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Kevin Vaughn

Richard Sutter

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DENTAL FLUCTUATING ASYMMETRY AS A MEASURE OF ENVIRONMENTAL STRESS IN NASCA

A Thesis

Submitted to the Faculty

of

Purdue University

by

Shawna L. Follis

In Partial Fulfillment of the

Requirements for the Degree

of

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In memory of Brenda Follis

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ABSTRACT

Follis, Shawna L. M.S., Purdue University, August 2014. Dental Fluctuating Asymmetry as a Measure of Environmental Stress in Nasca. Major Professor: Kevin Vaughn.

This thesis evaluates how environmental stressors affected three groups (Nasca, Loro, and Chakipampa) that lived in Nasca during the Early Intermediate Period (ca. A.D. 1-750) and the Middle Horizon (ca. A.D. 750-1000). Using fluctuating asymmetry analysis as a proxy for developmental instability, biological evidence is assessed for differential stress levels incurred by groups occupying the Peruvian south coast. This study found high levels of stress in the Middle Horizon, supporting the hypothesis that populations living in Nasca were unfavorably affected by Wari colonizers. However, stress was found to be highest among the Chakipampa. This is attributed to Wari imperialistic occupation and extraction of resources. Conversely, the contemporaneous Loro affiliated population, who presumably avoided Wari influence, experienced the lowest levels of stress among the samples. This research reveals a large distinction between the effects of environmental stressors on the two Middle Horizon groups.

CHAPTER 1. INTRODUCTION

1.1 Introduction

The Nasca culture (ca. A.D. 1-750) and later Loro and Chakipampa affiliated groups (ca. A.D. 750-1000) occupied one the driest places on earth, the Atacama Desert along the Western foothills of the Andes Mountains. Archaeological investigations of these cultures have explored topics such as the Nasca Lines (Aveni 2000; Isla Cuadrado and Reindel 2005), trophy heads (Forgey 2006; Verano 1995), below ground aqueducts referred to as puquios, (Schrieber and Lancho Rojas 2003), and the large ceremonial center, Cahuachi (Orefici 2012; Silverman 2002). Many of these topics closely relate to the overarching question of rapid sociopolitical and cultural change that occurred towards the end of the Early Intermediate Period. Material culture provides a timeline of these changes, but it is only through osteological analysis that the human impact of environmental and social change can be directly assessed.

Bioarchaeological research elucidates the complex relationship between biology, culture, and the environment in past societies through evidence collected from human remains and is interpreted alongside contextual information from archaeological research. The biocultural perspective provides a framework for evaluating the biological consequences of multiple interacting cultural and biological stressors that affected Nasca inhabitants through time (Goodman et al. 1988). Fluctuating asymmetry, defined by "the inability of organisms to develop in precisely determined paths" on both sides of the body (Van Valen 1962:126), is particularly helpful in biocultural studies because it is a bioindicator of environmental stress in populations (Palmer and Strobeck 1986).

This study aims to gain insight into the human condition among individuals that lived in Nasca from the Early Intermediate Period (ca. A.D. 1 – 750) and the Middle Horizon (ca. A.D. 750 – 1000) through the analysis of human phenotypic dental trait data. Specifically, stress incurred through childhood was assessed through the analysis of fluctuating asymmetry. Results of this analysis are interpreted in terms of archaeological data in order to determine environmental stressors that negatively affected societies through time.

1.2 Problem Statement

The purpose of this thesis is to provide insight into how populations experienced stress in Nasca through the Early Intermediate Period and the Middle Horizon. The dental trait data come from human remains held at the Museo Nacional de Arqueologia, Anthropologia y Historia del Peru in Lima, Peru. They were collected by Peruvian archaeologist Julio C. Tello during his 1927 field expedition in the Rio Grande de Nasca Drainage area. An analysis of fluctuating asymmetry evaluates the stressors theorized to have affected Nasca populations.

As environmental conditions degraded over time and influence from the neighboring Wari society brought on drastically changing sociopolitical circumstances in the Middle Horizon, I hypothesize that levels of stress in Nasca populations increased over time from the Early Intermediate Period to the Middle Horizon; and the Middle Horizon individuals who maintained a close relationship to Wari imperialists, Chakipampa style burials, experienced higher levels of stress compared to Middle Horizon individuals that avoided the Wari, Loro style burials. I expect that this will be represented as increased phenotypic dental trait variation in right/left antimeres over time, reaching its highest level among Chakipampa individuals.

1.3 Thesis Overview

The thesis begins by describing the necessary contextual background. Chapter two gives an overview of the Nasca location and environment, followed by a detailed description of the archaeological context including the human cultural history of the region. Chapter three outlines the research approach used in this study to evaluate stress in Nasca populations. The biocultural perspective is used to interpret human adaptation, measured through fluctuating asymmetry analysis, to stressors in Nasca outlined in the previous chapter.

The next section of this thesis focuses on the current study of fluctuating asymmetry in Nasca. Chapter four describes the sample of human dentition analyzed for this study and the methodology used to assess levels of fluctuating asymmetry in the samples. Chapter five synthesizes the results of this study with prior archaeological and osteological research. This chapter concludes the thesis by summarizing how Nasca culture groups adapted to environmental stressors.

CHAPTER 2. NASCA: ENVIRONMENT AND CULTURE

This chapter reviews the location, environmental background, and culture history of the Nasca region during the Early Intermediate Period through the Middle Horizon. The history of each time period is described, including Nasca and Middle Horizon culture groups. Prior archaeological research has uncovered environmental stressors that occurred within the two time periods. These stressors are described and evaluated.

2.1 Regional Background

The central Andean environment is considered one of the most diverse in the world encompassing the Amazon Rainforest, the Andes Mountain Range, and the Atacama Desert. Despite environmental challenges, humans have culturally and biologically adapted to each of these extreme environments, and the Nasca culture is no exception.

Archaeological remains from the Nasca culture appear in a large area along the south coastal area of Peru. Archaeologists define the limits of the south coast culture area by the modern day Department of Ica, including the valleys of Ica and the Acari (Silverman and Proulx 2002). This region is uniquely situated along the western outskirts of the Andes Mountains with the Pacific coast to the east. It spans from the Pisco Valley in the north to the Acari Valley in the south.

However, the heart of the Nasca civilization was located at the Rio Grande de Nasca drainage area in the modern-day Peruvian province of Nasca. This research analyzes samples from the Southern Nasca Region (SNR) and the Central Nasca Region (CNR). However, the vast majority (92%) of samples were excavated from cemeteries located in the SNR. This region is composed of four river valleys, displayed in Figure 2.1 below: Aja, Tierras Blancas, Taruga, and Las Trancas.

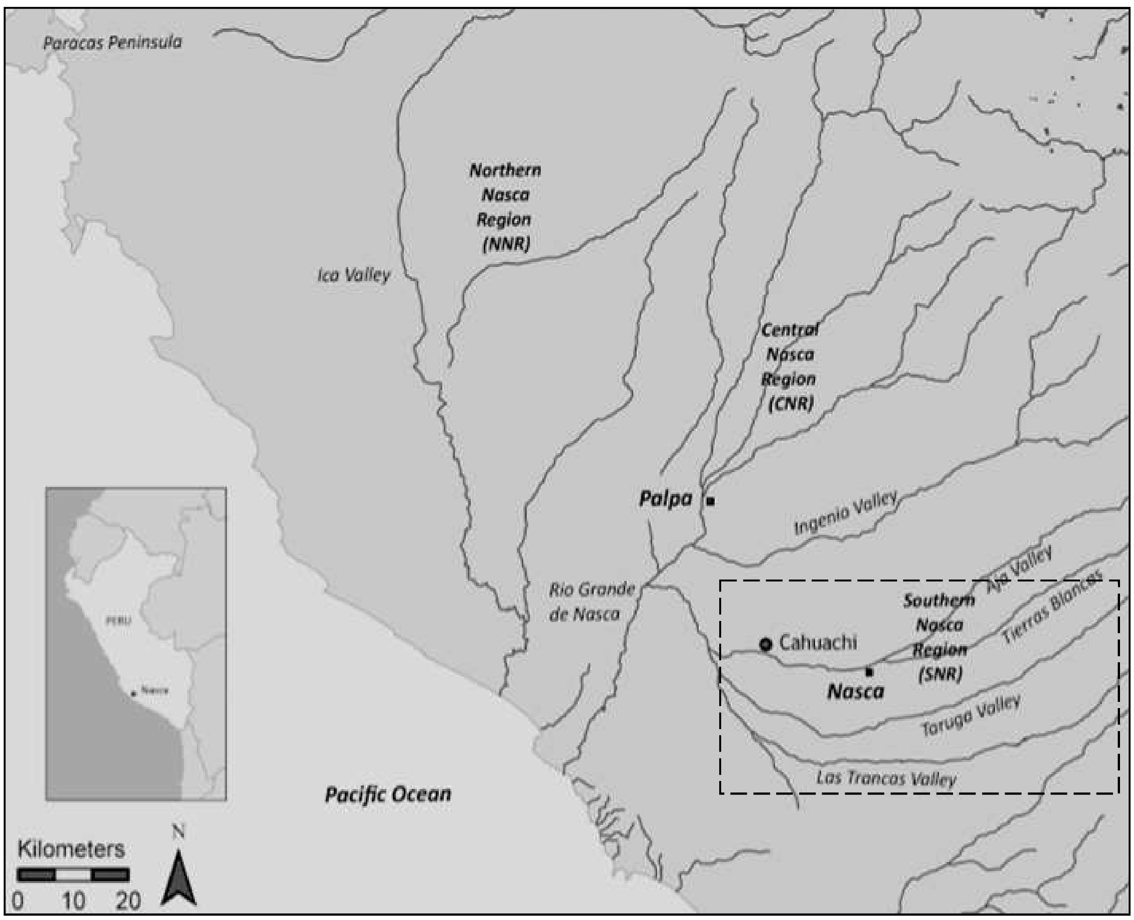

Figure 2.1 Map of the south coast of Peru. The box delimits the SNR. Adapted from a map drawn by Stefanie Bautista.

2.2 Environmental Background

The Atacama Desert subsumes the region and defines the climate. The Oficina Nacional de Evaluación de Recursos Naturales (ONERN) refers to this area as a pre-mountain desert formation with an average rainfall of 20 millimeters per year, causing an extremely arid environment (ONERN 1971:42). While rivers run from the Andes Mountains westward to the Pacific Ocean, they become sub-surface rivers flowing beneath the middle valley of Nasca. Few rivers stream the surface of the middle valley, and those that do become near dry during winter months (Beresford-Jones 2011). Water for sustaining agriculture is lacking in the middle valley with the exception of years experiencing El Niño effects (Schreiber and Lancho Rojas 2003). Following this trend, the Nasca River reemerges at the ceremonial site of Cahuachi. According to Schreiber and Lancho Rojas (2003), the Nasca regarded the location of Cahuachi as sacred due to the abundance of surface water, a rarity in region.

Recognized as one of the driest places on Earth, sporadic El Niño Southern Oscillation (ENSO) weather events interrupt the chronic aridity of the Atacama Desert. This highly variable climatic phenomenon causes unusually harsh environmental conditions as it disrupts weather patterns. Damaging river valley flooding resulting from shifting ocean current bring patterns unusually large amounts of rainfall (Shimada et al. 1991). El Niño events caused both physical and mental stress to Nasca inhabitants as agricultural productivity slowed or halted due to water damage. Despite highly variable weather patterns and extreme aridity, the human population in the Nasca region adapted and thrived in the environment.

2.3 Human Prehistory in Nasca

The present day province of Nasca shares its name with the human society that occupied the south coast area in the Early Intermediate Period (ca. A.D. 1-750), though they are not the only human group to live in the region. The region was first inhabited during the Paleoindian Period (Table 2.1) and continues to be home to many modern populations today. This research evaluates populations living in the Nasca region in the Early Intermediate Period and the Middle Horizon time periods (Table 2.1).

Table 2.1 Chronology for the South Coast of Peru

Andean Sequence	Nasca Cultures	Approximate Dates
Late Horizon	Inca	A.D. 1476 – 1532
Late Intermediate Period	Tiza	A.D. 1000 – 1476
Middle Horizon	Loro/Wari	A.D. 750 – 1000
Early Intermediate Period	Late Nasca	A.D. 550 – 750
	Middle Nasca	A.D. 450 – 550
	Early Nasca	A.D. 1 – 450
Early Horizon	Proto Nasca	100 B.C. – A.D. 1
	Paracas	800 – 100 B.C.
Initial Period		1800 – 800 B.C.
Preceramic/Archaic Period		10000 – 1800 B.C.
Paleoindian Period		+10000 B.C.

The Andean time sequence, depicted in Table 2.1 above, begins during the Paleoindian Period, dating from the first inhabitants of the region until 10,000 B.C. However, no evidence for human life in the Nasca region has been found to date from this time period. Evidence for the first human occupation of the Andean cultural area occurs in the Archaic Period (ca. 10000 – 1800 B.C.) (Carmichael 1991). Radiocarbon dates from a burial at Pernil Alto present the oldest traces of life in Palpa between 3800 and 3380 cal B.C. (Reindel 2009). Dating to ca. 2500 B.C., La Esmeralda is considered the oldest site in Nasca. This cemetery site was found at the Cahuachi complex, which is primarily considered an Early Intermediate Period site (Isla Cuadrado 1990). Overall, little evidence for human societies has been found until the Initial Period (ca. 1800-800 B.C.) in which archaeological remains of settlements begin to increase in number and complexity. Marcus Reindel (2009:439) attributes the surge of immigrants to favorable climatic conditions beginning in the Initial Period. This trend continues into the Early Horizon and lasting until the Early Intermediate Period (ca. 800 - 100 B.C.).

The Paracas culture occupied Nasca during the Early Horizon, bringing a growth in human population and the amount of permanent settlements. This society largely occupied locations in the Grande valley and the Ica valley to the north of the Nasca region. Nasca scholars consider them to be the ancestral culture of the Nasca (Proulx 2008). The transition between Paracas and the subsequent Nasca culture is complex. Archaeologically, this new culture is characterized by a major shift in ceramic technology from post-fire resin painting in Paracas pottery to pre-fire slip painting in Nasca and a shift from artistic decoration of textiles to ceramics (Menzel 1971). As for the human population, the Nasca largely descend from the Paracas people and occupied many of the same sites, such as La Puntilla, a SNR site occupied during the Paracas - Proto Nasca transition (Van Gijseghem 2006).

Another major shift in transition from Paracas to Nasca is regional importance the monumental site, Cahuachi as a ceremonial and pilgrimage center (Silverman and Proulx 2002). The distribution of Cahuachi ceramics during ceremony and pilgrimage at the site began during the proto-Nasca phase, Nasca 1 (100 B.C. - A.D. 1). Cahuachi experienced an increase in both religious activities and construction throughout the beginning of the Early Intermediate Period (A.D. 1 – 750; Vaughn and Van Gijseghem 2007). This period continued with vast transitions in settlement patterns, from small settlements near rivers to large settlements in the middle valleys. Degrading ecological conditions, technological innovations, foreign influence, and rapidly changing sociopolitical complexity characterize this period.

2.4 Nasca Cultural History

2.4.1 Early Nasca

Early Nasca (A.D. 1-450) settlement patterns suggest that they were a confederation of small polities, loosely allied through shared religion and ritual. Elites held power as leaders of the religion, dispersing materialized ideology in the form of polychrome ceramics from the ceremonial and pilgrimage center, Cahuachi (Vaughn et al. 2006). The small and scattered polities were relatively self-sufficient (Vaughn 2009). Settlements were located at the Andean foothills in the upper, less arid portions of the valleys and the lower valley near reliable sources of river water. Water in these rivers was plentiful and supported the population (Eitel et al. 2005). Schreiber and Lancho Rojas (1995) refer to the beginning of the Early Intermediate Period as having comparatively favorable living conditions.

Ceramic iconography is characterized as naturalistic and realistic design themes such as birds and fruit. Trophy heads are depicted in conjunction with mythical beings (Proulx 1994). Polychrome ceramics originating from Cahuachi are found at Early Nasca settlements suggesting the polities were joined through a common religious ideology centered at Cahuachi. Cahuachi served as both a ceremonial center and a pilgrimage center. Kantner and Vaughn (2012) used the costly signal model to describe the relationship between the Nasca cult and Cahuachi through an analysis of social prestige acquired through pilgrimage. In this model, Nasca people from various sites would make the pilgrimage to Cahuachi as a demonstration of the pilgrim's dedication to the religious ideology. Materialized ideology in the form of ceramics featuring iconography was taken from Cahuachi back home as a symbol of the pilgrimage. For Cahuachi, the distribution of ceramics serves to reinforce the power of the religious ideology throughout the widely dispersed Nasca area.

2.4.2 Middle Nasca

The Middle Nasca period (ca. A.D. 450 – 550) was a time of environmental instability and stress. Glacial ice core data from the highland Andes demonstrates highly variable weather patterns including droughts and flooding (Thompson et al. 1985). Long-term manipulation of the environment, through cutting down trees for agricultural fields and firewood along with frequent and harsh El Niño events, likely breached the ecological threshold at this time (Beresford-Jones et al. 2009). Towards the end of this period a system of aqueducts (puquios) was developed that allowed the Nasca to access groundwater. This alleviated some effects of drought and assisted in agricultural production. Puquios were built in middle valleys that had previously been too dry to support life. This innovative technology allowed for human life in newly habitable valleys (Schreiber and Lancho Rojas 1995).

Building of large middle valley settlements resulted from populations aggregating around puquio water sources in the area coupled with population growth throughout Early Nasca. Many Nasca regions such as the valleys of Palpa peaked in population density during Middle Nasca (Reindel 2009). Nasca residents abandoned prior settlements near dry rivers and the Andean foothills. Some moved further up valley were river water was more abundant and others moved near puquios in middle valleys (Schreiber and Lancho Rojas 1995).

Drastic environmental changes sparked sociopolitical and cultural change. Construction at Cahuachi came to a close in Middle Nasca (A.D. 450-550), suggesting abandonment of the site during this period. The prominent religious ideology lost vigor, and subsequently lost control that allowed for the labor necessary to expand the ceremonial center. This site continued to be used, though much less intensely for pilgrimage and burials in the surrounding cemeteries (Silverman and Proulx 2002). Settlement patterns differed in form and place than those of Early Nasca as new settlements increased in size and concurrently levels of social hierarchy (Vaughn et al. 2006). Osteological analysis of dental carie rates reveals increased differences in oral health correlated to higher levels of status differentiation than in Early Nasca (Tomasto Cagigao 2009a).

Archaeological evidence shows changes in ceramic iconography from naturalistic to abstract motifs increasingly depicting warfare (Proulx 1994). The nature of trophy head taking, a regional practice carrying over from the Paracas culture, shifted during this period. For the first time the demographics of trophy heads began to include predominantly warrior men (Verano 1995). This suggests that violence was a concern to the Middle Nasca population and a prime motivator for trophy head taking beginning in Middle Nasca and carrying over through Late Nasca (Forgey 2006). Trophy head taking is also linked to ancestor veneration and rituals to promote crop fertility (Conlee 2007).

Concern with warfare and fertility, as suggested through studies of trophy heads, correlates to osteological evidence for interpersonal violence. The highest levels of interpersonal violence from the Archaic Period to the Middle Horizon occurred during the latter Early Intermediate Period (Tomasto Cagigao 2009b). Pathological conditions such as linear enamel hypoplasia (an indicator of nutritional stress) increase in Middle Nasca (Kellner 2002). Worsening environmental conditions began to affect Nasca populations in the latter part of the Early Intermediate Period causing physical stress.

2.4.3 Late Nasca

Societal reorganization continued into Late Nasca (ca. A.D. 550-750). A period of increased aridity is attributed to many changes implemented in this period, including settlement sizes, and the continued construction of hydraulic technology (Reindel 2009; Schreiber 1999). The presence of elaborate tombs in addition to simple ones (Carmichael 1988; Menzel 1971) and greater variation in oral health statuses gives evidence for increased social differentiation that led to differential access to resources including high quality foods and burial goods in Nasca.

However, a recent study by Whalen (2014) suggests that leadership and ritual practice became regionalized as local community identity was reimagined following the collapse of the Cahuachi cult. Late Nasca sociopolitical complexity differed greatly between regions, having increased in the Northern Nasca Region (NNR) and the CNR, but not in the SNR. Towns in middle valleys continued to increase in size and political complexity into Late Nasca, a stark contrast to the SNR, and the small and dispersed polities typical of Early Nasca (Schreiber and Lancho Rojas 1995).

Violence was a common theme in Late Nasca. This is known through an increase in violent injuries (Kellner 2002), trophy head taking (Knudson et al. 2009), and iconographic representations of warfare (Proulx 1995). Ceramic design continued to transform towards depictions of violent conflict and concern with fertility (Proulx 1994). Concern with life and violence is better understood through osteological analyses, which reveal a stark increase in cranial trauma occurred during this time (Kellner 2002; Tomasto Cagigao 2009b). This evidence suggests a rise in the amount of interpersonal combat faced by Late Nasca populations.

Cultural contact between the neighboring Nasca and Huarpa (the precursor to Wari in Ayacucho) societies intensified through the end of the Early Intermediate Period. Menzel (1964) first recognized this relationship through ceramic similarities between the Wari and Nasca. The Nasca increasingly influenced the ceramic technology of the Wari antecedent culture, Huarpa, in both structure and style during Late Nasca. This is seen in the style and design of Huarpa ceramics. Huarpa's red and black on white slip paintings began to morph into colorful Nasca style designs. The trend continued into the cultural transition from the Huarpa to the Wari culture in the Middle Horizon (Leoni 2004).

Late Nasca ties with the highland groups such as Estrella are apparent at Cocahuischo, and perhaps resulted from an expanding social network that allowed access to goods such as camelids during a time of resource strain (Whalen 2014: 353) Regionalism in the Late Nasca period resulted in the SNR and NNR maintaining social ties with local highland groups, while the CNR seems to have maintained a stronger relationship among Late Nasca groups (Whalen 2014). While the Early Intermediate Period is comprised of three temporal Nasca groups (Early, Middle, and Late Nasca), two distinct ceramic styles in the Middle Horizon population (Chakipampa and Loro) may reflect two contemporaneous cultural groups in the Nasca region that began formation in the Late Nasca period through intra- and inter-regional social ties.

2.4.4 Middle Horizon

The Early Intermediate Period came to an end with the highland Wari, an expansive state that had a dynamic influence throughout the Andean region in the Middle Horizon (A.D. 750-1000). In Nasca, the Wari influence intensified as major transformations occurred within the society. The local Nasca experienced a diverse range of interaction with the Wari, from cultural influence to conquest. As research concerning Wari interaction in Nasca continues, the complexity of this relationship is coming to light. Menzel (1964) acknowledged the close relationship between the two cultures but assumed that the Nasca served a prestigious and powerful role because of their place within the Wari Empire. While this view continues to hold true for some parts of Nasca, it does not explain the lack of Wari influence among others.

Archaeological investigations have begun to elucidate the impact of Wari presence in Nasca, which resulted in stark regional changes. Decreased human population and settlements in the Northern Nasca Region suggests a population shift to the Southern Nasca Region (Conlee 2010). This left the Northern Nasca Region with cemetery sites but an abandonment of many settlements (Silverman 2002; Isla Cuadrado and Reindel

2005). Many members of the Nasca population shifted south to Las Trancas Valley but here also, there was an overall decrease in population size. Conversely, the population at the largest settlement site in the Southern Nasca Region, Huaca del Loro, increased in size (Schreiber and Lancho Rojas 2003).

Evidence for the Wari presence is most obvious in the Southern Nasca Region at sites other than the site of Huaca del Loro, which is affiliated with the local Nasca tradition. The Middle Horizon is comprised of two ceramic styles, which may reflect two separate but contemporaneous cultures within the Nasca region: the local Nasca Loro style, and the non-local Chakipampa style (Kellner 2002). Loro is the Nasca tradition of the Middle Horizon, and Chakipampa is a Nasca – Wari hybridized ceramic style (Menzel 1964). Chakipampa is the Nasca influenced, non-local Wari ceramic style found throughout the Nasca region in the Middle Horizon.

Burial patterns from sites such as La Tiza and Pataraya reveal Chakipampa's sociopolitical complexity during the Middle Horizon. Wari style burials appear contemporaneously with local Nasca style, Loro burials. At La Tiza, Nasca pit style burials continued into the Middle Horizon alongside a new Wari style burial tradition. These were elaborate aboveground tombs with multiple individuals interred. Strontium and oxygen isotopic analysis from Wari style tombs revealed the interred to be non-local Wari individuals buried among local Nasca individuals (Conlee 2010). Buzon et al. (2012) attribute differential patterns of cultural change among the Nasca at La Tiza to the prestige involved with affiliating with the powerful Wari. As Menzel (1964) hypothesized, local Nasca who adopted Wari cultural elements, represented here as Wari high status mortuary practices, gained social prestige and acquired Wari material goods including ceramics, Spondylus shell, and metals (Conlee 2010:109). Other locals remained unaffiliated and continued Nasca burial patterns.

Similar Wari style burials exist at Pataraya, a Wari site in the Nasca Valley (Schreiber 2001). Located along an ancient road connecting to the highlands is a Wari administrative outpost in the Southern Nasca Region. They may have invaded Nasca to gain access to coastal land that could sustain crops unable to grow in their highland location. These crops include cotton, coca, and maize, all of which can only grow at lower altitudes such as the Nasca region (Edwards 2010; Schreiber 2005). They controlled maize production in other colonized regions, but a study of Nasca maize consumption did not show a change after imperial influence suggesting that they did not monopolize Nasca maize production (Kellner and Schoeninger 2008). This site served as an outpost for transportation of information, people, and goods such as cotton between the highland Wari region and the Nasca region (Edwards 2010).

Archaeological evidence from Pataraya suggests Wari extracted resources from Nasca to the Wari heartland (Edwards 2010). The Wari occupation at Pacheco was one of economic control such as co-opted terraces (Schreiber 2000). This model of the Wari presence in Nasca suggests that the Wari colonized local Nasca people to fulfill economic needs. If the Wari forced their political system onto Nasca communities for the extraction of resources, this factor would result in increased stress incurred by the Chakipampa.

Some Nasca appear to have integrated with the Wari as integrated cultural styles at sites such as La Tiza and Pacheco suggest, but it is not known if this was forced or voluntary. Others relocated as a form of resistance to the foreigners (Schreiber 2005). Huaca del Loro, a populous centralized chiefdom in the SNR is recognized as the local

Nasca Middle Horizon political center (Conlee and Schreiber 2006). Once thought to be a highland site due to the unique architectural style, it is now interpreted as the Nasca center of political centralization in the Middle Horizon (Schreiber 1988). The genesis of the Loro style was not just a form of resistance to Wari imperialists, but also has its roots in Late Nasca at communities such as Cocahuischo (Whalen 2014). Following the downfall of Cahuachi, Nasca populations began to regionally reconstruct Nasca identity leading to the Loro culture in the Middle Horizon.

The relationship between Loro and Chakipampa groups remains unclear. At Nasca sites such as La Tiza, the Wari style local and non-local burials suggest that they held an elite role, while the Nasca style burials were low status. On the other hand, osteological data have suggested that the Wari affiliated population experienced higher levels of stress than the Loro. Given the evidence suggesting that Wari co-opted economic control in Nasca communities to obtain resources, the Chakipampa group may represent a local Nasca population colonized by the Wari.

2.5 Summary: Environment and Stress

Early Nasca flourished with relatively good environmental conditions. A central religious ideology united Nasca chiefdoms and continued to expand Cahuachi. Population size increased during this period. Ceramic iconography depicts naturalistic themes with few signs of conflict. Earlier Nasca times had better health indices according to osteological analyses by Tomasto Cagigao (2009a) and Kellner (2002). Kellner found that the occurrence of linear enamel hypoplasia, an indicator of stunted growth during development, was low in Early Nasca and reached its highest levels in the Middle

Horizon. Evidence for climate change in Nasca, largely indirect, revealed a general trend of favorable environmental conditions in Early Nasca, later degrading from Middle Nasca to the Middle Horizon (Kantner and Vaughn 2012).

Sporadic El Nino climatic events have been attributed to drastically altering the typical ecology, causing unforeseen environmental changes in Middle Nasca (Shimada et al. 1991). Though, more recent work by Beresford-Jones (2011) provides direct evidence for gradual human-induced landscape change coupled with major El Niño events. From the latter part of the Early Intermediate Period into the Middle Horizon, environmental degradation affected the lives of Nasca inhabitants through drought and decreased agricultural productivity.

Beresford-Jones et al. (2011) suggests that environmental degradation was initiated by the long-term removal of the desert woodlands. In particular, the huarango tree played a large role in the Nasca ecosystem. Long roots pumping water from underground sources to the surface hydrate otherwise dry surface soil, making the land fertile for agricultural production. Furthermore, the large trees provided fuel for fires and shelter from harsh winds. Humans living in the Nasca region gradually overused the slow growing tree for fuel and to make more room for agricultural land near river valleys, causing a slow decline in the riparian vegetation. The environmental impact of deforestation remained minimal until the Early Intermediate Period. On the verge of disaster at the time of a major El Niño flooding event, the threshold was breached leading to drastic environmental changes beginning in the Middle Nasca period (Beresford-Jones et al. 2009). Ice-core data from Andean glaciers confirms a massive pan-Andean drought during the Late Nasca period (Thompson et al. 1985). Human-induced environmental changes reached the tipping point, contributing to periods of extreme drought in the Middle and Late Nasca periods.

As conditions worsened, Cahuachi lost its following. Puquios alleviated some stress by providing access to groundwater, but conditions did not improve according to osteological data (Tomasto Cagigao 2009a; Kellner 2002). These circumstances persisted into the Late Nasca period. As settlement sizes grew, violent conflict and social hierarchy also increased. Archaeological and osteological data point towards increased mental and somatic stress incurred among members of the population towards the end of the Early Intermediate Period, evidenced by declining osteological conditions and sociopolitical upheaval.

The Middle Horizon population may have incurred high levels of stress due to a number of environmental stressors. This time period was characterized by Wari influence. Archaeologically, this influence is most apparent in the new Nasca-Wari hybrid ceramic style, Chakipampa. The local Nasca ceramic style Loro, coalesced in the Southern Nasca Region and largely lacked Wari influence. Environmental conditions remained arid and highly variable as they had been at the end of the Early Intermediate Period, but the expansion and integration of the Wari Empire into the Nasca region added another stressor onto the population.

The Wari were well integrated into many Nasca societies, resulting in immense change throughout the region. Many Nasca residents relocated to the Southern Nasca Region and erected large and heavily populated settlements. Life in large and populous towns is known to increase susceptibility to disease (Bocquet-Appel 2006). Frequencies of pathological conditions such as cranial porosities peaked among individuals in the

Middle Horizon compared to the Early Intermediate Period, especially among Chakipampa individuals (Kellner 2002:59). Analysis of paleodemography in Palpa revealed a higher life expectancy during the Early Intermediate Period compared to the Middle Horizon (Drusini et al. 2001).

Evidence for a high rate of violence among males suggests the highest rates of conflict during this period (Kellner 2002:83). Variable and poor environmental conditions, disease, and trauma are biophysical causes of stress that likely affected the Middle Horizon population in Nasca. It is likely that the Middle Horizon population experienced high rates of stress as rates of pathological conditions increased. I propose that stress –both internal, perceived stress along with external, biophysical stress-increased in the Middle Horizon when compared to the Early Intermediate Period.

Furthermore, stress levels may differ between Loro and Chakipampa individuals within the Middle Horizon. If the Wari granted an elite role to Chakipampa individuals, stress levels would be low in this group (Menzel 1964; Conlee 2010). However, if the Wari extracted resources from Nasca (Edwards 2010) and took political control of Nasca communities (Schreiber 200), Chakipampa associated individuals would represent a colonization of Nasca people, and should exhibit higher stress levels.

CHAPTER 3. RESEARCH APPROACH AND HYPOTHESIS

This chapter describes the research approach used in this study to evaluate stress in Nasca populations. The methodology comes from the bioarchaeological perspective, which aims to understand the relationship between biology, culture, and the environment in past populations. Bioarchaeology uses methods such as DNA analysis, isotopic analysis, and osteological analysis to derive knowledge about he human experience in the past (Larson 2010). Osteological analysis of human skeletal remains serves as a bioindicator of the human condition in past populations (Little and Sussman 2010). Specifically, this study evaluates differential levels of environmental stress incurred between groups in Nasca by analyzing physical manifestations of stress.

In this study, analysis of human dentition provides direct evidence of metabolic insult from stress. Growth disruption, the study of recovery from episodes of growth arrest during developmental years, is evaluated through fluctuating asymmetry analysis of human remains from Nasca. If environmental stressors were a cause of the vast changes in Nasca society, an analysis of fluctuating asymmetry should reveal increasing stress incurred by the population over time.

3.1 Stress in Bioarchaeology

Growth disruption is examined through skeletal markers on human remains to determine deviations from homeostasis, stable internal bodily functions, among individuals and patterns among populations in various biocultural systems and environments. The biocultural approach recognizes the complex relationship between skeletal lesions, health status, and human behavior (Huss-Ashmore 1982). Stress markers on skeletal remains serve as a measure of population adaptation to the environment. Viewed in this way, a population's ability to adapt to various stressors can be assessed. Furthermore, the ability for a population to exploit specific ecological and cultural niches can be evaluated.

The study of stress in biological anthropology can be used to test hypotheses regarding the life history of individuals within and between societies in the past. "Stress is anything (physical, chemical, genetic, psychological, etc.) dissipating energy away from growth and production," (Graham et al. 2010:501). As adaptive biological responses result from stressors, this method directly addresses the costs and limits of adaptation (Goodman et al. 1988). The stress concept allows bioarchaeologists to reconstruct adaptation in the past. Osteological examination of adaptation through rates of stress episodes can reveal patterns of stress experienced in populations through time. In this way, analysis of skeletal material can decipher temporal and social differences in health patterns of past populations.

3.1.1 History of Stress

The multidisciplinary study of biological stress has its roots in the work of Hans Selye. He theorized a universal stress response that continues to play an important role in modern studies of stress at an individual and population level. Selye's concept of the General Adaptation Syndrome has influenced more recent perspectives to research approaches in the field of anthropology studying nonspecific manifestations of stress in human populations both present and past (Selye 1936). It has led to modern analyses of the human condition through skeletal changes such as stature in past populations (Evans and Cohen 1987). The biocultural model, used in this research, is another perspective influenced by Seylean Stress. It has broadened the realm of anthropological research questions that can be addressed in bioarchaeology by incorporating the study of sociocultural factors in past populations.

General Adaptation Syndrome is useful for gathering information pertaining to the stress levels in populations, but cannot link manifestations of stress to stressors. It posits that stress is caused by the perception of a stressor, both physical and psychological (Selye 1955). This methodology focuses on identifying somatic manifestations of stress such as increased levels of corticosteroids in urine and blood samples for present populations. Seylean stress attempts to link stress to psychosocial factors of perceived stress. However, the identification of somatic stress does not offer further insight into the causes of these reactions. It advocates for nonspecific manifestations of stress and does not attempt to differentiate markers of stress. Further, it attributes stress to psychosocial causes such as perceived threat. This limits the possibilities for the methodology to be used in addressing archaeological research questions (Goodman et al. 1988).

Contentions with Sylean Stress and the General Adaptation Syndrome were overcome in anthropological stress research following the integration of evolutionary approaches rather than descriptive, which led to new methodologies in the 1970s and 1980s including paleodemography (Huss-Ashmore et al. 1982). This method examines population structure through recording sex and age at death from population samples. In this model, health in past populations is measured by indicators of stress on skeletal material to answer questions regarding a population's adaptation to stressors.

The underlying assumption in paleodemography that skeletal samples represented the structure of living populations was challenged in the 1980s. Osteological analysis assumed that health patterns in the skeletal sample reflect the health patterns of the population that produced them. The validity of this depends on the implicit assumption that skeletal samples are representative of the living population (Cohen et al. 1994). Proponents of the Osteological Paradox challenged this assumption and forced a reexamination of long assumed premises (Wood et al. 1992b).

Wood et al. (1992a) argues that individuals who do not exhibit skeletal lesions may not have been stress free and healthy. The lack of stress indicators is not an indicator of low stress levels. In fact, it could be that the person suffered from acute stress that resulted in death quickly so that the body did not have time to respond and stress markers to manifest. In this case, the individual would have suffered from stress so extreme he could not adapt at all before succumbing to the stressor. This alternative interpretation of osteological methods poses an issue for the accuracy of osteological studies.

Conversely, Goodman (1993) suggests this alternative interpretation is an invalid portrayal of paleodemographic methods. This view is supported by studies of living populations that have demonstrated poor environmental factors are directly related to population level expression of osteological stress indicators. May and colleagues (1993) monitored bone and enamel formation in populations subjected to differing environmental stressors. Healthy individuals, who were less often ill, displayed lower rates of linear enamel hypoplasia and hand-wrist ossification. The results of this study suggest that stress indicators accurately portray rates of stress experienced by past populations.

The theoretical anomalies addressed by the Osteological Paradox forced the field of biological archaeology to reconsider assumed underlying premises to skeletal analyses. It reemphasized the complexity of the concept and measure of health in past populations. The field was forced to resolve the points presented by the Osteological Paradox, which led to a strengthening of theoretical perspectives. Awareness of untested assumptions in bioarchaeology guides research to increasingly test hypotheses of health status in past populations through osteological analyses that further incorporates archaeological data to situate skeletal samples in a temporal, spatial, and cultural context. Epidemiological approaches focus on disease in populations rather than interpretations from individuals. Larsen (2010) suggests the use of multiple skeletal indicators of health in past populations. As methods in bioarchaeology progress such as with DNA, chemical, and statistical analyses, and interpretation of pathological conditions are refined, osteological interpretations are now better understood (Wright and Yoder 2003).

Health, a culturally bound phenomenon, can only be understood through a cultural and biological perspective. Bircher defines health as “a dynamic state of well-being characterized by a physical and mental potential, which satisfies the demands of life commensurate with age, culture, and personal responsibility" (Bircher 2005:338). In bioarchaeology, health status is evaluated through mortality, nutritional status, fertility, etc. Within the biocultural framework health status refers to the continued biological, physiological, and/or cultural ability for individuals or populations to rally from stressors through human population adaptation (Goodman et al. 1988). However, archaeological interpretations of health are problematic and cannot be accomplished because a society's cultural perception of health cannot be known from the archaeological record.

Following the Osteological Paradox, it was recognized that the dynamic relationship between culture and biology was critical in human variation and adaptation. Bioarchaeology increasingly incorporated cultural perspectives into the interpretations of analyses. The anthropological perspective of Sociocultural Epidemiology reflected the growing realization of the importance of the social environment on health and adaptation (Goodman et al. 1988). Research concentrated on evolutionary sciences for interpreting issues of adaptation and understanding underlying population structure and the human condition in past societies. Stress could be studied anthropologically, through daily routines in human life rather than contrived laboratory experiments that characterized past methodologies.

This had direct value in bioarchaeological studies of past populations. Stress manifestations in human remains are interpreted as products of the social events that occurred through daily life. Following this advancement, the methodology of paleoepidemiology used skeletal stress markers as indicators of population adaptation to the environment in past populations (Shuler 2005). Epidemiological models in bioarchaeology interpret health from the human skeleton as the continued ability to overcome both physiological and cultural stressors and ways in which adaptation results from overcoming stressors (Cohen and Armelagos 1984). Skeletal stress markers indicate population adaptation to the environment as they result from the physiological response to environmental stressors. The importance of sociocultural factors as environmental stressors in this paradigm has broadened the realm of research questions that can be addressed allowing the study of social relationships in past populations.

3.1.2 Biocultural Model

Armelagos and Goodman (1991) point out that the epidemiological model provides a method for evaluating the relationship between humans and the environment but undervalues the role of human agency and sociopolitical processes in shaping health patterns in societies. The biocultural model, however, recognizes the role that both biological and cultural determinants have in health patterns. It views stress as a dynamic relationship between environmental constraints, culture, biological resistance factors, and physiological disruption to human hosts (Cohen and Armelagos 1984).

From Seyle’s model, the biocultural model concentrates on the important role psychosocial components have in causing stress. However, it somewhat lacks applicability to biocultural research in that causes of stress are not distinguished, and Selye maintains that manifestations of stress in the human body cannot distinguish causative factors because all stressors result in somatic stress markers in the same way (Selye 1936). To move past this, Goodman’s model incorporates recent advances in attributing certain stress markers to various environmental factors, in order to connect somatic stress with the causal factors both biological and cultural.

This model was used, for example, by Danforth (1999) to explore the relationship between nutritional stress and sociopolitical complexity, an environmental stressor caused by cultural adaptation. This study found an association between levels of sociopolitical complexity and stress levels in archaeological populations of North America and Mesoamerica. The importance of human culture in the creation of stressors is crucial to the interpretation of stress in the human population. By connecting manifestations of stress on the human population to nutritional stress, the study was able elucidate the role this single factor played among many levels of sociopolitical complexity.

All adaptation begins with environmental constraints and is mitigated through biological and/or cultural adaptations. The relationship between environmental conditions and stress response is a cyclical one that can be traced through bioarchaeological research outlined in Figure 3.1. Firstly, the critical stressors and their interactions in a sample are identified. The process of somatic stress begins with causation, the environmental conditions. The environment can induce stress on the host through various and interacting stressors, perceived and tangible. While culture may serve as a buffering system to alleviate environmental stressors, it may also be the cause of stressors, such as human pollution. Stressors in a sample are defined by intensity and distribution in time and space through the frequency, duration, and distribution. The next step is to evaluate the impact, response, and consequence of the somatic stress response (Goodman et al. 1988). This theoretical perspective aims to decipher the real life impact of environmental stressors. In order to accomplish this, interpretation of the effects on lifestyle must be examined.

Cyclically, these consequences on daily life then feedback to environmental conditions as they likely create new stressors in one's life.

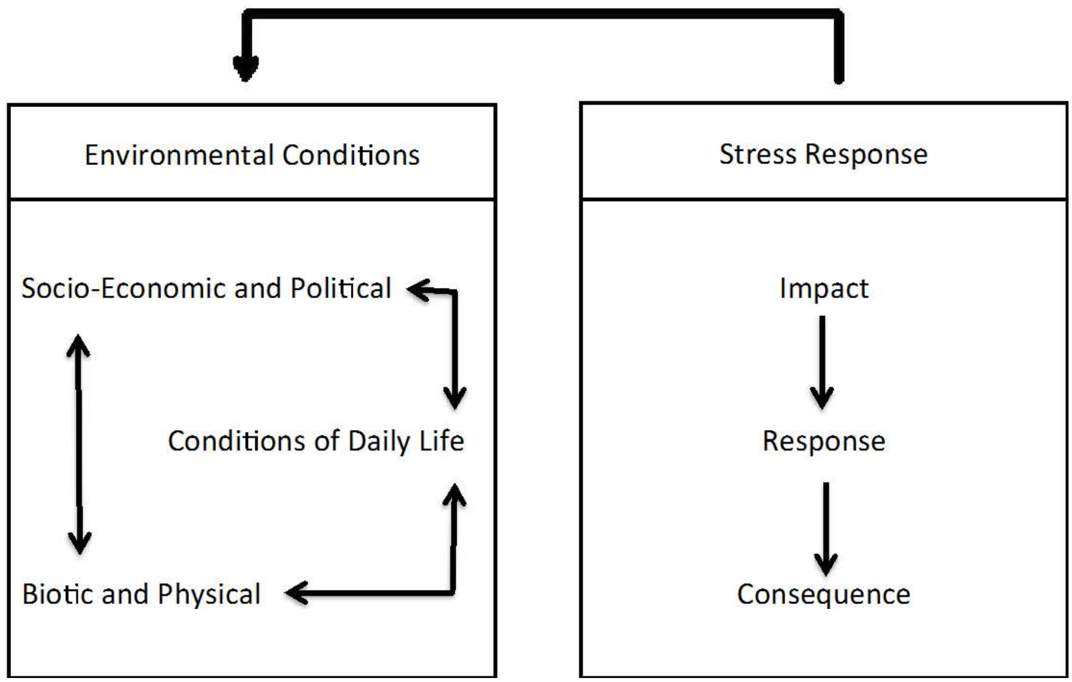

Figure 3.1 Model of stress process redrawn from Goodman et al. (1988:195)

Stress markers on skeletal remains serve as a measure of population adaptation to the environment. Analysis of stress markers on a sample of a population provides a record of human adaptation to environments through time with the use of cultural and biological host resistance factors. There are several methods used in skeletal analysis for the identification of stress incurred by an individual, and through a large sample, population stress and adaptation can be observed. Past health patterns are accessed through skeletal and dental indicators left by diseases and nutritional inadequacies. By connecting stress indicators to specific causes, bioarchaeologists can connect specific stressors to populations. Further, bioarchaeologists can interpret ways in which stressors and stress responses affected the life of the hosts (Knudson and Stojanowski 2008).

Bush and Zvelebil (1991:17) define stress as “the somatic response to internal and external agents (stressors) that maintains homeostasis.” Acute and chronic stress can result in both protective and damaging effects on the body. Acute stress triggers the body to acclimate with an immediate response that can restore the body to homeostasis quickly. The body overcomes chronic stress events by taking energy away from body functions and dispersing it to fight off the stressor (McEwen 2008). These body functions that were slowed result in observable skeletal features such as short stature and fluctuating asymmetry.

Stressors are linked to developmental interruption including nutritional stress and vitamin and mineral deficiencies (Goodman et al. 1988). Growth patterns provide information regarding stressors such as nutritional status and infection. Infection often leads to nutritional stress because the immune response requires a large amount of amino acids to create antibodies that fight pathogens (Larsen 1999). Growth disruption is studied through analyses of fluctuating asymmetry, linear enamel hypoplasia, Harris Lines, diaphyseal length, and cortical bone thickness and area. Stress effects regular development through interrupting growth as somatic stress responses leave markers on the skeleton (Buikstra and Ubelaker 1994).

Biocultural anthropology provides a framework for evaluating cultural variation through biological processes. It utilizes both biological and cultural theories and methods to determine the human condition in the past by evaluating the multiple interacting stressors that result from biocultural components (Hruschka et al. 2005). The Biocultural

Model of Health assesses how human biology is shaped by political-economic, ideological, and sociocultural contexts (Goodman and Leatherman 1998). Culture is recognized as a complex variable that acts both to alleviate the effects of stressors and create new stressors. Biology works to overcome stress through adaptation, both acclimatization on the individual level, and genetic adaptation on the population level through evolution (Relethford 1994).

By connecting these diseases to specific causes, biological anthropologists can connect specific stressors to populations; revealing factors such as duration, intensity, and distribution in time and place of stress episodes (Larsen 2010). Even more, they can interpret ways in which stressors and stress responses affect the life of the hosts (Knudson and Stojanowski 2008). Skeletal manifestations of stress indicate specific and unique stressful experiences that can be elucidated using contextual data from archaeological studies of the population. Bioarchaeologists make inferences about the complex relationship between biology, culture, and the environment in past societies utilizing contextual information from archaeology. In this model, skeletal indicators of stress and adaptation determine health status in past populations.

Population stress levels are conceptualized as the interaction of environmental and cultural stressors, buffered through cultural and biological resistance factors. Stressors result in a biological response, physiological change or death if the stress is severe. Bioarchaeological studies assess this physiological response to determine population stress levels and evaluate the success of cultural adaptation. This study assesses population stress levels through one particular physiological manifestation of stress, fluctuating asymmetry.

3.2 Fluctuating Asymmetry

"It might have been anticipated that deviations from the law of symmetry would not have been inherited." (Darwin 1868:456)

Dental fluctuating asymmetry is one of several indices for distinguishing environmental stress incurred by individuals within an archaeological population. Fluctuating asymmetry is a bioindicator of growth disruption due to stress incurred by an individual through development. This study evaluates fluctuating asymmetry of the dentition on individuals in Nasca to evaluate levels of stress experienced through changes in sociopolitical and environmental conditions.

Symmetry of many differing types is an important trait in all living organisms because it requires less energy to develop and maintain symmetrical body systems (Graham et al. 2010). Bilateral symmetry is the mirror image across the midline of the body, so that structures on the right side mirror the left side. In humans, for example, bilateral symmetry aids locomotive efficiency. Asymmetry, deviations from bilateral symmetry, can occur in three forms: directional asymmetry, antisymmetry, and fluctuating asymmetry (Van Valen 1962). Directional asymmetry refers to constant deviations from perfect symmetry in a species in which one side is consistently more developed than the other side. Antisymmetry refers to traits in which one side is larger than the other in an individual, but the larger side differs between individuals within a population (Palmer and Strobeck 1986). The only type of asymmetry reactive to somatic stress is fluctuating asymmetry, defined as random deviations from perfect bilateral symmetry (Van Dongen and Gangestad 2011).

Environmental stressors can impact an organism to the point that the body releases stress hormones in response. Developmental noise is the term for the threshold of stress that an organism can withstand. Developmental noise leads to stress hormones that disrupt bodily functions and limit productivity, including the ability to maintain the mechanisms that prevent asymmetry, buffering and stabilization (Graham et al. 2010). It reduces fitness of an individual by disrupting homeostasis.

As levels of developmental noise increase, the body is less able to maintain homeostasis and symmetry during developmental years. Right – left symmetry is compromised causing measurable differences in the phenotypic expression of tooth traits. This difference is assessed by analyzing the degree of variation between the phenotypic expression of traits on the right and left side of the dentition. Increased levels of fluctuating asymmetry indicate increased stress incurred by a population (Saunders and Mayhall 1982).

Dental traits do not exhibit asymmetry to the same degree. Some traits are under more selective control and thus develop with more stably than others (Carchini et al 2000). The dentition develops in four fields chronologically from the most mesial member of each field, the key tooth, to the most distal member (Butler 1939). The key tooth begins mineralization around birth, while the last (the distal molars) mineralize in later childhood. Dahlberg (1945) theorized that the more distally located teeth experience lower concentrations of chemical morphogens than mesial teeth resulting in increased developmental instability. Current work has disproven the chemical morphogens hypothesis, but his theory of developmental instability among later developing teeth in each field is supported through the idea that later developing teeth spend more time in post-natal development and have more time to experience more stress hormones (Scott and Turner 2000).

The key tooth in each morphogenetic field is the least asymmetric, and asymmetry is greatest in the most distal, latest developing tooth of each class (Saunders and Mayhall 1982). Harris and Nweeia (1980: 140) found that maxillary teeth are more asymmetric than mandibular; the pattern of asymmetry corresponds to morphogenetic gradients within each tooth field. He states that “asymmetry in the molar field is straightforward: M1<M2<M3.”

Extending the theory of morphogenetic fields within the development of dentition, Peiris and colleagues (2013) found that this developmental instability affects the latest developing cusps in each field. This may explain why Harris and Nweeia (1980) observed that the hypocone, a distal molar cusp, was especially asymmetric. Fluctuating asymmetry is thought to be the greatest in the maxillary third molar due to its position as the most distal tooth in its field and the prolonged period of post-natal development (Scott and Turner 1997).

Fluctuating asymmetry analysis is the quantification of the observable deviations from bilateral symmetry in antimeres of an individual’s teeth that reveal levels of stress incurred by an individual and population (Saunders and Mayhall 1982). The analysis of later developing teeth in each tooth field, especially the last molars may offer a more accurate view into stress experienced by individuals throughout life.

The bones and teeth are especially sensitive to pathological conditions during development as they are continually adding new bone and enamel (Larsen 1999). Tooth size is a developmentally plastic trait that is receptive to chronic somatic stress. Dental tissues are unique to other skeletal material used in osteological analysis of past populations as they cease remodeling after becoming fully developed in early life unlike bone, which remodels throughout life. Because of this, fluctuating asymmetry only measures stress experienced during childhood. The dentition preserve in archaeological contexts comparatively better than the skeleton. These features, outlined by Palmer and Strobeck (2003) as reliable traits for the study of fluctuating asymmetry, make the teeth an ideal material for studying stress incurred during development through fluctuating asymmetry. However, due to the use and exposure of teeth, wear and caries may obscure data.

Dental fluctuating asymmetry analysis reveals an individual's somatic stress in response to environmental stressors such as lack of nutrition, water, and illness experienced during development (Graham et al. 2010:501). Comparing population levels of fluctuating asymmetry across time periods allows insight into changes in population level stress over time. These changes can be better understood when taken alongside archaeological data for contemporaneous environmental stressors.

3.3 Hypothesis

Following the above discussion, the principal hypothesis to be tested in this research is that local populations in Nasca experienced increasing levels of environmental stress over time from the Early Intermediate Period to the Middle Horizon due to (1) Wari influence instigating drastically changing sociopolitical circumstances and (2) degrading environmental conditions beginning in the latter part of the Early Intermediate Period.

Furthermore, if the Chakipampa were granted an elite role by the Wari, they would exhibit lower levels of stress compared to Loro. However, if the Chakipampa represent Wari colonized locals, they would exhibit higher stress levels than the Loro who avoided the Wari. I expect that the Chakipampa group, who maintained a close relationship to Wari imperialists, experienced differing levels of stress compared to the Loro group who avoided the Wari. This will be represented in the fluctuating asymmetry analysis as increased phenotypic dental trait variation in right/left antimeres over time, reaching its highest level in the Middle Horizon, and significantly differing between the Chakipampa and Loro groups.

CHAPTER 4. METHODS AND ANALYSIS

This chapter describes the methods used in this research to analyze levels of fluctuating asymmetry through time in Nasca. The sample is described including size, dental trait composition, and cemetery locations. Data collection is outlined followed by a description of the data analysis.

4.1 Sample Composition

The human remains studied for this research come from six cemetery sites and surface collections in Nasca. The archaeological cemeteries in the Nasca region include Los Medanos, El Pampon, La Marcha, Chiquerillo, La Sentella, and Wayuri (Figure 4.1). These cemeteries are among the many excavated by Julio C. Tello on the 1927 Museo de Arqueologia Peruana expedition (Shady Solis and Novoa Bellota 2002). They are all multicomponent, dating from the Early Intermediate Period to the Middle Horizon (ca. A.D. 1 – 1000). Material from this expedition is held in Lima, Peru at the Museo Nacional de Antropologia, Arqueologia e Historia del Peru.

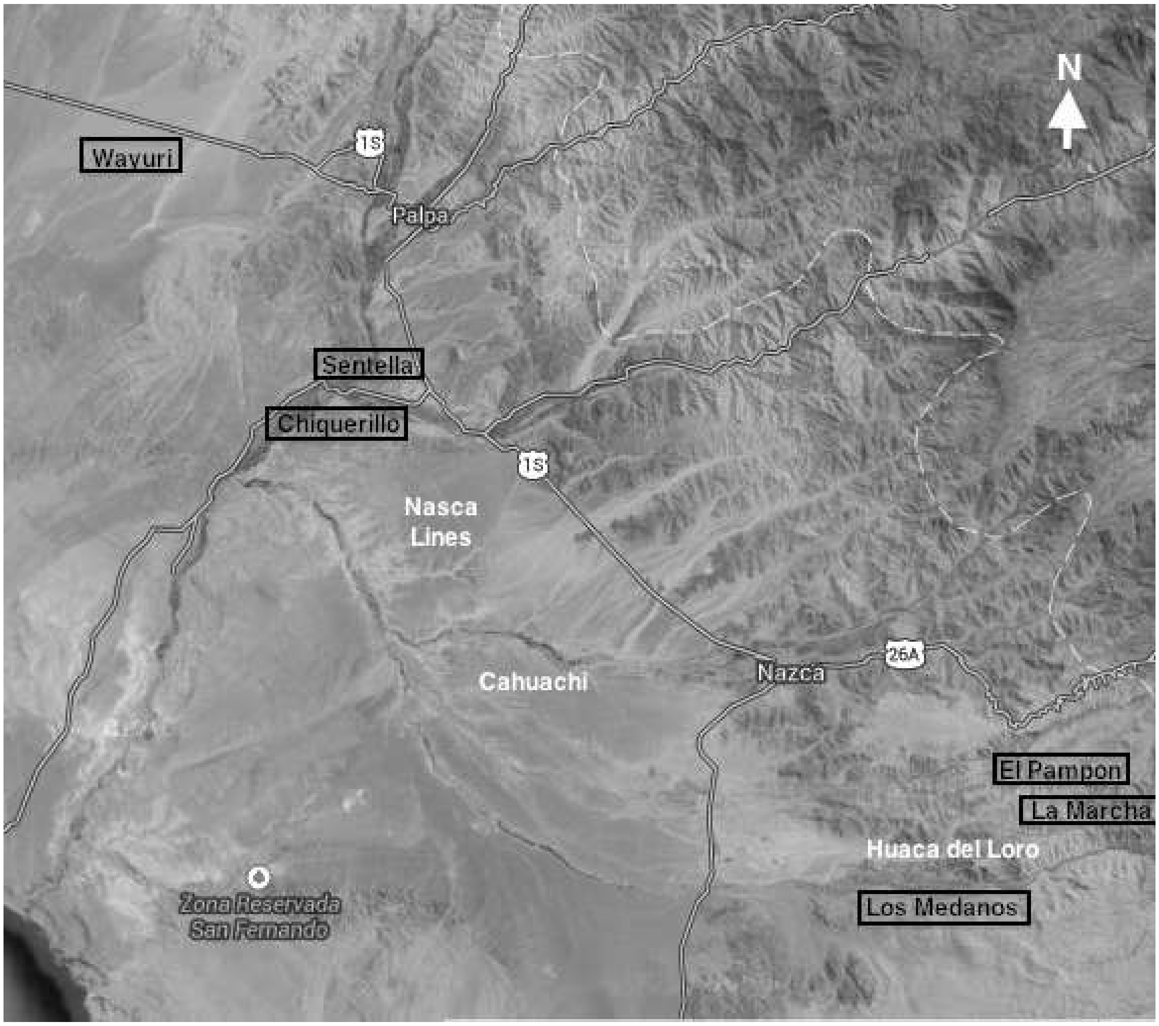

Figure 4.1 Map of cemetery locations. Cemeteries boxed in black.

Recent studies using this collection have been conducted by Johny Isla Cuadrado (2001) and Corina Kellner (2002). Kellner performed a bioarchaeological analysis on skeletal material from El Pampon, La Marcha, and Los Medanos. Isla Cuadrado studied the mortuary contexts to analyze changes in funerary customs from the Early Intermediate Period to the Middle Horizon. Through ceramic analysis he assigned cultural and temporal information to all of the skeletal material used for this study (Isla Cuadrado, personal communication 2014).

The sample size for each trait does not reflect the true sample size of the study. Due to missing teeth, and the fragmentary nature of some dental remains it was not possible to score dental trait expression for many individuals. This significantly reduced the sample size to N=205. The largest sample comes from Los Medanos with 156 individuals. It is associated with Huaca del Loro, a local Middle Horizon residential center (Tello 2002). This cemetery as well as El Pampon and La Marcha are located in the Las Trancas Valley. Chiquerillo is located northwest in the Rio Grande Valley and Wayuri is situated farther northwest in the eastern Santa Cruz Valley (see map, Figure 4.1). The sample size from each cemetery is noted in Table 4.1.

Table 4.1 Description of samples

Cemetery	**N**	**% of Total**
Los Medanos	156	76%
Pampon	15	7%
La Marcha	13	6%
Wayuri	8	4%
Chiqueriilo	6	3%
Sentella	3	2%
Surface Collections	4	2%
Total	205	100%

4.2 Data Collection

The dental trait data used in this analysis were collected by Sarah Cross in 2009 at the Museo Nacional de Antropologia, Arqueologia y Historia del Peru and later analyzed by the author. Human nonmetric dental traits on each tooth were scored according to the standards for the observation of dental morphological variants outlined in the ASU Dental Anthropology System (Turner et al. 1991). ASU Dental Standard Reference Plaques that display gradients of each trait were used for the scoring of 36 morphological traits in order to foster replicability and comparability between studies of fluctuating asymmetry and to decrease measurement error. One such plaque, Carabelli's trait on the mesiolingual cusp of upper molars, is scored on a scale from absent (0) to present in its full form (7) (Figure 4.2). This trait is scored by comparing the size and form of sample tooth to the plaque and assigning a score. This procedure is repeated for each trait, tooth, and individual in the sample.

Figure 4.2 Dental plaque depicting 0-7 scores for Carabelli's Cusp

Many teeth in this sample were absent or too worn to assign a score. Fluctuating asymmetry can only be assessed from teeth with both antimeres present for comparison of traits. The eight dental traits used in this analysis were chosen for the greatest amount of traits per individual to maximize sample size. Scoring procedures from Turner et al. (1991) for each trait used are described on Table 4.2.

Table 4.2 Measuring procedures for all dental traits used in this analysis

Dental Non-Metric Trait	Abbreviation	Score
Upper Molar 1 Metacone	UM1Met	0 absent 1 attached ridge at metacone site 2 faint cuspule with free apex present 3 weak cusp present 4 metacone large 5 metacone very large
Upper Molar 1 Hypocone	UM1Hyp	0 absent 1 faint ridging present at site 2 faint cuspule present 3 small cusp present 4 large cusp present 5 very large cusp present
Upper Molar 1 Carabelli's trait	UM1Car	0 mesiolingual aspect of cusp 1 is smooth 1 groove is present 2 pit is present 3 small Y-shaped depression present 4 large Y-shaped depression present 5 small cusp without a free apex 6 medium cusp with an attached apex 7 large free cusp present
Upper Molar 2 Metacone	UM2Met	0 absent 1 attached ridge at metacone site 2 faint cuspule with free apex present 3 weak cusp present 4 metacone large 5 metacone very large
Upper Molar 2 Hypocone	UM2Hyp	0 absent 1 faint ridging present at site 2 faint cuspule present 3 small cusp present 4 large cusp present 5 very large cusp present
Upper Molar 2 Cusp 5	UM2C5	0 site of cusp 5 is smooth 1 faint cuspule present 2 trace cuspule present 3 small cuspule present 4 small cusp present 5 medium-sized cusp present
Upper Molar 2 Carabelli's trait	UM2Car	0 smooth mesiolingual aspect of cusp 1 1 groove is present 2 pit is present 3 small Y-shaped depression present 4 large Y-shaped depression present 5 small cusp without a free apex 6 medium cusp with an attached apex 7 large free cusp present
Upper Molar 2 Enamel extension	UM2Ex	0 enamel border is straight 1 faint, 1 mm extension toward the root present 2 medium, 2 mm extension toward the root 3 extension > 4 mm long

4.3 Data Analysis

Data analysis adhered to guidelines from Palmer and Strobeck (2003). Nonmetric dental trait asymmetry was recorded two ways, following Palmer and Strobeck (2003:49) indices FA1 and FA12. The first index FA1 calculates the absolute value of the difference between the nonmetric values of the right (R) and left (L) antimeres or |R-L| for each trait on all individuals. The second, FA12 calculates nonmetric asymmetry of an individual based on multiple traits. Here, the amount of asymmetrical traits in each individual was assessed as present/absent, independent of the extent of the deviation between sides. Asymmetry was recorded as 0=symmetric 1=asymmetric between antimeres of each trait. Both indexes were analyzed for fluctuating asymmetry between samples using the Statistical Package for Social Science (SPSS).

Traits exhibiting directional asymmetry or antisymmetry may have a genetic basis and not reveal developmental noise, which can only be revealed through fluctuating asymmetry (Saunders and Mayhall 1982). However, unless these types of asymmetry far outweigh fluctuating asymmetry, they should not be eliminated as this may bias the analysis (Palmer and Strobeck 2003). Departures from normality including skew and kurtosis reveal the presence of directional asymmetry, antisymmetry, and outliers that may be results from measurement error. Departures from normality were visually inspected on a scatterplot of the right versus left sides of each trait. Non-normality poses a concern and if present should be further inspected to determine the cause.

The sample of individuals was separated for analysis in two ways. First, samples were separated into either EIP or MH. Second, samples were further divided into five groups: Early Nasca, Middle Nasca, Late Nasca, Loro, and Chakipampa. Separating the samples into groups based on temporal/cultural affiliation caused a reduction in the sample size because many lacked this information. The 99 individuals analyzed for differences in fluctuating asymmetry between groups are listed in the appendix (Table A 1).

Index FA12 of fluctuating asymmetry combines data from multiple traits for considerably more powerful analysis than index FA1 because it is based on single trait analysis (Graham et al. 2010). However, comparing amongst multiple traits results in a smaller sample size than a comparison of single traits due to missing trait data. Variance in FA12 fluctuating asymmetry between groups was compared for multiple traits using a two-way analysis of variance (two-way ANOVA). FA1 fluctuating asymmetry was analyzed with Levene's Test of Equality of Variance for each trait separately in order to determine the effect of each trait independently.

Eight traits from each individual were combined for a two-way ANOVA, testing for variation in fluctuating asymmetry between groups. The overall effect of samples from multiple traits per individual rather than a single trait yields a more powerful and accurate estimate of fluctuating asymmetry while alleviating the possibly confounding effects of trait size dependence of fluctuating asymmetry (Palmer and Strobeck 1986). Fluctuating asymmetry was compared between cultural groups and multiple traits (samples × traits). Variation between the levels of fluctuating asymmetry in the samples was detected through the effect of the samples. A statistically significant ANOVA test statistic for samples reveals different levels of fluctuating asymmetry in at least one of the samples. Bonferroni, a multiple comparison test, was run to evaluate which samples were significantly different. In the lack of statistical significance between samples, interaction between sample means was examined through interaction plots. Interaction Means Squared (MS) indicates how consistent a trait is at revealing among sample differences in fluctuating asymmetry. Significant variation between traits reveals that some traits are repeatedly less developmentally stable than others. This source of variation was further tested using Levene's Test for each trait independently.

Levene's Test of Equality of Variance was used to analyze fluctuating asymmetry between groups for single traits in order to elucidate variation in patterns of fluctuating asymmetry between samples that may differ for traits (Van Valen 1978, Palmer 1984). For this test, fluctuating asymmetry was calculated using index FA1. Eight traits were analyzed independently between time periods. Marginal means of statistically significant traits were displayed on interactions plots to determine which time periods significantly differed in levels of fluctuating asymmetry.

CHAPTER 5. RESULTS

This chapter reports results from the analysis of dental nonmetric fluctuating asymmetry in a sample of individuals from the Early Intermediate Period (EIP) and Middle Horizon (MH) in Nasca. Asymmetry was found to reflect developmental instability, allowing for statistical analysis of fluctuating asymmetry levels between groups. The results for fluctuating asymmetry between groups were statistically significant for some traits, supporting the hypothesis that stress incurred by Nasca populations increased in the Middle Horizon.

5.1 Analysis of Asymmetry

Eight dental nonmetric traits were tested for variation in fluctuating asymmetry between groups of individuals. The eight traits used in this study represent all of the traits with sample sizes over 50 individuals. Due to the archaeological preservation of the remains, many traits were missing or fragmented and could not be scored. Furthermore, many individuals could not be assigned to a cultural group. While 205 individuals were scored for asymmetry, only 99 of these individuals could be assigned to culture groups. The sample size for the analysis of fluctuating asymmetry between culture groups was N=99 (appendix Table A 1).

Small sample sizes for many dental traits resulted in exclusion from the analysis. Descriptive statistics for each dental trait are presented in Table 5.1. Scatterplots of each trait displayed no indication of departures from normality representative of antisymmetry or directional asymmetry. Three possible outliers were further inspected on UM1Car but were determined not to be the result of measurement error and thus not eliminated.

Table 5.1 Descriptive statistics for dental traits

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
UM2Hyp	55	0	1	.40	.494	.244
UM1Met	67	0	2	.21	.445	.198
UM2C5	53	0	3	.30	.696	.484
UM1Car	53	0	5	.87	1.373	1.886
UM1Hyp	69	0	1	.14	.355	.126
UM2Met	71	0	1	.17	.377	.142
UM2Car	56	0	2	.13	.470	.220
UM2Ex	57	0	3	.39	.701	.491

5.2 Analysis of EIP and MH Groups

The two-way ANOVA of index FA12 fluctuating asymmetry, 8 traits × 2 time periods tested for variation of fluctuating asymmetry across Early Intermediate Period and Middle Horizon for all eight traits. No statistically significant variation between time periods was found with a P-value of .804 (Table 5.2).

Table 5.2 EIP and MH two-way ANOVA test results

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.981[a]	15	.265	1.455	.124
Intercept	11.059	1	11.059	60.629	.000
Culture	.011	1	.011	.062	.804
Trait	1.517	7	.217	1.188	.310
Culture * Trait	1.456	7	.208	1.140	.339
Error	39.582	217	.182		
Total	58.000	233			
Corrected Total	43.562	232			

a. R Squared = .091

Levene's Test of Equality of Variance was used to evaluate patterns of fluctuating asymmetry displayed by each trait independently between the two time periods. Four of the eight traits revealed statistically significant inequality of variance between time periods (Table 5.3). Interaction plots of these traits were visually assessed to determine the effect of time periods on levels of fluctuating asymmetry. Three of the four statistically significant traits, UM2C5, UM1Met, and UM2Hyp (Figures 5.1 – 5.3), indicate that the Middle Horizon populations experienced significantly more fluctuating asymmetry than the Early Intermediate Period. One trait, UM2Met (Figure 5.4), indicates the opposite effect with fluctuating asymmetry being lower in the Middle Horizon.

Table 5.3 Levene's Test results for EIP and MH

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
UM1Car	.165	1	33	.687
UM2C5	6.650	1	31	.015
UM1Met	17.490	1	40	.000
UM2Met	3.718	1	39	.061
UM2Hyp	3.505	1	32	.070
UM2Car	.100	1	34	.754
UM1Hyp	1.468	1	42	.232
UM2Ex	.540	1	33	.468

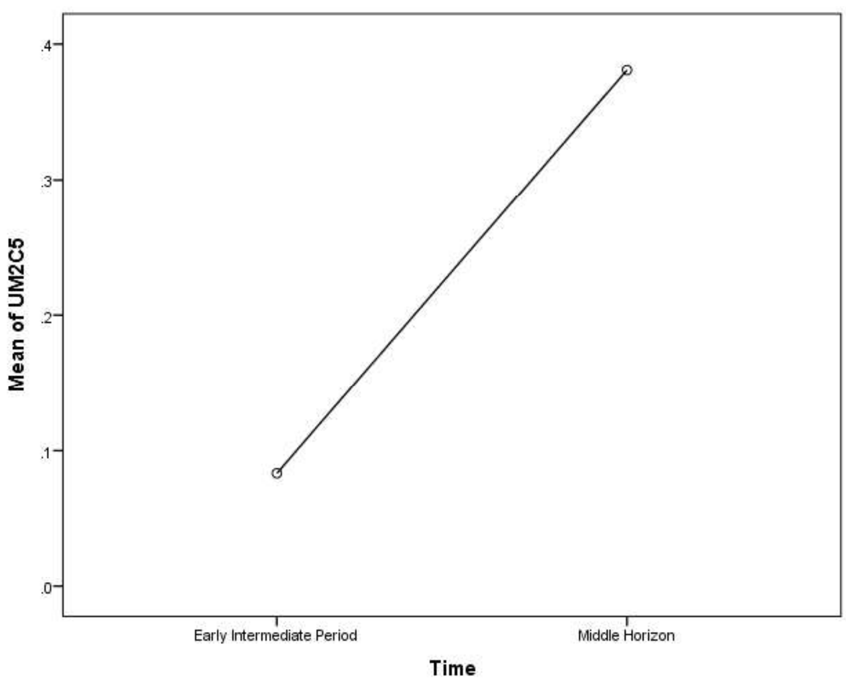

Figure 5.1 Interaction plots of UM2C5

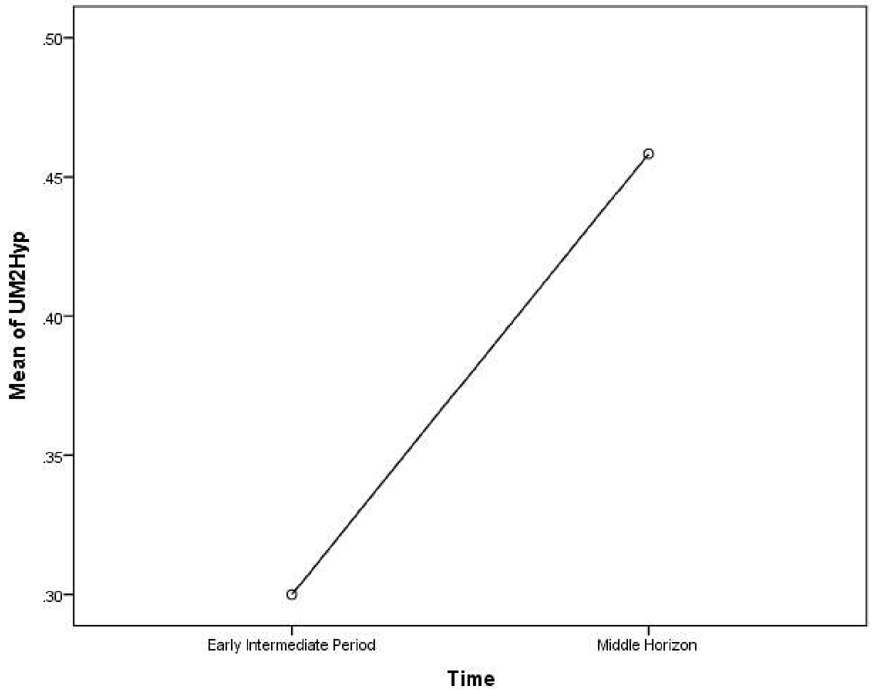

Figure 5.2 Interaction plots of UM2Hyp

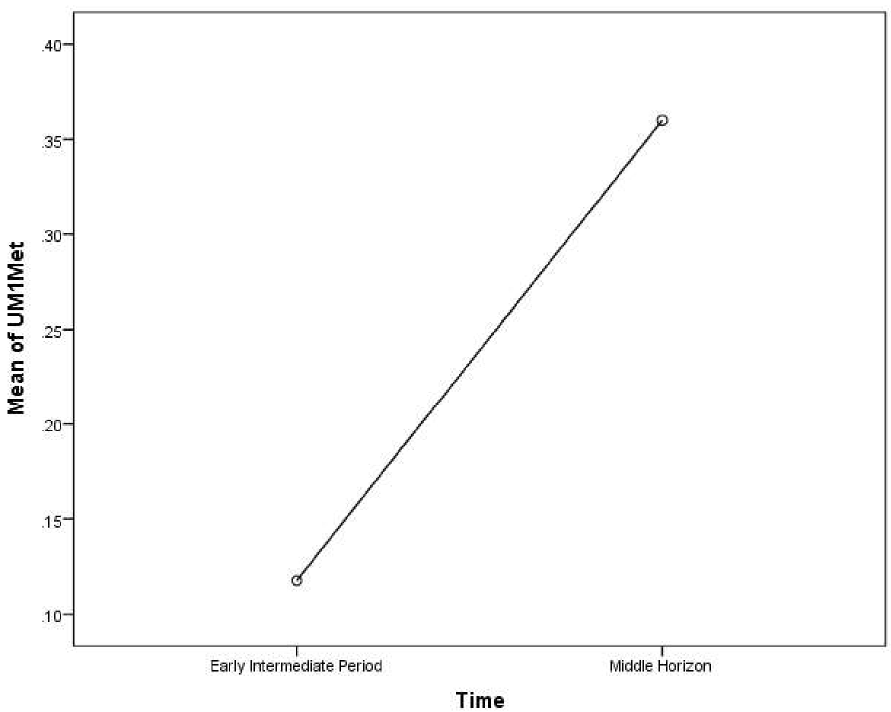

Figure 5.3 Interaction plots of UM1Met

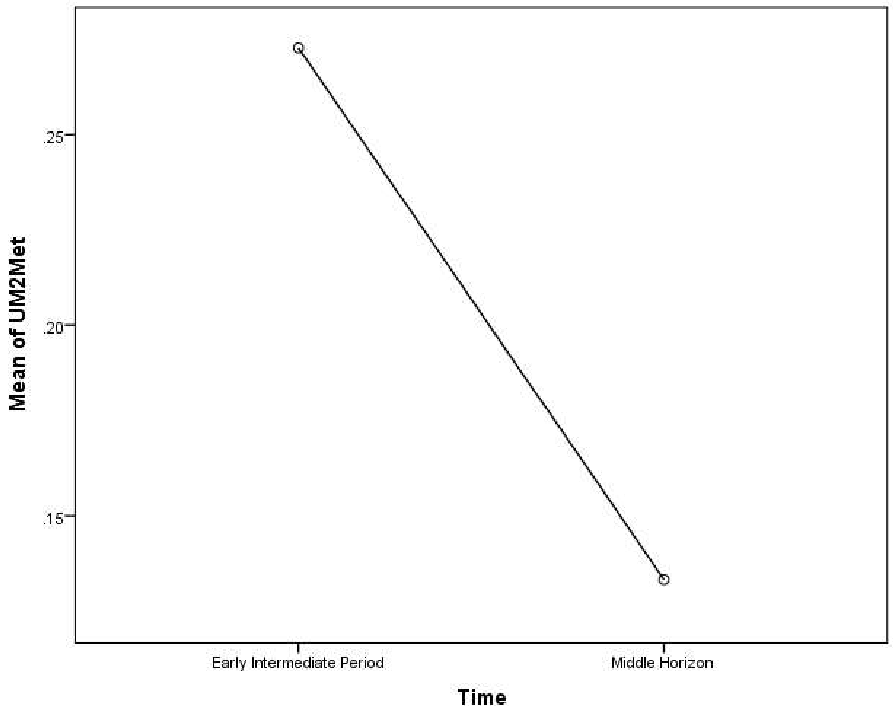

Figure 5.4 Interaction plots of UM2Met

5.3 Analysis of Culture Groups

The groups were further divided to analyze variation in levels of asymmetry within the time periods. The two time periods were split into the four groups: Middle Nasca, Late Nasca, Loro, and Chakipampa. The Early Nasca sample was excluded due to the small sample (n = 3). The test statistic for the variance between cultures in the two-way ANOVA of 8 traits × 4 groups is p = .160 (Table 5.4), not statistically significance at the alpha p = .10 level, though much more significant than the two-way ANOVA between the Early Intermediate Period and the Middle Horizon, with p = .804. The R-squared value for this analysis shows that the four small groups account for more of the variance in fluctuating asymmetry between groups (R-squared = 20.7%) than the two time periods (R-squared = 9.1%).

Table 5.4 Two-way ANOVA of 8 traits x 4 groups

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	22.748[a]	33	.689	1.574	.032
Intercept	12.829	1	12.829	29.298	.000
Groups	2.913	4	.728	1.663	.160
Traits	10.992	7	1.570	3.586	.001
Goups * Traits	9.312	22	.423	.967	.508
Error	87.141	199	.438		
Total	136.000	233			
Corrected Total	109.888	232			

a. R Squared = .207

Visual inspection of the effect of cultures via interaction plot displays differing levels of fluctuating asymmetry between each group (Figure 5.5). Fluctuating asymmetry is at its highest levels among the Chakipampa and lowest during the Middle Nasca Period. Traits displayed statistically significant variance (p = .001). This source of variance suggests that some traits are repeatedly less developmentally stable than others. This warranted further investigation in attempt to elucidate which traits displayed fluctuating asymmetry at differing levels.

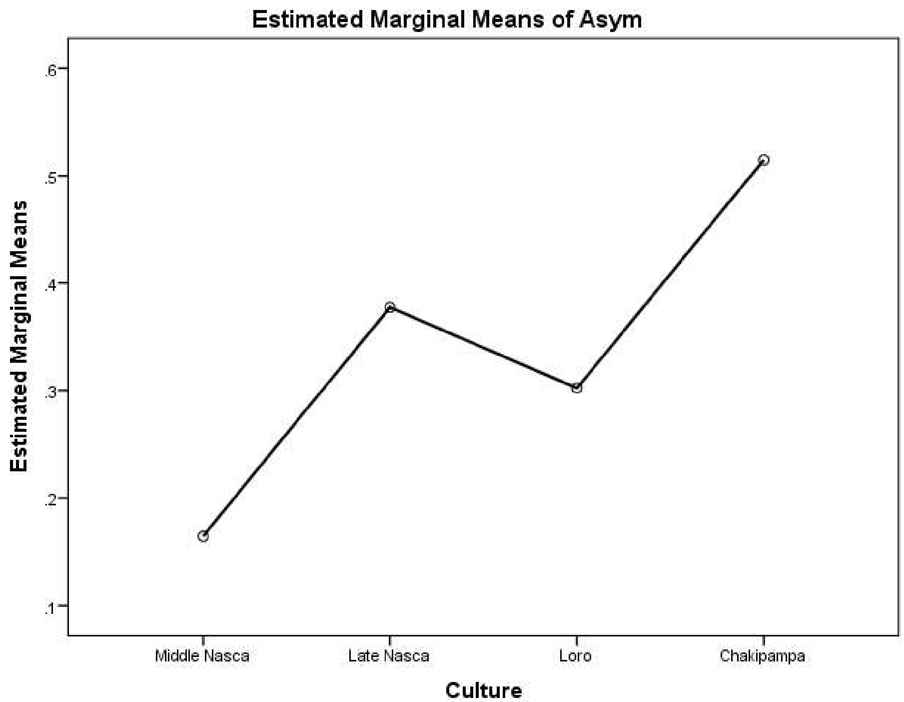

Figure 5.5 Interaction plot of two-way ANOVA test between cultures

Levene's Test for 8 traits × 4 groups displayed consistent patterns of fluctuating asymmetry between groups (Table 5.5). The effect of fluctuating asymmetry here is also consistent with the effect from the two-way ANOVA of fluctuating asymmetry between the four groups. Two traits, UM2Car and UM2Ex were not included in this analysis because each had one group with too small of a sample size for the analysis. Patterns of asymmetry between groups in statistically significant traits are displayed in Figures 5.6 – 5.9. The interaction plots display quite consistent patterns of fluctuating asymmetry with Chakipampa experiencing the highest levels.

Table 5.5 Levene's Test between cultures

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
UM2Hyp	2.661	3	26	.069
UM2C5	18.737	3	24	.000
UM1Met	15.605	3	31	.000
UM2Met	1.886	3	32	.152
UM1Hyp	.253	3	32	.859
UM1Car	3.089	3	24	.046

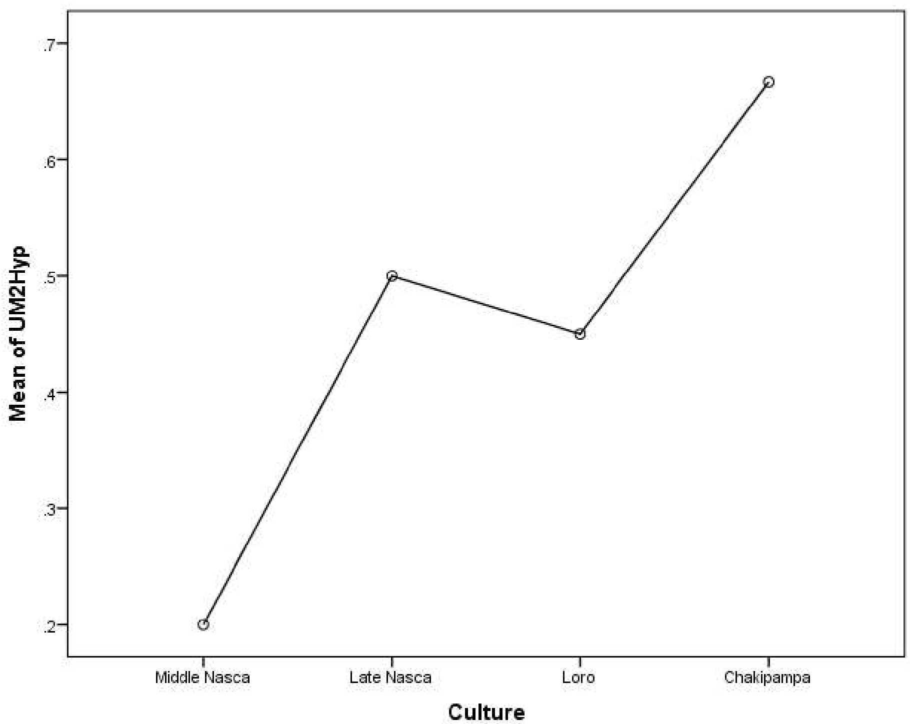

Figure 5.6 Interaction plots for Levene's Test of UM2Hyp

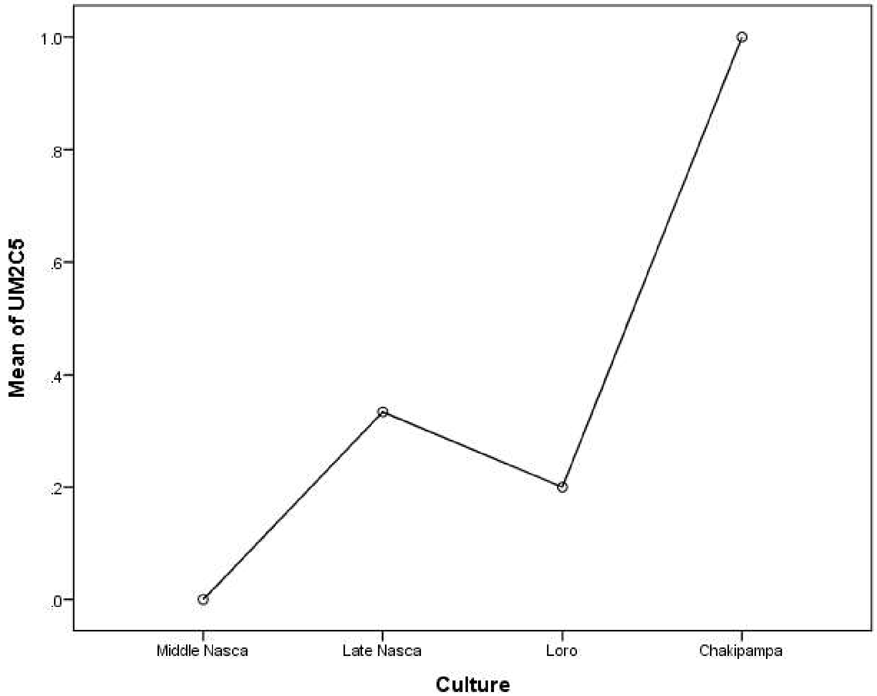

Figure 5.7 Interaction plots for Levene's Test of UM2C5

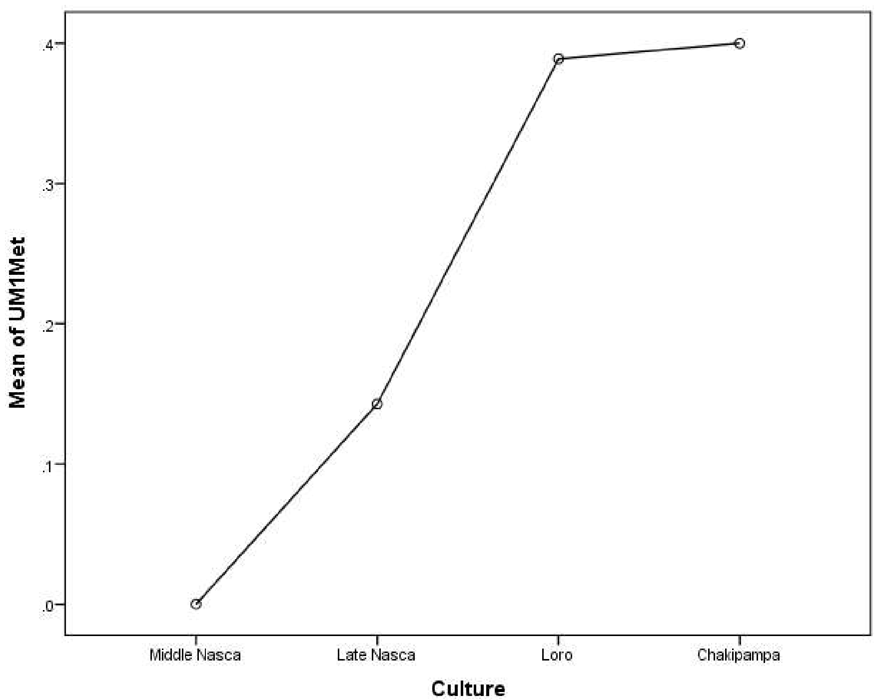

Figure 5.8 Interaction plots for Levene's Test of UM1Met

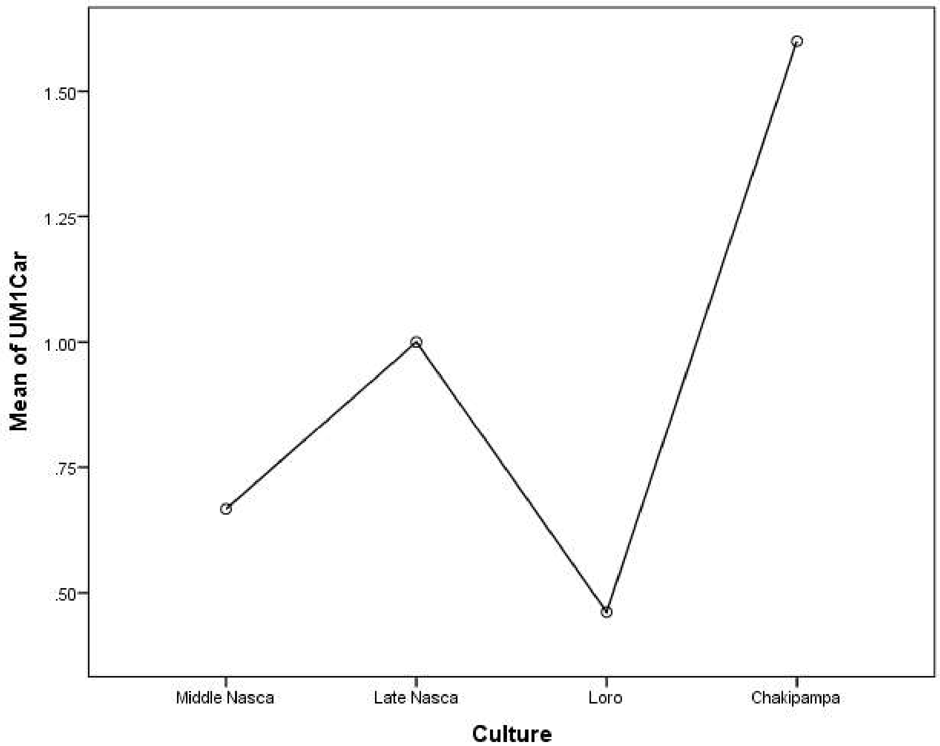

Figure 5.9 Interaction plots for Levene's Test of UM1Car

CHAPTER 6. DISCUSSION AND CONCLUSION

Fluctuating asymmetry analysis of dental nonmetric traits revealed patterns of stress incurred by populations living in Nasca during the Early Intermediate Period and Middle Horizon. The results of this analysis are discussed in regards to archaeological evidence for environmental stress between groups. This chapter concludes the thesis and addresses the hypothesis.

6.1 Discussion

The Nasca in the Early Intermediate Period experienced relatively favorable living conditions during Early Nasca, while ecological and sociopolitical degradation plagued the latter part of the Early Intermediate Period, extending into the Middle Horizon. Archaeological and ecological evidence indicate increased stressors later in time, specifically caused by both environmental and sociopolitical conditions (Beresford-Jones et al. 2009; Drusini et al. 2001; Kellner 2002; Schreiber and Lancho Rojas 1995; Thompson et al. 1985). Increased aridity resulted in droughts causing food shortages. The highland Wari began invading the Nasca territory. The Loro ceramic style represents the local Nasca tradition while the Chakipampa style represents an incorporation of Wari culture and people. This study addresses how environmental stressors impacted humans living in Nasca through these time periods.

6.1.1 Discussion of Hypothesis

The two-way ANOVA of fluctuating asymmetry between two time periods failed to show differences in variance of fluctuating asymmetry between the Early Intermediate Period and Middle Horizon. However, an analysis of each trait independently displayed an effect between time periods with 75% of the statistically significant traits indicating increased fluctuating asymmetry in the Middle Horizon. The inconclusive results of fluctuating asymmetry between these two time periods can be attributed to the large amount of time and events encompassed within each period.

Archeological evidence suggests that the Early Intermediate Period includes times of prosperity and relatively low stress, namely Early Nasca (Schreiber and Lancho Rojas 1995), but also times of environmental distress and increased violence in Middle and Late Nasca (Proulx 1994). The Middle Horizon encompasses less time than the Early Intermediate Period, but two groups are included in this sample that may have experienced different environmental stressors, Loro and Chakipampa. With the variability of stressors occurring within each time period, a more nuanced view into fluctuating asymmetry in each time period was warranted.

Division of the large time periods into distinct groups provided a way to interpret differential stress patterns as connected to unique stressors within each time period. The two-way ANOVA testing the interaction between fluctuating asymmetry of multiple traits and four groups (Middle Nasca, Late Nasca, Loro, and Chakipampa) better explained the source of variation with R-squared = 20.7% in this analysis compared to R-squared = 9.1% of variation being explained by the Early Intermediate Period and Middle Horizon grouping. The smaller groups also resulted in a more significant variance in fluctuating asymmetry between groups at p = .160 compared to p = .804 for the analysis of two time periods. Inspection of the interaction plot revealed variation between each group with an overall increase in fluctuating asymmetry through time.

Traits displayed statistically significant variance (p = .001). This source of variance suggests that some traits are repeatedly less developmentally stable than others. This warranted further investigation in attempt to elucidate which traits displayed fluctuating asymmetry at differing levels. Levene's Test was used to analyze fluctuating asymmetry between each trait separately. Statistically significant traits, revealed very similar trends that correlated with the two-way ANOVA test of variance between four groups. Fluctuating asymmetry in each trait was highest in Chakipampa and lowest in Middle Nasca. Once again Loro experienced lower levels of asymmetry than Chakipampa.

The analysis of fluctuating asymmetry between groups in Nasca supports the hypothesis that environmental stress increased through time from the Early Intermediate Period to the Middle Horizon. The increase in stress occurred only among Chakipampa individuals in the Middle Horizon. As expected, Loro experienced low levels of stress compared to the Chakipampa, but also low levels compared to Early Intermediate Period populations.

6.1.2 Stress in Nasca

Stress is produced through a complex interaction between environmental stressors, biological host resistance factors, cultural adaptation to resist stressors, and stressors resulting from cultural adaptation (Goodman and Martin 2002). Biological adaptation does not account for differences in adaptation to stressors that exist between groups in

Nasca because they are biologically similar populations. Differences in stress levels between populations observed in this study likely resulted from cultural factors. Archaeological evidence suggests human-induced environmental change and Wari imperialism are likely the cultural factors correlated with increased stress in Nasca populations.

The Middle Nasca sample displayed the lowest level of fluctuating asymmetry. This result was unexpected as archaeological data suggest this time period suffered from extreme drought. While low levels of surface water plagued this time period, a technological innovation is hypothesized to have lessened the effects of drought, at least temporarily. Puquios, an aqueduct system developed during this time period, tapped into underground water systems. This helped to reduce environmental stress by alleviating the affects and the fear of drought (Schreiber and Lancho Rojas 2003).

Results from this study suggest that environmental stressors in Middle Nasca may have caused less stress than in Late Nasca. Another possible explanation is that the Middle Nasca individuals in this sample may reflect a unique group that did not experience environmental upheaval theorized to have occurred at the latter part of the Early Intermediate Period. Whalen (2014: 341) has suggested that "(b)oth Middle and Late Nasca…present overlapping and regionally situated reactions to the collapse of Cahuachi." Radiocarbon dates from the Late Nasca site, Cocahuischo indicate that building commenced shortly after the collapse of Cahuachi in Early Nasca. Similar to these results, osteological analysis by Kellner (2002: 106) found that "the Middle Nasca period individuals exhibit an interesting mix of data regarding health, activity patterns, and cultural practices." While a trend can be seen in these studies, the fluctuating asymmetry results from Middle Nasca should be taken with caution because of the small sample size for this period (n=10).

A spike in fluctuating asymmetry occurred during the Late Nasca period. Increased stress experienced by individuals in Late Nasca correlates with prior osteological data from Kellner (2002) and Tomasto Cagigao (2009a). Along with population size, settlement size and sociopolitical complexity also increased during this period. Social stratification led to greater health inequality (Carmichael 1988; Tomasto Cagigao 2009a). Higher stress levels are tied to increased interpersonal violence (Kellner 2002; Tomasto Cagigao 2009b; Knudson et al. 2009). Evidence for violent conflict correlates with increased Wari influence during Late Nasca (Proulx 1994). The end of the Early Intermediate Period saw an influx of new stressors including Wari influence, violence, and increased social inequality.

Table 6.1 Prior osteological results for stress indicators from the Early Intermediate Period to the Middle Horizon

	Early Intermediate Period	**Middle Horizon**
Drusini et al. 2001	Low infant mortality rate. High life expectancy.	High infant mortality rate. Low life expectancy.
Kellner 2002	**Early**: n=21. Low rates of linear enamel hypoplasia, porosities, osteoarthritis. High rate of dental pathologies and trauma.	**Chakipampa**: n=28. Highest rates of linear enamel hypoplasia, osteoperiostitis, and dental pathologies. Higher rates of trauma, porosities, osteoarthritis than Loro.
	Middle: n=28. High rates of osteoarthritis and elevated levels dental pathologies. Lower trauma than Early Nasca.	
	Late: n=22. High rates of cranial porosities, cranial trauma, and trophy head taking. Decreased stature. Low rates of dental pathologies.	**Loro**: n=123. High rates of osteoarthritis. Lower rates of linear enamel hypoplasia, trauma, porosities, and osteoarthritis than Chakipampa.
Tomasto Cagigao 2009a	n=114. Lower rates of carious lesions than Middle Horizon.	n=34. High rates of carious lesions.
Tomasto Cagigao 2009b	n=92. High rates of trauma.	n=19. High rates of spongiosclerosis.

These trends (summarized in Table 6.1) continued with the Chakipampa in the Middle Horizon. In this time period, two groups lived in the Nasca region. Loro is the ceramic style affiliated with the continued local Nasca identity, while Chakipampa represented the local Nasca -Wari hybrid style. In this study these two groups are only differentiated by associated ceramic styles in burials; they may represent distinct cultural groups (Kellner 2002). The two groups experienced very different levels of fluctuating asymmetry, suggesting that individuals within a ceramic style experienced common stressors. The role adopted by Wari immigrants in the Nasca region is thought to be an administrative position, extracting resources from the area and eliciting the help of local people (Edwards, 2010).

Beresford-Jones (2011) concludes that ecological degradation correlates with archaeological evidence for degrading conditions beginning in the Late Nasca period and continuing into the Middle Horizon. Tomasto (2009) found that increased osteological indicators of stress manifested on the skeletal remains of the Middle Horizon sample compared to earlier time periods, but she reports a small sample size. Kellner's (2002) Middle Horizon conclusion is consistent with Tomasto's, as she reports the need for an osteological study with a larger sample size to produce a more nuanced view into the human condition in the Middle Horizon. Drusini (2001) too concludes worsening conditions in the Middle Horizon. Similar to past studies, the results reported here support the scenario of worsening conditions in the Middle Horizon. However, this study suggests that the Middle Horizon was not a homogenous population and the Loro experienced far less environmental stress than the Chakipampa.

The Chakipampa exhibited the highest levels of fluctuating asymmetry of all of the samples and Loro exhibited relatively low levels. Kellner (2002:110) concluded that Chakipampa individuals exhibited far more cranial trauma as Loro individuals. The stress and violence experienced by Chakipampa individuals may have resulted from tension between the Wari imperialists and local Nasca. This tension was not found in Loro individuals. Furthermore, the Southern Nasca Region experienced a decrease in population size, while Huaca del Loro experienced an increase (Schreiber and Lancho Rojas 2003). Loro population growth and low rates of violence correlates with the low stress levels found among Loro individuals in this study.

I suggest that cultural factors resulted in differing stress levels between the two Middle Horizon populations. The two groups lived with very different environmental stressors, though they occupied some of the same areas. Chakipampa individuals suffered from the Wari's successful gain of control. Archaeological evidence from Pataraya suggests Wari extracted resources such as cotton from Nasca to the Wari heartland (Edwards 2010). They co-opted the economy of some Nasca communities (Schreiber 2000). Sociopolitical change as the Wari gained power coupled with their removal of Nasca resources, may account for increased stress incurred by the Chakipampa. Meanwhile, the Loro avoided the stress involved with Wari colonization.

6.1.3 Limitations of Results

Osteological analysis is limited by the archaeological preservation of human remains. Preservation of samples posed a concern in this study. Sample sizes are relatively small due to tooth wear obscuring many occlusal traits and many missing teeth, which decreased the statistical power. The small sample size from this study reflects populations from only six cemeteries in Nasca. Furthermore, the Early Nasca sample was too small to be included in the analysis. A larger sample from this period would have more accurately portrayed stress levels throughout the Early Intermediate Period.

As pointed out in the Osteological Paradox, stress markers on skeletal remains do not portray acute and severe stressful experiences that lead to death before affecting the skeleton (Wood et al. 1992b). This study aimed to overcome these uncertainties by interpreting the results of the fluctuating asymmetry analysis in terms of archaeological data for stressors. These limitations can be further overcome through continued analysis of this collection utilizing diverse osteological methods and a larger sample size.

6.1.4 Summary of Discussion

Fluctuating asymmetry levels presented in this study, taken with low levels of violence and population growth found in prior studies supports the hypothesis that Loro individuals experienced less stress throughout life than did Chakipampa individuals. The Nasca were faced with multiple interacting stressors during the Early Intermediate Period including environmental and sociopolitical stressors. Through the innovation of puquios they became better adapted to sporadic droughts that plagued the Middle Nasca period. If stress is taken as a measure of population adaptation to the environment, they became better adapted to the environment than Chakipampa. Taken together, multiple interacting stressors account for the high level of developmental instability among the Chakipampa.

6.2 Conclusion

The purpose of this thesis is to provide insight into the human experience in Nasca, specifically in regards to stress experienced through the Early Intermediate Period and the Middle Horizon. Skeletal analyses of human remains allow bioarchaeologists to make inferences about the complex relationship between biology, culture, and the environment in past societies utilizing contextual information from archaeology. The biocultural perspective provides a framework for evaluating the biological consequences of multiple interacting stressors at work including environmental, political-economic, ideological, and sociocultural stressors in Nasca. Comparing population levels of fluctuating asymmetry across time periods allows insight into changes in population level stress over time. Stressors are better understood alongside archaeological data of environmental and cultural conditions contemporaneous with changes in population level fluctuating asymmetry.

In summary, biological consequences of environmental stressors were evaluated through an analysis of dental fluctuating asymmetry, a measure of developmental instability resulting from stress. Results support the hypothesis that stress levels peaked during the Middle Horizon among the Chakipampa. Stress differed among groups within each time period. The Early Nasca sample could not be analyzed due to a small sample size. Developmental instability rose from the Middle Nasca period to the Late Nasca period. The Middle Horizon groups, Loro and Chakipampa, experienced different levels of fluctuating asymmetry. Loro individuals experienced the lowest levels of all groups. Conversely, Chakipampa experienced the highest levels. The relationship between the Wari and the local Nasca in the Middle Horizon is poorly understood. The results here suggest that the two groups lived with very different environmental stressors, and support the scenario that the Wari colonized local Nasca people to fulfill economic needs. In this model the Chakipampa represent Wari colonized people who lived in Nasca and suffered from stress involved with colonization, and the Loro represent the local Nasca that avoided colonization.

Future research should further investigate societal differences in health patterns and the relationship between the Loro and Chakipampa in the Middle Horizon. A larger sample size for Middle Horizon populations would provide greater insight into stress incurred by both populations. More broadly, these populations provide a long-term evaluation of the human condition in response to colonization and human-induced climate change.

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APPENDIX

APPENDIX

Table A 1 List of Burials

ID	Burial ID	Cemetery	Cultural Group	Sex	LUM2 Hyp	RUM2 HYP	LUM1 MET	RUM1 MET	LUM2 C5	RUM2 C5	LUM1 CAR	RUM1 CAR	LUM2 MET	RUM2 MET	LUM1 HYP	RUM1 HYP	LUM2 CAR	RUM2 CAR	LUM2 EX	RUM2 EX
86	2/2485	Pampon	Late Nasca				5	5			0	0			5	5				
94	3/108	La Marcha	Loro	Male						0				5						
97	3/2906	La Marcha	Early Nasca	Female		2		5		0				4		5				
101	5/3208	La Marcha	Middle Nasca	Male	4	4	4		0	0			3.5	3	5					
107	5/187	La Marcha	Loro	Male									4	4						
109	5/203	La Marcha	Loro	Female	1		4	5	0				3.5		4	4				
115	5/3310	La Marcha	Loro	Male					0	0			4	4				0		
117	5/3287	La Marcha	Loro	Male																
119	2/2655	Pampon	Late Nasca	Female			4				3	3			4		0		0	
126	5/178	La Marcha	Loro	Female																
134	30/72		Loro	Male	1	2	5	4	0	0			4	4	4	4				
135	30/81		Loro	Male		1				0				4			0	0	0	0
137	30/176		Middle Nasca	Male																
141	30/47		Loro	Female		3		5		0	0	0		5	4	4	0		0	
143	2/2529	Pampon	Late Nasca				4	4			0	0			4	5	0	0	0	0
144	2/324	Pampon	Middle Nasca		1	2	4	4	0	0	1	1	4	4	4	4				
148	1/317	Los Medanos	Middle Nasca	Male														0		0
153	1/316	Los Medanos	Middle Nasca	Male	3	3	5	5	0	0			4	4	4	4	2	2	0	0
156	1/900	Los Medanos	Middle Nasca	Female			3.5	3.5			0	0			3.5	4				

ID	Burial ID	Cemetery	Cultural Group	Sex	LUM 2Hyp	RUM 2HYP	LUM1 MET	RUM1 MET	LUM2 C5	RUM2 C5	LUM1 CAR	RUM1 CAR	LUM2 MET	RUM2 MET	LUM1 HYP	RUM1 HYP	LUM2 CAR	RUM2 CAR	LUM2 EX	RUM2 EX
157	1/1311	Los Medanos	Chakipampa	Female			5	5			1	1			4	4			0	0
161	1/2231	Los Medanos	Loro	Female																
163	1/3705	Los Medanos	Chakipampa	Male																
164	1/1473	Los Medanos	Loro				5				5	5			5			0		
168	1/3652	Los Medanos	Chakipampa	Male		3	4			0	0	0		4	4		0			
169	1/3819	Los Medanos	Loro		3	3	4	5	0	0	0	0	4	4	5	4				
170	1/1354	Los Medanos	Loro	Male													2	0	3	0
171	1/995	Los Medanos	Chakipampa	Female													1			
173	1/1353	Los Medanos	Chakipampa	Female	3.5				0				2							
176	1/1886	Los Medanos	Loro	Female	3	3	4		2		0	0	3.5	3.5	5					
178	10/4625	Chiquerillo	Loro	Female	3	4	5	5	0	0	0	0	4	4	4	4				
181	1/1457	Los Medanos	Loro	Male	3	3							4	4			5		0	
188	1/1990	Los Medanos	Late Nasca	Female	3				0	0			4	4						
192	1/1958	Los Medanos	Loro	Female																
193	1/3521	Los Medanos	Loro	Male																
194	1/520	Los Medanos	Chakipampa		2	2		3	0	0			3	3		3				
198	1/1645	Los Medanos	Chakipampa	Female	3				0				4							
201	1/846	Los Medanos	Loro	Female		0		3.5						3		4				
202	1/846	Los Medanos	Late Nasca	Female													0	0	0	
203	1/1565	Los Medanos	Loro		3	3	3.5	3.5	0	0	0	0	3	3	3	3			0	0
206	1/1614	Los Medanos	Loro	Female	2		3.5	4	0		0	0	3		4	3.5	0			
207	1/1205	Los Medanos	Early Nasca	Male													0	0	2	0
209	1/43	Los Medanos	Late Nasca	Male																0
210	1/683	Los Medanos	Loro	Female			4	4			0	0			4	4				
211	1/2137	Los Medanos	Loro				3.5	4							4	4				
214	1/132	Los Medanos	Loro																	
216	1/2124	Los Medanos	Loro		1	2	4	5		0	0	0		4	4	4				

ID	Burial ID	Cemetery	Cultural Group	Sex	LUM 2Hyp	RUM 2HYP	LUM1 MET	RUM1 MET	LUM2 C5	RUM2 C5	LUM1 CAR	RUM1 CAR	LUM2 MET	RUM2 MET	LUM1 HYP	RUM1 HYP	LUM2 CAR	RUM2 CAR	LUM2 EX	RUM2 EX
217	11/4777	Wayuri	Chakipampa	Male													0	0	0	0
218	11/4769	Wayuri	Chakipampa	Female	2	99	4	99	0	99	0	0	3.5	99	3.5	99				
219	1/46	Los Medanos	Late Nasca	Female			3.5	4			3	3			4	4	0	0	0	0
220	1/1004	Los Medanos	Chakipampa	Female													99	0	99	2
221	1/1240	Los Medanos	Early Nasca	Male			4	99							3.5	99	99	0	99	0
223	1/129	Los Medanos	Loro	Female													0	0		
224	1/49'	Los Medanos	Late Nasca	Male	1	99							4	99						
226	11/477'	Wayuri	Chakipampa		1	2	4	5	2	0	0	0	4	5	4	4				
239	1/055	Los Medanos	Late Nasca	Male																
240	1/41	Los Medanos	Late Nasca	Female													1	0	0	1
247	11/4770	Wayuri	Chakipampa	Female																
251	1/123	Los Medanos	Loro		1	1	4	4	0	0			4	4	3.5	3.5	0	99	0	99
253	1/1811	Los Medanos	Loro	Female																
256	1/3972	Los Medanos	Loro	Male			4	4							5	5				
265	1/099	Los Medanos	Loro																	
266	1/096	Los Medanos	Late Nasca	Male													0	99	0	99
271	1/095	Los Medanos	Late Nasca	F	3	3	3.5	3.5	0	0	2	2	3.5	3	4	4	0	0	0	0
285	1/093	Los Medanos	Late Nasca	Male																
293	1/430	Los Medanos	Late Nasca		3	2	4	4	0	1	3	3	3.5	3.5	5	5				
298	10/4647	Chiquerillo	Loro	Female	3	3			99	2			3	3						
299	1/875	Los Medanos	Loro	Female	3	3	4	99	0	0	0	0	3	3	3	99	0	0		
300	1/3651	Los Medanos	Chakipampa	Female	3.5	99	4	99	0	99	0	0	4	99	4	99	0	0	0	0
302	1/1328	Los Medanos	Chakipampa	Female	99	2			0	0			3.5	3.5					1	99
306	1/3814	Los Medanos	Loro		2	2	3.5	3.5	0	0			4	3.5	5	5	99	0	99	99
307	1/345	Los Medanos	Loro				99	4			3	3			99	4	2	2	0	0
308	1/599	Los Medanos	Loro	Female									99	4						
309	1/1026	Los Medanos	Loro	Female	99	2	4	4	99	0	3	3	99	3	4	4				

ID	Burial ID	Cemetery	Cultural Group	Sex	LUM 2Hyp	RUM 2HYP	LUM1 MET	RUM1 MET	LUM2 C5	RUM2 C5	LUM1 CAR	RUM1 CAR	LUM2 MET	RUM2 MET	LUM1 HYP	RUM1 HYP	LUM2 CAR	RUM2 CAR	LUM2 EX	RUM2 EX
310	1/880	Los Medanos	Loro	Male	99	3	4	4	99	0	0	0	99	3	4	4	0	0		
314	1/1388	Los Medanos	Chakipampa	Female	99	2			99	0			99	3						
315	1/133	Los Medanos	Loro	Female	2	1			0	1			4	3.5					99	0
316	1/422	Los Medanos	Late Nasca	Male													99	0	99	1
317	1/1977	Los Medanos	Late Nasca	Female			3	3			0	0			3	3	99	0	99	0
322	1/734	Los Medanos	Loro		2	3	4	4	0	0	99	99	4	4	5	5				
325	1/1179	Los Medanos	Early Nasca	Male																
327	1/269	Los Medanos	Loro	Female			99	3.5							99	3	0	0	0	0
328	1/1614	Los Medanos	Loro				4	99			0	0			4	99				
329	1/2194	Los Medanos	Loro	Female	3	99	4	99	0	99			3.5	99	3.5	99				
330	10/4691	Chiquerillo	Chakipampa	Male	3	99			0	99			3.5	99			99	99	99	99
338	1/769	Los Medanos	Chakipampa				4	4			0	0			3.5	3.5				
339	1/130	Los Medanos	Loro	Female	99	4	4	4	99	0			4	4	4	4	0	0	2	99
350	1/1974	Los Medanos	Loro				3.5	4			0	0			3	3.5	99	1	0	99
352	1/431	Los Medanos	Loro	Female	2	2	3	4	0	0	0	0	3	3	4	4	0	0	0	0
353	1/255	Los Medanos	Loro	Female	2	99	99	4	3	99	99	99	3	3	99	4			0	0
356	1/796	Los Medanos	Late Nasca		1	99	4	4	0	99	2	2	3	99	3.5	3.5				
358	1/3631	Los Medanos	Loro	Male	3	99	5	99			0	0	5	99	5	99				
366	1/203	Los Medanos	Late Nasca	Female													0	0	1	0
370	1/3462'	Los Medanos	Chakipampa				3.5	3.5							5	4	99	0	99	0
379	30/34		Loro	Female	2	1	4	99	0	0	0	0	4	4	3	99				
386	1/326	Los Medanos	Middle Nasca	Male	2	1			0	1			4	4						
381	1/574	Los Medanos	Loro	Male																
413	1/517	Los Medanos	Loro	Female					99	0							0	0		
414	1/2264	Los Medanos	Middle Nasca	Male					99	0										
415	1/953	Los Medanos	Middle Nasca	Female					0	0										