site comparisons. In order to discuss trends in movement and OA evidence, I have included the seven joint surfaces modeled frequencies, their ordinal scores with types of OA present, and statistically significant results.

Within the Katari Valley

The sites of Kirawi, Lukurmata, and Pokachi Kontu were compared to test for evidence of activity, levels of repetitive labor, and any significant differences during the Tiwanaku state within the Katari Valley[19]. The results within the Katari Valley are shown in Table 7.3. Due to lack of comparative sample, only the **shoulder** and **wrist** joints could be evaluated for OA. In the **shoulder** joint, modeled rates were higher for individuals from the site of Pokachi Kontu when compared to Lukurmata, but these results were not statistically significant. The evidence of OA in the **shoulder** showed lipping from Lukurmata, while Pokachi Kontu had a greater prevalence of porosity and osteophyte formation (Table 7.4). In the **elbow** joint, rates were highest from Lukurmata,

[19] All five sites had the potential to be included, but no results were noted for Qeya Kontu and UriKatu Kontu peoples during the Tiwanaku time period for OA.

lower at Pokachi Kontu, and lowest from Kirawi, with all three sites showing the same ordinal scores with OA evidence of lipping.

From these results, people who lived at different sites within the Katari Valley worked at different repetitive tasks in the **shoulder** and **elbow**, and these were significantly different in the **elbow** between Lukurmata and Kirawi, as well as Pokachi Kontu and Kirawi. Since Lukurmata was the largest city settlement in the Katari Valley and had been suggested as home to valley administrators or ritual specialists, it was interesting that they had high rates of OA in the **elbow**, **wrist**, **hip**, and **sacroiliac**, lower rates in the **shoulder** and **ankle**, and no evidence of OA in the **knee** joint (Appendix C, Table C.5). However, the agriculturally positioned sites of Kirawi and Pokachi Kontu had dissimilar OA rates in the arm joints. Kirawi had low OA modeled rates in the **elbow**, while Pokachi Kontu had high rates in the **shoulder** joint.

In summary, within the Katari Valley, people worked at different tasks and there was heterogeneity to jobs between the different settlements. Lukurmata was likely home to a variety of people, especially those who worked at many different types of repetitive tasks, and likely not just as ritual specialists or administrators. Additionally, because rates of OA were lower at the rural Kirawi, and higher at Lukurmata, it may have been that Lukurmata's residents were a local source of labor.

Table 7.3 OA Intra-Area Katari Valley GEE Chi-Square Results during the Tiwanaku Phase (df=1)

JOINT AREA	Site / Modeled %	Lukurmata	Pokachi Kontu
SHOULDER n=31	Kirawi / %	-[a]	-[a]
	Lukurmata /15%	-	χ^2=1.34 *p*=.25
	Pokachi Kontu /33%	-	-
ELBOW n=93	Kirawi /14%	**8.65 .003**	**4.32 .04**
	Lukurmata /54%	-	0.75 .39
	Pokachi Kontu /40%	-	-

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table 7.4 OA Intra-Area Katari Valley Ordinal Mean Scores during the Tiwanaku Phase with Percentage of Joint Involvement[20]

JOINT AREA	Kirawi Lip-ping / %	Lukur-mata Lipping / %	Pokachi Kontu Lipping / %	Kirawi Porosity / %	Lukur-mata Porosity / %	Pokachi Kontu Porosity / %	Kirawi Osteo-phyte / %	Lukur-mata Osteophyt e / %	Pokachi Kontu Osteo-phyte / %
SHOULDER	0	1 / 0-33%	0	0	0	2 / 33-66%	0	0	1 / 0-33%
ELBOW	1 / 0-33%	1 / 0-33%	1 / 0-33%	0	0	0	0	0	0

<u>Within the Tiwanaku Valley</u>

The multiple site-by-site comparisons for individuals within the Tiwanaku Valley are presented for the upper body joints in Table 7.5 and the ordinal scores in Table 7.6. <u>Overall, the modeled rates of OA vary by joint and for each site, which could suggest that each of these areas worked at different, but repetitive, activities.</u> In the **shoulder** joint, modeled OA rates were highest from Akapana, then lower at Marka Pata, and lowest from Mollo Kontu, although all of these rates were within 10 percentage points of each

[20] Average eburnation scores were zero and therefore not included in this ordinal table.

other and were not statistically significant. In addition, Akapana had the greatest OA intensity in the **shoulder** joint with evidence of lipping and porosity over a third to two-thirds of the joint's surface.

There were multiple statistically significant comparisons within the Tiwanaku Valley in the **elbow** joint, primarily between the sites with the highest modeled rates and all other sites, as noted in Table 7.5. Mollo Kontu had the greatest modeled percentage of OA, with Ch'iji Jawira only 4% lower. Rates drop by about 20% when compared to the next lowest site of Marka Pata and rates were even lower at Akapana, Akapana East, and Putuni. Intensity scores for the **elbow** joint showed that Mollo Kontu presented with all four types of OA involvement (i.e. lipping, porosity, osteophyte formation, and eburnation). In addition to the **elbow** joint, the **wrist** joint modeled rates were highest from Mollo Kontu, with lower rates at Akapana, Marka Pata, and Ch'iji Jawira, but no significant differences between the sites. The ordinal scores were also high with similar percentages of joint involvement from Mollo Kontu and Akapana.

The OA results for the mid and lower body are shown in Table 7.7 and the ordinal scores in Table 7.8. Within mid-body joints, the **sacroiliac** joint had high rates of OA from all sites except Akapana and this translates into significant differences between Akapana and the sites of Ch'iji Jawira, Marka Pata, and Mollo Kontu. In addition, all four of these sites show some evidence of lipping, porosity, and osteophyte formation in the **sacroiliac** joint with Mollo Kontu and Marka Pata having the greatest intensity scores and area of joint involvement. In the **hip** joint, Marka Pata had very low modeled rates of OA, while Ch'iji Jawira and Mollo Kontu have the highest and these two sites were significantly different from Marka Pata.

Within the leg joints, OA **knee** joint modeled rates were comparably high from La K'araña at 67% and significantly different for knee OA with all other sites. The site with the next highest OA rate (30%), Ch'iji Jawira, was significantly different from Akapana with very low OA **knee** modeled frequency (3%). Marka Pata and Mollo Kontu were 50% and 60% lower respectively from La K'araña, which suggests there were major differences in repetitive **knee** joint movement by residents of this site. It was also interesting to note that Akapana with its relatively low **knee** OA rate had the highest OA rate in the **ankle** joint and there was no direct explanation for this disparity. Mollo Kontu also had relatively high **ankle** OA rates and both Akapana and Mollo Kontu were significantly different from Marka Pata, which had the least amount of **ankle** OA.

<u>These results suggest a variety of repetitive activities from sites around the city of Tiwanaku, but the results do not suggest that one specific area worked solely at repetitive labors.</u> Overall, in the upper body, Mollo Kontu, Marka Pata, and Akapana performed the greatest variety of repetitive tasks associated with evidence of OA in the arm, while in the lower body, OA rates range for each site even though intensity scores were relatively similar. Ch'iji Jawira also had significantly high modeled rates of OA in the **elbow** joint, but lower in the **wrist**. These results suggest some kind of repetitive **elbow** activity with low **wrist** movement that Ch'iji Jawira residents performed more than their counterparts in other areas of the Tiwanaku city did. As this site had been associated with ceramic production, it was possible that this OA evidence reflects repetitive motion injuries with this specific type of craft production. In addition, Ch'iji Jawira had high **sacroiliac** and **hip** joint OA modeled rates, but these do not translate into high **knee** and **ankle** joint OA,

and I would suggest that these mid-body activity differences were not associated with mobility.

The low rates of **sacroiliac**, **hip**, and **knee** OA from people who were buried in the Akapana area, but high rates of OA in the **ankle**, suggest low mobility and likely that these people were not involved in carrying goods on their backs. Instead, combined with the higher OA rates in the arm joints, the results suggest Akapana people, on average, worked at tasks that involved repetitive arm and **foot** movements. As Akapana people may have been ritual offerings on the Akapana pyramid, it was unclear what kinds of repetitive jobs in which they may have participated.

The high rates of OA throughout the upper and lower body joints among the people from Mollo Kontu suggest that residents of this area performed many repetitive activities. This area may have been home to *llameros* (camelid herders and butchers) (Vallières 2010, 2012). The OA evidence does not indicate one specific repetitive activity, and I would suggest that Mollo Kontu peoples may have been embedded specialists who worked at household tasks while being *llameros*.

The idea elite administrators in the Tiwanaku core does not explain the different levels of OA from the people of La K'araña, noted as a possible site home to elites and/or ritual specialists. The highest OA rates and intensity scores with evidence of sharp ridges of OA lipping in the **knee** were reported among people from this area. Modern OA studies (Felson et al. 1991; Hunter et al. 2002; Järvholm et al. 2008; Rytter et al. 2009) noted that knee joint damage is generally related to occupation, but it was unclear what type of kneeling or knee-bending activities were performed by residents of La K'araña. In addition, the evidence of OA does not discount that these people could have been elites or ritual specialists, but they were working or at least kneeling elite peoples.

Table 7.5 OA Intra-Area Upper Anatomy Tiwanaku Valley GEE Chi-Square (df=1) Results during the Tiwanaku Phase

JOINT AREA	Site / Modeled %	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
SHOULDER n=49	Akapana /39%	-[a]	-[a]	-[a]	χ^2=0.1 p=.78	0.27 .60	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata /33%	-	-	-	-	0.11 .74	-[a]
	Mollo Kontu /27%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
ELBOW n=255	Akapana /27%	0.93 .33	**6.80** **.009**	-[a]	0.35 .55	2.69 .10	3.09 .08
	Akapana East /20%	-	**266.2** **<.0001**	-[a]	**6.54** **.01**	**6.64** **.01**	2.84 .09
	Ch'iji Jawira /50%	-	-	-[a]	**8.46** **.003**	0.07 .79	**45.74** **<.0001**
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata /32%	-	-	-	-	1.90 .17	**8.85** **.003**
	Mollo Kontu /54%	-	-	-	-	-	**9.26** **.002**
	Putuni /14%	-	-	-	-	-	-
WRIST n=97	Akapana /31%	-[a]	2.11 .15	-[a]	0.03 .85	0.24 .63	-[a]
	Akapana East /%	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira /17%	-		-[a]	1.80 .18	3.03 .08	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata /28%	-	-	-	-	0.44 .51	-[a]
	Mollo Kontu /41%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table 7.6 OA Intra-Area Tiwanaku Valley Ordinal Mean Scores for Arm Joints during the Tiwanaku Phase with Percentage of Joint Surface Involvement

JOINT AREA and Involvement	Akapana	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
SHOULDER LIPPING	2 / 33-66%	0	0	0	1 / 33-66%	1 / 33-66%	0
SHOULDER POROSITY	2 / 33-66%	0	0	0	1 / 33-66%	1 / 33-66%	0
SHOULDER OSTEOPHYTES	0	0	0	0	0	1 / 0-33%	0
SHOULDER EBURNATION	0	0	0	0	0	0	0
ELBOW LIPPING	1 / 0-33%	0	0	1 / 0-33%	1 / 33-66%	1 / 33-66%	0
ELBOW POROSITY	0	0	0	0	0	1 / 0-33%	1 / 33-66%
ELBOW OSTEOPHYTES	1 / 0-33%	0	0	0	1 / 0-33%	1 / 33-66%	1 / 0-33%
ELBOW EBURNATION	0	0	0	0	0	1 / 0-33%	0
WRIST LIPPING	1 / 33-66%	0	0	0	1 / 0-33%	1 / 33-66%	0
WRIST POROSITY	1 / 66-100%	0	0	0	0	1 / 33-66%	0
WRIST OSTEOPHYTES	1 / 0-33%	0	0	0	0	1 / 66-100%	0
WRIST EBURNATION	0	0	0	0	0	0	0

Table 7.7 OA Intra-Area Lower Anatomy Tiwanaku Valley GEE Chi-Square (df=1) Results during the Tiwanaku Phase

JOINT AREA	Site / Modeled %	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
SACRO-ILIAC n=58	Akapana /22%	-[a]	**χ^2=10.9 *p*=.001**	-[a]	**5.37 .02**	**8.56 .003**	-[a]
	Akapana East /%	-	-[a]	-[a]	0.15 .70	1.71 .19	-[a]
	Ch'iji Jawira /75%	-		-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata /71%	-	-	-	-	1.77 .18	-[a]
	Mollo Kontu /92%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
HIP n=59	Akapana /20%	-[a]	3.51 .06	-[a]	1.53 .22	0.94 .33	-[a]
	Akapana East /%	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira /50%	-	-[a]	-[a]	**8.96 .003**	0.64 .43	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata /5%	-	-	-	-	**4.58 .03**	-[a]
	Mollo Kontu /38%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
KNEE n=147	Akapana /3%	-[a]	**6.58 .01**	**22.60 <.0001**	1.77 .18	0.44 .51	-[a]
	Akapana East /%	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira /30%	-	-[a]	**8.18 .004**	2.55 .11	1.99 .16	-[a]
	La K'araña /67%	-	-	-	**24.00 <.0001**	**8.93 .003**	-[a]
	Marka Pata /11%	-	-	-	-	0.14 .71	-[a]
	Mollo Kontu /7%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
ANKLE n=70	Akapana /52%	-[a]	-[a]	-[a]	**6.10 .01**	0.58 .45	-[a]
	Akapana East /%	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata /12%	-	-	-	-	**6.70 .01**	-[a]
	Mollo Kontu /40%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table 7.8 OA Intra-Area Tiwanaku Valley Ordinal Mean Scores for Arm Joints during the Tiwanaku Phase with Percentage of Joint Surface Involvement

JOINT AREA and Involvement	Akapana	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
SACROILIAC LIPPING	2 / 66-100%	0	1 / 66-100%	0	2 / 33-66%	2 / 33-66%	0
SACROILIAC POROSITY	0	0	0	0	1 / 0-33%	1 / 33-66%	0
SACROILIAC OSTEOPHYTES	1 / 0-33%	0	2 / 0-33%	0	1 / 33-66%	1 / 0-33%	0
SACROILIAC EBURNATION	0	0	0	0	0	0	0
HIP LIPPING	1 / 0-33%	0	1 / 0-33%	0	1 / 0-33%	1 / 33-66%	0
HIP POROSITY	1 / 33-66%	0	0	0	0	1 / 33-66%	0
HIP OSTEOPHYTES	0	0	0	0	0	1 / 33-66%	0
HIP EBURNATION	0	0	0	0	0	0	0
KNEE LIPPING	0	0	1 / 0-33%	2 / 33-66%	0	2 / 33-66%	0
KNEE POROSITY	1 / 0-33%	0	0	0	1 / 0-33%	0	0
KNEE OSTEOPHYTES	0	1 / 0-33%	0	0	0	1 / 33-66%	0
KNEE EBURNATION	0	0	0	0	0	0	0
ANKLE LIPPING	2 / 33-66%	1 / 0-33%	0	0	1 / 0-33%	1 / 0-33%	0
ANKLE POROSITY	0	0	0	0	1 / 0-33%	0	0
ANKLE OSTEOPHYTES	1 / 33-66%	0	0	0	0	0	0
ANKLE EBURNATION	0	0	0	0	0	0	0

Within the Moquegua Valley

Results within the Moquegua Valley are shown in Table 7.9 and the ordinal results in Table 7.10. Throughout the body, Chen Chen showed the lowest modeled rates of OA, but all sites show similar ordinal scores of OA intensity. In the upper body joints, Rio Muerto had the highest modeled OA rates in the **shoulder** and **elbow** and Omo had the highest in the **wrist**. Chen Chen was significantly different from Rio Muerto in the **shoulder** and **elbow** joints, and Omo in the **elbow** joint. In the mid- and lower body joints, Omo had modeled rates of OA that were greater than Rio Muerto except in the **knee** joint. In addition, in all the lower body joints except the **knee**, Chen Chen and Omo were significantly different.

<u>These results suggest that Tiwanaku colonists buried in both the Omo and Rio Muerto areas may have performed similar levels of repetitive tasks because they do not have any significant OA differences between them.</u> However, Chen Chen peoples, likely involved in canal-irrigated agricultural production (Bandy et al. 1996; Goldstein 2000; Williams 2006), labored much less repetitively than Omo's or Rio Muerto's residents. The higher upper body rates for Rio Muerto suggest these people performed repetitive tasks that used the joints in the **shoulder**, **elbow**, and **wrist**, and practiced different occupations or a different style of agriculture than Chen Chen's residents. Residents of the Omo region, likely home to pastoralists and llama caravanners (Goldstein 1993a, 2005), had high levels of mid- and lower body OA. These Omo data support the idea of greater levels of mobility and the movement of goods. <u>Overall, the data suggest a lack of forced, *mit'a*-type labor from a centralized elite core in the highlands.</u>

Table 7.9 OA Intra-Area Moquegua Valley GEE Chi-Square Results during the Tiwanaku Phase (df=1)

JOINT AREA	Site / Modeled %	Omo	Rio Muerto
SHOULDER n=546	Chen Chen / 16%	χ^2=1.54 *p*=.21	**8.25 .004**
	Omo / 14%	-	2.03 .15
	Rio Muerto / 35%	-	-
ELBOW n=2559	Chen Chen / 25%	**6.67 .01**	**7.66 .006**
	Omo / 36%	-	0.35 .56
	Rio Muerto / 40%	-	-
WRIST n=438	Chen Chen / 20%	0.16 .69	0.00 .96
	Omo / 23%	-	0.12 .73
	Rio Muerto / 20%	-	-
SACRO-ILIAC n=310	Chen Chen / 38%	**4.41 .04**	1.67 .20
	Omo / 55%	-	0.32 .57
	Rio Muerto / 49%	-	-
HIP n=339	Chen Chen / 12%	**10.31 .001**	3.13 .08
	Omo / 32%	-	0.94 .33
	Rio Muerto / 23%	-	-
KNEE n=659	Chen Chen / 20%	0.10 .75	0.25 .62
	Omo / 22%	-	0.05 .82
	Rio Muerto / 24%	-	-
ANKLE n=492	Chen Chen / 11%	**13.76 .0002**	1.77 .18
	Omo / 28%	-	1.32 .25
	Rio Muerto / 18%	-	-

Table 7.10 OA Intra-Area Moquegua Valley Ordinal Mean Scores during the Tiwanaku Phase with Percentage of Joint Surface Involvement[21]

JOINT AREA	Chen Chen Lipping / %	Omo Lipping / %	Rio Muerto Lipping / %	Chen Chen Porosity / %	Omo Porosity / %	Rio Muerto Porosity / %	Chen Chen Osteophyte / %	Omo Osteophyte / %	Rio Muerto Osteophyte / %
SHOULDER	1 / 33-66%	2 / 33-66%	1 / 33-66%	0	0	1 / 0-33%	0	0	0
ELBOW	1 / 33-66%	1 / 33-66%	1 / 33-66%	1 / 0-33%	0	0	0	0	0
WRIST	1 / 33-66%	1 / 33-66%	1 / 33-66%	0	0	0	1 / 0-33%	0	0
SACROILIAC	1 / 33-66%	1 / 33-66%	1 / 66-100%	1 / 33-66%	1 / 33-66%	1 / 0-33%	1 / 0-33%	1 / 0-33%	1 / 0-33%
HIP	1 / 33-66%	1 / 0-33%	1 / 0-33%	1 / 0-33%	1 / 66-100%	1 / 0-33%	1 / 0-33%	0	0
KNEE	1 / 33-66%	1 / 33-66%	1 / 33-66%	1 / 33-66%	0	0	0	0	1 / 0-33%
ANKLE	1 / 33-66%	2 / 33-66%	1 / 33-66%	0	0	1 / 0-33%	0	0	0

7.6 Chronological OA Results

The chronological comparison between the core and the colony during the Tiwanaku phase was presented in Section 7.3, as it is also the regional comparison. The evaluation of the Tiwanaku phase showed differences in modeled rates with prevalence being higher in the core than the colony, and significantly so on a few joints as well as one combined joint surface (i.e. **sacroiliac**). From these overall results, I suggest that people labored repetitively at different tasks in both the core and colony during the Tiwanaku state and that both groups were working at a variety of tasks. Additionally, the chronological comparison of these two areas suggests that during the Tiwanaku state, the Moquegua area colony may have been under local control. What follows are the intra-core and intra-colony chronological results in which I looked for change over time within these regions.

[21] Average eburnation scores were zero and therefore not included in this ordinal table.

Intra-Core

The core highland area change over time for OA was noted both during the transition from prior to the state (i.e. Late Formative to the Tiwanaku phases – Table 7.11, full results in Appendix C, Table C.6) as well as after the state (i.e. Tiwanaku to the Post-Tiwanaku phases – Table 7.12, full results in Appendix C, Table C.7). During the transition to Tiwanaku statehood, rates were higher during the Late Formative in the **shoulder**, **elbow**, **wrist**, **knee**, and **ankle** joints (Table 7.11). In the mid-body joints, OA modeled rates were higher during the Tiwanaku phase. Ordinal scores (Table 7.13) show similar prevalence of lipping, porosity, and osteophyte formation. These results indicate that people who lived and died in the highlands performed work that involved overuse of the **shoulder** joint during the Late Formative period and that this lessened during the later Tiwanaku phase. In addition, these data show that repetitive labors were greater during the Late Formative phase.

The change from the Tiwanaku phase to the post-Tiwanaku phase OA results are found in Table 7.12 and ordinal scores in Table 7.14. Although ordinal scores and percentage of joint involvement were higher during the Tiwanaku state, results were comparable between these two phases except in two joints: **sacroiliac** and **knee**. In the **sacroiliac**, rates were significantly higher during the Tiwanaku phase, while in the **knee** modeled OA rates were higher post-Tiwanaku, although not significantly different. The **sacroiliac** joint results could be mobility differences. However, with no other major differences in **hip** and **ankle**, and lower rates during the Tiwanaku phase in the **knee** joint, this seems unlikely. Instead, I would suggest that these significant results during the Tiwanaku period may also have something to do with people transporting goods using an *aguayo*. In addition, hormonal changes in the **sacroiliac** joint are noted for women during pregnancy (Gariola et al. 1989) and this may account for some of the evidence of OA during the Tiwanaku state. In addition, the results in the **knee** joint between Tiwanaku and post-Tiwanaku phases may indicate some kind of repetitive activity change among those who lived in the region after the collapse of the Tiwanaku state. While the modeled OA results in the **knee** were not significant, the ordinal results do show a greater intensity of **knee** use during the Tiwanaku phase. As such, **knee** joint OA can possibly be explained through some lifestyle change during the post-Tiwanaku period.

Overall, these chronological results in the core area of the Tiwanaku state suggest that upper body labor may have been at greater levels of repetitive damage during the Late Formative phase for all joints except mid-body (i.e. **sacroiliac** and **hip**). Thus, it was possible that people worked harder at more repetitive tasks prior to the state, and this may be one, in addition to other cultural and ideological, reasons the Tiwanaku state formed. In addition, the higher rates during the Tiwanaku state in the **sacroiliac** and **hip** joints may show more about birth rates or the use of an *aguayo* to transport goods during the state. These significantly high **sacroiliac** rates were also reported in the Tiwanaku to post-Tiwanaku time period comparison and may suggest the same thing – goods transport or possibly birth rate differences during the state. The comparable rates (except for the aforementioned **sacroiliac** OA results) during the Tiwanaku phase and post-Tiwanaku phase may suggest more local control over labor and labor mitigation with the collapse of the state.

Table 7.11 Intra-Core OA Results from Late Formative Phase to the Tiwanaku Phase

JOINT AREA	n=	LF Modeled % frequency	TW Modeled % frequency	χ^2 value (df=1)	*p*-value
SHOULDER	**109**	**61%**	**25%**	**7.30**	**.007**
ELBOW	443	46%	36%	1.49	.22
WRIST	177	44%	30%	1.28	.26
SACROILIAC	100	44%	64%	1.55	.21
HIP	109	20%	22%	0.02	.89
KNEE	321	26%	17%	1.57	.21
ANKLE	168	26%	22%	0.15	.70

Table 7.12 Intra-Core OA Results from Tiwanaku Phase to Post-Tiwanaku Phase

JOINT AREA	n=	TW Modeled % frequency	PT Modeled % frequency	χ^2 value (df=1)	*p*-value
SHOULDER	97	25%	25%	0.00	1.0
ELBOW	407	36%	31%	0.28	.60
WRIST	161	30%	25%	0.28	.60
SACROILIAC	**94**	**64%**	**17%**	**7.95**	**.005**
HIP	101	22%	-	-	-[a]
KNEE	275	17%	32%	2.23	.13
ANKLE	133	22%	23%	0.00	.95

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table 7.13 Intra-Core Tiwanaku Phase to Post-Tiwanaku Phase OA Ordinal Mean Scores with Percentage of Joint Involvement

JOINT AREA	TW Lipping / %	PT Lipping / %	TW Porosity / %	PT Porosity / %	TW Osteophyte / %	PT Osteophyte / %	TW Eburnation / %	PT Eburnation / %
SHOULDER	2 / 33-66%	1 / 0-33%	1 / 33-66%	1 / 0-33%	0	0	0	0
ELBOW	2/ 66-100%	1 / 0-33%	1 / 33-66%	0	1 / 33-66%	1 / 0-33%	0	0
WRIST	1 / 0-33%	1 / 0-33%	1 / 0-33%	1 / 0-33%	0	1 / 0-33%	0	0
SACROILIAC	2 / 33-66%	1 / 33-66%	1 / 0-33%	0	0	0	0	0
HIP	2 / 33-66%	0	2/ 66-100%	0	2 / 33-66%	0	0	0
KNEE	2 / 33-66%	1 / 0-33%	1 / 33-66%	0	1 / 33-66%	0	0	0
ANKLE	2 / 33-66%	2 / 33-66%	0	0	0	0	0	0

Table 7.14 Intra-Core Late Formative Phase to Tiwanaku Phase OA Ordinal Mean Scores with Percentage of Joint Involvement

JOINT AREA	LF Lipping / %	TW Lipping / %	LF Porosity / %	TW Porosity / %	LF Osteophyte / %	TW Osteophyte / %	LF Eburnation / %	TW Eburnation / %
SHOULDER	2 / 33-66%	2 / 33-66%	1 / 33-66%	1 / 33-66%	2 / 33-66%	0	1 / 33-66%	0
ELBOW	2 / 33-66%	2/ 66-100%	0	1 / 33-66%	0	1 / 33-66%	0	0
WRIST	1 / 0-33%	1 / 0-33%	1 / 0-33%	1 / 0-33%	0	0	0	0
SACROILIAC	1 / 0-33%	2 / 33-66%	1 / 33-66%	1 / 0-33%	1 / 33-66%	0	0	0
HIP	2 / 33-66%	2 / 33-66%	1 / 66-100%	2/ 66-100%	1 / 33-66%	2 / 33-66%	0	0
KNEE	1 / 33-66%	2 / 33-66%	1 / 33-66%	1 / 33-66%	1 / 0-33%	1 / 33-66%	0	0
ANKLE	1 / 33-66%	2 / 33-66%	0	0	0	0	0	0

Intra-Colony

The chronological comparisons in the colony area for OA are shown in the transition from prior to the state (i.e. Late Formative to the Tiwanaku phases – Table 7.15) as well as after the state (i.e. Tiwanaku to the Post-Tiwanaku phases Table 7.16, full results in Appendix C, Table C.8). The ordinal scores for the Late Formative and Tiwanaku phases comparison are shown in Table 7.17. Modeled rates for the **elbow**,

sacroiliac, **hip**, and **ankle** were all higher for the Huaracane people (i.e. before Tiwanaku colonists settled in the Moquegua Valley region) and the same in the **knee** joint. The **elbow**, **hip**, and **ankle** joints were also statistically significant. These results suggest labor was heavier and more repetitive prior to Tiwanaku people settling in this region. It was also possible that because these were different (i.e. non-Tiwanaku) peoples, OA may be genetically more common in this population as has been noted clinically for other groups (Felson 2004; Felson and Zhang 1998).

The results for the Tiwanaku to post-Tiwanaku phase comparisons (Table 7.16) ordinal scores are in Table 7.18. Modeled OA rates were higher in all joints, except the **shoulder**, during the Tiwanaku phase and ordinal scores were similar. This comparison was significantly higher in the **elbow** joint. As the Tumilaca people were likely descendants of the Tiwanaku colonists, the results may indicate a reduction in repetitive tasks after the state lost control in this region.

Table 7.15 Intra-Colony OA Results from Late Formative Phase to the Tiwanaku Phase

JOINT AREA	n=	LF Modeled % frequency	TW Modeled % frequency	χ^2 value (df=1)	*p*-value
SHOULDER	550	-	-	-	-[a]
ELBOW	**2573**	**64%**	**29%**	**313.5**	**<.0001**
WRIST	877	-	-	-	-[a]
SACROILIAC	613	60%	43%	0.90	.34
HIP	**676**	**75%**	**16%**	**8.37**	**.004**
KNEE	1375	22%	22%	0.00	.99
ANKLE	**1000**	**40%**	**16%**	**103.1**	**<.0001**

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table 7.16 Intra-Colony OA Results from Tiwanaku Phase to Post-Tiwanaku Phase

JOINT AREA	n=	TW Modeled % frequency	PT Modeled % frequency	χ^2 value (df=1)	*p*-value
SHOULDER	557	20%	27%	0.27	.60
ELBOW	**2604**	**29%**	**11%**	**6.48**	**.01**
WRIST	889	20%	13%	0.89	.34
SACROILIAC	617	-	-	-	-[a]
HIP	682	16%	10%	0.29	.59
KNEE	1405	22%	8%	3.08	.08
ANKLE	1026	-	-	-	-[a]

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table 7.17 Intra-Colony Late Formative to Tiwanaku Phases OA Ordinal Mean Scores with Percentage of Joint Involvement

JOINT AREA	LF Lipping / %	TW Lipping / %	LF Porosity / %	TW Porosity / %	LF Osteophyte / %	TW Osteophyte / %	LF Eburnation / %	TW Eburnation / %
SHOULDER	2 / 33-66%	1 / 33-66%	0	0	0	0	0	0
ELBOW	1/ 0-33%	1 / 33-66%	0	1/ 0-33%	1/ 0-33%	0	0	0
WRIST	1/ 0-33%	1 / 33-66%	0	0	0	1 / 0-33%	0	0
SACROILIAC	1/ 0-33%	1 / 33-66%	1/ 0-33%	1/ 33-66%	1/ 0-33%	1 / 0-33%	0	0
HIP	1 / 33-66%	1 / 0-33%	0	1/ 0-33%	1/ 0-33%	0	0	0
KNEE	0	1 / 33-66%	0	0	0	1 / 0-33%	0	1 / 0-33%
ANKLE	1/ 0-33%	1 / 33-66%	0	0	0	0	0	0

Table 7.18 Intra-Colony Tiwanaku to Post-Tiwanaku Phases OA Ordinal Mean Scores with Percentage of Joint Involvement

JOINT AREA	TW Lipping / %	PT Lipping / %	TW Porosity / %	PT Porosity / %	TW Osteophyte / %	PT Osteophyte / %	TW Eburnation / %	PT Eburnation / %
SHOULDER	1 / 33-66%	1 / 33-66%	0	0	0	0	0	0
ELBOW	1 / 33-66%	1 / 33-66%	1/ 0-33%	0	0	0	0	0
WRIST	1 / 33-66%	1 / 33-66%	0	0	1 / 0-33%	1 / 0-33%	0	0
SACROILIAC	-	-	-	-	-	-	-	-
HIP	1 / 0-33%	1 / 33-66%	1/ 0-33%	0	0	0	0	0
KNEE	1 / 33-66%	1 / 33-66%	0	0	1 / 0-33%	1 / 0-33%	1 / 0-33%	0
ANKLE	-	-	-	-	-	-	-	-

7.7 Composition of the State's Workforce Using OA

Another component to this research concerns who comprised the Tiwanaku state's workforce. As such, I was interested in how modeled rates of OA, ordinal scores with types of OA, and significant differences between subgroups by age-at-death and sex reflect the social structure of repetitive activity across the landscape. The results are presented in the following sections in order to discuss age and sex related tasks geographically throughout the Tiwanaku state.

Regional OA Comparison by Sex and by Age

Results for females in the core and colony area are presented in Table 7.19 (full results presented in Appendix C, Table C.9) and ordinal scores in Table 7.20. The modeled OA rates for females varied as sometimes evidence of repetitive joint usage was higher in the core and other times in the colony. In addition, there were two significant comparisons: the sacrum auricular surface and the whole **sacroiliac** joint. The modeled frequency was higher in the core than the colony among females for both of these significant joint areas. Evidence of lipping, porosity, and osteophyte formation was also greater and with more joint area involvement for core females.

The labor comparison between males from the core and colony are shown in Table 7.21 (full results presented in Appendix C, Table C.10) and ordinal scores for males in Table 7.22. While modeled OA rates in the **knee** and **ankle** joints were similar between core and colony males, OA results for males in the arm and mid-body joints showed that core modeled rates were higher than colony modeled rates. In the arm, four individual areas (i.e. trochlea, capitulum, radial notch of the ulna, and radius distal articulation) were significantly higher in the core. The **elbow** joint overall was also significantly different between core and colony males with greater modeled rates from the core. In the mid-body, the auricular surface of the sacrum in the **sacroiliac** joint was significantly different, with higher rates from the core. In addition, the ordinal scores for both of these significant joint surfaces were similar between core and colony males.

In summary, the comparison between core and colony males, as well as core and colony females for evidence of OA showed that rates were higher for core residents, that there were some **elbow** joint and **sacroiliac** joint significant differences. These results suggest that there were differences in repetitive tasks between core and colony males and females. With the significant **sacroiliac** joint OA differences in both core males and females, it seems likely that core people may have been involved in the repetitive transport of goods using something akin to an *aguayo*. In addition, the different modeled rates of OA in the arms of core males may be explained by different agriculture practices in the core and in the colony. It was possible that repetitive movement differences in growing food in a raised-field system versus maize in a riverine canal-based system

(Erickson 1985, 2006; Erickson and Candler 1989; Goldstein 2005; Janusek 2004a, 2008) may account for these significant OA differences. Thus, these significant OA comparisons show that both women and men within the core worked at repetitive tasks, and that type of agriculture as well as goods transport affecting the lower back and **sacroiliac** joint may have been a major difference between the two regions.

Regional age comparisons were evaluated between groups within each of the five age-at-death categories, 15-19 years, 20-29 years, 30-39 years, 40-49 years, and 50+ years. Prior research (Jurmain 1999; Jurmain et al. 2012; Kennedy 1989, 1998; Weiss and Jurmain 2007) had shown that OA can be age-dependent and the older the individual, the greater the likelihood that he or she will show evidence of OA. By restricting age comparisons to each age-at-death category and not judging between age groups, problems with survivorship (an individual's ability to survive to an older age) are limited. Thus, these results provide information on repetitive joint use and significant activity differences adults were subjected to within each age-at-death category that may have been age-dependent tasks within the Tiwanaku state.

Age-at-death comparisons between the core and colony regions for each age-at-death can be found in Appendix C, Table C.11 and the significant results are shown below in Table 7.23. Within these comparisons, there were significant results for people in the 15-19, 40-49, and 50+ age-at-death categories and all modeled rates were higher for core residents. The youngest people in this study (15-19 years) had significant **hip** joint OA and the oldest (i.e. 50+ years) people had significant **wrist** joint modeled OA rates. The 40-49 age-at-death category had the most differences with OA in the **shoulder**,

sacroiliac, and **hip**. In general, ordinal scores showed similar levels of OA and percentage of joint involvement.

These results suggest that there were some age-related differences between the core and colony in repetitive tasks, especially between the youngest and oldest people. Overall, it was unclear what kinds of **hip** related tasks younger people (15-19 years) performed at greater levels in the core. It was also interesting to note the degree to which individuals age 40 and older worked at repetitive tasks in the core. In general, I suggest that older people (40 years and older) in the core may have labored repetitively longer than their counterparts in the colony thus showing higher modeled rates of OA. What these tasks were is unclear, but it was possible they were related to differences in subsistence between core and colonists.

Table 7.19 OA Core vs. Colony Results during Tiwanaku Phase for FEMALES

JOINT AREA	n=	Core Modeled % frequency	Colony Modeled % frequency	χ^2 value (df=1)	*p*-value
SHOULDER	328	20%	22%	0.08	.78
ELBOW	1512	32%	28%	0.41	.52
WRIST	536	25%	19%	0.60	.44
SACROILIAC	**395**	**80%**	**49%**	**8.66**	**.003**
HIP	416	19%	17%	0.09	.77
KNEE	775	11%	20%	1.86	.17
ANKLE	563	14%	14%	0.01	.93

Table 7.20 Core vs. Colony OA Ordinal Mean Scores during the Tiwanaku Phase with Percentage of Joint Involvement for FEMALES

JOINT AREA	Core Lipping / %	Colony Lipping / %	Core Porosity / %	Colony Porosity / %	Core Osteophyte / %	Colony Osteophyte / %	Core Eburnation / %	Colony Eburnation / %
SHOULDER	1 / 33-66%	0	1 / 0-33%	0	0	0	0	0
ELBOW	2 / 33-66%	1 / 33-66%	0	1/ 0-33%	1/ 33-66%	0	0	0
WRIST	1 / 33-66%	0	1 / 33-66%	0	1 / 33-66%	1 / 0-33%	0	0
SACROILIAC	2 / 33-66%	1 / 33-66%	2 / 33-66%	1/ 33-66%	1 / 33-66%	1 / 0-33%	0	0
HIP	1 / 33-66%	1 / 0-33%	1 / 33-66%	1/ 0-33%	1 / 33-66%	0	0	0
KNEE	2 / 33-66%	1 / 33-66%	1 / 0-33%	0	1 / 0-33%	1 / 0-33%	1 / 0-33%	1 / 0-33%
ANKLE	2 / 33-66%	1 / 33-66%	0	0	0	0	0	0

Table 7.21 OA Core vs. Colony Results during Tiwanaku Phase for MALES

JOINT AREA	n=	Core Modeled % frequency	Colony Modeled % frequency	χ^2 value (df=1)	*p*-value
SHOULDER	221	38%	19%	2.73	.10
ELBOW	**1006**	**49%**	**32%**	**4.77**	**.03**
WRIST	328	39%	21%	3.71	.054
SACROILIAC	261	51%	35%	1.79	.18
HIP	286	29%	14%	2.36	.12
KNEE	612	25%	23%	0.08	.77
ANKLE	398	24%	18%	0.76	.38

Table 7.22 Core vs. Colony OA Ordinal Mean Scores during the Tiwanaku Phase with Percentage of Joint Involvement for MALES

JOINT AREA	Core Lipping / %	Colony Lipping / %	Core Porosity / %	Colony Porosity / %	Core Osteophyte / %	Colony Osteophyte / %	Core Eburnation / %	Colony Eburnation / %
SHOULDER	1 / 33-66%	1 / 33-66%	1 / 0-33%	0	0	0	0	0
ELBOW	1 / 33-66%	1 / 33-66%	2/ 0-33%	1/ 0-33%	1/ 33-66%	0	0	0
WRIST	2 / 33-66%	1 / 33-66%	1 / 33-66%	0	1 / 33-66%	1 / 0-33%	0	0
SACROILIAC	1 / 33-66%	1 / 33-66%	1 / 33-66%	2/ 33-66%	1 / 33-66%	1 / 0-33%	0	0
HIP	1 / 33-66%	0	0	0	1 / 33-66%	0	0	0
KNEE	2 / 33-66%	1 / 33-66%	1 / 0-33%	0	2 / 0-33%	1 / 0-33%	0	0
ANKLE	2 / 33-66%	1 / 33-66%	0	0	0	0	0	0

Table 7.23 OA Core vs. Colony Results during Tiwanaku Phase by AGE-AT-DEATH

JOINT AREA	N=	Core Modeled % frequency	Colony Modeled % frequency	χ^2 value (df=1)	p-value
15-19 years					
HIP	**68**	**33%**	**3%**	**5.38**	**.02**
40-49 years					
SHOULDER	**69**	**60%**	**20%**	**4.78**	**.03**
SACROILIAC	**88**	**89%**	**38%**	**10.39**	**.001**
HIP	**97**	**47%**	**15%**	**4.67**	**.03**
50+ years					
WRIST	**74**	**75%**	**41%**	**5.90**	**.02**

Inter-Highland Area OA Comparison by Sex and by Age

In comparing individuals from the Katari Valley and Tiwanaku Valley by sex, rates were similar and there were no significant differences for females (Appendix C, Table C.12). Results for males are noted in Table 7.24 and ordinal scores showed medium levels of lipping and porosity in less than two-thirds of the joint surfaces. Overall, males showed significant **shoulder** and **elbow** joint OA differences between individuals from the Katari Valley and the Tiwanaku Valley, with higher modeled rates in the **shoulder** for Tiwanaku Valley males and higher modeled rates in the **elbow** for Katari Valley males. As the Katari Valley was noted as the main agricultural area of the highland region, it was interesting that they were higher in the **elbow**, but not **shoulder**. These results suggest that workload involving the **shoulder** was more repetitive in the Tiwanaku Valley region for males, but more repetitive for **elbow** OA in the Katari Valley. Overall, the results indicate some variation in tasks, but that the majority of work was similar between these two highland valleys.

Age-at-death significant comparisons between individuals from these two highland valleys are shown in Table 7.25 (full results noted in Appendix C, Table C.13). There were only two significant age-at-death OA differences in the Katari and Tiwanaku Valley comparisons. There were **knee** OA differences for people in their twenties and **elbow** OA differences for people in their thirties, both with higher rates in the Katari area. As this was the agricultural area of the Tiwanaku highlands and these two ages were prime ages for performing manual labor, it was likely they were indicative of physical and repetitive work.

Overall, these results suggest there were few differences in repetitive labors between Katari Valley and Tiwanaku Valley males and females who lived in these two highland regions. In addition, I would suggest that the few significant differences by age-at-death between the Katari Valley and Tiwanaku Valley indicate that many labors were similar or performed at similar levels of intensity in the highlands.

Table 7.24 Inter-Highland Area OA Results during the Tiwanaku Phase for MALES

JOINT AREA	n=	Katari Valley Modeled % frequency	Tiwanaku Valley Modeled % frequency	χ^2 value (df=1)	*p*-value
SHOULDER	**26**	**11%**	**53%**	**4.11**	**.04**
ELBOW	**144**	**77%**	**38%**	**6.78**	**.009**
WRIST	49	54%	33%	0.93	.34
SACROILIAC	41	45%	53%	0.12	.73
HIP	38	60%	18%	2.01	.16
KNEE	89	36%	16%	2.40	.12
ANKLE	45	24%	25%	0.01	.91

Table 7.25 OA Inter-Highland area Results during Tiwanaku Phase by AGE-AT-DEATH

JOINT AREA	N=	Katari Valley Modeled % frequency	Tiwanaku Valley Modeled % frequency	χ^2 value (df=1)	p-value
20-29 years					
KNEE	**85**	**18%**	**2%**	**5.38**	**.02**
30-39 years					
ELBOW	**107**	**69%**	**35%**	**8.25**	**.004**

<u>Intra-Area OA Comparison by Sex and by Age</u>

In the following sections, I present data from within the Katari Valley, within the Tiwanaku Valley, and within the Moquegua Valley for OA comparisons in order to discuss the composition of the workforce within the Tiwanaku state. A brief note is needed on the presentation of data as each OA comparison by sex or age-at-death are not provided in this section, with full results presented in Appendix C. In addition, for the Katari and Moquegua Valley results by sex, data are presented side-by-side for females and males. Due to the large amount of comparative data within the Tiwanaku Valley, data are given first for females and then for males.

Within the Katari Valley

The results for females and males in site-by-site comparisons for the Katari Valley are shown in Table 7.26 (see Appendix C, Table C.14 for full results). For females, the modeled frequencies were highest from Pokachi Kontu and lowest from Lukurmata, with significant differences in the **shoulder** joint. Males from the Katari Valley showed significantly higher rates in the **elbow** joint when Lukurmata and Kirawi were compared. For all groups, ordinal scores were similar with evidence of lipping, porosity, and osteophyte formation.

Within the Katari Valley, significant age-at-death OA site comparisons are shown in Table 7.27. There were no significant results for people in the 15-19, 20-29, 40-49, or 50+ age categories. The only significant results were found in people from the 30-39 age-at-death categories and only in the **elbow** joint. People from Lukurmata in their thirties had significantly higher rates when compared to Pokachi Kontu.

Overall, the OA results show Pokachi Kontu females performed some kind of repetitive **shoulder** task at significantly greater rates than Lukurmata females, while Lukurmata males had higher rates of **elbow** OA than Kirawi males. While not straightforward, these results suggest there were different types of repetitive activities performed within the Katari Valley. As previously discussed, if Lukurmata was a hub of ritual specialists and regional administrators who performed very little manual labor, then these results suggest that only females, and not males, performed these duties. However, as Lukurmata women show significantly lower levels of OA in the **shoulder** joint, then it was just as likely that they worked repetitively, but at different jobs than Pokachi Kontu females or that there may have been more family demand on female labor at Pokachi Kontu. Additionally, Lukurmata males had high modeled levels of OA and the results do not suggest that any one area in the Katari Valley labored repetitively for the state elites in a centralized system. If life was tougher under elites during the Tiwanaku state in the rural sites as suggested by the hierarchical model (Kolata 1991:120), I would have expected people from both Kirawi and Pokachi Kontu to show high levels of OA and be significantly different. Instead, it may be that men and women of all ages worked at a variety of tasks in the Tiwanaku state and there were only a few divisions in labor by gender or age within the Katari Valley, although comparable sample sizes were somewhat small in this area and this must be remembered when interpreting results.

Table 7.26 OA Intra-Area Katari Valley GEE Chi-Square Results during the Tiwanaku Phase (df=1) for FEMALES and MALES

	FEMALES			**MALES**		
JOINT AREA	Site / Modeled %	Lukurmata	Pokachi Kontu	Site / Modeled %	Lukurmata	Pokachi Kontu
SHOULDER N=17 **F** N=9 **M**	Kirawi / %	-[a]	-[a]	Kirawi /%	-[a]	-[a]
	Lukurmata /15%	-	**χ^2=6.01 p=.01**	Lukurmata /%	-	-[a]
	Pokachi Kontu /50%	-	-	Pokachi Kontu /%	-	-
ELBOW N=45 **F** N=43 **M**	Kirawi /%	-[a]	2.52 .11	Kirawi /20%	**21.59 <.0001**	-[a]
	Lukurmata /31%	-	-[a]	Lukurmata /84%	-	-[a]
	Pokachi Kontu /50%	-	-	Pokachi Kontu /%	-	-

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table 7.27 OA Intra-Area Katari Valley Results during Tiwanaku Phase by AGE-AT-DEATH

JOINT AREA	N=	Lukurmata Modeled % frequency	Pokachi Kontu Modeled % frequency	χ^2 value (df=1)	p-value
30-39 years					
ELBOW	**32**	**74%**	**40%**	**3.95**	**.047**

Within the Tiwanaku Valley

Intra-area OA results for females from the Tiwanaku Valley are found in Table 7.28 and ordinal scores in Table 7.29 and for males in 7.30 and ordinal scores in Table 7.31. Only the **elbow** joint showed results for OA with females from Putuni showing the lowest modeled OA rates. Putuni was also significantly different from all the other sites. Females from Akapana had the second lowest rates and were significantly different from females with the highest modeled **elbow** OA rates from Ch'iji Jawira. Ordinal scores were also similar between sites with evidence of lipping, porosity, osteophyte formation, and eburnation. For males, only one joint, the **ankle**, showed results for the Akapana and Marka Pata comparison. Akapana had significantly higher modeled rates of **ankle** OA and ordinal results showed lipping and osteophyte formation as OA evidence, while Marka Pata males showed lipping and porosity.

OA results by age-at-death within the Tiwanaku Valley are presented in Table 7.32. There were no significant differences for people in the 15-19, 20-29, or 50+ by age-at-death and only the results for the 30-39 and 40-49 categories are shown below. For the 30-39 and 40-49 age-at-death groups, Akapana, Mollo Kontu, and Marka Pata had the greatest number of comparisons within the Tiwanaku Valley and the results are presented in this chapter. For people in their thirties, Marka Pata had modeled rates that were 10%

higher for **shoulder** OA, although the results were not statistically significant. For people in the 40-49 age-at-death category, the **shoulder**, **elbow**, **wrist**, and **ankle** joints all showed evidence of OA. Akapana had the highest modeled OA rates in the **shoulder**, Mollo Kontu peoples had the highest in the **elbow**, and Marka Pata peoples had the greatest frequencies of OA in the **wrist** and **ankle** joints. Only the Mollo Kontu and Akapana comparison in the **elbow** joint showed significant results by age-at-death. Additionally, ordinal scores showed higher rates of lipping and osteophyte formation for the sites of Marka Pata and Mollo Kontu with approximately one to two-thirds of the joint surface presenting with OA.

While there were significant OA differences for both females (i.e. **elbow** joint OA) and males (i.e. **ankle** joint OA), these results were not straightforward. Overall, these data suggest there were few significant differences in repetitive activity differences by sex within the Tiwanaku Valley. In addition, these results suggest there may have been task related differences by age within this valley. Thus, results within the Tiwanaku Valley do show differences in repetitive movement among residents of this area, with fewer differences in sexual division of labor and more age-based tasks during the Tiwanaku state.

Table 7.28 OA Intra-Area Upper Anatomy Tiwanaku Valley GEE Chi-Square (df=1) Results during the Tiwanaku Phase for FEMALES

JOINT AREA	Site / Modeled %	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
ELBOW n=81	Akapana / 23%	-[a]	**χ^2=85.9 *p*=<.0001**	-[a]	1.17 .28	3.07 .08	**66.7 <.0001**
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / 50%	-	-	-[a]	0.76 .38	0.24 .62	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 37%	-	-	-	-	0.11 .74	**8.09 .004**
	Mollo Kontu / 43%	-	-	-	-	-	**14.7 .0001**
	Putuni / 9%	-	-	-	-	-	-

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table 7.29 OA Intra-Area Tiwanaku Valley Ordinal Mean Scores during the Tiwanaku Phase with Percentage of Joint Surface Involvement for FEMALES

JOINT AREA	Akapana	Ch'iji Jawira	Marka Pata	Mollo Kontu	Putuni
ELBOW LIPPING	1 / 0-33%	1 / 0-33%	1 / 33-66%	1 / 33-66%	0
ELBOW POROSITY	0	1 / 0-33%	0	1 / 0-33%	1 / 33-66%
ELBOW OSTEOPHYTES	1 / 0-33%	0	1 / 0-33%	1 / 33-66%	1 / 0-33%
ELBOW EBURNATION	0	0	0	1 / 0-33%	0

Table 7.30 OA Intra-Area Tiwanaku Valley GEE Chi-Square (df=1) Results during the Tiwanaku Phase for MALES

JOINT AREA	Site / Modeled %	Marka Pata
ANKLE n=28	Akapana / 46%	**χ^2=4.97 *p*=.03**
	Marka Pata / 7%	-

Table 7.31 OA Intra-Area Tiwanaku Valley Ordinal Mean Scores during the Tiwanaku Phase with Percentage of Joint Surface Involvement for MALES

JOINT AREA	Akapana	Marka Pata
ANKLE LIPPING	2 / 33-66%	1 / 33-66%
ANKLE POROSITY	0	1 / 0-33%
ANKLE OSTEOPHYTES	1 / 33-66%	0
ANKLE EBURNATION	0	0

Table 7.32 OA Intra-Area Tiwanaku Valley GEE Chi-Square (df=1) Results during the Tiwanaku Phase by AGE-AT-DEATH

JOINT AREA	Site / Modeled %	Marka Pata	Mollo Kontu
	Age 30-39		
SHOULDER n=10	Akapana /33%	χ^2=0.07 *p*=.78	-
	Marka Pata /43%	-	-
	Mollo Kontu /%	-	-
	Age 40-49		
SHOULDER n=12	Akapana /83%	0.30 .58	1.62 .20
	Marka Pata /67%	-	-
	Mollo Kontu /33%	-	-
ELBOW n=65	Akapana /41%	0.00 .95	**6.04 .01**
	Marka Pata /43%	-	-
	Mollo Kontu /92%	-	-
WRIST n=30	Akapana /36%	1.46 .23	0.72 .40
	Marka Pata /67%	-	-
	Mollo Kontu /60%	-	-
ANKLE n=11	Akapana /25%	0.09 .77	-
	Marka Pata /33%	-	-
	Mollo Kontu /%	-	-

Within the Moquegua Valley

Results within the Moquegua Valley for females and males are presented in Table 7.33. In general, rates were comparable among females and there were no significant differences between the samples from Chen Chen, Omo, and Rio Muerto. Ordinal scores (Table 7.34) show that evidence of lipping was comparable between the sites for females, with Rio Muerto having a slightly greater percentage of joint involvement. For porosity and osteophyte formation, Omo and Rio Muerto have a greater prevalence of joint involvement than Chen Chen.

Unlike females, OA comparisons between males from sites within the Moquegua Valley showed five significant comparisons. Akin to the Moquegua Valley sample not divided by sex, Chen Chen had the lowest OA rates by joint and these low modeled rates translated into significant OA differences between Chen Chen and Rio Muerto in the **shoulder** and **sacroiliac** joints. There were also significant differences between Chen Chen and Omo in the **sacroiliac**, **hip**, and **ankle** joints. Ordinal scores for males (Table 7.35) showed that both Omo and Rio Muerto had consistently higher scores, percentages of joint involvement, and a greater range of OA evidence.

Overall, the intra-Moquegua Valley results indicated that females who lived and died within this region worked tasks with similar levels of repetition as shown by the modeled OA rates and no significant differences. The data also indicate that males from Chen Chen had the least repetitive workload and this translated into many significant differences between the three sites. I would suggest that males performed a variety of jobs that suggest site-by-site divisions of labor within the Moquegua area. In addition, as Omo was likely home to some camelid herders (Goldstein 2005), this evidence supports the idea that Omo males may have been more mobile than their counterparts at the Chen

Chen site. The data also support that Rio Muerto males worked at repetitive tasks, but the levels of repetition were not different enough to be significant in comparisons with Omo. However, they were statistically different enough from Chen Chen in the **shoulder** and **sacroiliac** joints.

<u>Overall, the Moquegua Valley age-at-death results had the most age-related repetitive task evidence during the Tiwanaku state for all the intra-area comparisons for the Tiwanaku state.</u> <u>Age-at-death</u> significant OA comparisons within the Moquegua Valley during the Tiwanaku state are shown in Table 7.36 (full results, Appendix C, Table C.15). People in the 20-29, 30-39, and 50+ age-at-death categories all had significant OA results, suggesting differences in repetitive activity among these three age groups. Ordinal scores were similar to the overall results with heavier OA evidence from Omo and Rio Muerto age groups and lower OA rates from Chen Chen.

For people in the 20-29 age-at-death category, the OA rates for the **shoulder**, **elbow**, and **sacroiliac** joints were significant. The differences were between Chen Chen, with the lowest modeled OA rates, and Rio Muerto, with the highest rates for all people in their twenties. For people in the 30-39 age-at-death category, this same pattern of lowest OA rates in Chen Chen individuals was also noted with **shoulder**, **elbow**, **wrist**, **sacroiliac**, **hip**, and **ankle** joints affected. In this age-at-death group, the differences were primarily between Omo and Chen Chen in all significant joints. Omo was also significantly different from Rio Muerto in evidence of **wrist** joint OA. Rio Muerto was significantly different from Chen Chen in the **shoulder**, **elbow**, and **sacroiliac** joints.

In older individuals from the 50 and above age-at-death category, there were significant modeled OA results for the **wrist**, **sacroiliac**, and **ankle** joints. Chen Chen had the lowest OA rates in the **wrist** and **ankle** joints, but highest in the **sacroiliac**. Chen Chen was significantly different from Rio Muerto peoples over 50 years of age who had the lowest **sacroiliac** OA rates. In the **wrist**, Chen Chen and Rio Muerto were significantly different, and in the **ankle** joint, Omo had very high OA rates and was significantly different from both Chen Chen and Rio Muerto.

Overall, these age-at-death data suggest that there were different age-related tasks for individuals from all three sites within the Moquegua Valley. Omo had higher modeled rates and ordinal OA scores for people in the 30-39 and the evidence of **ankle** OA in older individuals. An explanation for this could be that people from Omo had a lifetime of mobility differences. The labor data may also reflect repetitive labor with agricultural production for younger people from Rio Muerto, who may have been dry-wash farming as opposed to canal-fed farming in the Chen Chen area.

In addition, Chen Chen likely had a large population (Goldstein 2005; Owen 1997), hence it was also possible that the significant results could be related to population differences. Rio Muerto peoples may have had to work repetitively more frequently, while Chen Chen colonizers could have spread the work out over a larger population. Additionally, people from Chen Chen may have worked repetitive tasks, such as carrying goods using an *aguayo*, and this along with survivorship was the reason for the high **sacroiliac** joint OA rates in people 50+ years. It was also possible that with the higher population buried at Chen Chen that the birth rates were also higher at this site during the Tiwanaku state, thus the OA in the **sacroiliac** joint could be a product of higher lifetime rates of pregnancy. However, as there was no direct evidence from females, this idea is still being explored.

Finally, some of these age-at-death results could represent survivorship. Rio Muerto people may have had a harder lifestyle as younger individuals, thus the high rates of OA for people who died in their twenties. Omo people may have generally survived into their thirties and had the highest rates of OA in that age-at-death group. Chen Chen people had the lowest modeled OA rates for all age groups (except for the **sacroiliac** joint results in the 50+ years). Thus, Chen Chen people may have had the least highest rates of survivorship to an older age and least repetitive tasks within the Moquegua Valley during the Tiwanaku state.

Table 7.33 OA Intra-Area Moquegua Valley GEE Chi-Square Results during the Tiwanaku Phase (df=1) for FEMALES and MALES

	FEMALES			MALES		
JOINT AREA	Site / Modeled %	Omo	Rio Muerto	Site / Modeled %	Omo	Rio Muerto
SHOULDER n=288 **F** n=195 **M**	Chen Chen / 18%	χ^2=0.40 *p*=.53	2.61 .11	Chen Chen / 8%	χ^2=3.11 *p*=0.08	**8.55 .004**
	Omo / 24%	-	0.55 .46	Omo / 23%	-	1.06 .30
	Rio Muerto / 36%	-	-	Rio Muerto / 36%	-	-
ELBOW n=1386 **F** n=862 **M**	Chen Chen / 26%	1.77 .18	2.51 .11	Chen Chen / 25%	3.07 .08	3.09 .08
	Omo / 34%	-	0.16 .69	Omo / 38%	-	0.04 .85
	Rio Muerto / 37%	-	-	Rio Muerto / 40%	-	-
WRIST n=485 **F** n=279 **M**	Chen Chen / 19%	0.80 .37	0.32 .57	Chen Chen / 17%	1.01 .31	0.57 .45
	Omo / 27%	-	1.02 .31	Omo / 26%	-	0.02 .88
	Rio Muerto / 13%	-	-	Rio Muerto / 24%	-	-
SACRO-ILIAC n=360 **F** n=220 **M**	Chen Chen / 45%	1.80 .18	1.65 .20	Chen Chen / 24%	**4.09 .04**	**4.12 .04**
	Omo / 58%	-	0.01 .93	Omo / 46%	-	0.03 .87
	Rio Muerto / 60%	-	-	Rio Muerto / 49%	-	-
HIP n=379 **F** n=248 **M**	Chen Chen / 15%	0.64 .42	1.93 .16	Chen Chen / 5%	**8.59 .003**	3.80 .051
	Omo / 20%	-	0.31 .58	Omo / 28%	-	0.58 .45
	Rio Muerto / 26%	-	-	Rio Muerto / 19%	-	-
KNEE n=679 **F** n=523 **M**	Chen Chen / 21%	0.16 .69	0.00 .97	Chen Chen / 19%	0.02 .88	1.64 .20
	Omo / 17%	-	0.14 .71	Omo / 18%	-	1.58 .21
	Rio Muerto / 21%	-	-	Rio Muerto / 31%	-	-
ANKLE n=512 **F** n=353 **M**	Chen Chen / 13%	0.90 .34	0.30 .59	Chen Chen / 9%	**11.24 .001**	2.06 .15
	Omo / 19%	-	0.06 .80	Omo / 30%	-	0.78 .38
	Rio Muerto / 17%	-	-	Rio Muerto / 21%	-	-

Table 7.34 OA Intra-Area Moquegua Valley Ordinal Mean Scores during the Tiwanaku Phase with Percentage of Joint Surface Involvement for FEMALES[22]

JOINT AREA	Chen Chen Lipping / %	Omo Lipping / %	Rio Muerto Lipping / %	Chen Chen Porosity / %	Omo Porosity / %	Rio Muerto Porosity / %	Chen Chen Osteophyte / %	Omo Osteophyte / %	Rio Muerto Osteophyte / %
SHOULDER	1 / 33-66%	1 / 33-66%	1 / 33-66%	0	2 / 33-66%	1 / 0-33%	0	0	0
ELBOW	1 / 33-66%	1 / 33-66%	1 / 33-66%	1 / 0-33%	1 / 33-66%	0	0	1 / 0-33%	0
WRIST	1 / 33-66%	1 / 33-66%	1 / 33-66%	0	1 / 33-66%	0	1 / 0-33%	0	0
SACROILIAC	1 / 33-66%	1 / 33-66%	1 / 66-100%	1 / 33-66%	1 / 33-66%	1 / 0-33%	1 / 0-33%	1 / 0-33%	1 / 0-33%
HIP	1 / 33-66%	1 / 0-33%	1 / 0-33%	1 / 0-33%	1 / 0-33%	1 / 0-33%	1 / 0-33%	0	0
KNEE	1 / 33-66%	2 / 33-66%	1 / 33-66%	1 / 33-66%	1 / 33-66%	0	0	0	1 / 0-33%
ANKLE	1 / 33-66%	2 / 33-66%	1 / 33-66%	0	2 / 33-66%	1 / 0-33%	0	0	0

Table 7.35 OA Intra-Area Moquegua Valley Ordinal Mean Scores during the Tiwanaku Phase with Percentage of Joint Surface Involvement for MALES[23]

JOINT AREA	Chen Chen Lipping / %	Omo Lipping / %	Rio Muerto Lipping / %	Chen Chen Porosity / %	Omo Porosity / %	Rio Muerto Porosity / %	Chen Chen Osteophyte / %	Omo Osteophyte / %	Rio Muerto Osteophyte / %
SHOULDER	1 / 0-33%	1 / 33-66%	1 / 33-66%	0	0	1 / 0-33%	0	0	0
ELBOW	1 / 33-66%	1 / 33-66%	1 / 33-66%	1 / 0-33%	1 / 33-66%	0-33%	0-33%	1 / 0-33%	0
WRIST	1 / 33-66%	1 / 33-66%	1 / 33-66%	0	1 / 33-66%	0-33%	1 / 0-33%	0	0
SACROILIAC	1 / 33-66%	1 / 0-33%	1 / 0-33%	1 / 33-66%	1 / 33-66%	1 / 0-33%	1 / 0-33%	1 / 0-33%	1 / 0-33%
HIP	1 / 33-66%	1 / 0-33%	1 / 0-33%	1 / 0-33%	1 / 0-33%	1 / 0-33%	1 / 0-33%	0	0
KNEE	1 / 33-66%	2 / 0-33%	1 / 33-66%	1 / 33-66%	1 / 33-66%	0	0	0	1 / 0-33%
ANKLE	1 / 33-66%	2 / 0-33%	1 / 33-66%	0	2 / 33-66%	1 / 0-33%	0	0	0

[22] Average eburnation scores were zero and therefore not included in this ordinal table.

[23] Average eburnation scores were zero and therefore not included in this ordinal table.

Table 7.36 OA Intra-Area Moquegua Valley GEE Chi-Square Results during the Tiwanaku Phase (df=1) for AGE-AT-DEATH

JOINT AREA	Site / Modeled %	Omo	Rio Muerto
20-29 years			
SHOULDER n=150	Chen Chen / 11%	χ^2=0.77/ *p*=.38	**5.86 / *p*=.02**
	Omo / 5%	-	**4.99 / .03**
	Rio Muerto / 41%	-	-
ELBOW n=724	Chen Chen / 17%	0.46 / .50	**7.09 / .008**
	Omo / 20%	-	**4.62 / .03**
	Rio Muerto / 40%	-	-
SACRO-ILIAC n=173	Chen Chen / 22%	2.98 / .08	**13.56 / .0002**
	Omo / 40%	-	**3.87 / .049**
	Rio Muerto / 69%	-	-
30-39 years			
SHOULDER n=239	Chen Chen / 16%	**6.77 / .009**	**6.97 / .008**
	Omo / 37%	-	0.09 / .76
	Rio Muerto / 41%	-	-
ELBOW n=1054	Chen Chen / 26%	**13.72 / .0002**	**8.98 / .003**
	Omo / 47%	-	0.01 / .93
	Rio Muerto / 48%	-	-
WRIST n=381	Chen Chen / 15%	**4.67 / .03**	0.02 / .89
	Omo / 32%	-	**3.88 / .049**
	Rio Muerto / 14%	-	-
SACRO-ILIAC n=262	Chen Chen / 46%	**6.77 / .009**	**8.14 / .004**
	Omo / 74%	-	0.04 / .84
	Rio Muerto / 76%	-	-
HIP n=276	Chen Chen / 16%	**9.10 / .003**	3.60 / .06
	Omo / 39%	-	0.22 / .64
	Rio Muerto / 33%	-	-
ANKLE n=439	Chen Chen / 15%	**16.38 / <.0001**	0.33 / .57
	Omo / 38%	-	3.22 / .07
	Rio Muerto / 19%	-	-
50-59 years			
WRIST n=70	Chen Chen / 27%	0.25 / .62	**12.79 / .0003**
	Omo / 43%	-	1.04 / .31
	Rio Muerto / 78%	-	-
SACRO-ILIAC n=46	Chen Chen / 61%	1.67 / .20	**4.71 / .03**
	Omo / 50%	-	3.04 / .08
	Rio Muerto / 30%	-	-
ANKLE n=65	Chen Chen / 20%	**27.93 / <.0001**	0.18 / .67
	Omo / 67%	-	**5.48 / .02**
	Rio Muerto / 27%	-	-

7.8 Summary

Overall, data were presented in this chapter in Sections 7.3 through 7.7 and summarized in the above Section 7.2. These results are further discussed in Chapter 8 and then conclusions provided in Chapter 9.

Chapter 8
Summary and Discussion:
Skeletal Evidence of Labor in the Tiwanaku State

8.1 Introduction

In this chapter, I discuss the results for the five combined MSM use-areas[24] in the body as well as the seven joint surfaces[25] for which OA was recorded. I have organized the summary and discussion of these results by geographic area: (1) regional core versus colony (Section 8.2), (2) inter-highland area (i.e. Katari Valley versus Tiwanaku Valley) (Section 8.3), and (3) intra-area (i.e. within each valley – the Katari, the Tiwanaku, and the Moquegua) (Section 8.4). In Section 8.5, I provide a summary and discussion of the chronological changes. I was also interested in the composition of the workforce and in Section 8.6, I provide a summary and discussion of the MSM and OA labor changes across the Tiwanaku landscape by sex and age-at-death. By contextualizing these data within the archaeological record, I am able to discuss possible social relationships and the roles of individual laborers, including gendered division of labor and age-related tasks.

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[24] The five MSM use-areas are: upper arm, forearm, mid-body, lower body, and foot. See Chapter 5, Table 5.1 for the full list of each of the 37 MSM.

[25] The seven OA joints are: shoulder, elbow, wrist, hip, sacroiliac, knee, and ankle. See Chapter 5, Table 5.2 for a full list of each of the 24 different joint surfaces.

8.2 Summary and Discussion of Regional Core versus Colony Results

In the core versus colony comparisons, frequency rates of MSM and OA were higher for the people from the highland core of the Tiwanaku state than those in the colony. For MSM, there were significant differences in the **upper arm**, **forearm**, **mid-body**, and **lower body** musculature. For OA, the only significant difference was in the **sacroiliac** joint, with higher rates of OA in the in the **shoulder**, **elbow**, **wrist**, **hip**, and **sacroiliac** joints for people from the core. In the **knee** and **ankle**, rates were similar between the core and the colony. Highlanders performed more repeated activities in their arms and mid-body joints (i.e. **hip** and **sacroiliac**) than their counterparts in the colony did, while both groups had similar levels of repetitive mobility as shown in the knee and ankle joints. A possible explanation for the mid-body, but not mobility difference, is that highlanders transported more goods on their backs using a cloth carryall (i.e. *aguayo*) than those in the colony did.

The MSM and OA data suggest two things, first, that colonists were performing different tasks from highlanders, evidence which has been supported by prior archaeological excavations (e.g. Goldstein 2005; Janusek 2004a, 2008; Kolata 1986, 1993a, b, 2003b; Kolata and Ortloff 1989 and others). Second, living in the highlands generally required a heavier and more repetitive labor demand when compared to colonists working in the Moquegua Valley. While MSM differences suggest both significant differences in upper body and lower body movements, the OA data indicate these movements were only appreciably repetitive in the upper body. In the lower body, the regional comparisons of OA do not support changes noted with MSM. However, this does not mean that these two skeletal indicators of activity are not correlative. Instead, it means that repetitive movements in these lower body joints were not significantly different between the two regions.

8.3 Summary and Discussion of Inter-Highland Area Results

The MSM and OA inter-highland area (i.e. between the Katari Valley and the Tiwanaku Valley) results showed similar activity rates and no significant comparisons between people from either of these valleys. It was unlikely that there were major labor differences between Tiwanaku Valley or the Katari Valley as people probably participated in similar activities throughout the highland core.

8.4 Summary and Discussion of Intra-Area Results

Within the Katari Valley

OA and MSM differences were found between the Lukurmata, Kirawi, and Pokachi Kontu sites. MSM rates were highest from the Lukurmata site and there was one significant difference in the **lower body** musculature between Lukurmata and Pokachi Kontu. In addition, the highest MSM ordinal scores, which help calculate workload intensity, were from the Lukurmata site. For the OA results, the **elbow** joint was statistically significantly and rates were highest from Lukurmata, lower at Pokachi Kontu, and lowest from Kirawi. Overall, Lukurmata, likely home to a varied population of farmers, crafters, and local administrators (Bermann 1994, 2003; Janusek 2004a), had higher MSM and OA rates, while the more agriculturally oriented sites of Kirawi and Pokachi Kontu had relatively lower MSM, muscle-use intensity ordinal scores, and OA.

Within the Tiwanaku Valley

The MSM and OA results within the Tiwanaku Valley suggest that people within this area did not work intensely and homogenously at one type of labor, instead a variety of workloads and repetitive tasks were found. For MSM, there were significant differences in the **upper arm**, **forearm**, **mid-body**, **lower body**, and **foot between** people from the Akapana, Akapana East, Ch'iji Jawira, La K'araña, Marka Pata, Mollo Kontu, and Putuni sites. The results also indicate that people from Akapana, Akapana East, Ch'iji Jawira, Marka Pata, and Mollo Kontu worked more heavily than their counterparts at Putuni and La K'araña, who had lower MSM rates and the lowest ordinal (i.e. workload intensity) scores. The OA site-by-site comparisons varied by joint and for each site, which suggests different, but repetitive, activities within the Tiwanaku Valley. Overall, in the **shoulder**, **elbow**, and **wrist** joints, Mollo Kontu, Marka Pata, and Akapana performed the greatest variety of repetitive tasks associated with evidence of OA, while in the hip and leg joints, OA rates range for each site even though intensity scores were relatively similar.

The labor data when combined with the archaeological context by site shows that there were various communities of workers performing different tasks. The MSM modeled frequencies and significant results from Akapana East's residents suggest that these people worked at tasks that involved **upper arm** and **forearm** musculature. Prior studies (Berryman 2011; Janusek 2005a, 2008) of Akapana East suggest its residents were ritual specialists involved in *chicha* production, and my MSM results do not dispute this. Individuals buried here were actively working the muscles of their arms, especially when compared to other sites. Along with the archaeological evidence of ritual paraphernalia in burials (Janusek 2008:148) and isotopic evidence of high maize-based diets (Berryman 2011:39, 290-291), it seems probable that the Akapana East people were *chicha* brewers who developed heavy **upper arm** musculature required to stir the pots and possibly the **lower body** musculature required to hoist and move the brewed corn beer.

Ch'iji Jawira residents' **upper arm** and **forearm** MSM indicated that these people performed tasks that were different from other people within the Tiwanaku Valley, except Akapana East. Ch'iji Jawira peoples had significantly high modeled rates of OA in the **elbow** joint, but lower in the **wrist**. As forearm musculature is generally active in more precision tasks, these results support the archaeological evidence of Ch'iji Jawira as a ceramic production center (Janusek 2004a; Rivera 1994, 2003). The lower ordinal MSM scores could also support the idea that Ch'iji Jawira's residents were craft specialists, but not working heavily in service to the state's elite.

The results for Marka Pata peoples in the **mid-body** and **foot** musculature were relatively high. With the evidence of stone tool manufacture at Marka Pata and high levels of maize consumed (Berryman 2011; Berryman et al. 2009), these peoples may have carried loads of stone or maize and were paid for their labors in *chicha*, as noted in other regions (Goldstein et al. 2009; Jennings and Bowser 2009; Mayer 2002; Perlov 2009). Grinding with the feet (Bruno 2011. Pers. comm) or the use of a foot plow is also relatively common among modern highland Aymara people in Bolivia and may account for some of the **foot** musculature evidence. Also, while not directly noted in the diet of Marka Pata peoples, the production of freeze-dried potatoes (*chuño)* in the *altiplano* involves repeated walking on these small tubers to process them into a dry-good suitable for later use. C*huño* was likely a staple crop during the Tiwanaku state, and its production may have taken **mid-body** and **foot** muscle balance in order to walk on the potatoes and produce large quantities for storage.

Mollo Kontu people had high **mid-body**, **lower body**, and **foot** rates of MSM and high rates of OA throughout the upper and lower body joints. This suggests that residents performed heavy labors, repetitive activities, and were highly mobile. These activity pattern data, noted with increases in arm strength that could have been from working and butchering camelids as well as lower body musculature that could have developed from long distance travel, reinforce the dietary (Berryman 2011; Berryman et al. 2007) and archaeological evidence (Couture et al. 2008; Vallières 2010, 2012) of the Mollo Kontu people as pastoralists.

People from the sites of La K'araña and Putuni, suggested as home to elites (Couture and Sampeck 2003; Escalante 2003), had significantly low modeled rates of MSM throughout the body and the lowest muscle-use intensity ordinal scores, supporting the idea that these people worked less than their counterparts and were not highly mobile. Labor data shows that Putuni peoples were distinct from other groups in the area and that these individuals on average performed less heavy labor than their counterparts did in other areas close to the ceremonial core (e.g. Akapana, Akapana East, and La K'araña). However, the highest OA rates and intensity scores in the **knee** were reported among people from La K'araña. Modern OA studies (Felson et al. 1991; Hunter et al. 2002; Järvholm et al. 2008; Rytter et al. 2009) noted that knee joint damage is generally related to occupation, but it is unclear what type of kneeling or knee-bending activities were performed by residents of La K'araña. Thus, the evidence of OA does not discount that these people could have been elites or ritual specialists, but they were working elite peoples.

Within the Moquegua Valley

Tiwanaku colonists buried in both the Omo and Rio Muerto areas may have performed similar tasks because they do not have any significant MSM or OA differences. The results also suggest that Omo peoples worked hard at whatever tasks they performed, be it *chicha* brewing, farming, or herding (Goldstein 1993a, 2005). Rio Muerto peoples worked at similar tasks and nearly as intensely as those from Omo did. However, Chen Chen peoples, involved in canal-irrigated agricultural production (Bandy et al. 1996; Goldstein 2000; Williams 2006), labored much less intensely and repetitively than Omo's or Rio Muerto's residents. The significant **foot** results, with higher modeled rates from Chen Chen, could indicate grinding maize with the feet (Bruno 2011. Pers. comm) or use of a *chakitaqllaa* (i.e. Andean foot plow). The significantly higher OA rates in the **shoulder** and **elbow** joints for the residents of Rio Muerto than the people of Chen Chen also suggests differences in occupation or a different style of agriculture than Chen Chen's residents. From these activity data, I also suggest that residents of the Omo region, likely home to pastoralists and llama caravanners (Goldstein 1993a, 2005), had greater levels of mobility and movement.

8.5 Summary and Discussion of Chronological Results

The activity data were evaluated by time period, with the Late Formative phase (250 BC – AD 500) compared to the Tiwanaku phase (AD 500-1100), and the Tiwanaku phase to the post-Tiwanaku phase (after AD 1100 in the core, and after ca. AD 1000 in the colony). In the highland core, MSM and OA activity rates were higher prior to the Tiwanaku state during the Late Formative phase in the **upper arm** musculature, as well as the **shoulder**, **elbow**, **wrist**, **knee**, and **ankle** joints. The transition from Tiwanaku phase to post-Tiwanaku phase in the core showed generally comparable labor rates and no significant MSM differences. For OA, rates were comparable except in two joints: **sacroiliac** and **knee**. In the **sacroiliac**, rates were significantly higher during the Tiwanaku phase, while in the **knee** modeled OA rates were higher post-Tiwanaku. While the cause of higher OA rates during post-Tiwanaku phase in the **knee** is unclear, the **sacroiliac** joint results could be related to people transporting goods using an *aguayo*. Overall, these results indicate that people who lived and died within the core had heavier labor demands prior to the Tiwanaku-state, but that labor levels were generally equal before and after state collapse.

As colonists only settled the Moquegua Valley during the Tiwanaku phase, the comparison between this time period to the post-Tiwanaku phase showed labor rates were higher during the Tiwanaku phase in almost all comparisons. Significant labor differences with higher rates during the Tiwanaku phase were noted in the in the **lower body** musculature and the **elbow** joint. These results indicate a reduction in activity after the state lost control in the Moquegua Valley. It was also possible that the **lower body** MSM data represent a reduction in mobility among Moquegua Valley peoples, possibly reduced llama trade caravans to the highlands after the collapse of the Tiwanaku polity. This lack of long distance trade has been noted archaeologically in the highlands with the change to fortified settlements and reduction in the movement of goods in highland regions such as the Katari Valley (Bermann 2003; Janusek 2004a).

8.6 Summary and Discussion of the Composition of the State's Workforce by Sex and by Age

I also addressed who labored within the state by taking estimates of sex and age-at-death and comparing them with the archaeological record across the Tiwanaku landscape. The discussion and summary of the results have been divided into the same geographic comparisons as the data not divided by sex or age-at-death (i.e. (1) regional comparisons, (2) inter-highland area comparisons, and (3) intra-area comparisons)

Regional Results by Sex and by Age

In the **regional comparison** by sex, females from the core worked at significantly different tasks than those in the colony did as was noted with significant **upper arm** and **lower body** MSM differences. However, these were not highly repetitive tasks as both groups had similar rates of OA and the only significant difference was in the **sacroiliac** joint. Highland females likely used an *aguayo* to transport goods on their backs, and this is one explanation for these **sacroiliac** OA results. Males in the core also worked at significantly different tasks than male colonists did, with greater labor rates in the core. There were significantly higher rates for the **upper arm**, **forearm**, **mid-body**, and **lower body** musculature as well as significant differences in the **elbow** joint for OA. As agriculture can be tough on arm joints (Bridges 1989b, 1991a, b, 1992; Eshed et al. 2010; Goodman et al. 1984; Steckel and Rose 2002), as well as correlate with an increase in muscle mass (Bridges 1989a; Eshed et al. 2004; Hawkey 1988; Hawkey and Merbs 1995; Larsen 1997), it was possible that these highlanders, especially the males, were farmers or participating in farming. Archaeological evidence noted that farming methods used were different between the two regions, where agriculture in the Tiwanaku colony area would have focused more on riverine floodplain and canal farming (Goldstein 1989, 1993a, 2005; Williams and Nash 2002), and highland agriculture would have used raised-fields between water canals (Erickson 1985, 1988b, 1992, 1993, 2006; Erickson and Candler 1989). Thus, the labor differences in the arms of core females and males may be explained by different agriculture practices in the core and in the colony – a raised-field system in the highlands versus maize in the riverine canal-based colony system. In addition, males may also have been involved in stone tool manufacture because the significant individual muscle markers (as noted in Chapter 6) show less precise hand motion (e.g. weaving) and stronger forearm motion (e.g. climbing).

Overall, the regional comparisons when partitioned by age show that adults of various ages were working in ways that developed their musculature, and that many of the MSM were statistically significant. Of the significant results, all were due to higher frequencies in the core. These results suggest that there were labor differences between the core and colony between all age groups. I would also suggest that people began work at a younger age in the highlands than they did in the colony.

Inter-Highland Area Comparisons by Sex and by Age

In the inter-highland area sex comparisons between the Katari Valley and the Tiwanaku Valley, there were few overall differences by sex and by age-at-death. Females showed no labor differences, but there were two significant differences for males in the arm joints for OA. Katari Valley males had higher **elbow** OA modeled rates and Tiwanaku Valley males had higher **shoulder** OA frequencies, which indicate some kind of upper body repetitive activity difference between males in these two areas. When the results were separated by age, MSM results showed that younger individuals worked at higher rates in the Katari Valley, while older individuals had higher modeled rates in the Tiwanaku Valley. For the OA data, there were significant differences for people in their twenties in the **knee** joint and thirties in the **elbow** joint, both with higher rates in the Katari Valley. These results, when divided by sex and by age-at-death, may be somewhat inflated and due to the small sample size. Thus, I cautiously suggest that there were few age or sex related labor differences in the inter-highland area comparisons. Instead, it was likely that tasks were similar between people who lived in the highland core region during the Tiwanaku state.

Intra-Area Comparisons by Sex and by Age

Intra-area sex comparisons for individuals within the Katari Valley showed gendered divisions of labor, especially between Lukurmata's female residents and females buried at other sites within this valley in the MSM comparisons. In addition, Katari Valley people's comparisons by age-at-death showed labor differences for people in their twenties and thirties with generally higher rates from Lukurmata when compared to residents of the other areas. These results suggest some division of labor by sex and by age within the Katari Valley.

Within the Tiwanaku Valley, the sex comparisons yielded many divisions of labor. For example, along with archaeological (Vallières 2010, 2012), dietary evidence (Berryman 2011), and modern studies (Tripcevich 2008), labor data supported the possibility that both males and females from Mollo Kontu labored as *llameros* and worked at tasks like holding or directing llama leads during transport or butchering camelids upon arrival in the city of Tiwanaku. In addition, Akapana East also had high rates of forearm MSM for males. Akin to the archaeological evidence (Berryman 2011; Janusek 2008:148), it could have been that these males were priests, rulers, or bureaucrats involved in tasks that predominantly used forearm musculature, possibly precision tasks that involved *chicha* grinding and brewing. Age-at-death comparisons within the Tiwanaku Valley supported the idea that people began working at heavy muscle building tasks as young people (i.e. under age 15), as has been shown in many modern Andean communities (Bolin 2006; Lucy 2005).

Within the Moquegua Valley labor differences divided by sex showed few labor differences for females. Instead, males showed clear patterns in that both Omo and Rio Muerto males had higher labor rates, suggesting that males from Chen Chen worked at lighter and less repetitive tasks than their male counterparts from Omo and Rio Muerto did. In addition, there were age-related divisions of labor within this colony region as Rio Muerto people worked at more repetitive tasks in their twenties, Omo people in their thirties, and Chen Chen residents had generally low rates for all age groups.

Chapter 9
Conclusions:
Labor in the Tiwanaku State

9.1 Revisiting the Research Questions

In this dissertation, I looked at skeletal indicators of activity present on the bodies of those who participated in the Tiwanaku state as a record of temporal and geographic labor distribution. Prior research has argued that this polity was hierarchical with labor organized under a central core of elites (Kolata 1991, 1993a, b; Stanish 1994, 2003) or that it was heterarchical with allied settlements, akin to modern Andean *ayllus*, in which labor control was decentralized and spread across the landscape (Albarracín-Jordán 2003; Erickson 2006; Goldstein 2005; Janusek 2004a, 2008; Owen 2001). From these larger concepts of Tiwanaku state formation, I expected that activity organized in a centralized labor model would show the greatest differences between the core and colony, with higher labor rates from the colony because colonists would function as corvée laborers in a *mit'a*-style system for the state. Also within this model, elites in the Tiwanaku Valley would have controlled the nearby Katari Valley. The Katari people would also have been corvée laborers with higher activity rates than people in the Tiwanaku Valley. Within each valley (i.e. intra-area), only elite areas within the Tiwanaku Valley would show lower activity rates when compared to other sites. In addition, there would have been significant temporal changes in labor, with the highest rates during the Tiwanaku phase at the height of the state in both the core and the colony.

In contrast, I expected that with a decentralized labor model, activity differences would be greatest between sites within each area (i.e. intra-area), with few differences between core and colony or between the Katari Valley and Tiwanaku Valley in the core (i.e. inter-highland area) because of localized control of labor. Temporally, labor rates would not have varied over time, as groups should have been able to mitigate state formation and collapse better with localized control over labor.

From these models, the results for changes in labor did not directly support either supposition of labor organization within the Tiwanaku state. Instead, results showed that the people from the core highland region had the highest rates and their skeletal indicators of activity were significantly different from their counterparts in the colony region. These results are not what would be expected if the Tiwanaku state were centralized and organized under a *mit'a*-style system. The expectation that colonists would have had the greatest demand on their labor, especially if colonists were subject to the core elite's demands for goods like maize or coca in a corvée labor system, were not met. However, there were significant regional labor differences between the core and colony regions, which were not what was expected in the decentralized and locally controlled labor model. In addition, inter-highland area labor comparisons showed very few labor changes between residents of the Katari Valley and the Tiwanaku Valley.

Labor differences were also greatest in the site-by-site comparisons within each of the valleys (i.e. intra-area). In regards to labor organization with state formation, the Katari Valley was known to be the main agricultural area in the core of the Tiwanaku state and the various rural sites should have shown a heavy labor demand under a more centralized and *mit'a*/corvée system. Instead, Lukurmata's residents in the "second city" had the highest levels of repetitive work and greatest labor rates with the heaviest ordinal work intensity scores. This means Lukurmata's residents were often called upon to work and that this site was not solely home to regional administrators or local elites, as had been previously speculated (Bermann 1994:159, 177; Janusek 2004a:56; Janusek and Kolata 2003). In addition, the activity results for the rural sites of Kirawi, with lower labor rates, and Pokachi Kontu, with higher labor rates, does not make sense if these people worked as corvée laborers in the raised-fields for the state.

Labors within the Tiwanaku Valley do show some degree of difference between elite and non-elite areas. On average, Putuni and La K'araña had lower activity rates and labor intensity when compared to all other sites within the city of Tiwanaku. This could indicate locally centralized labor control or at least that elites did not work at as often as non-elites. The various other sites where people worked harder, such as Mollo Kontu or Akapana East, also do not labor patterns that would indicate that these people worked at the behest of elites as some kind of serving or slave class. Instead, I would suggest that these people worked at a variety of tasks and that they were more embedded laborers, akin to a guild, within the state.

Within the colony, labor rates were lowest with the lowest workload intensity from the Chen Chen burials. Omo and Rio Muerto have somewhat similar labor rates with few significant results between these two areas. It is unclear why Chen Chen, likely the burial area for the agricultural population, had such lower labor rates. It is possible that the style of agriculture performed by Chen Chen people was less intensive than their neighbors in either the Rio Muerto or Omo regions. The results also show mobility rates were higher for Omo peoples, adding support to the idea that these people were *llameros* who moved low elevation products up to the core. Whatever the difference in occupation, the fact that there were differences within the colony indicates that these people were not working intensely as slaves or corvée laborers for the elite populations in a *mit'a* system.

Overall, because labor rates were higher in the core than in the colony and there were few inter-highland area labor differences and more intra-area task differentiation, I would suggest that the control of labor was more decentralized and locally managed. I would also suggest that labor reciprocity was important to the peoples of the Tiwanaku state. Modern Andean *ayllu* labor is reciprocal, and if Tiwanaku people labored in a similar fashion during this state, it makes sense that the highland core region would have had higher labor rates than colonists in Peru. Highland Tiwanaku residents would have had a greater opportunity to call on local neighbors and friends for help because the nearby settlement areas were within an easy walk of each other. In fact, the modern trail between the towns of Tiwanaku and Lukurmata in Bolivia is a only a two to three hour walk (Janusek 2004a:56). Settlements in the Moquegua Valley, Peru, located approximately 400km from the core, with an 1800m difference in elevation, would have taken a week or more to walk the distance between the core and colony. Reciprocal labor becomes somewhat of an impossibility if it requires a week's walk every time a favor was asked or returned. It was possible that colonists returned to the highlands for major labor events, but that the distance between the core and the colony likely precluded most reciprocal favors.

Chronological comparisons showed that labor rates in the colony went down after the state lost control of this region, supporting the idea that long distance trade between those in the Moquegua Valley and the Titicaca Basin was reduced, if not completely absent. This would make sense in a centralized state, but it also makes sense if there was a lowered demand for luxury items, less labor reciprocity, and a reduction in trade with Tiwanaku state collapse (Bermann 2003; Janusek 2004a). In contrast, in the core, labor demand was greatest prior to the Tiwanaku state (i.e. Late Formative phase). From a worker's perspective, because labor rates decreased in the highlands with the advent of the Tiwanaku state, it could have been beneficial for residents to be part of this polity with a larger network of reciprocal laborers. This reciprocity likely continued after the state collapsed in the highlands, as there were no significant labor differences between the Tiwanaku phase and the post-Tiwanaku phase.

In addition to Tiwanaku state formation and labor organization, I was interested in subgroup composition and the role of individuals in the workforce. As part of the bioarchaeological approach to understanding people in prehistory, I estimated the sex and age-at-death of individuals along with the local archaeological context in order to discuss divisions of labor by gender or age that could provide a picture of Tiwanaku daily life, labor, and habitual activity.

In the comparisons of labor between the core and the colony, both females and males from the core worked at different tasks than females in the colony, with higher activity rates in the core. Some of the task differences may have included female highlanders transporting goods on their backs using an *aguayo* more often than female colonists did. In addition, differences in agriculture could account for some of the differences between core and colony males. From these labor results, I would also suggest that canal-oriented agriculture in the colony may have required less labor than raised-field farming in the highlands. In addition, regional comparisons between the different age groups showed that all ages worked at heavier and more repetitive tasks in the highlands. Labor for highlanders likely began at a young age, akin to modern studies of labor in the Andes where children under the age of 10 have many family-oriented labor responsibilities (Bolin 1998, 2006; Hardman 1976, 1981; Lucy 2005).

There were also few differences in labor by sex and age-at-death between the two highland valleys of Katari and Tiwanaku. Instead, the most noteworthy picture of life in the Tiwanaku state was from the intra-area results. The intra-area data expressed the heterogeneity of the Tiwanaku state's workforce, as had been suggested by other scholars (e.g. Albarracín-Jordán 1999; Berryman 2011; Blom 1999; Janusek 2003a, 2004a, 2005b, 2008; Knudson and Price 2007; Knudson et al. 2004; Kolata 1993a; Rivera 2003 and others). For example, within the Katari Valley, there were gendered divisions of labor, especially between Lukurmata's female residents and females buried at other sites, although there were fewer age-related activity differences.

Within the Tiwanaku Valley, there were many distinctions in labor that were site based. For example, the labor data correlated with the archaeological record show that Mollo Kontu was home to both female and male camelid pastoralists (i.e. *llameros*), including occupational evidence of females butchering these animals. This labor data adds support to the isotopic and zooarchaeological evidence of camelids as a major food source at Mollo Kontu (Berryman 2011; Berryman et al. 2009; Vallières 2010, 2012). In addition, there were other possible gendered occupations, such as men brewing *chicha* at Akapana East or Marka Pata men transporting goods and involved in maize grinding with the feet, *chuño* production, or using an Andean foot plow. In addition, these labor data support that Tiwanaku Valley residents began working at muscle building tasks as young people, as has been shown in many modern Andean communities (Bolin 2006; Lucy 2005). Thus, my results support the idea that there were distinct neighborhoods within the city of Tiwanaku where people performed different types of labor during the Tiwanaku state.

Within the Moquegua Valley comparisons, there were few site-by-site divisions of labor for females, indicating that female colonists may have performed many similar tasks. Males showed clearer distinctions where Chen Chen males worked at fewer and less repetitive tasks than their counterparts from Omo or Rio Muerto. I would suggest that population differences may have played a role in labor reciprocity. Chen Chen may have had a larger population, and in a reciprocal labor network, tasks could be been divided up between more people, where Omo and Rio Muerto men had to perform more tasks more often. It could also be that Chen Chen males, and Chen Chen people in general, worked less than others in the Moquegua Valley. In addition, age-related divisions of labor were noted with Rio Muerto people working more repetitive tasks in their twenties, Omo people in their thirties, and Chen Chen residents had generally low rates for all age groups. Thus, it could be that Chen Chen people worked less and survived to an older age than others in the Moquegua Valley.

9.2 Conclusions

Labor within the Tiwanaku state likely formed around some kind of decentralized and *ayllu*-based cooperative network, akin to the way modern Aymara people work within their communities today. I believe these data have shown that social obligations with labor during the Tiwanaku state were strongest among the people who lived closest to each other in the Bolivian highlands. However, these social obligations do not solely explain why people would have formed into a larger polity around AD 500. Instead, I have shown that labor and activity levels were higher before the Tiwanaku state and including other social and ideological reasons, highland peoples who formed this state may have worked less heavily and repetitively during the state than peoples who lived in the core region prior to the Tiwanaku state. Working less and sharing labors may have been one reason to embrace becoming a member of this polity.

As noted by Ingold (2000:325), "the particular kinds of tasks a person performs are an index of personal and social identity: the tasks you do depend on who you are, and in a sense, the performance of certain tasks *makes* you the person who you are" [author's emphasis]. As such, I believe these labor data support the idea of Tiwanaku as a multiethnic community, with people who worked a variety of tasks. In the Tiwanaku culture, people adapted their bodies and kept their individuality through visible distinctions, such as artificial cranial modification (Blom 1999, 2005; Blom and Knudson 2007). It may also have been that jobs Tiwanaku people performed were a reflection of their status and ethnicity within this culture. In the same sense as the old adage, "you are what you eat," laborers in Tiwanaku could be considered "you are what you do," and their gender and age can be discussed as part of their identity. These activity and labor data results showed a pattern of the workforce within the Tiwanaku state, in the same way that the last names of "Carpenter," "Butcher," and "Baker" are a legacy of the workforce of modern Western culture.

Appendix A. Ordinal Scales of Involvement for MSM and OA

Ordinal Scale for MSM involvement after Hawkey and Merbs (1995)

Robusticity:

1 Faint with a rounded cortex that can be felt and not easily visible

2 Moderate with uneven cortical surfaces, mound-shaped elevation easily visible, and no crests

3 Strong with distinct, sharp crests.

Stress:

1 Mild involvement - shallow furrow, pitting in the cortex, lytic-like appearance

2 Moderate involvement - pitting is deeper and covers more surface area, 1-3mm in depth, no longer than 5mm

3 Full involvement - pitting is marked, greater than 3mm in depth, longer than 5mm in length

Ossification:

1 Faint - slight exostosis, usually rounded in appearance, extends less than 2mm from the cortical surface

2 Moderate - distinct exostosis, varied in shape, that extends more than 2mm, but less than 5mm from the surface of the cortex

3 Strong involvement - exostosis extends more than 5mm from the surface of bone, or else covers an extensive amount of cortical surface

Ordinal Scale for OA Involvement after Buikstra and Ubelaker (1994)

Lipping:

1 Barely discernible

2 Sharp ridge

3 Extensive spicule formation

4 Ankylosis (no joint movement)

Surface porosity:

1 Pinpoint

2 Coalesced

3 Both pinpoint and coalesced

Osteophytes:

1 Barely discernible

2 Clearly present

Eburnation:

1 Barely discernible

2 Polish only

3 Polish with groove(s)

Percentage of Joint Surface Involvement for OA Scales:

1 < 1/3

2 1/3 – 2/3

3 > 2/3

Appendix B. Additional MSM Data Tables

Table B.1 Tiwanaku Core vs. Colony Right Side MSM Comparisons

MSM	Insertion (I), Origin (O), or Ligament (L)/ Bone	n=	Core Modeled % frequency	Core Ordinal Score Mean	Colony Modeled % frequency	Colony Ordinal Score Mean	χ^2 value (df=1)	p-value
Conoid Ligament	L / Clavicle	200	84%	1.57	81%	1.20	0.09	.76
Costoclavicular Ligament	L / Clavicle	204	-	-	-	-	-	-[a]
Subclavius	**I / Clavicle**	**208**	**43%**	**1.82**	**18%**	**0.90**	**7.17**	**.007**
Trapezoid Ligament	L / Clavicle	192	50%	1.95	32%	1.10	2.18	.14
Trapezius	I / Scapula	129	33%	1.73	47%	1.13	1.19	.28
Pectoralis Minor	I / Scapula	130	64%	1.14	41%	1.22	2.64	.10
Coracobrachialis	I / Humerus	271	33%	1.13	25%	0.60	1.03	.31
Deltoideus	I / Humerus	278	-	-	-	-	-	-[a]
Infraspinatus	I / Humerus	134	28%	1.13	18%	0.97	0.85	.36
Latissimus dorsi	**I / Humerus**	**132**	**19%**	**1.15**	**18%**	**0.60**	**7.12**	**.008**
Pectoralis Major	I / Humerus	266	94%	2.3	93%	1.29	0.85	.02
Subscapularis	I / Humerus	144	44%	1.56	56%	1.17	0.79	.38
Supraspinatus	I / Humerus	144	17%	1.07	24%	1.06	0.49	.48
Teres Major	I / Humerus	143	65%	1.52	59%	0.81	0.21	.65
Teres Minor	I / Humerus	134	44%	1.17	33%	1.11	0.84	.36
UPPER ARM		**2954**	**59%**	**1.51**	**48%**	**1.03**	**6.15**	**.01**
Extensors CO	**O / Humerus**	**233**	**19%**	**.87**	**43%**	**1.22**	**3.99**	**.046**
Flexors CO	O / Humerus	232	21%	1.56	21%	0.93	0.00	.97
Anconeus	I / Ulna	246	61%	1.57	44%	0.80	1.92	.17
Brachialis	I / Ulna	267	83%	2.23	79%	1.37	0.28	.60
Triceps Brachii	**I / Ulna**	**238**	**60%**	**1.85**	**28%**	**1.14**	**5.87**	**.02**
Biceps Brachii	I / Radius	251	93%	1.98	90%	1.24	0.28	.60
Brachioradialis	**I / Radius**	**168**	**59%**	**1.83**	**30%**	**1.01**	**5.11**	**.02**

Pronator Quadratus	I / Radius	190	50%	1.4	40%	0.87	0.85	.36
Pronator Teres	**I / Radius**	**245**	**54%**	**1.4**	**34%**	**0.66**	**3.84**	**.05**
Supinator	**I / Radius**	**250**	**47%**	**1.41**	**18%**	**0.60**	**11.51**	**.0007**
FOREARM		**2320**	**56%**	**1.61**	**44%**	**0.98**	**8.01**	**.005**
Gluteus Maximus	I / Femur	271	92%	2.35	88%	1.31	0.68	.41
Gluteus Medius	I / Femur	166	50%	1.71	35%	0.99	1.04	.31
Gluteus Minimus	I / Femur	178	65%	1.71	56%	1.22	0.46	.50
Piriformes	I / Femur	170	54%	1.7	38%	0.97	1.24	.26
Psoas Major/Iliacus	I / Femur	187	81%	1.65	70%	1.04	1.07	.30
MID-BODY		972	75%	1.82	60%	1.11	3.16	.08
Linea Aspera	**I / Femur**	**277**	**73%**	**2.23**	**21%**	**1.04**	**35.11**	**<.0001**
Quadriceps Tendon	Patella	129	33%	1.47	36%	1.32	0.05	.82
Patellar Ligament	L / Tibia	185	75%	1.20	60%	1.11	1.64	.20
LOWER BODY		**591**	**65%**	**1.63**	**37%**	**1.16**	**17.25**	**<.0001**
Soleal (Soleus)	**O / Tibia**	**241**	**91%**	**1.42**	**48%**	**0.88**	**10.48**	**.001**
Abductor Hallucis	O / Calcaneus	155	33%	1.39	31%	0.86	0.03	.86
Achilles Tendon	Calcaneus	201	73%	1.88	59%	1.10	1.15	.28
Flexor Digitorum Brevis	O / Calcaneus	160	50%	1.38	44%	0.78	0.13	.72
FOOT		**757**	**70%**	**1.52**	**46%**	**0.91**	**6.99**	**.008**

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table B.2 Tiwanaku Core vs. Colony Left Side MSM Comparisons

MSM	Insertion (I), Origin (O), or Ligament (L)/ Bone	n=	Core Modeled % frequency	Core Ordinal Score Mean	Colony Modeled % frequency	Colony Ordinal Score Mean	χ^2 value (df=1)	p-value
Conoid Ligament	L / Clavicle	216	86%	1.94	84%	1.23	0.07	.79
Costoclavicular Ligament	L / Clavicle	196	91%	1.95	80%	1.18	1.43	.23
Subclavius	**I / Clavicle**	**220**	**45%**	**1.65**	**20%**	**0.99**	**8.21**	**.004**
Trapezoid Ligament	**L / Clavicle**	**210**	**78%**	**1.89**	**28%**	**1.20**	**20.3**	**<.0001**

Trapezius	I / Scapula	118	57%	1.76	43%	1.21	1.02	.31
Pectoralis Minor	I / Scapula	129	60%	1.37	40%	1.19	1.48	.22
Coracobrachialis	**I / Humerus**	**257**	**50%**	**1.43**	**18%**	**0.64**	**13.71**	**.0002**
Deltoideus	I / Humerus	260	-	1.78	-	1.08	-	-[a]
Infraspinatus	I / Humerus	117	31%	1.5	16%	0.94	2.13	1.44
Latissimus dorsi	**I / Humerus**	**115**	**25%**	**1.35**	**4%**	**0.71**	**7.21**	**.007**
Pectoralis Major	I / Humerus	251	89%	2.37	87%	1.22	0.04	.84
Subscapularis	I / Humerus	125	61%	2.05	60%	1.24	0.01	.92
Supraspinatus	I / Humerus	125	28%	1.67	23%	0.86	0.16	.69
Teres Major	**I / Humerus**	**125**	**94%**	**1.59**	**52%**	**0.81**	**6.85**	**.009**
Teres Minor	**I / Humerus**	**123**	**56%**	**1.51**	**21%**	**1.06**	**8.51**	**.004**
UPPER ARM		**2847**	**67%**	**1.72**	**46%**	**1.04**	**22.26**	**<.0001**
Extensors CO	O / Humerus	225	28%	1.24	39%	1.11	1.05	.31
Flexors CO	O / Humerus	222	18%	1.14	15%	0.70	0.18	.67
Anconeus	I / Ulna	252	56%	1.53	37%	.63	3.38	.07
Brachialis	I / Ulna	271	90%	2.19	84%	1.43	0.77	.38
Triceps Brachii	**I / Ulna**	**239**	**72%**	**1.52**	**24%**	**1.18**	**19.77**	**<.0001**
Biceps Brachii	I / Radius	232	90%	2.02	91%	1.17	0.04	.85
Brachioradialis	I / Radius	158	46%	1.37	26%	0.93	2.23	.14
Pronator Quadratus	I / Radius	176	31%	1.04	40%	0.82	0.50	.48
Pronator Teres	**I / Radius**	**240**	**57%**	**1.10**	**34%**	**0.65**	**4.09**	**.04**
Supinator	**I / Radius**	**234**	**47%**	**1.18**	**19%**	**0.66**	**7.77**	**.005**
FOREARM		**2249**	**56%**	**1.43**	**42%**	**0.93**	**9.68**	**.002**
Gluteus Maximus	I / Femur	261	97%	2.35	91%	1.31	1.33	.25
Gluteus Medius	**I / Femur**	**175**	**64%**	**1.64**	**23%**	**.97**	**9.51**	**.002**
Gluteus Minimus	I / Femur	182	65%	1.76	82%	1.13	1.05	.31
Piriformes	I / Femur	171	50%	1.69	36%	1.02	1.03	.31
Psoas Major/Iliacus	I / Femur	183	85%	1.53	68%	1.04	2.22	.14
MID-BODY		**972**	**78%**	**1.79**	**57%**	**1.09**	**8.81**	**.003**
Linea Aspera	**I / Femur**	**277**	**69%**	**2.12**	**36%**	**1.12**	**15.17**	**<.000**

								1
Quadriceps Tendon	Patella	124	29%	1.63	32%	1.26	0.04	.85
Patellar Ligament	L / Tibia	184	64%	1.43	58%	1.04	0.31	.58
LOWER BODY		**858**	**60%**	**1.73**	**42%**	**1.14**	**8.01**	**.005**
Soleal (Soleus)	**O / Tibia**	**238**	**77%**	**1.60**	**53%**	**0.81**	**5.58**	**.02**
Abductor Hallucis	O / Calcaneus	166	33%	1.29	34%	0.93	0.01	.94
Achilles Tendon	Calcaneus	188	56%	1.91	58%	1.08	0.03	.87
Flexor Digitorum Brevis	O / Calcaneus	161	38%	1.52	48%	0.82	1.41	.23
FOOT		753	55%	1.58	49%	0.91	0.52	.47

Table B.3 Core vs. Colony MSM Results during Tiwanaku Phase

MSM	Insertion (I), Origin (O), or Ligament (L)/ Bone	n=	Core Modeled % frequency	Core Ordinal Score Mean	Colony Modeled % frequency	Colony Ordinal Score Mean	χ^2 value (df=1)	*p*-value
Conoid Ligament	L / Clavicle	416	85%	1.77	82%	1.22	0.13	.71
Costoclavicular Ligament	L / Clavicle	400	96%	1.88	85%	1.15	3.26	.07
Subclavius	**I / Clavicle**	**428**	**44%**	**1.72**	**19%**	**0.95**	**12.23**	**.0005**
Trapezoid Ligament	**L / Clavicle**	**402**	**67%**	**1.91**	**36%**	**1.15**	**15.94**	**<.0001**
Trapezius	I / Scapula	247	44%	1.75	45%	1.17	0.02	.90
Pectoralis Minor	I / Scapula	259	63%	1.24	40%	1.21	3.14	.08
Coracobrachialis	**I / Humerus**	**528**	**42%**	**1.29**	**22%**	**0.62**	**10.62**	**.001**
Deltoideus	I / Humerus	538	-	-	-	-	-	-[a]
Infraspinatus	I / Humerus	251	29%	1.31	17%	0.95	2.48	.12
Latissimus dorsi	**I / Humerus**	**247**	**22%**	**1.26**	**3%**	**0.67**	**14.34**	**.0002**
Pectoralis Major	I / Humerus	517	91%	2.34	90%	1.26	0.04	.83
Subscapularis	I / Humerus	269	53%	1.81	58%	1.2	0.20	.65
Supraspinatus	I / Humerus	269	22%	1.40	24%	0.97	0.04	.84
Teres Major	**I / Humerus**	**268**	**80%**	**1.56**	**56%**	**0.81**	**6.04**	**.01**

Teres Minor	**I / Humerus**	**257**	**50%**	**1.38**	**27%**	**1.09**	**5.12**	**.02**
UPPER ARM		**5801**	**63%**	**1.62**	**47%**	**1.03**	**15.99**	**<.0001**
Extensors CO	**O / Humerus**	**458**	**24%**	**1.13**	**41%**	**1.17**	**4.61**	**.03**
Flexors CO	O / Humerus	454	20%	1.40	18%	0.84	0.06	.80
Anconeus	I / Ulna	498	58%	1.55	40%	0.72	3.74	.053
Brachialis	I / Ulna	538	87%	2.21	82%	1.40	2.04	.15
Triceps Brachii	**I / Ulna**	**477**	**68%**	**1.64**	**26%**	**1.15**	**21.1**	**<.0001**
Biceps Brachii	I / Radius	483	92%	2.00	90%	1.21	0.08	.78
Brachioradialis	**I / Radius**	**326**	**53%**	**1.67**	**28%**	**0.97**	**5.34**	**.02**
Pronator Quadratus	I / Radius	366	42%	1.28	40%	0.84	0.08	.78
Pronator Teres	**I / Radius**	**485**	**55%**	**1.24**	**34%**	**0.65**	**6.94**	**.008**
Supinator	**I / Radius**	**484**	**47%**	**1.31**	**18%**	**0.63**	**15.22**	**<.0001**
FOREARM		**4569**	**56%**	**1.54**	**43%**	**0.96**	**12.0**	**.0005**
Gluteus Maximus	I / Femur	532	94%	2.35	89%	1.31	1.83	.18
Gluteus Medius	**I / Femur**	**341**	**58%**	**1.67**	**29%**	**0.98**	**8.54**	**.004**
Gluteus Minimus	I / Femur	360	65%	1.74	54%	1.18	1.39	.24
Piriformes	I / Femur	341	52%	1.7	37%	0.99	1.93	.16
Psoas Major/Iliacus	I / Femur	370	83%	1.58	69%	1.04	3.29	.07
MID-BODY		**1941**	**77%**	**1.81**	**58%**	**1.10**	**8.54**	**.004**
Linea Aspera	**I / Femur**	**554**	**71%**	**2.18**	**28%**	**1.09**	**34.01**	**<.0001**
Quadriceps Tendon	Patella	253	31%	1.54	34%	1.29	0.08	.78
Patellar Ligament	L / Tibia	369	69%	1.32	59%	1.08	1.34	.25
LOWER BODY		**1449**	**62%**	**1.68**	**39%**	**1.15**	**18.78**	**<.0001**
Soleal (Soleus)	**O / Tibia**	**479**	**83%**	**1.51**	**50%**	**0.85**	**12.98**	**.0003**
Abductor Hallucis	O / Calcaneus	321	33%	1.33	32%	0.90	0.01	.94
Achilles Tendon	Calcaneus	389	65%	1.89	59%	1.09	0.30	.59
Flexor Digitorum Brevis	O / Calcaneus	321	39%	1.45	46%	0.80	0.27	.60
FOOT		1510	62%	1.55	48%	0.91	3.33	.07

Table B.4 MSM Inter-Highland Area Significant Results during the Tiwanaku Phase

MSM	Insertion (I), Origin (O), or Ligament (L)/ Bone	n=	Katari Valley Modeled % frequency	Katari Valley Ordinal Score Mean	Tiwanaku Valley Modeled % frequency	Tiwanaku Valley Ordinal Score Mean	χ^2 value (df=1)	*p*-value
Pronator Teres	**I / Radius**	**46**	**43%**	**1.26**	**16%**	**1.24**	**4.07**	**.04**

Table B.5 Intra-Katari Valley MSM Comparisons

MSM	Site /Modeled %	Lukurmata	Pokachi Kontu	MSM	Site /Modeled %	Lukurmata	Pokachi Kontu
Conoid Ligament N=14	Kirawi / %	-[a]	-[a]	Extensors N=13	Kirawi /%	-[a]	-[a]
	Lukurmata / 69%	-	-[a]		Lukurmata / 33%	-	-[a]
	Pokachi Kontu / %	-	-		Pokachi Kontu / %	-	-
Costoclavicular Ligament N=13	Kirawi / %	-[a]	-[a]	Flexors N=10	Kirawi /%	-[a]	-[a]
	Lukurmata / 92%	-	-[a]		Lukurmata / 20%	-	-[a]
	Pokachi Kontu / %	-	-		Pokachi Kontu / %	-	-
Subclavius N=17	Kirawi / %	-[a]	-[a]	Anconeus N=14	Kirawi /%	-[a]	-[a]
	Lukurmata / 56%	-	-[a]		Lukurmata /50%	-	-[a]
	Pokachi Kontu / %	-	-		Pokachi Kontu / %	-	-
Trapezoid Ligament N=10	Kirawi / %	-[a]	-[a]	Brachialis N=16	Kirawi /%	-[a]	-[a]
	Lukurmata / 54%	-	-[a]		Lukurmata / 88%	-	-[a]
	Pokachi Kontu / %	-	-		Pokachi Kontu / %	-	-
Trapezius N=12	Kirawi / %	-[a]	-[a]	Triceps Brachii N=11	Kirawi /%	-[a]	-[a]
	Lukurmata / 45%	-	-[a]		Lukurmata / 82%	-	-[a]
	Pokachi Kontu / %	-	-		Pokachi Kontu / %	-	-
Pectoralis Minor N=11	Kirawi / %	-[a]	-[a]	Biceps Brachii	Kirawi / %	-[a]	-[a]
	Lukurmata / 64%	-	-[a]		Lukurmata / %	-	-[a]
	Pokachi Kontu / %	-	-		Pokachi Kontu / %	-	-
Coracobrachialis N=20	Kirawi / 25%	χ^2=0.65 p=.42	-[a]	Brachio-radialis N=3	Kirawi	-[a]	-[a]
	Lukurmata / 50%	-	-[a]		Lukurmata / 33%	-	-[a]
	Pokachi Kontu / %	-	-		Pokachi Kontu / %	-	-
Deltoideus	Kirawi /%	-[a]	-[a]	Pronator Quadratu	Kirawi / %	-[a]	-[a]
	Lukurmata	-	-[a]		Lukurmata / 29%	-	-[a]

	/ %			sN=7			
	Pokachi Kontu / %	-	-		Pokachi Kontu / %	-	-
Infraspinatus N=12	Kirawi /%	-[a]	-[a]	Pronator Teres N=11	Kirawi / %	-[a]	-[a]
	Lukurmata / 36%	-	-[a]		Lukurmata /73%	-	-[a]
	Pokachi Kontu / %	-	-		Pokachi Kontu / %	-	-
Latissims dorsi N=10	Kirawi /%	-[a]	-[a]	Supinator N=11	Kirawi /%	-[a]	-[a]
	Lukurmata /44%	-	-[a]		Lukurmata /64 %	-	-[a]
	Pokachi Kontu / %	-	-		Pokachi Kontu / %	-	-
Pectoralis Major	Kirawi /%	-[a]	-[a]	Forearm n=118	Kirawi / 50%	χ^2=0.11 p=.74	χ^2=0.00 p=1.00
	Lukurmata / %	-	-[a]		Lukurmata / 62%	-	-[a]
	Pokachi Kontu / %	-	-		Pokachi Kontu / 50%	-	-
Subscapularis N=9	Kirawi /%	-[a]	-[a]	Gluteus Maximus N=22	Kirawi /80%	-[a]	-[a]
	Lukurmata /50%	-	-[a]		Lukurmata / %	-	-[a]
	Pokachi Kontu / %	-	-		Pokachi Kontu / %	-	-
Supraspinatus N=9	Kirawi /%	-[a]	-[a]	Gluteus Medius N=4	Kirawi /%	-[a]	-[a]
	Lukurmata / 25%	-	-[a]		Lukurmata / 33%	-	-[a]
	Pokachi Kontu / %	-	-		Pokachi Kontu / %	-	-
Teres Major	Kirawi /%	-[a]	-[a]	Gluteus Minimus N=6	Kirawi /%	-[a]	-[a]
	Lukurmata / %	-	-[a]		Lukurmata /67%	-	-[a]
	Pokachi Kontu / %	-	-		Pokachi Kontu / %	-	-
Teres Minor N=12	Kirawi /%	-[a]	-[a]	Piriformes N=4	Kirawi /%	-[a]	-[a]
	Lukurmata / 45%	-	-[a]		Lukurmata / 50%	-	-[a]
	Pokachi Kontu / %	-	-		Pokachi Kontu / %	-	-
Upper Arm n=253	Kirawi / 62%	χ^2=0.32 p=.57	χ^2=0.89 p=.35	Psoas Major/ Iliacus	Kirawi /%	-[a]	-[a]
	Lukurmata / 67%	-	-[a]		Lukurmata / %	-	-[a]
	Pokachi Kontu/ 55%	-	-		Pokachi Kontu / %	-	-
Mid-body N=51	Kirawi / 67%	χ^2=2.53 p=.11	χ^2=0.41 p=.52	Soleal (Soleus) N=17	Kirawi / 50 %	χ^2=2.50 p=.11	-[a]
	Lukurmata / 84%	-	-[a]		Lukurmata / 92%	-	-[a]
	Pokachi Kontu / 75%	-	-		Pokachi Kontu / %	-	-
Linea Aspera N=27	Kirawi /40%	χ^2=3.80 p=.051	-[a]	Abductor Hallucis N=7	Kirawi /%	-[a]	-[a]
	Lukurmata /86%	-	-[a]		Lukurmata / 43%	-	-[a]
	Pokachi Kontu / %	-	-		Pokachi Kontu / %	-	-

Quadriceps Tendon N=11	Kirawi / %	-[a]	-[a]	Achilles Tendon N=8	Kirawi /%	-[a]	-[a]
	Lukurmata / 27%	-	-[a]		Lukurmata / 63%	-	-[a]
	Pokachi Kontu / %	-	-		Pokachi Kontu / %	-	-
Patellar Ligament N=15	Kirawi /50%	χ^2=1.96 p=.16	-[a]	Flexor Digitorum Brevis N= 6	Kirawi / %	-[a]	-[a]
	Lukurmata / 92%	-	-[a]		Lukurmata /50%	-	-[a]
	Pokachi Kontu / %	-	-		Pokachi Kontu / %	-	-
Lower Body N=66	Kirawi / 43%	χ^2=1.79 p=.18	χ^2=0.04 p=.85	Foot N=41	Kirawi / 50%	χ^2=0.27 p=.60	χ^2=0.14 p=.71
	Lukurmata / 74%	-	**11.43 .0007**		Lukurmata / 68%	-	-[a]
	Pokachi Kontu / 38%	-	-		Pokachi Kontu / 67%	-	-

Table B.6 Intra-Area within the Tiwanaku Valley MSM Comparisons

MSM	Site / Modeled %	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
Conoid Ligament	Akapana /%	-[a]	-[a]	-[a]	-[a]	-[a]	-[a]
	Akapana East/ %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña /%	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / %	-	-	-	-	-[a]	-[a]
	Mollo Kontu / %	-	-	-	-	-	-[a]
	Putuni /%	-	-	-	-	-	-
Costo-clavicular Ligament	Akapana /%	-[a]	-[a]	-[a]	-[a]	-[a]	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / %	-	-	-	-	-[a]	-[a]
	Mollo Kontu / %	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
Subclavius N=22	Akapana / 36%	χ^2=0.14 p=.71	-[a]	-[a]	0.00 .95	2.62 .11	-[a]
	Akapana East / 50%	-	-[a]	-[a]	0.09 .76	0.45 .50	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 38%	-	-	-	-	1.72 .19	-[a]
	Mollo Kontu / 75%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
MSM	Site / Modeled %	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
Trapezoid Ligament N=23	Akapana / 93%	-[a]	-[a]	-[a]	χ^2=2.00 p=.16	-[a]	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 67%	-	-	-	-	-[a]	-[a]

	Mollo Kontu / %	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
Trapezius N=12	Akapana / 57%	-[a]	-[a]	-[a]	0.02 .90	0.09 .77	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 60%	-	-	-	-	0.04 .84	-[a]
	Mollo Kontu / 67%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
Pectoralis Minor N=8	Akapana / 75%	-[a]	-[a]	-[a]	1.05 .31	0.0 1.0	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 33%	-	-	-	-	1.13 .29	-[a]
	Mollo Kontu / 75%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
Coraco-brachialis N=28	Akapana /50 %	-[a]	-[a]	-[a]	1.02 .31	0.44 .51	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 33%	-	-	-	-	1.71 .19	-[a]
	Mollo Kontu / 67%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
Deltoideus N=14	Akapana /38 %	-[a]	-[a]	-[a]	0.81 .37	-[a]	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 17%	-	-	-	-	-[a]	-[a]
	Mollo Kontu / %	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
Infraspinatus N=14	Akapana /38%	-[a]	-[a]	-[a]	0.81 .37	-[a]	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 17%	-	-	-	-	-[a]	-[a]
	Mollo Kontu / %	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
MSM	Site / Modeled %	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
Latissimus dorsi N=8	Akapana /25 %	-[a]	-[a]	-[a]	-[a]	χ^2=0.44 p=.51	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / %	-	-	-	-	-[a]	-[a]
	Mollo Kontu / 50%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
Pectoralis Major	Akapana /88%	-[a]	-[a]	1.44 .23	0.09 .77	-[a]	-[a]

N=28	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / 50%	-	-	-	0.97 .32	-[a]	-[a]
	Marka Pata / 83%	-	-	-	-	-[a]	-[a]
	Mollo Kontu / %	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
Sub- scapularis N=12	Akapana /67%	-[a]	-[a]	-[a]	1.58 .21	0.00 1.00	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 29%	-	-	-	-	1.10 .29	-[a]
	Mollo Kontu / 67%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
Supra- spinatus N=12	Akapana / 22 %	-[a]	-[a]	2.90 .09	-[a]	1.86 .17	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / 50%	-	-	-	-[a]	0.32 .57	-[a]
	Marka Pata / %	-	-	-	-	-[a]	-[a]
	Mollo Kontu / 67%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
Teres Major N=16	Akapana /67%	-[a]	-[a]	1.08 .30	0.91 .34	-[a]	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / 50%	-	-	-	3.61 .06	-[a]	-[a]
	Marka Pata / 86%	-	-	-	-	-[a]	-[a]
	Mollo Kontu / %	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
Teres Minor N=14	Akapana /63 %	-[a]	-[a]	-[a]	0.99 .32	-[a]	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 33%	-	-	-	-	-[a]	-[a]
	Mollo Kontu / %	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
MSM	Site / Modeled %	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
Extensors CO N=15	Akapana /8%	-[a]	-[a]	-[a]	χ^2=0.00 p=.95	0.63 .43	**5.82** **.02**
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 8%	-	-	-	-	0.72 .40	**6.22** **.01**
	Mollo Kontu / 25%	-	-	-	-	-	1.56 .21
	Putuni / 67%	-	-	-	-	-	-
Flexors CO N=27	Akapana /17 %	-[a]	-[a]	-[a]	0.51 .48	1.58 .21	3.23 .07
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]

	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 7%	-	-	-	-	**4.77** **.03**	**7.61** **.006**
	Mollo Kontu / 50%	-	-	-	-	-	0.48 .49
	Putuni / 67%	-	-	-	-	-	-
Anconeus N=19	Akapana /50 %	-[a]	-[a]	-[a]	1.03 .31	0.09 .76	0.00 1.00
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 73%	-	-	-	-	0.19 .67	0.39 .53
	Mollo Kontu / 60%	-	-	-	-	-	0.05 .82
	Putuni / 50%	-	-	-	-	-	-
Brachialis N=27	Akapana /92%	-[a]	-[a]	-[a]	0.14 .71	0.10 .76	0.93 .33
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-		-[a]	-[a]
	Marka Pata / 87%	-	-	-	-	0.00 .96	0.30 .59
	Mollo Kontu / 88%	-	-	-	-	-	0.35 .56
	Putuni / 75%	-	-	-	-	-	-
Triceps Brachii N=17	Akapana /63%	-[a]	-[a]	-[a]	0.00 .97	0.13 .72	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 62%	-	-	-	-	0.11 .74	-[a]
	Mollo Kontu / 50%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
MSM	Site / Modeled %	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
Biceps Brachii N=24	Akapana /93 %	-[a]	-[a]	-[a]	χ^2=0.06 p=.80	-[a]	**7.28** **.007**
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 90%	-	-	-	-		**4.96** **.03**
	Mollo Kontu / %	-	-	-	-	-	-[a]
	Putuni / 33%	-	-	-	-	-	-
Brachio-radialis N=15	Akapana / 38%	-[a]	-[a]	-[a]	0.04 .83	-[a]	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 43%	-	-	-	-	-[a]	-[a]
	Mollo Kontu / %	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
Pronator Quadratus N=19	Akapana / 50%	-[a]	-[a]	0.00 1.00	0.11 .74	1.20 .27	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]

	La K'araña / 50%	-	-	-	0.33 .56	2.21 .14	-[a]
	Marka Pata / 44%	-	-	-	-	0.91 .34	-[a]
	Mollo Kontu / 29%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
Pronator Teres N=24	Akapana / 50%	-[a]	-[a]	-[a]	0.00 1.00	0.00 1.00	0.00 1.00
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 50%	-	-	-	-	0.00 1.00	0.00 1.00
	Mollo Kontu / 50%	-	-	-	-	-	0.00 1.00
	Putuni / 50%	-	-	-	-	-	-
Supinator N=23	Akapana /31%	-[a]	-[a]	-[a]	2.75 .10	0.11 .74	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 70%	-	-	-	-	1.64 .20	-[a]
	Mollo Kontu / 38%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
MSM	Site / Modeled %	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
Gluteus Maximus N=11	Akapana / %	-[a]	-[a]	-[a]	-[a]	-[a]	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / %	-	-	-	-	-[a]	-[a]
	Mollo Kontu / 92%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
Gluteus Medius N=19	Akapana /55%	-[a]	-[a]	-[a]	χ^2=2.14 p=.14	-[a]	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 89%	-	-	-	-	-[a]	-[a]
	Mollo Kontu / %	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
Gluteus Minimus N=24	Akapana /67%	-[a]	-[a]	-[a]	0.21 .65	-[a]	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 75%	-	-	-	-	-[a]	-[a]
	Mollo Kontu / %	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
Piriformes N=20	Akapana /45%	-[a]	-[a]	-[a]	0.79 .37	-[a]	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 67%	-	-	-	-	-[a]	-[a]
	Mollo Kontu / %	-	-	-	-	-	-[a]

	Putuni / %	-	-	-	-	-	-
Psoas Major/ Iliacus N=23	Akapana / 77%	-[a]	-[a]	-[a]	0.66 .42	0.54 .46	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 90%	-	-	-	-	1.61 .20	-[a]
	Mollo Kontu / 60%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
Linea Aspera N=28	Akapana / 60%	-[a]	-[a]	0.41 .52	1.60 .21	2.88 .09	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / 50%	-	-	-	**4.42** **.04**	**5.90** **.02**	-[a]
	Marka Pata / 85%	-	-	-	-	0.29 .59	-[a]
	Mollo Kontu / 92%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
MSM	Site / Modeled %	Akapana East	Ch'iji Jawira	La K'araña	Marka Pata	Mollo Kontu	Putuni
Quadriceps Tendon N=7	Akapana /40%	-[a]	-[a]	χ^2=0.11 p=.75	-[a]	0.93 .34	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / 50%	-	-	-	-[a]	1.36 .24	-[a]
	Marka Pata / %	-	-	-	-	-[a]	-[a]
	Mollo Kontu / 75%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
Patellar Ligament N=16	Akapana /40%	0.06 .81	-[a]	-[a]	0.31 .58	-[a]	-[a]
	Akapana East / 50%	-	-[a]	-[a]	0.01 .90	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 55%	-	-	-	-	-[a]	-[a]
	Mollo Kontu / %	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
Soleal (Soleus) N=22	Akapana / %	-[a]	-[a]	-[a]	-[a]	-[a]	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 79%	-	-	-	-	0.26 .61	2.43 .12
	Mollo Kontu / 88%	-	-	-	-	-	**4.22** **.04**
	Putuni / 50%	-	-	-	-	-	-
Abductor Hallucis N=11	Akapana /29 %	-[a]	-[a]	-[a]	0.30 .58	0.02 .89	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 50%	-	-	-	-	0.16 .69	-[a]
	Mollo Kontu / 33%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-

Achilles Tendon N=15	Akapana /89%	-[a]	-[a]	-[a]	1.04 .31	0.60 .44	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 67%	-	-	-	-	0.00 1.00	-[a]
	Mollo Kontu / 67%	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-
Flexor Digitorum Brevis N=12	Akapana /43%	-[a]	-[a]	-[a]	0.24 .62	-[a]	-[a]
	Akapana East / %	-	-[a]	-[a]	-[a]	-[a]	-[a]
	Ch'iji Jawira / %	-	-	-[a]	-[a]	-[a]	-[a]
	La K'araña / %	-	-	-	-[a]	-[a]	-[a]
	Marka Pata / 60%	-	-	-	-	-[a]	-[a]
	Mollo Kontu / %	-	-	-	-	-	-[a]
	Putuni / %	-	-	-	-	-	-

Table B.7 Intra-Area within the Moquegua Valley MSM Comparisons - Chen Chen vs. Omo

MSM	Insertion (I), Origin (O), or Ligament (L)/ Bone	N=	Chen Chen Modeled % frequency	Chen Chen Ordinal Score Mean	Omo Modeled % frequency	Omo Ordinal Score Mean	χ^2 value (df=1)	p-value
Conoid Ligament	L / Clavicle	369	79%	1.06	91%	1.6	3.82	.05
Costoclavicular Ligament	L / Clavicle	354	83%	1.08	87%	1.42	.61	.44
Subclavius	**I / Clavicle**	**376**	**14%**	**0.70**	**32%**	**1.28**	**7.72**	**.006**
Trapezoid Ligament	**L / Clavicle**	**357**	**21%**	**0.94**	**48%**	**1.39**	**12.93**	**.0003**
Trapezius	I / Scapula	215	47%	0.99	26%	1.47	5.35	.02
Pectoralis Minor	I / Scapula	235	35%	0.92	39%	1.65	0.21	.64
Coracobrachialis	I / Humerus	468	24%	0.59	13%	.89	3.73	.053
Deltoideus	I / Humerus	469	80%	0.98	81%	1.5	0.06	.80
Infraspinatus	I / Humerus	217	12%	0.78	22%	1.09	2.39	.12
Latissimus dorsi	I / Humerus	215	2%	0.67	6%	.67	1.40	.24
Pectoralis Major	I / Humerus	450	89%	1.09	88%	1.81	0.04	.85
Subscapularis	I / Humerus	233	54%	0.97	58%	1.67	0.26	.61
Supraspinatus	I / Humerus	233	21%	0.74	27%	1.2	0.47	.49
Teres Major	I / Humerus	233	53%	0.70	65%	1.19	1.5	.22
Teres Minor	I / Humerus	221	22%	0.87	27%	1.38	0.42	.52
UPPER ARM		5080	45%	0.87	49%	1.35	1.35	.17
Extensors CO	O / Humerus	412	37%	1.02	49%	1.56	2.43	.12
Flexors CO	O / Humerus	408	17%	0.73	17%	1.28	0.00	.99

Anconeus	I / Ulna	454	43%	0.63	33%	1.16	1.80	.18
Brachialis	**I / Ulna**	**476**	**78%**	**1.21**	**92%**	**1.93**	**4.82**	**.03**
Triceps Brachii	**I / Ulna**	**436**	**24%**	**0.97**	**40%**	**1.56**	**5.18**	**.02**
Biceps Brachii	I / Radius	432	89%	1.04	94%	1.7	1.31	.25
Brachioradialis	I / Radius	296	29%	0.74	27%	1.56	0.07	.80
Pronator Quadratus	I / Radius	328	42%	0.75	40%	1.09	0.06	.81
Pronator Teres	I / Radius	435	36%	0.48	47%	1.24	2.21	.14
Supinator	I / Radius	434	18%	0.44	25%	1.09	1.32	.25
FOREARM		4111	42%	0.80	47%	1.42	1.89	.18
Gluteus Maximus	I / Femur	459	-	-	-	-	-	-[a]
Gluteus Medius	I / Femur	315	31%	0.82	28%	1.54	0.10	.75
Gluteus Minimus	I / Femur	326	54%	0.94	52%	1.76	0.05	.82
Piriformes	I / Femur	314	39%	0.82	35%	1.50	0.33	.57
Psoas Major/Iliacus	I / Femur	329	66%	0.90	73%	1.37	0.76	.38
MID-BODY		1743	58%	0.91	59%	1.67	0.06	.81
Linea Aspera	**I / Femur**	**468**	**26%**	**0.87**	**47%**	**1.66**	**8.72**	**.003**
Quadriceps Tendon	Patella	220	31%	1.13	26%	1.41	0.37	.54
Patellar Ligament	**L / Tibia**	**323**	**65%**	**0.94**	**38%**	1.58	**9.36**	**.002**
LOWER BODY		1011	39%	0.98	39%	1.55	0.00	.99
Soleal (Soleus)	O / Tibia	425	53%	0.73	56%	1.31	0.15	.69
Abductor Hallucis	**O / Calcaneus**	**297**	**27%**	**0.90**	**47%**	**0.94**	**5.39**	**.02**
Achilles Tendon	Calcaneus	358	61%	0.89	46%	1.74	2.96	.09
Flexor Digitorum Brevis	**O / Calcaneus**	**298**	**56%**	**0.79**	**20%**	**0.94**	**13.91**	**.0002**
FOOT		1378	50%	0.83	43%	1.23	2.44	.12

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table B.8 Intra-Area within the Moquegua Valley MSM Comparisons - Chen Chen vs. Rio Muerto

MSM	Insertion (I), Origin (O), or Ligament (L)/ Bone	N=	Chen Chen Modeled % frequency	Chen Chen Ordinal Score Mean	Rio Muerto Modeled % frequency	Rio Muerto Ordinal Score Mean	χ^2 value (df=1)	p-value
Conoid Ligament	L / Clavicle	369	79%	1.06	88%	1.36	2.48	.12
Costoclavicular Ligament	L / Clavicle	354	83%	1.08	90%	1.48	0.74	.39

Subclavius	I / Clavicle	376	14%	**0.70**	24%	1.22	1.61	.20
Trapezoid Ligament	**L / Clavicle**	**357**	**21%**	**0.94**	**49%**	**1.28**	**11.95**	**.0005**
Trapezius	I / Scapula	215	47%	0.99	58%	1.40	1.37	.24
Pectoralis Minor	**I / Scapula**	**235**	**35%**	**0.92**	**60%**	**1.43**	**5.37**	**.02**
Coracobrachialis	I / Humerus	468	24%	0.59	16%	0.63	1.51	.22
Deltoideus	I / Humerus	469	80%	0.98	76%	1.23	0.29	.59
Infraspinatus	I / Humerus	217	12%	0.78	26%	1.06	2.77	.10
Latissimus dorsi	I / Humerus	215	-	-	-	-	-	-[a]
Pectoralis Major	I / Humerus	450	-	-	-	-	-	-[a]
Subscapularis	I / Humerus	233	54%	0.97	70%	1.38	2.45	.12
Supraspinatus	I / Humerus	233	21%	0.74	28%	1.28	0.62	.43
Teres Major	I / Humerus	233	53%	0.70	56%	0.80	0.11	.74
Teres Minor	I / Humerus	221	22%	0.87	42%	1.22	3.78	.052
UPPER ARM		**5080**	**45%**	**0.87**	**53%**	**1.21**	**5.68**	**.02**
Extensors CO	O / Humerus	412	37%	1.02	50%	1.31	2.43	.12
Flexors CO	O / Humerus	408	17%	0.73	23%	0.85	0.85	.36
Anconeus	I / Ulna	454	43%	0.63	30%	0.96	2.53	.11
Brachialis	I / Ulna	476	78%	1.21	90%	1.79	3.73	.054
Triceps Brachii	I / Ulna	436	24%	0.97	20%	1.54	0.19	.67
Biceps Brachii	I / Radius	432	-	-	-	-	-	-[a]
Brachioradialis	I / Radius	296	29%	0.74	26%	1.36	0.15	.70
Pronator Quadratus	I / Radius	328	42%	0.75	34%	0.98	0.83	.36
Pronator Teres	**I / Radius**	**435**	**36%**	**0.48**	**10%**	**0.87**	**7.92**	**.005**
Supinator	I / Radius	434	18%	0.44	12%	0.78	0.58	.45
FOREARM		4111	42%	0.80	40%	1.20	0.62	.43
Gluteus Maximus	I / Femur	459	-	-	-	-	-	-[a]
Gluteus Medius	I / Femur	315	31%	0.82	20%	1.19	1.71	.19
Gluteus Minimus	I / Femur	326	54%	0.94	57%	1.56	0.10	.75
Piriformes	I / Femur	314	39%	0.82	29%	1.31	1.55	.21
Psoas Major/Iliacus	**I / Femur**	**329**	**66%**	**0.90**	**81%**	**1.21**	**4.12**	**.04**
MID-BODY		1743	58%	0.91	58%	1.38	0.01	.94
Linea Aspera	I / Femur	468	26%	0.87	20%	1.27	0.73	.39
Quadriceps Tendon	**Patella**	**220**	**31%**	**1.13**	**54%**	**1.54**	**4.58**	**.03**
Patellar Ligament	L / Tibia	323	65%	0.94	54%	1.45	1.66	.2
LOWER BODY		1011	39%	0.98	42%	1.42	0.19	.66

Soleal (Soleus)	**O / Tibia**	**425**	**53%**	**0.73**	**24%**	**1.06**	**12.6**	**.0004**
Abductor Hallucis	O / Calcaneus	297	27%	0.90	38%	0.84	1.58	.21
Achilles Tendon	Calcaneus	358	61%	0.89	64%	1.44	0.13	.72
Flexor Digitorum Brevis	**O / Calcaneus**	**298**	**56%**	**0.79**	**33%**	0.77	**7.73**	**.005**
FOOT		**1378**	**50%**	**0.83**	**40%**	**1.03**	**4.16**	**.04**

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table B.9 Intra-Area within the Moquegua Valley MSM Comparisons - Omo vs. Rio Muerto

MSM	Insertion (I), Origin (O), or Ligament (L)/ Bone	N=	Omo Modeled % frequency	Omo Ordinal Score Mean	Rio Muerto Modeled % frequency	Rio Muerto Ordinal Score Mean	χ^2 value (df=1)	p-value
Conoid Ligament	L / Clavicle	369	91%	1.60	88%	1.36	0.24	.63
Costoclavicular Ligament	L / Clavicle	354	87%	1.42	90%	1.48	0.12	.73
Subclavius	I / Clavicle	376	32%	1.28	24%	1.22	0.67	.41
Trapezoid Ligament	L / Clavicle	357	48%	1.39	49%	1.28	0.02	.90
Trapezius	**I / Scapula**	**215**	**26%**	**1.47**	**58%**	**1.40**	**8.17**	**.004**
Pectoralis Minor	I / Scapula	235	39%	1.65	60%	1.43	2.53	.11
Coracobrachialis	I / Humerus	468	13%	0.89	16%	0.63	0.17	.68
Deltoideus	I / Humerus	469	81%	1.50	76%	1.23	0.37	.54
Infraspinatus	I / Humerus	217	22%	1.09	26%	1.06	0.12	.72
Latissimus dorsi	I / Humerus	215	-	-	-	-	-	-[a]
Pectoralis Major	I / Humerus	450	-	-	-	-	-	-[a]
Subscapularis	I / Humerus	233	58%	1.67	70%	1.38	0.95	.33
Supraspinatus	I / Humerus	233	27%	1.20	28%	1.28	0.01	.94
Teres Major	I / Humerus	233	65%	1.19	56%	0.80	0.63	.43
Teres Minor	I / Humerus	221	27%	1.38	42%	1.22	1.47	.23
UPPER ARM		5080	49%	1.35	53%	1.21	0.74	.39
Extensors CO	O / Humerus	412	49%	1.56	50%	1.31	0.01	.94
Flexors CO	O / Humerus	408	17%	1.28	23%	0.85	0.49	.48
Anconeus	I / Ulna	454	33%	1.16	30%	0.96	0.12	.73
Brachialis	I / Ulna	476	92%	1.93	90%	1.79	0.09	.76
Triceps Brachii	I / Ulna	436	40%	1.56	20%	1.54	3.29	.07
Biceps Brachii	I / Radius	432	-	-	-	-	-	-[a]

Brachioradialis	I / Radius	296	27%	1.56	26%	1.36	0.02	.9
Pronator Quadratus	I / Radius	328	40%	1.09	34%	0.98	0.34	.56
Pronator Teres	**I / Radius**	**435**	**47%**	**1.24**	**10%**	**0.87**	**11.5**	**.0008**
Supinator	I / Radius	434	25%	1.09	12%	0.78	1.86	.17
FOREARM		4111	47%	1.42	40%	1.20	2.80	.09
Gluteus Maximus	I / Femur	459	-	-	-	-	-	-[a]
Gluteus Medius	I / Femur	315	28%	1.54	20%	1.19	0.79	.37
Gluteus Minimus	I / Femur	326	52%	1.76	57%	1.56	0.19	.66
Piriformes	I / Femur	314	35%	1.50	29%	1.31	0.30	.59
Psoas Major/Iliacus	I / Femur	329	73%	1.37	81%	1.21	0.89	.35
MID-BODY		1743	59%	1.67	58%	1.38	0.06	.80
Linea Aspera	**I / Femur**	**468**	**47%**	**1.66**	**20%**	**1.27**	**7.74**	**.005**
Quadriceps Tendon	**Patella**	**220**	**26%**	**1.41**	**54%**	**1.54**	**5.45**	**.02**
Patellar Ligament	L / Tibia	323	38%	1.58	54%	1.45	2.12	.15
LOWER BODY		1011	39%	1.55	42%	1.42	0.13	.72
Soleal (Soleus)	**O / Tibia**	**425**	**56%**	**1.31**	**24%**	**1.06**	**10.27**	**.001**
Abductor Hallucis	O / Calcaneus	297	47%	0.94	38%	0.84	0.66	.42
Achilles Tendon	Calcaneus	358	46%	1.74	64%	1.44	2.46	.12
Flexor Digitorum Brevis	O / Calcaneus	298	20%	0.94	33%	0.77	2.04	.15
FOOT		1378	43%	1.23	40%	1.03	0.32	.57

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table B.10 Core Upper Anatomy MSM Results from Late Formative to the Tiwanaku Phase

MSM	Insertion (I), Origin (O), or Ligament (L)/ Bone	n=	LF Modeled % frequency	LF Ordinal Score Mean	TW Modeled % frequency	TW Ordinal Score Mean	χ^2 value (df=1)	*p*-value
Conoid Ligament	L / Clavicle	72	-	-	-	-	-	-[a]
Costoclavicular Ligament	L / Clavicle	64	78%	1.67	96%	1.88	2.76	.10
Subclavius	I / Clavicle	70	55%	2.00	44%	1.72	0.42	.52
Trapezoid Ligament	L / Clavicle	-	-	-	-	-	-	-[a]
Trapezius	**I / Scapula**	**47**	**89%**	**1.53**	**44%**	**1.75**	**4.09**	**.04**
Pectoralis Minor	I / Scapula	40	50%	2.67	63%	1.24	0.29	.59

Coracobrachialis	I / Humerus	99	70%	1.17	42%	1.29	3.72	.054
Deltoideus	I / Humerus	108	-	-	-	-	-	-[a]
Infraspinatus	**I / Humerus**	**44**	**83%**	**1.67**	**29%**	**1.31**	**4.56**	**.03**
Latissimus dorsi	**I / Humerus**	**42**	**67%**	**1.11**	**22%**	**1.26**	**4.11**	**.04**
Pectoralis Major	I / Humerus	102	-	-	-	-	-	-[a]
Subscapularis	I / Humerus	52	-	-	-	-	-	-[a]
Supraspinatus	**I / Humerus**	**52**	**70%**	**1.50**	**22%**	**1.40**	**4.91**	**.03**
Teres Major	I / Humerus	51	90%	2.67	80%	1.56	0.48	.49
Teres Minor	I / Humerus	51	70%	1.53	50%	1.38	1.14	.29
UPPER ARM		**1074**	**82%**	**1.71**	**63%**	**1.62**	**7.74**	**.01**
Extensors CO	O / Humerus	65	27%	1.83	24%	1.13	0.06	.81
Flexors CO	O / Humerus	68	17%	0.33	20%	1.40	0.05	.83
Anconeus	I / Ulna	64	85%	1.46	58%	1.55	1.52	.22
Brachialis	I / Ulna	96	95%	1.91	87%	2.21	0.88	.35
Triceps Brachii	I / Ulna	60	92%	1.52	68%	1.64	2.63	.11
Biceps Brachii	I / Radius	78	-	-	-	-	-	-[a]
Brachioradialis	I / Radius	47	63%	0.78	53%	1.67	0.24	.62
Pronator Quadratus	I / Radius	63	64%	1.07	42%	1.28	2.88	.09
Pronator Teres	I / Radius	78	65%	0.95	55%	1.24	0.44	.51
Supinator	I / Radius	78	31%	0.33	47%	1.31	0.99	.32
FOREARM		697	66%	1.20	56%	1.54	2.29	.13
Gluteus Maximus	I / Femur	116	-	-	-	-	-	-[a]
Gluteus Medius	I / Femur	39	75%	1.78	58%	1.67	0.88	.35
Gluteus Minimus	I / Femur	51	90%	1.87	65%	1.74	2.36	.12
Piriformes	I / Femur	43	80%	1.47	52%	1.70	0.03	.86
Psoas Major/Iliacus	I / Femur	61	92%	1.24	83%	1.58	0.61	.43
MID-BODY		**310**	**90%**	**1.62**	**77%**	**1.81**	**4.11**	**.04**
Linea Aspera	**I / Femur**	**139**	**94**%	**1.50**	**71%**	**2.18**	**5.27**	**.02**
Quadriceps Tendon	Patella	61	53%	2.00	31%	1.54	1.52	.22
Patellar Ligament	L / Tibia	69	38%	1.17	69%	1.32	2.97	.08
LOWER BODY		269	70%	1.56	62%	1.68	0.98	.32
Soleal (Soleus)	O / Tibia	92	82%	1.15	83%	1.51	0.01	.92

Abductor Hallucis	O / Calcaneus	42	40%	0.33	33%	1.33	0.12	.73
Achilles Tendon	Calcaneus	51	82%	1.00	65%	1.89	1.12	.29
Flexor Digitorum Brevis	O / Calcaneus	42	60%	0.58	39%	1.45	0.81	.37
FOOT		227	70%	0.77	62%	1.55	0.61	.44

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table B.11 Core MSM Results from the Tiwanaku Phase to the Post-Tiwanaku Phase

MSM	Insertion (I), Origin (O), or Ligament (L)/ Bone	N=	TW Modeled % frequency	TW Ordinal Score Mean	PT Modeled % frequency	PT Ordinal Score Mean	χ^2 value (df=1)	p-value
Conoid Ligament	L / Clavicle	72	85%	-	75%	1.58	0.43	.51
Costoclavicular Ligament	L / Clavicle	64	96%	1.88	88%	2.38	0.74	.39
Subclavius	I / Clavicle	70	44%	1.72	50%	1.44	0.10	.75
Trapezoid Ligament	L / Clavicle	-	-	-	-	-	-	-[a]
Trapezius	I / Scapula	47	44%	1.75	40%	1.33	0.02	.88
Pectoralis Minor	I / Scapula	40	63%	1.24	44%	1.58	0.60	.44
Coracobrachialis	I / Humerus	99	42%	1.29	75%	1.17	3.79	.052
Deltoideus	I / Humerus	108	-	-	-	-	-	-[a]
Infraspinatus	I / Humerus	44	29%	1.31	25%	0.67	0.03	.86
Latissimus dorsi	I / Humerus	42	22%	1.26	25%	1.07	0.04	.85
Pectoralis Major	I / Humerus	102	-	-	-	-	-	-[a]
Subscapularis	I / Humerus	52	53%	1.81	40%	1.83	0.81	.37
Supraspinatus	I / Humerus	52	-	1.40	-	-	-	-[a]
Teres Major	I / Humerus	51	-	1.56	-	-	-	-[a]
Teres Minor	I / Humerus	51	-	1.38	-	-	-	-[a]
UPPER ARM		1074	63%	1.62	70%	1.52	0.56	.46
Extensors CO	O / Humerus	65	24%	1.13	25%	1.50	0.00	.96
Flexors CO	O / Humerus	68	20%	1.40	30%	1.56	0.53	.47
Anconeus	I / Ulna	64	58%	1.55	43%	1.67	0.57	.45
Brachialis	I / Ulna	96	87%	2.21	92%	2.18	0.27	.61
Triceps Brachii	I / Ulna	60	68%	1.64	29%	1.50	2.74	.10
Biceps Brachii	I / Radius	78	92%	2.00	82%	2.38	0.61	.44

Brachioradialis	I / Radius	47	53%	1.67	25%	1.89	1.04	.31
Pronator Quadratus	I / Radius	63	42%	1.28	50%	1.44	0.16	.69
Pronator Teres	I / Radius	78	55%	1.24	64%	1.05	0.25	.61
Supinator	I / Radius	78	47%	1.31	-	-	-	-[a]
FOREARM		697	56%	1.54	47%	1.68	0.95	.33
Gluteus Maximus	I / Femur	116	94%	2.35	94%	2.63	0.00	1.00
Gluteus Medius	I / Femur	39	58%	1.67	40%	1.50	0.78	.38
Gluteus Minimus	I / Femur	51	65%	1.74	71%	1.27	0.13	.71
Piriformes	I / Femur	43	52%	1.70	50%	1.44	0.01	.94
Psoas Major/Iliacus	I / Femur	61	-	1.58	-	-	-	-[a]
MID-BODY		310	77%	1.81	79%	1.66	0.11	.74
Linea Aspera	I / Femur	139	71%	2.18	95%	2.13	3.43	.06
Quadriceps Tendon	Patella	61	31%	1.54	33%	1.78	0.01	.92
Patellar Ligament	L / Tibia	69	69%	1.32	50%	1.13	1.05	.31
LOWER BODY		269	62%	1.68	68%	1.68	0.32	.57
Soleal (Soleus)	O / Tibia	92	83%	1.51	79%	1.51	0.10	.75
Abductor Hallucis	O / Calcaneus	42	33%	1.33	-	-	-	-[a]
Achilles Tendon	Calcaneus	51	65%	1.89	43%	1.67	0.88	.35
Flexor Digitorum Brevis	O / Calcaneus	42	39%	1.45	-	-	-	-[a]
FOOT		227	62%	1.55	41%	1.46	2.53	.11

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table B.12 Colony MSM Results from Tiwanaku to Post-Tiwanaku Phase

MSM	Insertion (I), Origin (O), or Ligament (L)/ Bone	n=	TW Modeled % frequency	TW Ordinal Score Mean	PT Modeled % frequency	PT Ordinal Score Mean	χ^2 value (df=1)	*p*-value
Conoid Ligament	L / Clavicle	403	83%	1.22	88%	1.50	0.59	.44
Costoclavicular Ligament	L / Clavicle	384	85%	1.20	86%	1.47	0.01	.92
Subclavius	I / Clavicle	411	19%	0.95	18%	1.50	0.01	.92
Trapezoid Ligament	L / Clavicle	389	30%	1.15	23%	1.05	0.52	.47
Trapezius	**I / Scapula**	**235**	**45%**	**1.17**	**72%**	**1.52**	**5.08**	**.02**
Pectoralis Minor	I / Scapula	264	40%	1.26	30%	1.39	0.76	.38

Coracobrachialis	**I / Humerus**	**508**	**22%**	**0.62**	**3%**	**1.33**	**5.35**	**.02**
Deltoideus	**I / Humerus**	**509**	**80%**	**1.09**	**61%**	**1.49**	**4.96**	**.03**
Infraspinatus	I / Humerus	233	17%	0.95	14%	0.83	0.09	.77
Latissimus dorsi	I / Humerus	231	-	-	-	-	-	-[a]
Pectoralis Major	I / Humerus	489	90%	1.26	89%	1.48	0.02	.88
Subscapularis	I / Humerus	255	58%	1.20	40%	1.17	1.33	.25
Supraspinatus	I / Humerus	255	24%	0.97	15%	1.22	0.51	.47
Teres Major	I / Humerus	255	56%	0.81	35%	1.48	1.94	.16
Teres Minor	I / Humerus	238	27%	1.09	7%	1.00	2.44	.12
UPPER ARM		5528	47%	1.03	41%	1.27	2.23	.14
Extensors CO	O / Humerus	449	41%	1.17	25%	1.33	2.41	.12
Flexors CO	O / Humerus	444	18%	0.84	15%	1.33	0.17	.68
Anconeus	I / Ulna	490	40%	0.72	49%	1.35	0.64	.42
Brachialis	I / Ulna	516	82%	1.40	95%	1.57	3.56	.06
Triceps Brachii	I / Ulna	475	26%	1.15	11%	1.25	2.76	.10
Biceps Brachii	I / Radius	468	91%	1.21	94%	1.55	0.42	.52
Brachioradialis	I / Radius	324	28%	0.97	22%	1.47	0.45	.50
Pronator Quadratus	I / Radius	361	40%	0.84	56%	1.18	2.26	.13
Pronator Teres	**I / Radius**	**472**	**34%**	**0.65**	**11%**	**0.92**	**7.71**	**.006**
Supinator	I / Radius	472	18%	0.63	11%	0.50	0.78	.38
FOREARM		4471	43%	0.96	39%	1.25	1.20	.27
Gluteus Maximus	I / Femur	495	89%	1.31	85%	1.54	0.27	.60
Gluteus Medius	I / Femur	334	29%	0.98	11%	1.00	2.80	.09
Gluteus Minimus	I / Femur	349	54%	1.18	32%	1.67	3.41	.06
Piriformes	**I / Femur**	**338**	**37%**	**0.99**	**13%**	**1.17**	**4.98**	**.03**
Psoas Major/Iliacus	I / Femur	355	69%	1.04	71%	1.35	0.03	.87
MID-BODY		1871	58%	1.10	48%	1.35	3.27	.07
Linea Aspera	I / Femur	503	28%	1.09	18%	1.27	1.11	.29
Quadriceps Tendon	**Patella**	**255**	**34%**	**1.29**	**9%**	**2.17**	**7.39**	**.007**

Patellar Ligament	**L / Tibia**	**340**	**59%**	**1.08**	**18%**	**1.17**	**9.00**	**.003**
LOWER BODY		**1098**	**39%**	**1.15**	**14%**	**1.53**	**11.82**	**.0006**
Soleal (Soleus)	O / Tibia	453	50%	0.85	37%	1.19	1.41	.23
Abductor Hallucis	O / Calcaneus	325	32%	0.90	23%	1.17	0.68	.41
Achilles Tendon	Calcaneus	401	59%	1.09	49%	1.25	0.96	.33
Flexor Digitorum Brevis	**O / Calcaneus**	**327**	**46%**	**0.80**	**17%**	**1.07**	**6.40**	**.01**
FOOT		1506	48%	0.91	34%	1.17	3.38	.07

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table B.13 MSM Core vs. Colony Results during Tiwanaku Phase for FEMALES

MSM	Insertion (I), Origin (O), or Ligament (L)/ Bone	n=	Core Modeled % frequency	Core Ordinal Score Mean	Colony Modeled % frequency	Colony Ordinal Score Mean	χ^2 value (df=1)	*p*-value
Conoid Ligament	L / Clavicle	205	85%	1.70	86%	1.22	.01	.92
Costoclavicular Ligament	L / Clavicle	192	-	-	-	-	-	-[a]
Subclavius	**I / Clavicle**	**209**	**48%**	**1.53**	**19%**	**1.86**	**6.74**	**.01**
Trapezoid Ligament	L / Clavicle	196	53%	1.85	31%	1.16	2.78	.10
Trapezius	I / Scapula	130	29%	1.37	36%	1.00	0.34	.56
Pectoralis Minor	I / Scapula	140	69%	1.14	40%	1.14	2.66	.10
Coracobrachialis	**I / Humerus**	**268**	**48%**	**1.06**	**22%**	**0.69**	**5.59**	**.02**
Deltoideus	I / Humerus	271	-	-	-	-	-	-[a]
Infraspinatus	I / Humerus	137	28%	1.17	16%	0.98	1.23	.27
Latissimus dorsi	**I / Humerus**	**135**	**29%**	**1.18**	**3%**	**0.73**	**10.55**	**.001**
Pectoralis Major	I / Humerus	257	92%	2.32	91%	1.19	0.03	.87
Subscapularis	I / Humerus	140	50%	1.87	57%	1.19	0.22	.64
Supraspinatus	I / Humerus	140	19%	1.28	23%	1.04	0.18	.67
Teres Major	I / Humerus	140	81%	2.32	57%	1.19	2.22	.14
Teres Minor	I /	137	53%	1.26	26%	1.09	3.35	.07

	Humerus							
UPPER ARM		**2933**	**62%**	**1.55**	**47%**	**1.11**	**6.01**	**.01**
Extensors CO	O / Humerus	243	23%	0.67	40%	1.17	2.52	.11
Flexors CO	O / Humerus	242	24%	1.19	23%	0.88	0.01	.92
Anconeus	I / Ulna	246	33%	1.58	41%	0.68	0.26	.61
Brachialis	I / Ulna	260	86%	2.15	84%	1.41	0.04	.84
Triceps Brachii	I / Ulna	237	50%	1.44	24%	1.09	3.66	.56
Biceps Brachii	I / Radius	243	94%	1.65	89%	1.15	0.32	.57
Brachioradialis	**I / Radius**	**169**	**67%**	**1.37**	**23%**	**0.87**	**4.09**	**.04**
Pronator Quadratus	I / Radius	189	33%	1.11	41%	0.79	0.31	.58
Pronator Teres	I / Radius	238	44%	1.00	36%	0.59	0.55	.46
Supinator	I / Radius	243	41%	1.22	21%	0.64	3.04	.08
FOREARM		2310	49%	1.34	43%	0.93	1.64	.20
Gluteus Maximus	I / Femur	259	97%	2.23	89%	1.23	1.43	.23
Gluteus Medius	I / Femur	188	45%	1.40	33%	0.97	0.67	.41
Gluteus Minimus	I / Femur	196	54%	1.56	60%	1.12	0.17	.68
Piriformes	I / Femur	186	50%	1.55	36%	1.01	0.72	.39
Psoas Major/Iliacus	I / Femur	196	88%	1.32	63%	0.98	3.23	.07
MID-BODY		1025	75%	1.61	58%	1.06	3.48	.06
Linea Aspera	**I / Femur**	**263**	**68%**	**2.10**	**19%**	**0.90**	**18.75**	**<.0001**
Quadriceps Tendon	Patella	110	24%	1.28	30%	1.25	0.21	.65
Patellar Ligament	L / Tibia	184	76%	1.26	61%	1.05	1.76	.18
LOWER BODY		**557**	**59%**	**1.55**	**35%**	**1.07**	**8.32**	**.004**
Soleal (Soleus)	**O / Tibia**	**232**	**86%**	**1.38**	**48%**	**0.79**	**10.21**	**.001**
Abductor Hallucis	O / Calcaneus	163	20%	1.33	31%	0.98	0.64	.42
Achilles Tendon	Calcaneus	182	62%	2.15	63%	1.04	0.01	.91
Flexor Digitorum Brevis	O / Calcaneus	162	22%	1.58	47%	0.80	1.06	.30
FOOT		739	57%	1.61	48%	0.90	0.97	.33

Table B.14 MSM Core vs. Colony Results during Tiwanaku Phase for MALES

MSM	Insertion (I), Origin (O), or Ligament (L)/ Bone	n=	Core Modeled % frequency	Core Ordinal Score Mean	Colony Modeled % frequency	Colony Ordinal Score Mean	χ^2 value (df=1)	*p*-value
Conoid Ligament	L / Clavicle	162	94%	1.76	78%	1.20	2.48	.12
Costoclavicular Ligament	L / Clavicle	165	95%	1.97	83%	1.25	1.79	.18
Subclavius	**I / Clavicle**	**171**	**48%**	**1.95**	**19%**	**0.98**	**6.76**	**.009**
Trapezoid Ligament	**L / Clavicle**	**160**	**65%**	**2.00**	**26%**	**1.04**	**6.95**	**.008**
Trapezius	I / Scapula	95	63%	1.90	57%	1.30	0.15	.70
Pectoralis Minor	I / Scapula	94	44%	2.27	39%	1.33	0.09	.77
Coracobrachialis	**I / Humerus**	**199**	**44%**	**1.45**	**23%**	**0.58**	**5.91**	**.02**
Deltoideus	I / Humerus	204	-	-	-	-	-	-[a]
Infraspinatus	**I / Humerus**	**88**	**50%**	**1.33**	**20%**	**0.92**	**4.18**	**.04**
Latissimus dorsi	I / Humerus	86	14%	1.20	1%	0.78	2.97	.09
Pectoralis Major	I / Humerus	201	87%	2.27	91%	1.33	0.24	.62
Subscapularis	I / Humerus	100	75%	1.59	55%	1.24	1.12	.29
Supraspinatus	I / Humerus	100	42%	1.61	24%	0.82	1.71	.19
Teres Major	I / Humerus	99	82%	1.68	59%	0.83	2.21	.14
Teres Minor	**I / Humerus**	**92**	**67%**	**1.39**	**30%**	**1.07**	**5.03**	**.02**
UPPER ARM		**2223**	**69%**	**1.75**	**47%**	**1.05**	**11.17**	**.001**
Extensors CO	O / Humerus	168	35%	1.48	38%	1.18	0.06	.81
Flexors CO	O / Humerus	164	25%	1.43	12%	0.78	1.99	.16
Anconeus	**I / Ulna**	**187**	**75%**	**1.55**	**37%**	**0.83**	**7.07**	**.008**
Brachialis	I / Ulna	201	92%	2.30	77%	1.45	3.00	.08
Triceps Brachii	**I / Ulna**	**176**	**88%**	**1.73**	**25%**	**1.23**	**17.31**	**<.0001**
Biceps Brachii	I / Radius	181	96%	2.18	92%	1.32	0.40	.53
Brachioradialis	**I / Radius**	**115**	**67%**	**1.60**	**33%**	**1.07**	**3.91**	**.048**
Pronator Quadratus	I / Radius	130	60%	1.30	38%	0.92	3.80	.051
Pronator	**I / Radius**	**189**	**61%**	**1.35**	**21%**	**0.74**	**5.95**	**.01**

Teres								
Supinator	**I / Radius**	**184**	**55%**	**1.38**	**16%**	**0.67**	**10.41**	**.001**
FOREARM		**1695**	**66%**	**1.63**	**16%**	**1.02**	**17.04**	**<.0001**
Gluteus Maximus	I / Femur	208	94%	2.34	91%	1.38	0.34	.56
Gluteus Medius	**I / Femur**	**120**	**67%**	**1.78**	**21%**	**0.93**	**6.14**	**.01**
Gluteus Minimus	**I / Femur**	**127**	**71%**	**1.73**	**41%**	**1.28**	**3.96**	**.047**
Piriformes	I / Femur	121	50%	2.00	34%	0.93	0.81	.37
Psoas Major/Iliacus	I / Femur	137	83%	1.78	80%	1.10	0.14	.71
MID-BODY		**713**	**79%**	**1.93**	**57%**	**1.12**	**4.04**	**.044**
Linea Aspera	**I / Femur**	**217**	**70%**	**2.01**	**39%**	**1.20**	**7.26**	**.007**
Quadriceps Tendon	Patella	114	36%	1.62	33%	1.25	0.04	.84
Patellar Ligament	L / Tibia	136	81%	1.31	58%	1.16	2.84	.09
LOWER BODY		**467**	**67%**	**1.65**	**43%**	**1.20**	**8.03**	**.005**
Soleal (Soleus)	O / Tibia	191	78%	1.62	50%	0.90	3.60	.058
Abductor Hallucis	O / Calcaneus	120	22%	1.50	32%	0.88	0.18	.67
Achilles Tendon	Calcaneus	155	62%	1.88	54%	1.09	0.24	.63
Flexor Digitorum Brevis	O / Calcaneus	123	33%	1.56	46%	0.84	0.40	.53
FOOT		589	57%	1.64	46%	0.93	0.79	.37

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table B.15 MSM Tiwanaku Core vs. Colony Comparisons – GEE Chi-Square (df=1) Significant Differences by AGE-AT-DEATH

MSM	Insertion (I), Origin (O), or Ligament (L)/ Bone	N=	Core Modeled % frequency	Colony Modeled % frequency	χ^2 value (df=1)	p-value
15-19 years						
Triceps Brachii	**I / Ulna**	**43**	**40%**	**5%**	**3.99**	**.046**
Linea Aspera	**I / Femur**	**51**	**63%**	**5%**	**17.55**	**<.0001**
Quadriceps Tendon	**Patella**	**28**	**67%**	**20%**	**4.70**	**.03**
Soleal (Soleus)	**O / Tibia**	**42**	**83%**	**36%**	**4.79**	**.03**
20-29 years						

Triceps Brachii	**I / Ulna**	**129**	**62%**	**16%**	**14.39**	**.0001**
Pronator Teres	**I / Radius**	**132**	**50%**	**20%**	**5.25**	**.02**
Supinator	**I / Radius**	**135**	**33%**	**7%**	**7.79**	**.005**
Linea Aspera	**I / Femur**	**152**	**40%**	**14%**	**5.62**	**.02**
30-39 years						
Subclavius	**I / Clavicle**	**196**	**64%**	**24%**	**9.62**	**.002**
Trapezoid Ligament	**L / Clavicle**	**184**	**67%**	**31%**	**6.05**	**.01**
Coracobrachialis	**I / Humerus**	**224**	**58%**	**24%**	**8.40**	**.004**
Latissimus dorsi	**I / Humerus**	**92**	**38%**	**24%**	**7.14**	**.008**
Extensors CO	**O / Humerus**	**190**	**7%**	**44%**	**4.68**	**.03**
Anconeus	**I / Ulna**	**217**	**79%**	**49%**	**4.17**	**.04**
Triceps Brachii	**I / Ulna**	**208**	**69%**	**33%**	**4.17**	**.04**
Supinator	**I / Radius**	**204**	**64%**	**25%**	**6.04**	**.01**
Linea Aspera	**I / Femur**	**241**	**77%**	**37%**	**13.06**	**.0003**
40-49 years						
Subclavius	**I / Clavicle**	**49**	**56%**	**10%**	**5.58**	**.02**
Trapezoid Ligament	**L / Clavicle**	**43**	**88%**	**31%**	**6.88**	**.009**
Triceps Brachii	**I / Ulna**	**56**	**88%**	**31%**	**5.69**	**.02**
Brachioradialis	**I / Radius**	**41**	**88%**	**24%**	**8.27**	**.004**

Table B.16 MSM Intra-Area Moquegua Valley GEE Chi-Square (df=1)Results during the Tiwanaku Time Period by AGE-AT-DEATH

MSM Use-Area	Site / Modeled %	Omo	Rio Muerto
15-19			
UPPER ARM N=474	Chen Chen / 31%	χ^2=0.81 p=.37	**8.55 .004**
	Omo / 35%	-	3.07 .08
	Rio Muerto / 45%	-	-
FORE-ARM N=350	Chen Chen / 22%	2.60 .11	1.62 .20
	Omo / 29%	-	0.09 .76
	Rio Muerto / 28%	-	-
MID-BODY N=146	Chen Chen / 34%	1.32 .25	0.11 .74
	Omo / 48%	-	1.49 .22
	Rio Muerto / 38%	-	-
LOWER BODY N=90	Chen Chen / 55%	0.10 0.753	4.69 .03
	Omo / 7%	-	2.68

			.10
	Rio Muerto / 26%	-	-
FOOT N=116	Chen Chen / 37%	0.03 .85	2.08 .15
	Omo / 39%	-	2.23 .14
	Rio Muerto / 24%	-	-
MSM Use-Area	Site / Modeled %	Omo	Rio Muerto
20-29			
UPPER ARM N=1394	Chen Chen / 37%	0.68 .41	4.58 .03
	Omo / 41%	-	1.89 .17
	Rio Muerto / 51%	-	-
FORE- ARM N=1127	Chen Chen / 35%	1.36 .24	0.07 .79
	Omo / 38%	-	0.90 .34
	Rio Muerto / 33%	-	-
MID- BODY N=480	Chen Chen / 47%	0.24 .63	3.25 .07
	Omo / 49%	-	2.22 .14
	Rio Muerto / 60%	-	-
LOWER BODY N=278	Chen Chen / 31%	0.44 .51	0.00 .96
	Omo / 24%	-	0.23 .63
	Rio Muerto / 30%	-	-
FOOT N=348	Chen Chen / 35%	1.84 .17	0.87 .35
	Omo / 26%	-	0.04 .84
	Rio Muerto / 27%	-	-
MSM Use-Area	Site / Modeled %	Omo	Rio Muerto
30-39			
UPPER ARM N=2235	Chen Chen / 49%	χ^2=3.42 p=.06	0.79 .37
	Omo / 56%	-	0.36 .55
	Rio Muerto / 53%	-	-
FORE- ARM N=1798	Chen Chen / 45%	**9.06** **.003**	0.47 .49
	Omo / 58%	-	7.25 .007
	Rio Muerto / 47%	-	-
MID- BODY N=768	Chen Chen / 66%	0.35 .55	0.21 .65
	Omo / 69%	-	0.73 .39

	Rio Muerto / 63%	-	-
LOWER BODY N=451	Chen Chen / 43%	**4.06** **.04**	0.23 .63
	Omo / 55%	-	0.81 .37
	Rio Muerto / 47%	-	-
FOOT N=645	Chen Chen / 54%	0.33 .57	0.00 .95
	Omo / 51%	-	0.24 .63
	Rio Muerto / 55%	-	-
MSM Use-Area	Site / Modeled %	Omo	Rio Muerto
40-49			
UPPER ARM N=523	Chen Chen / 50%	χ^2=0.03 p=.87	**108.58** **<.0001**
	Omo / 51%	-	**12.89** **.0003**
	Rio Muerto / 80%	-	-
FORE-ARM N=456	Chen Chen / 51%	2.64 .10	-[a]
	Omo / 35%	-	-[a]
	Rio Muerto / %	-	-
MID-BODY N=194	Chen Chen / 59%	1.71 .19	-[a]
	Omo / 52%	-	-[a]
	Rio Muerto / %	-	-
LOWER BODY N=100	Chen Chen / %		
	Omo / %	-	
	Rio Muerto / %	-	-
FOOT N=129	Chen Chen / 68%	1.94 .16	-[a]
	Omo / 52%	-	-[a]
	Rio Muerto / %	-	-
MSM Use-Area	Site / Modeled %	Omo	Rio Muerto
50+			
UPPER ARM N=364	Chen Chen / 54%	χ^2=0.0 p=.95	2.78 .10
	Omo / 55%	-	0.94 .33
	Rio Muerto / 67%	-	-
FORE-ARM N=280	Chen Chen / 53%	0.01 .94	1.14 .28
	Omo / 53%	-	0.44 .51
	Rio Muerto / 61%	-	-
MID-BODY N=114	Chen Chen / 66%	1.52 .22	0.44 .51
	Omo / 50%	-	2.87 .09
	Rio Muerto / 72%	-	-

LOWER BODY N=64	Chen Chen / 59%	1.72 .19	3.77 .052
	Omo / 33%	-	**6.27** **.01**
	Rio Muerto / 76%	-	-
FOOT N=90	Chen Chen / 52%	**9.28** **.002**	0.17 .68
	Omo / 29%	-	**32.21** **<.0001**
	Rio Muerto / 56%	-	-

Appendix C. Additional OA Data Tables

Table C.1 Tiwanaku Core vs. Colony <u>Right Side</u> OA Comparisons

OA	n=	Core Modeled % frequency	Colony Modeled % frequency	χ^2 value (df=1)	*p*-value
Glenoid Fossa	**166**	**43%**	**22%**	**4.29**	**.04**
Humerus Head	151	20%	20%	0.00	.96
SHOULDER	317	32%	21%	2.27	.13
Humerus Capitulum	207	43%	40%	0.09	.76
Humerus Trochlea	217	12%	11%	0.00	.97
Radius Head	199	15%	21%	.38	.54
Ulna Trochlear Notch	215	67%	52%	1.52	.22
Ulna Olecranon Process	200	38%	32%	0.19	.67
Ulna Coronoid Process	201	37%	38%	0.00	.95
Ulna Radial Notch	**211**	**35%**	**15%**	**4.77**	**.03**
ELBOW	1450	34%	30%	0.62	.43
Radius Ulnar Notch	180	28%	14%	3.10	.08
Radius Distal Articulation	176	44%	26%	3.14	.08
Ulna Distal Articulation	145	19%	15%	0.16	.09
WRIST	**501**	**32%**	**19%**	**4.12**	**.04**
Os Coxa Auricular Surface	181	50%	53%	0.06	.80
Sacrum Auricular Surface	**154**	**87%**	**33%**	**10.8**	**.001**
SACROILIAC	**335**	**65%**	**44%**	**4.43**	**.04**
Os Coxa Acetabulum	**184**	**41%**	**19%**	**4.34**	**.04**
Femur Head	191	8%	9%	0.02	.89
HIP	375	22%	14%	1.61	.20
Femur Medial Condyle	139	21%	27%	0.33	.57
Femur Lateral Condyle	145	26%	17%	0.92	.34
Patella Medial Facet	111	6%	27%	2.90	.08
Patella Lateral Facet	110	12%	26%	1.39	.24
Tibia Medial Condyle	159	16%	17%	0.02	.89
Tibia Lateral Condyle	156	21%	25%	0.13	.72
KNEE	820	17%	23%	0.91	.34
Tibia Distal Articulation	179	24%	12%	1.83	.18
Talus Superior Articulation	195	37%	20%	2.87	.09
Talus Medial Malleolar	179	25%	21%	0.16	.68
ANKLE	553	29%	17%	3.37	.07

Table C.2 Tiwanaku Core vs. Colony <u>Left Side</u> OA Comparisons

OA	n=	Core Modeled % frequency	Colony Modeled % frequency	χ^2 value (df=1)	*p*-value
Glenoid Fossa	174	21%	19%	0.03	.87
Humerus Head	134	15%	19%	0.22	.64
SHOULDER	308	18%	19%	0.04	.84
Humerus Capitulum	206	48%	36%	1.52	.22
Humerus Trochlea	210	29%	14%	3.67	.06
Radius Head	184	24%	21%	0.09	.76
Ulna Trochlear Notch	228	60%	50%	1.03	.31
Ulna Olecranon Process	201	24%	23%	0.01	.93
Ulna Coronoid Process	207	48%	35%	1.84	.18
Ulna Radial Notch	**221**	**37%**	**14%**	**8.13**	**.004**
ELBOW	**1457**	**40%**	**28%**	**4.28**	**.04**
Radius Ulnar Notch	175	5%	17%	1.72	.19
Radius Distal Articulation	173	48%	30%	2.41	.12
Ulna Distal Articulation	**153**	**32%**	**13%**	**4.55**	**.03**
WRIST	501	29%	21%	1.59	.21
Os Coxa Auricular Surface	194	58%	52%	0.34	.56
Sacrum Auricular Surface	**160**	**72%**	**33%**	**9.14**	**.003**
SACROILIAC	**354**	**64%**	**43%**	**5.03**	**.03**
Os Coxa Acetabulum	192	32%	24%	0.59	.44
Femur Head	192	13%	11%	0.05	.82
HIP	384	22%	18%	0.38	.54
Femur Medial Condyle	125	15%	20%	0.25	.62
Femur Lateral Condyle	141	25%	16%	1.11	.29
Patella Medial Facet	104	6%	24%	2.25	.13
Patella Lateral Facet	105	16%	25%	0.72	.40
Tibia Medial Condyle	154	10%	19%	1.11	.29
Tibia Lateral Condyle	152	24%	27%	0.07	.79
KNEE	781	16%	22%	0.85	.36
Tibia Distal Articulation	182	11%	8%	0.20	.66
Talus Superior Articulation	189	24%	20%	0.21	.64
Talus Medial Malleolar	178	12%	19%	0.55	.46
ANKLE	549	16%	15%	0.00	.96

Table C.3 OA Core vs. Colony Results during Tiwanaku Phase

OA	n=	Core Modeled % frequency	Colony Modeled % frequency	χ^2 value (df=1)	*p*-value
Glenoid Fossa	341	33%	20%	2.31	.13
Humerus Head	281	18%	20%	0.07	.78
SHOULDER	620	25%	20%	0.70	.40
Humerus Capitulum	413	46%	38%	0.92	.34
Humerus Trochlea	427	20%	13%	1.88	.17
Radius Head	383	19%	21%	0.05	.83
Ulna Trochlear Notch	443	63%	51%	2.09	.15
Ulna Olecranon Process	401	29%	28%	0.04	.84
Ulna Coronoid Process	408	44%	36%	0.84	.36
Ulna Radial Notch	**432**	**36%**	**15%**	**9.53**	**.002**
ELBOW	2907	37%	29%	3.10	.08
Radius Ulnar Notch	355	18%	16%	0.15	.70
Radius Distal Articulation	173	48%	30%	2.41	.12
Ulna Distal Articulation	**153**	**32%**	**13%**	**4.55**	**.03**
WRIST	501	29%	21%	1.59	.21
Os Coxa Auricular Surface	194	58%	52%	0.34	.56
Sacrum Auricular Surface	**160**	**72%**	**33%**	**9.14**	**.003**
SACROILIAC	**354**	**64%**	**43%**	**5.03**	**.03**
Os Coxa Acetabulum	192	32%	24%	0.59	.44
Femur Head	192	13%	11%	0.05	.82
HIP	384	22%	18%	0.38	.54
Femur Medial Condyle	125	15%	20%	0.25	.62
Femur Lateral Condyle	141	25%	16%	1.11	.29
Patella Medial Facet	104	6%	24%	2.25	.13
Patella Lateral Facet	105	16%	25%	0.72	.40
Tibia Medial Condyle	154	10%	19%	1.11	.29
Tibia Lateral Condyle	152	24%	27%	0.07	.79
KNEE	781	16%	22%	0.85	.36
Tibia Distal Articulation	182	11%	8%	0.20	.66
Talus Superior Articulation	189	24%	20%	0.21	.64
Talus Medial Malleolar	178	12%	19%	0.55	.46
ANKLE	549	16%	15%	0.00	.96

Table C.4 OA Inter-Highland Area Significant Results during the Tiwanaku Phase

OA	n=	Katari Modeled % frequency	Tiwanaku Modeled % frequency	χ^2 value (df=1)	*p*-value
Humerus Capitulum	**52**	**73%**	**35%**	**4.13**	**.04**
Radius Head	**48**	**40%**	**9%**	**4.57**	**.03**

Table C.5 OA Intra-Area Katari Valley GEE Chi-Square Results during the Tiwanaku Phase (df=1)

MSM Use-Area	Site / Modeled %	Lukurmata	Pokachi Kontu
SHOULDER n=31	Kirawi / %	-[a]	-[a]
	Lukurmata /15%	-	χ^2=1.34 *p*=.25
	Pokachi Kontu /33%	-	-
ELBOW n=93	Kirawi /14%	**8.65 .003**	**4.32 .04**
	Lukurmata /54%	-	0.75 .39
	Pokachi Kontu /40%	-	-
WRIST n=32	Kirawi / %	-[a]	-[a]
	Lukurmata /43%	-	-[a]
	Pokachi Kontu / %	-	-
SACROILIAC n=24	Kirawi / %	-[a]	-[a]
	Lukurmata / 70%	-	-[a]
	Pokachi Kontu / %	-	-
HIP n=28	Kirawi / %	-[a]	-[a]
	Lukurmata / 60%	-	-[a]
	Pokachi Kontu / %	-	-
KNEE n=88	Kirawi / %	-[a]	-[a]
	Lukurmata / 0%	-	-[a]
	Pokachi Kontu / %	-	-
ANKLE n=39	Kirawi / %	-[a]	-[a]
	Lukurmata / 29%	-	-[a]
	Pokachi Kontu / %	-	-

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table C.6 Intra-Core OA Results from <u>Late Formative</u> Phase to the <u>Tiwanaku</u> Phase

OA	n=	LF Modeled % frequency	TW Modeled % frequency	χ^2 value (df=1)	*p*-value
Glenoid Fossa	54	64%	33%	2.97	.08
Humerus Head	**55**	**57%**	**18%**	**4.88**	**.03**
SHOULDER	**109**	**61%**	**25%**	**7.30**	**.007**
Humerus Capitulum	66	57%	46%	0.58	.45
Humerus Trochlea	66	8%	20%	1.00	.32
Radius Head	61	8%	19%	0.82	.36
Ulna Trochlear Notch	67	87%	63%	2.54	.11
Ulna Olecranon Process	54	50%	29%	1.78	.18
Ulna Coronoid Process	62	46%	44%	0.02	.89
Ulna Radial Notch	67	56%	36%	1.80	.18
ELBOW	443	46%	36%	1.49	.22
Radius Ulnar Notch	65	30%	18%	0.96	.33
Radius Distal Articulation	61	53%	46%	0.19	.67
Ulna Distal Articulation	51	54%	26%	2.16	.14
WRIST	177	44%	30%	1.28	.26
Os Coxa Auricular Surface	61	50%	54%	0.05	.82
Sacrum Auricular Surface	39	33%	79%	3.49	.06
SACROILIAC	100	44%	64%	1.55	.21
Os Coxa Acetabulum	49	38%	36%	0.00	.95
Femur Head	60	8%	11%	0.05	.82
HIP	109	20%	22%	0.02	.89
Femur Medial Condyle	47	14%	18%	0.05	.82
Femur Lateral Condyle	56	25%	26%	0.00	.97
Patella Medial Facet	51	13%	6%	0.59	.44
Patella Lateral Facet	**54**	**44%**	**14%**	**4.60**	**.03**
Tibia Medial Condyle	58	29%	13%	2.06	.15
Tibia Lateral Condyle	55	21%	23%	0.00	.95
KNEE	321	26%	17%	1.57	.21
Tibia Distal Articulation	56	29%	17%	.93	.33
Talus Superior Articulation	60	24%	30%	0.21	.65
Talus Medial Malleolar	52	25%	18%	0.30	.58
ANKLE	168	26%	22%	0.15	.70

Table C.7 Intra-Core OA Results from Tiwanaku Phase to Post-Tiwanaku Phase

OA	n=	TW Modeled % frequency	PT Modeled % frequency	χ^2 value (df=1)	*p*-value
Glenoid Fossa	51	33%	40%	0.16	.69
Humerus Head	46	18%	-	-	-[a]
SHOULDER	97	25%	25%	0.00	1.0
Humerus Capitulum	60	46%	38%	0.16	.69
Humerus Trochlea	62	20%	25%	0.07	.79
Radius Head	55	19%	33%	0.53	.47
Ulna Trochlear Notch	61	63%	67%	0.05	.82
Ulna Olecranon Process	50	29%	25%	0.05	.82
Ulna Coronoid Process	58	44%	11%	3.23	.07
Ulna Radial Notch	61	36%	20%	0.97	.33
ELBOW	407	36%	31%	0.28	.60
Radius Ulnar Notch	56	18%	-	-	-[a]
Radius Distal Articulation	57	46%	40%	0.08	.78
Ulna Distal Articulation	48	26%	38%	0.29	.59
WRIST	161	30%	25%	0.28	.60
Os Coxa Auricular Surface	56	54%	14%	3.65	.06
Sacrum Auricular Surface	**38**	**79%**	**20%**	**4.10**	**.04**
SACROILIAC	**94**	**64%**	**17%**	**7.95**	**.005**
Os Coxa Acetabulum	47	36%	-	-	-[a]
Femur Head	54	11%	-	-	-[a]
HIP	101	22%	-	-	-[a]
Femur Medial Condyle	44	18%	60%	2.15	.14
Femur Lateral Condyle	49	26%	33%	0.12	.73
Patella Medial Facet	42	6%	29%	1.83	.18
Patella Lateral Facet	43	14%	50%	3.67	.06
Tibia Medial Condyle	49	13%	29%	1.33	.25
Tibia Lateral Condyle	48	23%	-	-	-[a]
KNEE	275	17%	32%	2.23	.13
Tibia Distal Articulation	44	17%	14%	0.03	.87
Talus Superior Articulation	47	30%	14%	0.64	.43
Talus Medial Malleolar	42	18%	38%	1.04	.31
ANKLE	133	22%	23%	0.00	.95

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table C.8 Intra-Colony OA Results from Tiwanaku Phase to Post-Tiwanaku Phase

OA	n=	TW Modeled % frequency	PT Modeled % frequency	χ^2 value (df=1)	*p*-value
Glenoid Fossa	309	20%	38%	0.99	.32
Humerus Head	248	-	-	-	-[a]
SHOULDER	557	20%	27%	0.27	.60
Humerus Capitulum	370	-	-	-	-[a]
Humerus Trochlea	382	-	-	-	-[a]
Radius Head	339	-	-	-	-[a]
Ulna Trochlear Notch	398	51%	43	0.26	.61
Ulna Olecranon Process	366	-	-	-	-[a]
Ulna Coronoid Process	363	36%	50	0.21	.65
Ulna Radial Notch	386	-	-	-	-[a]
ELBOW	**2604**	**29%**	**11%**	**6.48**	**.01**
Radius Ulnar Notch	317	-	-	-	-[a]
Radius Distal Articulation	310	28%	29%	0.00	.99
Ulna Distal Articulation	262	-	-	-	-[a]
WRIST	889	20%	13%	0.89	.34
Os Coxa Auricular Surface	331	-	-	-	-[a]
Sacrum Auricular Surface	286	-	-	-	-[a]
SACROILIAC	617	-	-	-	-[a]
Os Coxa Acetabulum	340	22%	25%	0.05	.82
Femur Head	342	-	-	-	-[a]
HIP	682	16%	10%	0.29	.59
Femur Medial Condyle	231	24%	17%	0.22	.64
Femur Lateral Condyle	248	-	-	-	-[a]
Patella Medial Facet	188	26%	13%	0.82	.37
Patella Lateral Facet	187	25%	12%	0.78	.38
Tibia Medial Condyle	278	-	-	-	-[a]
Tibia Lateral Condyle	273	-	-	-	-[a]
KNEE	1405	22%	8%	3.08	.08
Tibia Distal Articulation	337	-	-	-	-[a]
Talus Superior Articulation	353	-	-	-	-[a]
Talus Medial Malleolar	336	-	-	-	-[a]
ANKLE	1026	-	-	-	-[a]

Table C.9 OA Core vs. Colony Results during Tiwanaku Phase for FEMALES

OA	n=	Core Modeled % frequency	Colony Modeled % frequency	χ^2 value (df=1)	*p*-value
Glenoid Fossa	179	30%	21%	0.63	.43
Humerus Head	149	10%	22%	1.71	.19
SHOULDER	328	20%	22%	0.08	.78
Humerus Capitulum	217	41%	42%	0.00	.95
Humerus Trochlea	227	13%	12%	0.04	.85
Radius Head	200	7%	20%	1.36	.24
Ulna Trochlear Notch	224	65%	49%	1.11	.29
Ulna Olecranon Process	209	23%	26%	0.04	.84
Ulna Coronoid Process	212	50%	37%	0.85	.36
Ulna Radial Notch	223	22%	13%	1.18	.28
ELBOW	1512	32%	28%	0.41	.52
Radius Ulnar Notch	189	16%	15%	0.00	.96
Radius Distal Articulation	181	29%	30%	0.00	.97
Ulna Distal Articulation	166	33%	13%	3.41	.06
WRIST	536	25%	19%	0.60	.44
Os Coxa Auricular Surface	216	73%	61%	1.13	.29
Sacrum Auricular Surface	**179**	**92%**	**35%**	**8.29**	**.004**
SACROILIAC	**395**	**80%**	**49%**	**8.66**	**.003**
Os Coxa Acetabulum	210	41%	24%	1.69	.19
Femur Head	206	-	-	-	-[a]
HIP	416	19%	17%	0.09	.77
Femur Medial Condyle	130	7%	18%	1.06	.30
Femur Lateral Condyle	140	20%	13%	0.35	.55
Patella Medial Facet	98	6%	25%	2.50	.11
Patella Lateral Facet	99	5%	29%	3.34	.07
Tibia Medial Condyle	155	13%	18%	0.20	.66
Tibia Lateral Condyle	153	20%	24%	0.12	.73
KNEE	775	11%	20%	1.86	.17
Tibia Distal Articulation	181	6%	9%	0.14	.71
Talus Superior Articulation	203	22%	17%	0.26	.61
Talus Medial Malleolar	179	13%	17%	0.18	.67
ANKLE	563	14%	14%	0.01	.93

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table C.10 OA Core vs. Colony Results during Tiwanaku Phase for MALES

OA	n=	Core Modeled % frequency	Colony Modeled % frequency	χ^2 value (df=1)	*p*-value
Glenoid Fossa	126	38%	20%	1.75	.19
Humerus Head	95	40%	18%	2.31	.13
SHOULDER	221	38%	19%	2.73	.10
Humerus Capitulum	**149**	**67%**	**36%**	**4.67**	**.03**
Humerus Trochlea	**150**	**38%**	**15%**	**4.33**	**.04**
Radius Head	133	35%	25%	0.81	.37
Ulna Trochlear Notch	154	73%	53%	2.82	.09
Ulna Olecranon Process	136	33%	34%	0.00	.96
Ulna Coronoid Process	139	47%	38%	0.60	.44
Ulna Radial Notch	**145**	**50%**	**20%**	**5.22**	**.02**
ELBOW	**1006**	**49%**	**32%**	**4.77**	**.03**
Radius Ulnar Notch	115	25%	19%	0.28	.59
Radius Distal Articulation	**115**	**65%**	**29%**	**7.38**	**.007**
Ulna Distal Articulation	98	25%	15%	0.91	.34
WRIST	328	39%	21%	3.71	.054
Os Coxa Auricular Surface	144	42%	38%	0.07	.80
Sacrum Auricular Surface	**117**	**65%**	**30%**	**4.41**	**.04**
SACROILIAC	261	51%	35%	1.79	.18
Os Coxa Acetabulum	152	35%	17%	2.01	.16
Femur Head	134	22%	10%	1.61	.20
HIP	286	29%	14%	2.36	.12
Femur Medial Condyle	97	27%	32%	0.14	.70
Femur Lateral Condyle	106	35%	22%	0.78	.38
Patella Medial Facet	91	8%	23%	1.31	.25
Patella Lateral Facet	91	15%	19%	0.11	.74
Tibia Medial Condyle	115	19%	14%	0.23	.63
Tibia Lateral Condyle	112	38%	26%	0.71	.40
KNEE	612	25%	23%	0.08	.77
Tibia Distal Articulation	133	19%	9%	0.88	.35
Talus Superior Articulation	134	40%	22%	2.22	.14
Talus Medial Malleolar	131	14%	21%	0.39	.53
ANKLE	398	24%	18%	0.76	.38

Table C.11 OA Core vs. Colony Results during Tiwanaku Phase by AGE-AT-DEATH

OA	N=	Core Modeled % frequency	Colony Modeled % frequency	χ^2 value (df=1)	p-value
15-19 years					
SHOULDER	65	-	-	-	-[a]
ELBOW	273	13%	10%	0.11	.74
WRIST	72	-	-	-	-[a]
SACROILIAC	58	-	-	-	-[a]
HIP	**68**	**33%**	**3%**	**5.38**	**.02**
KNEE	170	4%	10%	0.85	.36
ANKLE	103	18%	7%	1.27	.26
20-29 years					
SHOULDER	180	7%	16%	1.70	.19
ELBOW	844	21%	22%	0.01	.92
WRIST	289	12%	10%	0.06	.80
SACROILIAC	200	44%	34%	0.45	.50
HIP	227	9%	10%	0.02	.89
KNEE	494	8%	19%	1.76	.18
ANKLE	300	19%	11%	0.54	.46
30-39 years					
SHOULDER	258	37%	25%	1.98	.16
ELBOW	1161	45%	33%	3.12	.08
WRIST	421	30%	19%	1.89	.17
SACROILIAC	289	56%	55%	0.00	.98
HIP	308	19%	23%	0.23	.63
KNEE	637	24%	24%	0.00	.95
ANKLE	487	23%	21%	0.06	.81
40-49 years					
SHOULDER	**69**	**60%**	**20%**	**4.78**	**.03**
ELBOW	375	59%	36%	3.61	.06
WRIST	128	58%	39%	2.06	.15
SACROILIAC	**88**	**89%**	**38%**	**10.39**	**.001**
HIP	**97**	**47%**	**15%**	**4.67**	**.03**
KNEE	148	37%	36%	0.00	.98
ANKLE	111	27%	13%	1.98	.16
50+ years					

SHOULDER	48	67%	29%	3.45	.06
ELBOW	197	60%	46%	0.54	.46
WRIST	**74**	**75%**	**41%**	**5.90**	**.02**
SACROILIAC	50	-	-	-	-[a]
HIP	49	-	-	-	-[a]
KNEE	114	-	-	-	-[a]
ANKLE	68	33%	26%	0.99	.32

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table C.12 Inter-Highland Area OA Results during the Tiwanaku Phase for FEMALES

OA	n=	Katari Valley Modeled % frequency	Tiwanaku Valley Modeled % frequency	χ^2 value (df=1)	*p*-value
SHOULDER	40	18%	22%	0.13	.72
ELBOW	126	31%	32%	0.01	.93
WRIST	51	35%	21%	0.91	.34
SACROILIAC	35	85%	77%	0.27	.61
HIP	37	13%	24%	0.79	.37
KNEE	96	23%	6%	2.79	.10
ANKLE	51	10%	16%	0.25	.62

Table C.13 OA Inter-Highland Area Results during Tiwanaku Phase by AGE-AT-DEATH (no results for 15-19 or 50+)

JOINT AREA	N=	Katari Valley Modeled % frequency	Tiwanaku Valley Modeled % frequency	χ^2 value (df=1)	p-value
20-29 years					
ELBOW	120	32%	16%	1.39	.24
WRIST	43	14%	10%	0.18	.67
SACROILIAC	27	63%	37%	0.66	.42
HIP	32	10%	9%	0.01	.94
KNEE	**85**	**18%**	**2%**	**5.38**	**.02**
ANKLE	36	6%	30%	2.17	.14
30-39 years					

SHOULDER	19	33%	40%	.16	.69
ELBOW	**107**	**69%**	**35%**	**8.25**	**.004**
WRIST	40	50%	21%	3.57	.06
SACROILIAC	27	58%	53%	0.08	.78
HIP	32	31%	11%	1.57	.21
KNEE	83	35%	17%	1.69	.19
ANKLE	48	26%	21%	0.13	.71
40-49 years					
SHOULDER	15	33%	67%	3.07	.08
ELBOW	75	-	-	-	-
WRIST	33	-	-	-	-
SACROILIAC	19	-	-	-	-
HIP	15	-	-	-	-
KNEE	30	45%	32%	1.40	.24
ANKLE	11	-	-	-	-

Table C.14 OA Intra-Area Katari Valley GEE Chi-Square Results during the Tiwanaku Phase (df=1) for FEMALES and MALES

	FEMALES			**MALES**		
OA Use-Area	Site / Modeled %	Lukurmata	Pokachi Kontu	Site / Modeled %	Lukurmata	Pokachi Kontu
SHOULDER N=17 **F** N=9 **M**	Kirawi / %	-[a]	-[a]	Kirawi /%	-[a]	-[a]
	Lukurmata /15%	-	**χ^2=6.01 p=.01**	Lukurmata /%	-	-[a]
	Pokachi Kontu /50%	-	-	Pokachi Kontu /%	-	-
ELBOW N=45 **F** N=43 **M**	Kirawi /%	-[a]	2.52 .11	Kirawi /20%	**21.59 <.0001**	-[a]
	Lukurmata /31%	-	-[a]	Lukurmata /84%	-	-[a]
	Pokachi Kontu /50%	-	-	Pokachi Kontu /%	-	-
WRIST N=17 **F** N=13 **M**	Kirawi /%	-[a]	-[a]	Kirawi /%	-[a]	-[a]
	Lukurmata /35%	-	-[a]	Lukurmata /54%	-	-[a]
	Pokachi Kontu /%	-	-	Pokachi Kontu /%	-	-
SACROILIAC N=13 **F** N=11 **M**	Kirawi /%	-[a]	-[a]	Kirawi /%	-[a]	-[a]
	Lukurmata /92%	-	-[a]	Lukurmata /45%	-	-[a]
	Pokachi Kontu /%	-	-	Pokachi Kontu /%	-	-
HIP N=16 **F**	Kirawi /%	-[a]	-[a]	Kirawi /%	-[a]	-[a]
	Lukurmata /%	-	-[a]	Lukurmata	-	-[a]

N=10 **M**				/60%		
	Pokachi Kontu /%	-	-	Pokachi Kontu /%	-	-
KNEE N=31 **F** N=39 **M**	Kirawi /%	-	-[a]	Kirawi /%	-	-[a]
	Lukurmata /%	-	-[a]	Lukurmata /%	-	-[a]
	Pokachi Kontu /%	-	-	Pokachi Kontu /%	-	-
ANKLE N=20 **F** N=17 **M**	Kirawi /%	-[a]	-[a]	Kirawi /%	-[a]	-[a]
	Lukurmata /13%	-	-[a]	Lukurmata /29%	-	-[a]
	Pokachi Kontu /%	-	-	Pokachi Kontu /%	-	-

[a]The generalized Hessian matrix is not positive definite and would not converge. No calculation could be obtained in GEE for this sample.

Table C.15 OA Intra-Area Moquegua Valley GEE Chi-Square Results during the Tiwanaku Phase (df=1) for AGE-AT-DEATH

MSM Use-Area	Site / Modeled %	Omo	Rio Muerto
15-19 years			
ELBOW n=242	Chen Chen / 6%	0.94 .33	0.33 .56
	Omo / 13%	-	0.40 .53
	Rio Muerto / 10%	-	-
KNEE n=144	Chen Chen / 6%	0.75 .39	1.17 .28
	Omo / 2%	-	3.26 .07
	Rio Muerto / 20%	-	-
ANKLE n=92	Chen Chen / 7%	0.05 .83	0.01 .93
	Omo / 6%	-	0.02 .88
	Rio Muerto / 7%	-	-
20-29 years			
SHOULDER n=150	Chen Chen / 11%	0.77 .38	**5.86** **.02**
	Omo / 5%	-	**4.99** **.03**
	Rio Muerto / 41%	-	-
ELBOW n=724	Chen Chen / 17%	0.46 .50	**7.09** **.008**
	Omo / 20%	-	**4.62** **.03**
	Rio Muerto / 40%	-	-
WRIST n=246	Chen Chen / 8%	0.12 .73	0.54 .46
	Omo / 11%	-	0.10

			.75
	Rio Muerto / 15%	-	-
SACRO-ILIAC n=173	Chen Chen / 22%	2.98 .08	**13.56** **.0002**
	Omo / 40%	-	**3.87** **.049**
	Rio Muerto / 69%	-	-
HIP n=195	Chen Chen / 5%	**4.49** **.03**	**4.27** **.04**
	Omo / 19%	-	0.04 .84
	Rio Muerto / 22%	-	-
KNEE n=409	Chen Chen / 18%	1.13 .29	0.94 .33
	Omo / 7%	-	2.34 .12
	Rio Muerto / 31%	-	-
ANKLE n=264	Chen Chen / 7%	3.57 .06	2.30 .13
	Omo / 22%	-	0.00 .99
	Rio Muerto / 22%	-	-
30-39 years			
SHOULDER n=239	Chen Chen / 16%	**6.77** **.009**	**6.97** **.008**
	Omo / 37%	-	0.09 .76
	Rio Muerto / 41%	-	-
ELBOW n=1054	Chen Chen / 26%	**13.72** **.0002**	**8.98** **.003**
	Omo / 47%	-	0.01 .93
	Rio Muerto / 48%	-	-
WRIST n=381	Chen Chen / 15%	**4.67** **.03**	0.02 .89
	Omo / 32%	-	**3.88** **.049**
	Rio Muerto / 14%	-	-
SACRO-ILIAC n=262	Chen Chen / 46%	**6.77** **.009**	**8.14** **.004**
	Omo / 74%	-	0.04 .84
	Rio Muerto / 76%	-	-
HIP n=276	Chen Chen / 16%	**9.10** **.003**	3.60 .06
	Omo / 39%	-	0.22 .64
	Rio Muerto / 33%	-	-
KNEE n=554	Chen Chen / 20%	3.56 .06	0.03 .86
	Omo / 33%	-	1.30 .25
	Rio Muerto / 22%	-	-

ANKLE n=439	Chen Chen / 15%	**16.38 <.0001**	0.33 .57
	Omo / 38%	-	3.22 .07
	Rio Muerto / 19%	-	-
40-49 years			
ELBOW n=300	Chen Chen / 35%	0.40 .53	-
	Omo / 45%	-	-
	Rio Muerto / %	-	-
WRIST n=95	Chen Chen / 41%	0.76 .38	-
	Omo / 29%	-	-
	Rio Muerto / %	-	-
SACRO- ILIAC n=69	Chen Chen / 39%	0.04 .85	-
	Omo / 33%	-	-
	Rio Muerto / %	-	-
HIP n=82	Chen Chen / 13%	0.45 .50	-
	Omo / 21%	-	-
	Rio Muerto / %	-	-
ANKLE n=100	Chen Chen / 12%	0.31 .58	-
	Omo / 17%	-	-
	Rio Muerto / %	-	-
50-59 years			
SHOULDER n=45	Chen Chen / 23%	0.27 .60	1.12 .29
	Omo / 14%	-	1.81 .18
	Rio Muerto / 50%	-	-
ELBOW n=187	Chen Chen / 41%	0.03 .87	1.71 .19
	Omo / 37%	-	1.06 .30
	Rio Muerto / 68%	-	-
WRIST n=70	Chen Chen / 27%	0.25 .62	**12.79 .0003**
	Omo / 43%	-	1.04 .31
	Rio Muerto / 78%	-	-
SACRO- ILIAC n=46	Chen Chen / 61%	1.67 .20	**4.71 .03**
	Omo / 50%	-	3.04 .08
	Rio Muerto / 30%	-	-
ANKLE n=65	Chen Chen / 20%	**27.93 <.0001**	0.18 .67
	Omo / 67%	-	**5.48 .02**
	Rio Muerto / 27%	-	-

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