FLUCTUATING ASYMMETRY: A CRANIOFACIAL COMPARISON TO BETTER UNDERSTAND CENTRAL AMERICAN AND MEXICAN MIGRATION

by

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DEDICATION

To 19-, 22-, and 32-year-old me. Thank you for not giving up. To future me, "I hope you live the life you are proud of. If you find that you are not, I hope you have the strength to start all over again".

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My go to coffee shops, thank you for giving me a space to get my life together.
Coffee Talk, Honolulu, HI
Blue Tree Cafe, Honolulu, HI
Morning Brew, Kakaako, HI
Tentra, San Marcos, TX
Mochas & Javas, San Marcos, TX
Wake the Dead Coffee House, San Marcos, TX
Jo on the Go, San Marcos, TX
The Coffee Bar, San Marcos, TX

My go to bars, thank you for giving me a space to let go.
Side Street Inn on the strip, Honolulu, HI
Sandvilla, Waikiki, HI
Zelicks, San Marcos, TX
Treffs, San Marcos, TX

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LIST OF ABBREVIATIONS

Abbreviation	Description
FA	Fluctuating Asymmetry
SES	Socioeconomic Status
NAFTA	North American Free Trade Agreement
IIRIRA	Immigration Reform and Immigration Responsibility Act
MS-13	Mara Salvatrucha 13
B-18	Barrio-18
UBC	Undocumented Border Crosser
USBP	United States Border Patrol
OpID	Operation Identification
PCOME	Pima County Office of the Medical Examiners
BDC	Bass Donated Collection
PAHO	Pan American Health Organization

I. INTRODUCTION

An extraordinary number of migrants from Latin America have fled their countries of origin to escape deteriorating social, economic, and political conditions. Seeking refuge in the United States, migrants have no choice but to risk their lives trekking through dangerous and deadly terrain to reach the U.S.-Mexico border. Attempts to reach the U.S. have led to thousands of migrant deaths every year (Anderson, 2008). It is estimated that 200 to 500 skeletal remains are found along the U.S.-Mexico border every year – a likely underestimation of deaths, as individuals remain unidentified and/or unrecovered (Alonso & Nienass, 2016; Anderson, 2008; Giordano & Spradley, 2017). Perpetuated by the destabilization of Latin America, the mounting loss of life along the U.S.-Mexico border and the lack of adequate resources for local and government agencies to cope characterizes this situation as a mass disaster (Ciottone, 2006; Francesch et al., 2009), which continues to remain largely unnoticed.

Following a series of Border Patrol policies beginning in the 1990s, the U.S. government began heavily funding and increasing border patrol personnel, criminalizing migration, and increasing deportations. In 1994, the Border Patrol implemented the "prevention through deterrence" strategic plan under the assumption that strengthened controls over major migration entry points would deter illegal entry into the United States (Argueta, 2016). Implemented in three phases, the plan proved to be ineffective and only pushed migration routes through inhospitable environments, particularly the Arizona Sonora Desert. "Prevention through deterrence" essentially created a "funneling" effect, giving migrants no other choice but to brave the harsh conditions of the desert, many times without sufficient supplies (Anderson, 2008). After the 9/11 attacks, the U.S.

government utilized the event to legitimize the reinforcement of the U.S.-Mexico border by constructing additional infrastructure, implementing military-style operation strategies, and using military-style technology (Jones, 2016).

The fortification of major migration entry points in California and New Mexico have pushed migration to remote areas of Texas and Arizona, which mark the points of entry where the majority of migrant deaths occur (Giordano & Spradley, 2017). Individuals migrating through the U.S.-Mexico border are primarily from Central America and Mexico. Since 2012, migration routes taken through the state of Texas have been predominantly taken by Central American migrants from the "Northern Triangle" (i.e., Guatemala, Honduras, and El Salvador), while routes through the state of Arizona have been taken by Mexican migrants (U.S. Customs and Border Patrol, 2019). Migration routes of Central Americans through Texas are likely chosen because they are the shortest distance between Central America and the U.S. (Isacson and Meyer, 2013). When reaching the border, Central American migrants continue north toward large cities like Dallas and Houston for greater employment opportunities (Isacson and Meyer, 2013). Mexican migration routes through the state of Arizona are likely due to pull factors resulting from historic U.S. migrant work programs, as well as proximity between both countries.

Several push factors force migration to the U.S. including economic inequality, gang/drug-violence, lack of opportunity, and political corruption (Pew Research Center, 2009; Lesser and Batalova, 2018). Dire social, economic, and political conditions in Latin America vary due to each country's historical context but are largely rooted in U.S. policies and intervention. These conditions cause environmental stressors that have

shown to have adverse effects on developmental stability, affecting physical growth and manifesting markers of developmental stress (Beasley, Bonisoli-Alquati, & Mousseau, 2013; Møller, 2006; Tomkins & Kotiaho, 2002).

Bilateral structures, namely the human skull, should develop symmetrically. However, challenged with developmental stress, deviations from perfect symmetry can arise, defined as fluctuating asymmetry (FA) (Palmer & Strobeck, 1986). Fluctuating asymmetry has served as a measure of phenotypic variability and environmental stress (Graham & Ozener, 2016; Ozener, 2010; Weisensee & Spradley, 2018). The purpose of the present research is to compare craniofacial FA between Central American and Mexican migrant groups to better understand skeletal manifestations of environmental stress, as they are likely related to deteriorating social and economic conditions in their home countries. There is reason to believe that the relationship between migrant FA and environmental stress is associated with historic U.S. policies and intervention, which has contributed to the destabilization of Latin America. To better understand environmental stress experienced by migrant and non-migrant groups, the present research will further compare craniofacial FA between both Central American and Mexican groups to a U.S. resident group. The goal of the present research is to explore the relationship between environmental stress and migrant push factors through craniofacial fluctuating asymmetry.

While the premise was to protect the U.S., the militarization of the border and the criminalization of migrants are structural expressions of oppression (Farmer, 1996). The barrier between the U.S. and Latin America is symbolic of the social forces in place that restrict access to resources and opportunities (Jones, 2016). The oppression of

marginalized Latin America groups is symptomatic of structural violence – a form of social structure that prevents people from receiving basic needs for survival, usually due to an unequal balance of power (Galtung, 1969). Uneven distribution of resources, income, food, access to healthcare, education, and power are invisible acts of violence that lead to unequal life chances (Galtung, 1969). In migrant home countries, social, political and economic systems deprive individuals of basic needs, impeding their quality of life (Chavez, 2004). Structural violence, often leading to direct violence in Central America and Mexico has led to mass exoduses of people escaping their circumstances and seeking asylum in the U.S. Countless lives lost along the U.S.-Mexico border is a global representation of structural violence affecting the very individuals escaping structural violence in their home countries.

The present research is important because it can bring greater attention to deteriorating conditions in migrant home countries and can show that perpetual environmental stress forces migration to the United States. Most importantly, the present research may produce evidence that will support immigration reform modification to redefine asylum criteria.

Background

U.S. militarization of the U.S.-Mexico border is at least partly driven by the destabilization it created in Latin America (Johnson & Woodhouse, 2018; Jones, 2016) and is single-handedly responsible for the perpetuation of migrant deaths along the U.S.-Mexico border. Decades of social, economic, and political instability, largely stemming from U.S. implemented policies and intervention, has assisted in creating push factors that heavily contribute to mass migration flows from Central America and (Kalsi, 2018;

Paley, 2017; Spohn, 2017; Weisbrot, 2014).

War on Drugs

The U.S. led War on Drugs campaign began cracking down on drug-trafficking in the Caribbean in the 1980s, shifting drug routes into Central America (Alexandrov, 2014; Hiskey, Córdova, Malone, & Orcés, 2018). While the goal was to combat drug trafficking, U.S. aid only intensified it. As the U.S. poured billions of dollars in aid, much of it was misused by Central American governments, leading to corruption and militarization (Paley, 2014). During the 1990s through the 2000s, gang-related violence in Honduras, El Salvador, and Guatemala led to increases in extortions, murders, and kidnapping (José Miguel, 2011). Newly established alliances between gangs and drug cartels further amplified violence and terror, which was used to control territory and drug trafficking operations (Paley, 2014). When Central American governments and local police began working with drug cartels and local gangs, drug-related crimes went largely unchecked (Alexandrov, 2014; Paley, 2014). Heavily impacted by government corruption and militarization, thousands of indigenous and campesino communities have been ousted off their lands, murdered, or disappeared in rural parts of Guatemala and Honduras, under the pretenses of community drug-trafficking involvement (Paley, 2014). Much of the ceased lands have been redistributed to foreign resource extracting companies, which conveniently run along known drug-trafficking routes (Paley, 2014).

As more drugs began flowing into Mexico from Central America in the 1980s, Mexican crime groups and drug traffickers became organized, establishing territories and drug trafficking routes (Global Conflict Tracker, 2020). The majority of the newly established cartels were strategically placed along the U.S-Mexico border and the Pacific

Ocean. Increases in the U.S. demand for drugs has led to conflicts between cartels who fight for control over the U.S. market, increasing instances of violence throughout Mexico, including murders, kidnapping, and disappearances. In 2007, the Merida Initiative was implemented to disrupt drug-related crime. Despite its aims, the Merida Initiative has proven to be ineffective, resulting in an escalation of violence and institutionalized corruption (Paley, 2014). Mexican cartels are still responsible for the majority of drugs entering the U.S.

Guatemala

In the exhaustive fight to rid the world of communism, the U.S. began intervening in Latin American affairs throughout the second half of the 20th century, supporting and funding military coups and civil wars in the countries that form the Northern Triangle. In Guatemala, the overestimated threat of communism and the fear of its spread to the rest of Latin America prompted the CIA to back the military coup of 1954, ousting democratically elected president Juan Jose Arevalo. The progressive agrarian land-reform program Arevalo implemented in Guatemala was immediately eliminated, exposing the economic interests that motivated the military coup, particularly those of U.S. based United Fruit Company (Getchell, 2015). A string of U.S. backed authoritarian dictatorships and a 36-year civil war followed the 1954 military coup, hitting its deadliest point between 1981 and 1983, when a genocide almost eliminated the Mayan population in the Guatemalan highlands, conveniently creating easier access to indigenous land (Paley, 2014).

Honduras

Economically crippled by over a hundred years of U.S. and Honduran elite

political and economic influences, Honduras currently holds the highest economic disparities in Central America (World Bank, 2019). Land struggles mirroring those of Guatemala, beginning in the 1960s through the 1980s, sparked anti-communist action by the U.S. trained Honduran military, suppressing peasant mobilization resistance and leading to illegal detentions, disappearances, and targeted killings (Webber & Gordon, 2013). Honduras's geographical position and its U.S. assisted military expansion facilitated the country as the perfect staging ground for anti-communism campaigns after the success of the Nicaraguan Sandinista Revolution in 1979 and the launch of left-winged guerilla resistances in Guatemala and El Salvador during the 1980s.

The end of the Cold War and the "success" of anti-communist campaigns in Honduras and throughout Central America ushered in export-oriented political measures that would widen the gap between the poor and the wealthy (Webber & Gordon, 2013). In Honduras, poverty rose dramatically throughout the 1990s and into the 2000s, largely due to the political measures that brought wealth to only the top 10% of the population. Meanwhile, dispossession of land grew significantly in rural areas forcing thousands to seek underpaying jobs in *maquiladoras* (i.e., exporting factories), new agricultural centers, and service sectors created by the export-oriented political measures implemented by the government (Webber & Gordon, 2013). Amid ongoing economic inequality and social unrest, democratically elected president Manuel Zelaya Rosales began introducing progressive social and economic reform (Paley, 2014; Webber & Gordon, 2013). Threatened by the new reforms, Honduran elites, backed by the U.S., led the 2009 military coup and ousted Zelaya, further weakening and corrupting the Honduran government (Webber & Gordon, 2013; Weisbrot, 2014).

El Salvador

In El Salvador, wealth disparity, government militarization, and political corruption led El Salvador to spiral into a twelve-year civil war, beginning in 1980 and ending in 1992. U.S. military aid and training further aggravated the long and brutal war that killed almost 75,000 people (McNamara, 2017). Numerous human rights abuses throughout the civil war, including the El Mozote massacre, were at the hands of the El Salvadoran military, specifically the notorious Atlacatl Battalion, trained at the U.S. Army's School of the Americas (Ching, 2016). Thousands fleeing the violence of the civil war in El Salvador sought refuge in the U.S., many settling in marginalized areas in major cities. In 1996, the U.S. implemented the Illegal Immigration Reform and Immigrant Responsibility Act (IIRIRA), originally targeting undocumented immigrants with felony offenses and later expanding to include minor offenses and petty crimes. Between 1996 and 2004, more than 46,000 individuals, many with gang affiliations, were deported back to Central America, the majority to El Salvador and Honduras (Arana, 2005; McNamara, 2017). Still recovering from the civil war, the El Salvadoran government lacked the resources to police many areas throughout the country, providing gang-affiliated deportees a place to flourish and continue criminal activities. Eventually, they grew to become two of the deadliest gangs in the world, known as Mara Salvatrucha (MS-13) and Barrio-18 (B-18 *Los Surenos*/ B-18 *Los Revolucionarios*) (Arana, 2005; Kalsi, 2018; McNamara, 2017). It is estimated that the number of MS-13 members has reached 35,000. Not far behind, membership of B-18 is estimated to have reached 25,000 (McNamara, 2017).

The explosion of gangs in Central America throughout the 1990s and 2000s

brought skyrocketing incidences of homicides, both El Salvador and Honduras surpassing the highest rates in the world (McNamara, 2017; World Bank, 2019). Contributing to their influence and growth, gangs have developed alliances with Mexican drug cartels and international criminal organizations, establishing criminal networks throughout North America, Latin America, and Europe. Tactics, such as kidnapping, sex trafficking, human trafficking, extortions, and money laundering are utilized to finance and maintain their influence over the civilian population (McNamara, 2017; Sullivan & Bunker, 2007). Civilians who refuse or do not cooperate are met with violent and brutal repercussions. Further exacerbating the problem, police and government corruption allows gang criminal activity to continue without consequences (Arana, 2005; McNamara, 2017). Between 2012 and 2014, both M-13 and B-18 negotiated terms for a truce with the El Salvadoran government, which was followed by a significant fall in inter-gang violence and homicide rates. Terms reached during the truce were further negotiated with 2014 presidential candidates from both major political parties, FMLN and ARENA. Once in office, FMLN president Sanchez Ceren fell through with the terms previously negotiated, sparking gang led assassinations of the military, judicial personnel, and local police (Farah 2016). Since the collapse of the truce in 2014, gangs in El Salvador have deepened their networks and are continuously devastating the population, sparking mass migrations of refugees to the U.S.

Currently, mass migration flows from Central America are largely driven by gang- and drug-related violence (Kalsi, 2018; Matthew, 2017). Economic disparity and political corruption further exacerbate dire conditions in these countries (Alexandrov, 2014; Spohn, 2017).

Mexico

Mexico and the U.S. share a long history of economic interdependence that stretches back to WWII. The U.S. has relied on Mexican workforces to fill low wage and low skilled jobs, mainly in the agricultural sector, beginning with the implementation of the Bracero Program. The Bracero guest worker program brought 4.5 million Mexican workers to the U.S. between 1942 and 1964 (Chávez, 2012; Minian, 2018). The temporary worker program and similar programs that followed established institutionalized networks and labor markets between Mexico and the U.S. (Migration Policy Institute, 2004). The economic interdependence between Mexico and the U.S. laid the foundation for the social processes that perpetuate today's migration flows from Mexico to the U.S. (Migration Policy Institute, 2004).

The end of the Bracero Program forced thousands of *braceros* to return to Mexico. Hoping for the reestablishment of the program or assistance from the Mexican government, many resettled in border towns of northern Mexico. Mexico's economic crises and rapid population growth during the 1970s created skyrocketing unemployment rates, affecting recently returned *braceros* and the general population (Minian, 2018). In the attempt to solve the chronic unemployment in Mexican border towns, the Mexican government implemented the Border Industrialization Program (BIM) (i.e., *maquiladoras*) in 1965, creating a free trade zone along the border. The program allowed foreign ownership of manufacturing and assembly facilities, as well as duty-free importation of raw materials and assembly components and exportation after assembly (Hing, 2010). Unable to solve the root problems causing unemployment throughout the rest of the country, the Mexican government regarded emigration as an acceptable

solution to the “surplus labor force”. Seeking economic opportunity, Mexican migrants traveled north (Minian, 2018). Between 1970 and 1977, apprehensions of migrants at the U.S.-Mexico border increased from 277,377 to almost 1 million (Minian, 2018).

The financial difficulties Mexico faced in the 1970s and 1980s led to the expansion of export-led development throughout the country. In 1988, Mexico began negotiations with the U.S. and Canada to create a free-trade zone in North America. Negotiations led to the creation of the North American Free Trade Agreement (NAFTA) in 1994 (Minian, 2018). NAFTA was predicted to improve Mexico’s economy and alleviate undocumented migration from Mexico. Although economic growth occurred in northern Mexico, it was not the case throughout the rest of the country. Already feeling the impacts of trade liberation in the 1990s, small farmers in rural parts of Mexico now faced competition with U.S. imports. Unable to compete, millions of small farmers were forced to seek better economic opportunities in the U.S. (Hing, 2010; Paley, 2017). Further worsening unemployment issues, non-*maquiladora* manufacturing jobs and wages experienced significant decreases throughout the years. Overall, NAFTA has had major negative impacts on Mexico’s work force, increasing poverty and inequality through the country (Hing, 2010; Paley, 2017; Sanderson, 2014).

Fluctuating Asymmetry

Human Skeletal Development

Biological plasticity is an adaptive strategy sparked by environmental pressures. While an indicator of adaptability, plasticity can also be indicative of environmental stress experienced during physical development (Lasker, 1969). Human skeletal growth and development begins in utero and continues until about 21 years of age when final

phases of bone unions occur (Schaefer, Black, & Scheuer, 2009). Normal skeletal growth and development are dependent on an organism's ability to maintain homeostasis under various genetic and environmental perturbations (Mopin, Chaumoître, Signoli, & Adalian, 2018). Developmental stability assists an organism to reach its projected phenotypic symmetric morphology (Mopin et al., 2018).

During physical development, the human skeleton is highly susceptible to environmental influences. An organism's inability to buffer genetic and environmental stressors have shown to cause deviations from symmetry known as fluctuating asymmetry (Graham & Ozener, 2016; Møller, 2006). Fluctuating asymmetry is the result of deviations from perfect bilateral symmetry, caused by the intensity and duration of environmental and genetic stress experienced during physical development (Palmer & Strobeck, 1986; Tomkins & Kotiaho, 2002).

Mechanisms that produce FA

Although mechanisms that produce FA are yet to be fully understood, Willmore (2005) generally categorizes three mechanisms that have the potential to produce between-sides variability in organisms. Willmore (2005) suggests that mechanical loading, random quality of genetic properties of developmental systems, and complex cellular processes in bone development influence increase between-sides variability in response to perturbations and/or limit an organism's ability to buffer perturbations. Building upon Willmore's (2005) cellular mechanisms of FA development, De Leon (2007) notes the necessity for organisms to acquire adequate input (i.e., energy, nutrients, resources) to follow projected phenotypic development. Bone development is the product of continuous remodeling – the process of bone deposition and resorption. Input impeded

by malnutrition and/or high parasitic load, for example, may inhibit ideal bone development, producing between-sides variability (De Leon, 2007).

Non-human and FA

Studies utilizing nonhuman models (Badyaev, Foresman, & Young, 2005; Beasley et al., 2013; Sciulli, Doyle, Siegel, Kelley, & Siegel, 1979; Siegel, Doyle, & Kelley, 1977) have found positive correlations between environmental stress and FA. Swaddle and Witter (1994) found that food deprivation contributed to feather asymmetry in birds compared to a controlled group with constant food availability. In moor frogs, Söderman, van Dongen, Pakkasmaa, and Merilä (2007) found that low pH levels in water act as an environmental stressor in developing larvae and tadpoles, contributing to higher degrees of FA in-bilateral skeletal elements. The authors note that reduced food availability in acidic environments may also reflect a relationship between nutrition and FA. In a conservation focused study, Tull and Brussard (2007) show a correlation between heavy use of Off-highway vehicles (OHV) on public lands and high levels FA in western fence lizards. While environment disruption is suggested to be the cause, further research is recommended.

Humans and FA (non-cranial)

In humans, bioarcheological studies have also shown correlations between various environmental stresses and FA (Deleon, 2007; Milella, Betz, Knusel, Larsen, & Dori, 2018; Ozener, 2011; Weisensee, 2013). Follis (2014) found that sociopolitical change, which brought decreases in resources along the Southern Peruvian coast, may have resulted in elevated levels of dental fluctuating asymmetry among the pre-Hispanic Chakipampa group. Mopin et al. (2018)’s geometric morphometric analysis of femora

proved to be an effective measure for fluctuating asymmetry, showing differences in developmental stability between a bioarcheological and a living population. In the Mopin et al. (2018) study, higher levels of fluctuating asymmetry were present in the bioarcheological population who experienced higher levels of cumulative health and nutritional stress.

Cranial plasticity and FA

While several forms of environmental and genetic stressors, including maternal drug use, natural disasters, and reduced heterozygosity have shown relationships with asymmetry in human populations (King et al., 2009; C. P. Klingenberg et al., 2010; Ozener, 2010), environmental stressors related to socioeconomic status on craniofacial development will be the focus of this study.

The concept of cranial plasticity was first introduced by Franz Boas (1912). Cranial plasticity relates to the skull's susceptibility to temporal environmental influences. Since Boas' 1912 study, which found cranial differences between European born individuals and their U.S. born offspring, recent studies have further shown cranial morphological changes due to environmental influences, including fluctuating asymmetry (Angel, 1982; Deleon, 2007; Jantz & Logan, 2010; Weisensee, 2013; Weisensee & Spradley, 2018). In a craniofacial FA comparison study, DeLeon (2007) found that high levels of nutrition/systematic stress increased developmental instability, manifesting greater craniofacial FA in an Early period medieval Nubian population. Utilizing geometric morphometric as a multi-trait analysis, DeLeon (2007) further showed that developmental instability is trait specific. Utilizing craniofacial FA as a means of measuring developmental instability in an identified skeletal collection, Weisensee,

(2013) found that individuals who died of degenerative diseases had higher levels of FA compared to individuals who died of infectious diseases. The results of the Weisensee (2013) study support the predictions of the Developmental Origins of Health and Disease (DOHaD) hypothesis, which links developmental instability with adult long-term health outcomes (Gluckman & Hanson, 2006).

Socioeconomic status and FA

Environmental stress can arise naturally (i.e., genetic) or as a result of indirect forces. Previous research has shown that environmental stress can arise as a result of social and economic circumstances, such as socioeconomic status (SES) (Hope et al., 2013; Ozener, 2011). Socioeconomic status relates to individual attainment of income, occupation, and education. Individuals living under low SES fall victims to socioeconomic disparities and its correlates — malnutrition and poor health (Eke et al., 2018; Hope et al., 2013; Ozener & Graham, 2014). This being the case, individuals living under low SES experience higher rates of environmental stress and are likely to show higher levels of craniofacial FA (Weisensee & Spradley, 2018). In the Weisensee and Spradley (2018) craniofacial FA comparison study, Mexican undocumented border crossers (UBCs) showed higher levels of FA compared to two groups of higher SES. The authors conclude that craniofacial FA can provide a useful biological marker to reconstruct environment and economic conditions among human populations.

Environmental stress influences morphological changes, hindering mechanisms that maintain homeostasis. In bilateral structures, FA has shown its utility to estimate the quality of environmental conditions, including socioeconomic status (Beasley et al., 2012; Özener, 2011). While some studies have not found correlations between FA and

environmental stress (Milne et al., 2003; Quinto-Sanchez et al., 2015), Graham and Ozener (2016) have cited sample size, measurement error, size scaling, unaccounted directional asymmetry, and statistical abuses as likely causes that have skewed results in previous studies.

Central America/Mexico and FA

Adverse living conditions in Central America and Mexico are the products of decades of economic inequality, gang/drug-related violence, and political corruption. Riddled with poverty and violence, living conditions in these countries embody low SES and have shown to have correlations with health disparities and nutrition inadequacy (Evans & Kim, 2007; Schreier & Chen, 2013). In the Ozener (2011) study, adolescents living in intense poverty exhibited higher levels of FA compared to adolescents from higher SES, indicating that low SES adversely impacts developmental stability. In a systematic review, Wright et al. (2017) found reasons to believe that childhood/adolescent exposure to physical and community violence is correlated with long-term physical health issues, such as asthma/respiratory illnesses, cardiovascular illnesses, and immunodeficiencies. While the relationship between physical violence and FA has not been studied, collectively, both nutrition inadequacy and exposure to violence may work together to produce FA.

As Weisensee and Spradley (2018) note, FA can be useful in reconstructing environmental and economic conditions in human populations. There is substantial research to suggest that low SES stressors, as a result of social and economic inequality in Central American and Mexico, impact developmental stability, affecting both physical development and long-term physical health (Calam, 2017; Evans & Kim, 2007; Hope et

al., 2013; Schreier & Chen, 2013). Considering the results from De Leon (2007), Ozener (2011), and Weisensee and Spradley (2018), the inability for an individual to buffer environmental stress due to low SES is likely to result in FA.

Structural violence continues to force Central American and Mexican migrants through remote and inhospitable environments to seek asylum and basic resources. More than often, the journey for many ends in the desert somewhere between Mexico and the U.S. Historically, gang/drug-related violence and economic disparity have been major push factors for Central American migration, while Mexican migration has been driven more so by economic factors (Hiskey et al., 2018; Kalsi, 2018; Matthew, 2017; Paley, 2017; Sanderson, 2014). Regardless of the difference, push factors reflect oppression and inequality in migrant home countries, which can be traced back to U.S. policy, intervention, and local political corruption.

Craniofacial FA reflects the duration and intensity of environmental stress during the critical period of physical development. High levels FA in Central American and Mexican migrants may reflect stress caused by the deteriorating social and economic conditions in Latin America. It is expected that high levels of environmental stress in migrant home counties, examined through FA, will support historic and current driving forces for migration, which would speak to the realities of structural violence in Central America and Mexico.

A U.S. resident group was used as a base measure of SES and environmental stress. The assumption is that individuals in the U.S. resident group are of higher SES, experiencing less environmental stress due to their access to resources in the U.S. It is expected that the U.S. resident group will show lower levels of craniofacial FA compared

to both migrant groups.

Research Questions

1. Is there a difference in levels of craniofacial FA between Central American and Mexican migrants?

2. Are there differences in levels of craniofacial FA between migrant and non-migrant groups?

3. Is there a relationship between environmental stress in migrant home countries and craniofacial FA?

4. Is there a relationship between environmental stress in migrant home countries and push factors for U.S. migration?

II. MATERIALS AND METHOD

Texas Migrant Skeletal Sample

Craniometric data from three skeletal samples will be utilized in this study. The first sample consists of skeletal remains recovered in south Texas and along the Texas-Mexico border. According to the United States Border Patrol (USBP) (2019), by 2012, the majority of UBC deaths were recovered in the Rio Grande Valley sector, with Brooks County experiencing the highest rates (U.S. Customs and Border Patrol, 2019). In the absence of a Medical Examiner's Office, Brooks County falls under the Justice of the Peace, who usually lack the education and resources to adequately conduct medicolegal death investigations (Drake, Cron, Giardino, Trevino, & Nolte, 2015). The lack of centralized record keeping during the abrupt rise in UBC deaths resulted in rapid burials of migrants without proper identifying documentation. Utilizing USBP apprehension rates as a proxy for country of origin, it can be reasonably assumed that these individuals are likely Central American in origin, specifically from Honduras, El Salvador, and Guatemala (Spradley, 2016). The Texas migrant skeletal sample derives from Operation Identification (OpID) cases, located at the Forensic Anthropology Center at Texas State University, San Marcos, Texas. Craniometric data was collected by Dr. Kate Spradley and the OpID team. In the present study, these individuals are classified as Central American and consist of 59 females, 107 males. Since 2013, OpID has identified 38 migrants. Individuals identified as Mexican were included in the Mexican group. The remaining individuals are still part of open OpID cases. Tables 1 and 2 provide demographic information for identified/unidentified Texas migrants including sex and country of origin. Age range for identified individuals is between 18 and 49.

Arizona Migrant Skeletal Sample

The second sample consists of skeletal remains recovered along the Arizona-Mexico border. The majority of UBC deaths that occur in Arizona are received at the Pima County Office of the Medical Examiner (PCOME) in Tucson, Arizona. Unlike the Justice of the Peace system in most southern counties of Texas, the PCOME has developed best practices to facilitate the identification of migrants found along the Arizona-Mexico border (Anderson & Spradley, 2016). Data collected by the W.H. Birkby Forensic Anthropology Laboratory at the PCOME indicate that, historically, the majority of the migrants recovered are males of Mexican origin, between the ages of 18 and 40 (Anderson, 2008; Spradley et al. 2018). The median age of under 30 years fits the demographic of migrant workers entering the U.S. labor market (Anderson, 2008; Spradley et al. 2018). Age range of identified Mexican individuals from OpID is between 23 and 57. As part of a large-scale NIJ data collection project, craniometric data was collected at the PCOME by Dr. Kate Spradley (Spradley, 2013). Individuals under study have been identified and consist of 36 females and 247 males (Tables 1 and 2). Other demographic data was not available.

Considering USBP apprehension rates since 2012 and the identification of migrants thus far, Central American migrants predominantly enter the U.S. through Texas, while the majority of Mexican migrants enter the U.S. through Arizona. Both identified and unidentified individuals will be analyzed to provide broader implications.

U.S. Resident Skeletal Sample

The third skeletal sample derives from the University of Tennessee William M. Bass Donated Skeletal Collection (BDC), which is representative of contemporary U.S. populations, primarily from the Southeastern U.S. As part of the donor program's data

collection procedures, demographic data such as sex, age at death, SES, health, etc. is known for the individuals in the present study. Overall, birth years range between the early to late twentieth century, however, most occurred during the mid-century. Age range is between 29 to 65 years. The individuals in this sample self-identified as White and consist of 63 females and 166 males. As part of the Weisensee and Spradley (2018) study, craniometric data was collected by graduate students working at the Forensic Anthropology Center at the University of Tennessee. The U.S. resident skeletal sample will be utilized to better understand environmental stress experienced by migrant and non-migrant groups. Expected levels of FA will be assessed during FA statistical analysis.

Table 1: Sample Size

Sample	N	Female	Male
OpID	166	59	107
PCOME	283	36	247
BDC	229	63	166
Total	678	158	520

Table 2: Identified Individuals in Craniometric Analysis

Country of Origin	OpID	PCOME
Mexico	5	283
El Salvador	7	
Guatemala	6	
Honduras	2	
Total	20	283

Craniometric Data

Utilizing a Microscribe 3DX digitizer, three-dimensional cranial landmark data

were collected from all 678 individuals. Twenty-two cranial landmarks were utilized for within and between group FA comparison and are presented in Appendix A. Using a generalized Procrustes least-squares superimposition, landmark data from all individuals were aligned in a common coordinate system to measure symmetry between individuals (Weisensee, 2013; Weisensee & Spradley, 2018). The human skull has an internal plane of symmetry (i.e., midsagittal plane), resulting in object symmetry – bilateral symmetry with mirroring right and left sides (Klingenberg, Barluenga, & Meyer, 2002). Using the methods presented in Klingenberg et al. (2002) and Mardia et al. (2000), asymmetry is distinguished in structures with object symmetry using Procrustes least-squares superimposition. Focusing on shape analysis, a generalized Procrustes least-squares superimposition separates non-shape components of symmetry and asymmetry variation, configurating landmarks from opposite sides (Klingenberg et al., 2002). The difference in actual and landmark configuration values provides information about asymmetry and determines Mahalanobis FA scores – the distance between two points in multivariate space. Methods described by Klingenberg and Monteiro (2005) were used to calculate individual FA scores in MorphoJ, a geometric morphometric analysis software (Klingenberg, 2011). These methods were utilized because they measure nonisotropic variation that cause FA, such as environmental stress (Klingenberg & Monteiro, 2005).

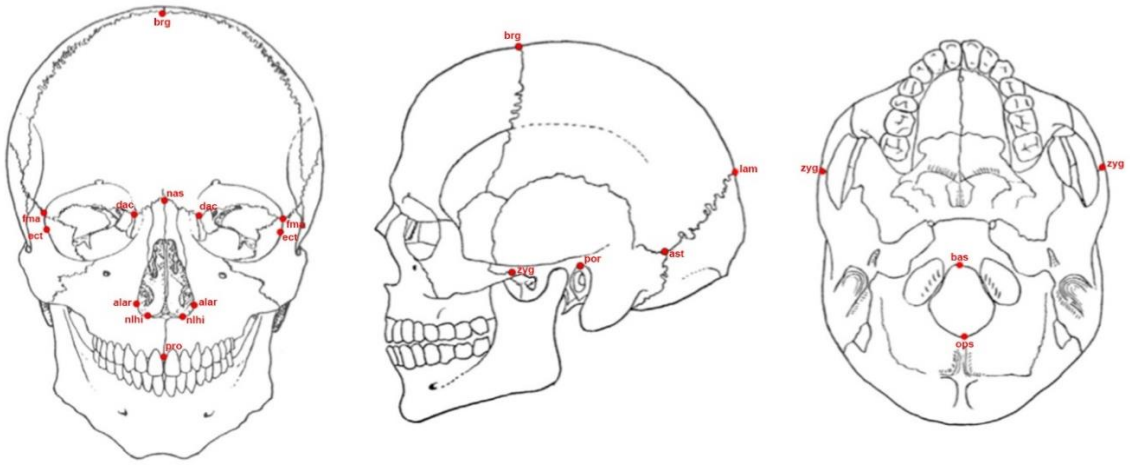


Figure 1: Anterior, lateral, and inferior views of craniofacial landmarks. Adapted from Weisensee and Spradley (2018).

Craniometric Analysis

MorphoJ

Once the 22 craniofacial landmarks from all 678 individuals were entered into MorphoJ, "3 dimensions" for dimensionality of data and "yes" for object symmetry were selected. A Procrustes fit with aligned principle axes and outlier inspection were carried out as preliminary steps before analysis. Once outliers were removed, a Procrustes ANOVA was conducted with "ID" selected as the classifier for effect and "Sex" and "Group" selected as additional main effects. Mahalanobis FA scores were retrieved from the "Shape FA scores" data set with "Sex and "Group" as classifiers. Mahalanobis FA scores were utilized for statistical analysis.

Analysis of Variance (ANOVA)

Before statistical analysis was carried out, assumption testing was conducted. This is necessary, as any violation of assumptions can lead to inaccuracies in results and interpretations. To determine significant results, p-values ≤ 0.05 were considered significant. All analyses were performed using SPSS Statistics 26 (IBM Corporation,

Chicago, IL, USA).

To address whether there are differences in craniofacial FA between Central American and Mexican migrants, as well as differences between migrant and non-migrant groups, Mahalanobis FA scores were compared for differences between and within groups using a Two-way ANOVA, One-way ANOVA, and One-way ANOVA with two levels.

A Two-way ANOVA determines the effect of two independent variables on a dependent variable. The dependent variable consists of the Mahalanobis FA scores. The independent variables consist of groups (Central American vs Mexican vs U.S. resident) and sex (male vs female). Histograms were used to test for assumptions of normality. A Levene's Test of Equality of Error Variances was used to test for homoscedasticity.

A One-Way ANOVA compared the variance in group means of one independent variable with three or more levels. The dependent variable consists of the Mahalanobis FA scores. The independent variable consists of groups (Central American vs Mexican vs U.S. resident). Histograms were used to test for assumptions of normality. A Levene's Test of Equality of Error Variances was used to test for homoscedasticity. A Tukey's HSD multiple comparison test was conducted to further investigate differences between means.

An ANOVA with two levels examined the magnitude of difference in Mahalanobis FA scores of overall males and females from all groups combined. Mahalanobis FA scores were the dependent variable and sex (male vs female) was the independent variable. An ANOVA with one dependent variable and one independent variable with two levels was conducted versus an independent t-test because the present

study examines variances and not simply differences in means. Histograms were used to test for assumptions of normality. A Levene's Test of Equality of Error Variances was used to test for homoscedasticity.

Environmental Stress

To address whether there is a relationship between environmental stress in migrant home countries and craniofacial FA, visual timeline graphs of estimated periods of development for each identified OpID individual, overlain with the timelines of major events in Central America and Mexico were created. The temporal relationships between developmental period and major events may further demonstrate a relationship between environmental stress and high levels of FA.

The El Salvadoran Civil War, the Guatemalan Civil War, and the period following the implementation of the Illegal Immigration Reform and Immigrant Responsibility Act (IIRIRA) in 1996 were chosen to compare with the Central American developmental periods. The financial crises of the 1980s and the period following the implementation of the North American Free Trade Agreement (NAFTA) in 1994 were chosen to compare with the Mexican developmental periods. These major events were selected because they have shown to have had major social and economic impacts on Central America and Mexico, leading to major migration waves to the U.S. The year 2012 was chosen as the estimated year of death. The developmental period between year of birth to 14 years of age was chosen for the present study because it is the critical period of physiological development. The inability for an individual to buffer environmental stress during this period will produce FA. Environmental stress experienced past 14 years of age is unlikely to have major physiological effects, as

physical development, osteological material in particular, is mostly complete.

Conditions created by war, violence, and economic instability create stressors that may impact developmental stability, manifesting in biological markers of stress. Comparing period of physical development during major events can demonstrate duration of stress exposure. High levels of FA may reflect long duration and intensity of stress exposure in migrant home countries

Second, line graphs showing poverty, unemployment, and homicide rates were created to further examine the relationship between environmental stress and FA. Pan American Health Organization (PAHO) (2018) health indicators (i.e., homicide, poverty, and unemployment rates) from El Salvador, Guatemala, Honduras, and Mexico were collected from the year 1990 through 2010. Data was not available before 1990. Health indicators are useful in characterizing the health of a population and can provide information regarding environmental stress.

To assess the relationship between environmental stress and major push factors for U.S. migration, the present study examined the results from Mahalanobis FA statistical analyses and temporal relationships between developmental periods and major events. Levels of group FA and temporal relationships, when compared to historic migration trends and personal narratives, may support a relationship between environmental stress and migration push factors.

III. RESULTS

Craniometric Analysis

A two-way ANOVA examined the magnitude of difference in Mahalanobis FA scores between Central Americans and Mexican migrants, as well as migrant and non-migrant groups. Histograms showed that FA for all three groups had relatively normal distribution, each with slight positive skews. A Levene's Test of Equality of Error showed equal variances. The results of the Two-way ANOVA did not show a significant main effect of sexes [F (1, 672) =1.002, p.= .317], however, the main effect of groups was trending [F (1, 672) = 2.550, p.= .079]. There was no significant interaction between sexes and groups [F (1, 672) = .976, p.= .377]. Descriptive statistics is presented below (Tables 3 and 4).

Table 3: Two-way ANOVA Results

Source	Type III Sum of Squares	df	Mean Square	F	*P-Value*
Corrected Model	15.698[a]	5	3.14	3.084	0.009
Intercept	10438.485	1	10438.49	10253.45	0
Sex	1.021	1	1.021	1.002	0.317
Group	5.192	2	2.596	2.55	0.079
Sex * Group	1.986	2	0.993	0.976	0.377
Error	684.127	672	1.018		
Total	16729.072	678			
Corrected Total	699.825	677			

Table 4: Descriptive Statistics

	Combined			Females			Males		
Sample	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**
Central America	166	4.75	1.02	59	4.6	0.85	107	4.83	1.1
Mexico	283	5.03	1.03	36	4.91	1.18	247	5.04	1.01
U.S. Resident	229	4.74	0.97	63	4.8	1.00	166	4.72	0.96
Total	678			158			520		

To further examine the magnitude of difference in Mahalanobis FA scores between all groups, a One-way ANOVA was run. A Levene's Test of Equality of Error showed equal variances. The results of the One-way ANOVA showed a significant main effect of groups on Mahalanobis FA scores [F (2, 675 = 6.36), p. = .002]. Tukey's HSD multiple comparison test showed that the Mexican group had significantly higher levels of FA (M= 5.03, SD= 1.03) than the Central American group (M= 4.75, SD= 1.02, p= .014) and the U.S. Resident group (M=4.74, SD= .97, p= .005). However, there was no significant difference in levels of FA between the Central American group (M= 4.75, SD= 1.02) and the U.S. resident group (M=4.74, SD= .97, p= .999) (Figure 2; Tables 5 and 6).

Table 5: One-way ANOVA Results

	Sum of squares	**F**	**df**	**Mean Square**	***P*-value**
Between Group	12.946	6.361	2	6.473	0.002

Table 6. Tukey's HDS Multiple Comparison Test

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	*P*-Value
Mexico	Central America	.277345*	0.09862	0.014
	U.S. Resident	.282244*	0.089663	0.005
Central America	Mexico	-.277345*	0.09862	0.014
	U.S. Resident	0.004899	0.102829	0.999
U.S. Resident	Mexico	-.282244*	0.089663	0.005
	Central America	-0.004899	0.102829	0.999

*. The mean difference is significant at the 0.05 level.

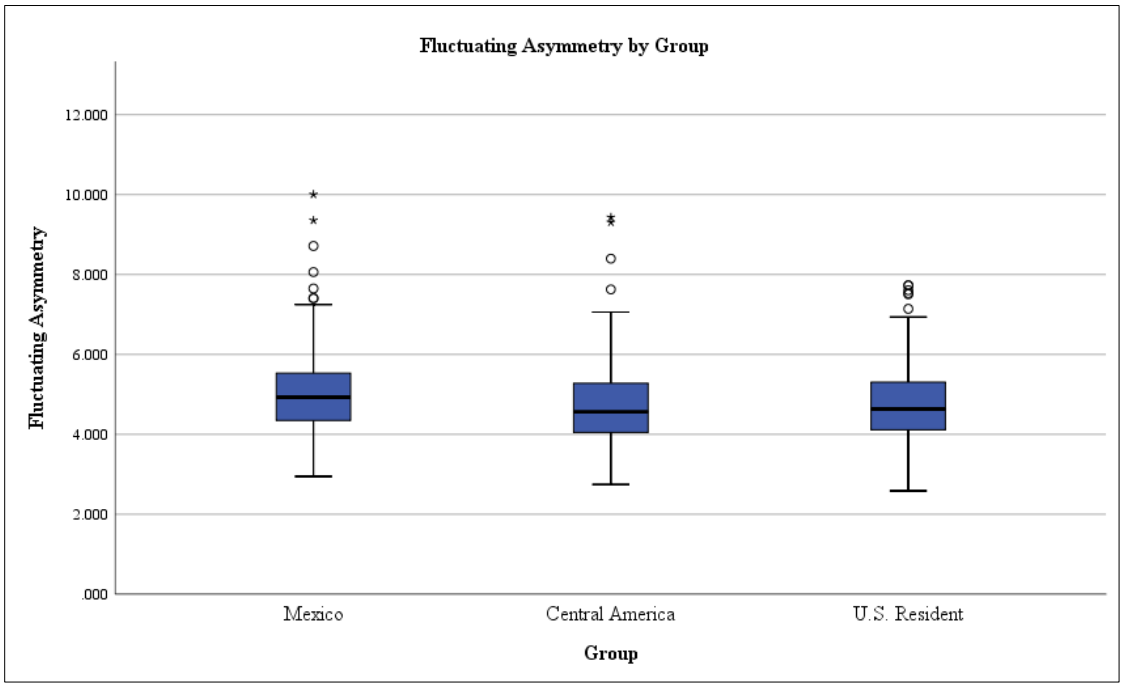


Figure 2: Boxplot of Fluctuating Asymmetry by Group.

Since there were no significant differences in levels of FA between sexes from each group after running the Two-way ANOVA analysis, a One-way ANOVA with two levels was run to examine the magnitude of difference in Mahalanobis FA scores between males and females from all groups combined. Histograms showed FA for males

and females had relatively normal distributions, each with slight positive skews. Levene's Test of Equality of Error showed equal variances. The results of the ANOVA showed no significant main effect of sex on Mahalanobis FA scores [F (1, 676) = 2.52, p.= .113], indicating that males (N= 520, M= 4.90, SD= 1.02) and females (N= 158, M= 4.75, SD= .99) exhibit similar levels of FA (Tables 7 and 8).

Table 7: One-way ANOVA Results (Overall Sex)

	Type III Sum of Squares	df	Mean Square	F	*P*-value
Sex	2.599	1	2.599	2.52	0.113

Table 8: Descriptive Statistics (Overall Sex)

	N	Mean	SD
Female	158	4.89643	0.993284
Male	520	4.74999	1.022227
Total	678		

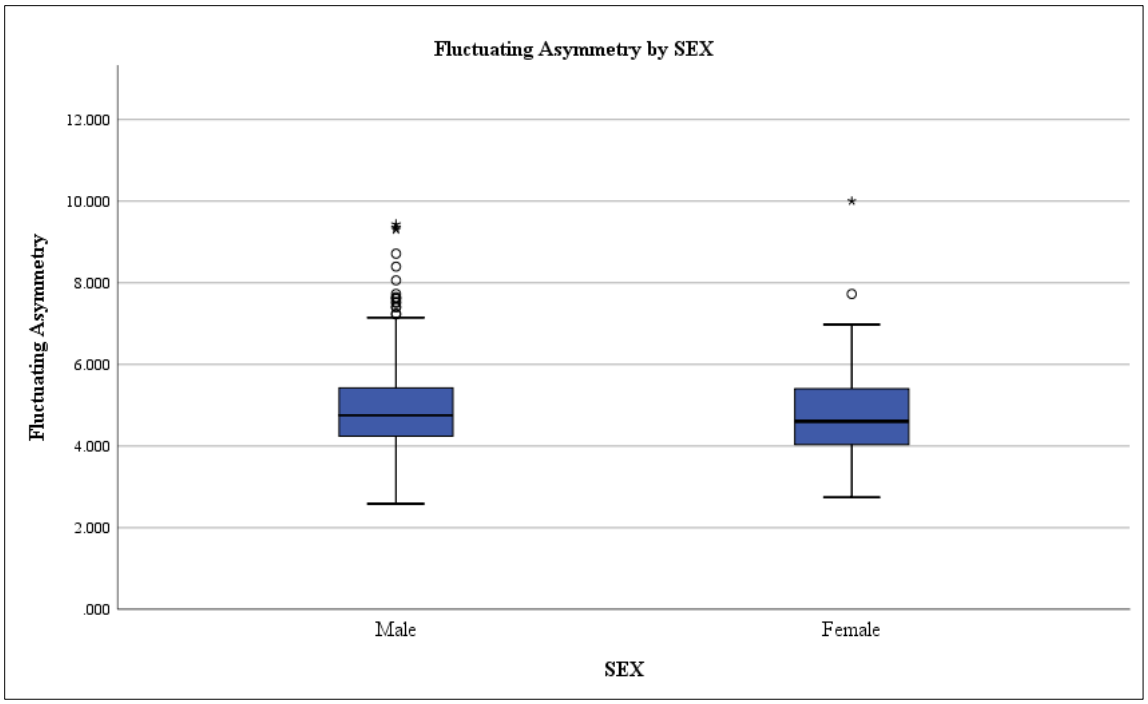
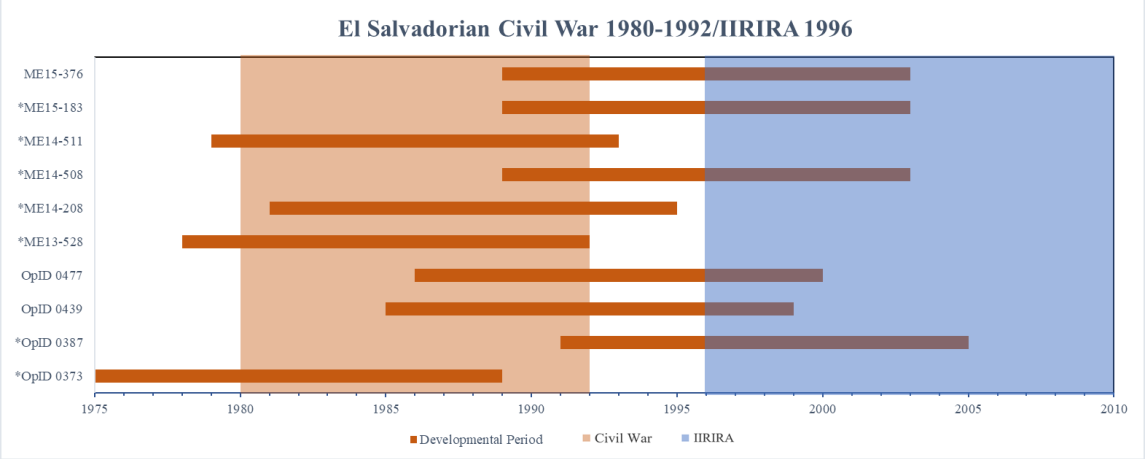


Figure 3: Boxplot of Fluctuating Asymmetry by SEX.

Environmental Stress: Developmental Period

Timeline graphs showing the estimated period of physical development for each identified individual overlain with timelines of major events in Central America and Mexico were examined to assess the relationship between environmental stress and FA.

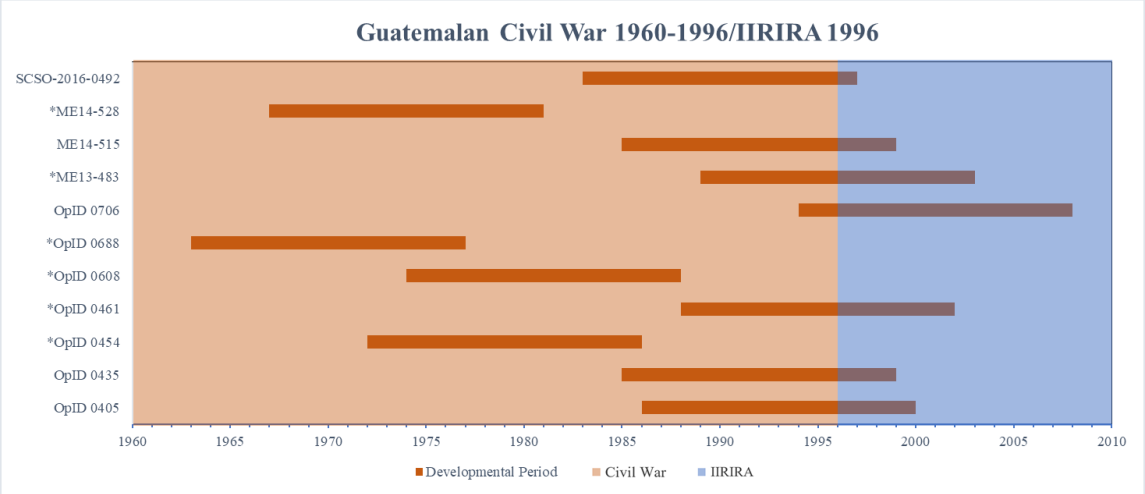
Figure 4 illustrates the developmental periods of identified El Salvadorians overlain with the period encompassing the El Salvadorian Civil War and the period following the implementation of IIRIRA. The graph showed that developmental periods of four individuals coincided significantly (i.e., more than half) with the El Salvadorian Civil War, while developmental periods of four individuals coincided significantly with the period following the implementation of IIRIRA. Three individuals showed periods of development extending prior to 1980.



*Included in craniometric analysis.

Figure 4: Developmental Timelines (0 to 14yrs) of Identified Salvadorian Migrants.

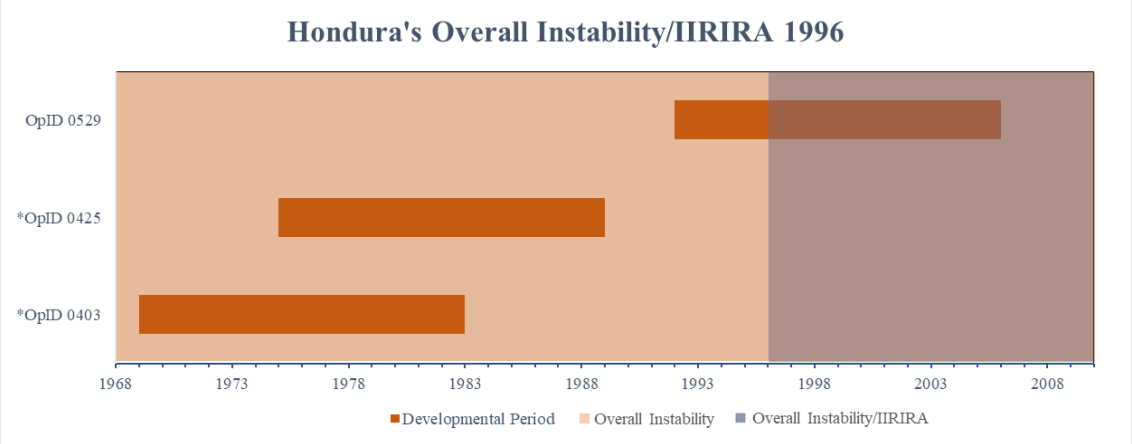
Figure 5 illustrates the developmental periods of identified Guatemalans overlain with the period encompassing the Guatemalan Civil War and the period following the implementation of IIRIRA. The graph showed developmental periods of nine individuals coinciding significantly with the Guatemalan Civil War, while developmental periods of two individuals coincided significantly with the period following the implementation of IIRIRA.



*Included in craniometric analysis.

Figure 5: Developmental Timelines (0 to 14yrs) of Identified Guatemalan Migrants.

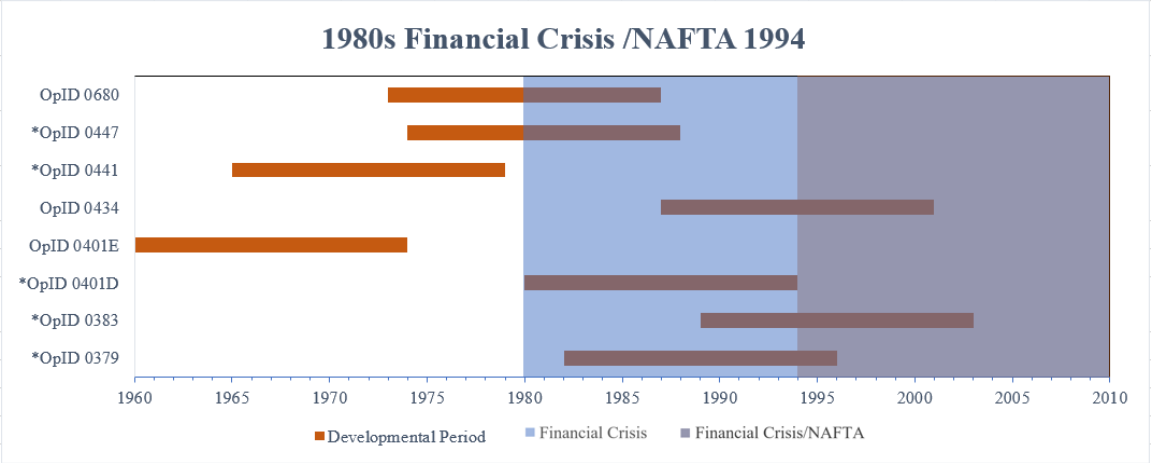
Honduras has a long history of economic and social instability, which still plagues the country today. The period of environmental stress chosen for the present study was the overall instability in the country and the implementation of IIRIRA. Figure 6 showed that periods of development for two Hondurans coincided significantly with the period during overall instability, while developmental periods of one individual coincided significantly with the period following the implementation of IIRIRA.



*Included in craniometric analysis.

Figure 6: Developmental Timelines (0 to 14yrs) of Identified Honduran Migrants.

Figure 7 illustrates the developmental period of identified Mexicans overlain with the period encompassing the 1980s Mexican financial crises and the period following the implementation of NAFTA. The graph showed that the developmental periods of six individuals coincided significantly with both the financial crisis and the period following the implementation of NAFTA. Two individuals showed developmental periods extending prior to 1974.



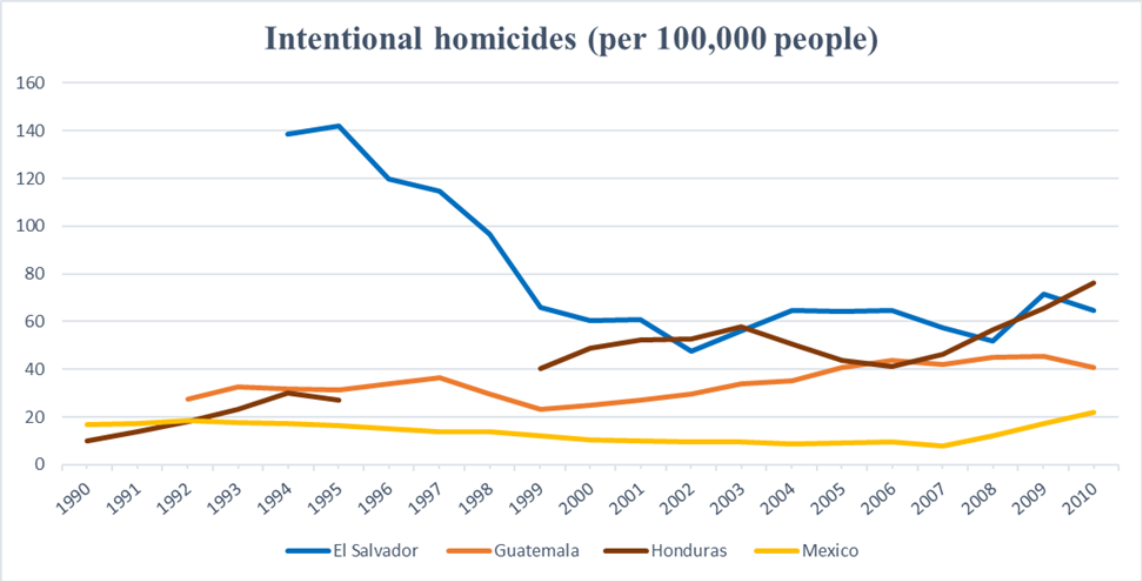
*Included in craniometric analysis.

Figure 7: Developmental Timelines (0 to 14yrs) of Identified Mexican Migrants.

Environmental Stress: Health Indicators 1990-2010

Since several individuals showed developmental periods extending past the 1990s, line graphs showing PAHO (2018) health indicator data: poverty, unemployment, and homicide rates between 1991 and 2010 for El Salvador, Guatemala, Honduras, and Mexico were created to further examine the relationship between environmental stress and FA.

Overall, homicide rates are higher in Central American counties compared to Mexico between the early 1990s and 2010 (Figure 8). Specifically, El Salvador shows significantly high rates of homicides beginning in the mid-1990s, peaking at 142.3 murders per 100,000 people in 1995. By 2008 rates were lower, however are still above all three countries at 71.4 murders per 100,000 people in 2009. Gradually increasing since 1990, Honduras homicide rates surpassed El Salvador, reaching 76.1 murders per 100,000 people by 2010. Homicide rates for Guatemala show a steady decrease between 1990 and 2007, however begin to increase after 2007, reaching 22 murders per 100,000 people in 2010.



Figures 8: PAHO International Homicide Rates (1990-2010).

Figure 9 shows that between 1991 and 2009, El Salvador had overall higher rates of unemployment compared to all three counties, peaking at 9.94 in 1993. By 2009, rates lowered but were still significantly high at 7.33. Mexico showed high rates of unemployment between 1994 and 1997, peaking at 6.89 in 1995. After falling to 2.49 in 1999, unemployment jumped back up to 5.36 in 2009. Honduras shows a fluctuating increase in unemployment beginning in 1992, reaching its highest at 5.99 in 2004. Guatemala shows a slight gradual increase between 1991 and 2010, reaching 3.5 in 2010.

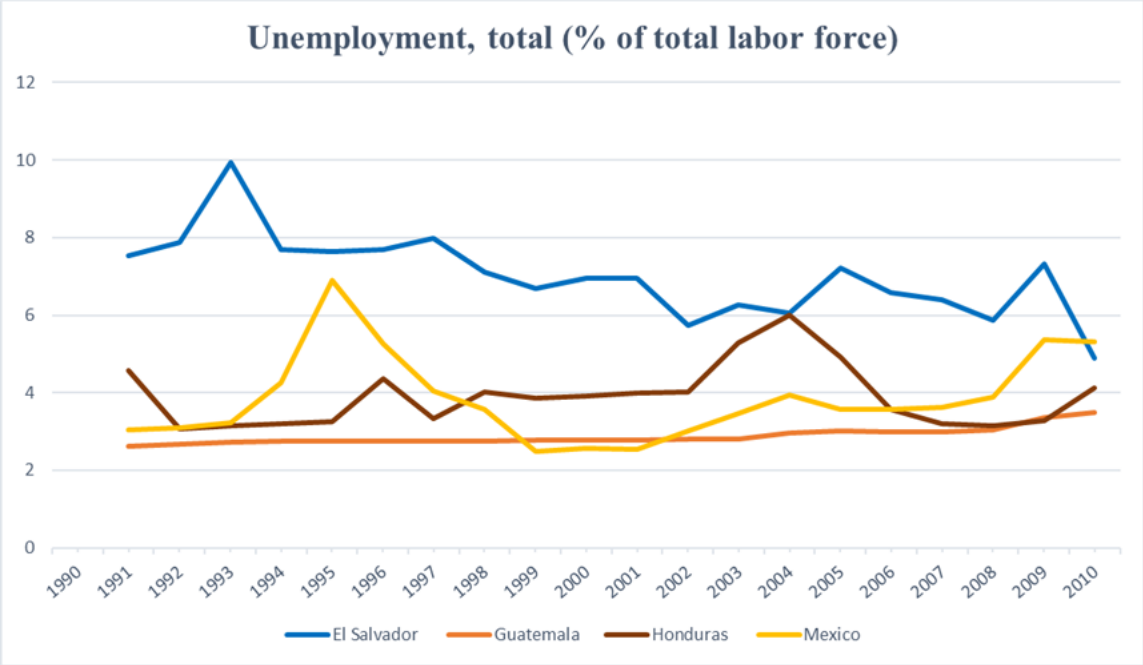


Figure 9: PAHO Unemployment Rates (1990-2010).

Figure 10 shows overall higher poverty rates in Honduras between 1990 and 2010 compared to El Salvador, Guatemala, and Mexico. Peaking at 44.3 percent in 1990, Honduran poverty rates show a decrease over the years but stay above all three counties. Mexico and El Salvador show similar trends between 1996 and 2010. Both show a height of 20 to 20.7 percent in the late 1990s with gradual decreases throughout the late 2000s. While significantly lacking, data for Guatemala show a steady decrease between 1998 and 2006.

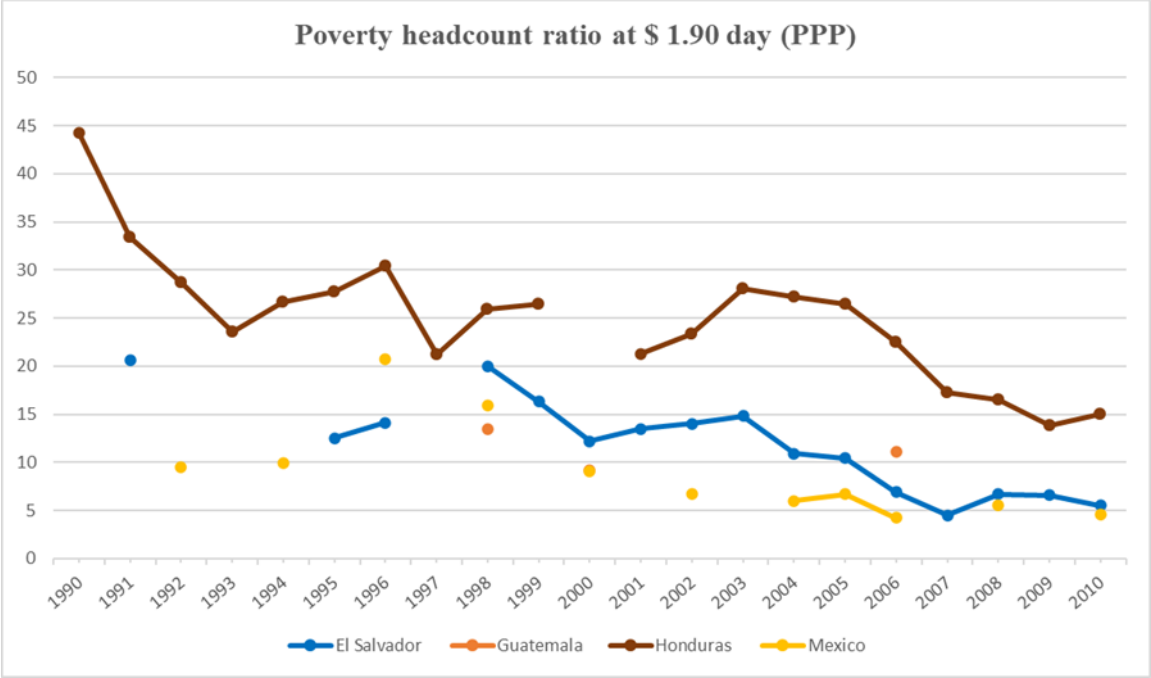


Figure 10: PAHO Poverty Rates (1990-2010).

IV. DISCUSSION

Differences in craniofacial FA between Central American and Mexican migrants, as well as between migrant and non-migrant groups were assessed using a One-way ANOVA to better understand skeletal manifestation of environmental stress in migrant home countries. Temporal relationships between developmental periods and major events were compared to levels of FA to assess the relationship between and environmental stress and FA. Results from FA statistical analysis and temporal relationships were compared to historic migration trends and personal narratives to assess the relationship between environmental stress and migrant push factors.

Mexican Group

The results from the One-way ANOVA indicate that the Mexican migrant group had significantly higher levels of FA compared to the Central American and the U.S. resident group, who had nearly identical levels of FA. The ANOVA results suggest that the Mexican migrant group maybe of lower SES, experiencing more environmental stress during their period of physical development. Identification criteria used by the PCOME to establish a UBC cultural profile has shown that UBCs entering through Arizona are young Mexican males of lower SES (Birkby, Fenton, & Anderson, 2008). Skeletal analyses have provided evidence of poor dental health, poorly administered dental restorations resulting in dental lesions, and shorter stature (Birkby et al., 2008), which likely reflect inadequate healthcare and nutritional deficiency –main correlates of low SES. Employing Willmore's (2005) cellular mechanism of FA development, both inadequate healthcare and nutritional deficiency experienced by Mexican migrants likely impair mechanisms of bone development resulting in higher levels of craniofacial FA.

Figure 7 illustrates identified Mexican developmental periods, length of the 1980s financial crisis, and the period following the implementation of NAFTA. Of the eight individuals used to examine the temporal relationship between migrant developmental period and both major events, six individuals' developmental period coincided significantly with either the period during the 1980s financial crisis, the period following NAFTA, or both. I acknowledge that it is necessary to have a larger sample of known birth years to make stronger inferences. However, of the five individuals included in the craniometric analysis, the overlap of the developmental period of individuals designated as OpID 0379 and OpID 0383, whose FA scores fell near or above the Mexican group mean of 5.03 (Table 4; Figure11), and major event suggests a relationship between environmental stress and high levels of FA within the Mexican migrant group.

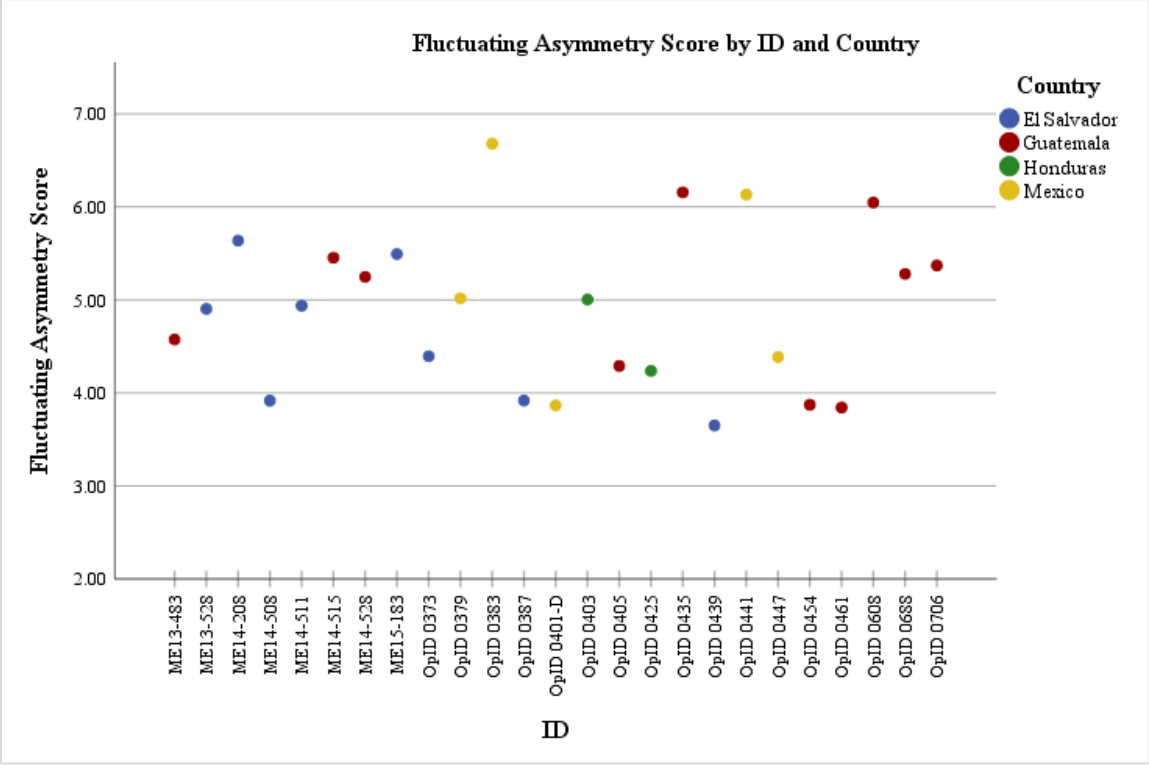


Figure 11: Fluctuating Asymmetry Score by ID and Country.

The social and economic costs of the financial crisis and NAFTA dramatically impacted the country's lower classes. The financial crisis of the 1980s was led by a series of events including the accumulation of foreign debt, devaluation of the peso, and the reckless spending by President José López Portillo's 1979-1982 administration (Hing, 2010). In an effort to stabilize the country, the proceeding president, Miguel de la Madrid, accepted a bailout loan with stipulations to cut public funding, raise taxes, and limit imports. By end of la Madrid's term in 1988, over 800,000 jobs disappeared, inflation climbed, subsidies and social programs were removed, and mass privatization of public services increased (Boullosa & Wallace, 2015; Hing, 2010). Mexico's shift to a free market economy led to the negotiation and implementation of NAFTA by President Carlos Salinas de Gortari in 1994, which further removed subsidies, social programs, and crop regulations. Interestingly, in 1987 there was one Mexican billionaire, by the end of Salinas de Gortari term in 1994, there were 24. In contrast, six years after the implementation of NAFTA, two million farmers from Central and Southern Mexico were forced to find work in the county's northern states (Boullosa & Wallace, 2015). Those who had the means migrated to the U.S. The Migration Policy (2004) indicates that undocumented Mexicans living in the U.S grew from two million to 4.8 million between 1990 and 2000.

Unemployment rates presented in Figure 9 showed that El Salvador experienced higher levels of unemployment compared to Mexico, Guatemala, and Honduras during the mid and late 1990s. However, Mexico showed an abrupt increase during the same time, surpassing both Guatemala and Honduras. At the same time, Honduras experienced higher rates of poverty compared to Mexico and El Salvador (Figure 10**).** However, both

Mexico's and El Salvador's rates were still relatively high at 20% of the population in 1996 and 1998, respectively. High unemployment and poverty rates in Mexico in the mid to late 1990s likely reflect the social and economic costs of the financial crisis and initial fallout from NAFTA. The developmental periods of at least four individuals in Figure 7 correspond with the high unemployment and poverty rates in Mexico during this time.

The confluence of events meant that the country's lower classes had less access to health care, education, and regulated food prices. In combination with stagnant wages, the financial crisis and NAFTA contributed to the uneven distribution of resources, increasing the likelihood of people living under low SES, which may have contributed to the high manifestations of FA in the Mexican migrant group. The present study suggests that higher levels of FA in the Mexican migrant group is at least partly attributed to the financial crisis and NAFTA. These conclusions could be strengthened with the inclusion of more identified Mexican migrants (when that data becomes available) and by examining other possible events that have created stressors in Mexico.

Historically, Mexicans migrate to the U.S. for economic reasons – work opportunities and stability. The results of this study support this trend and provide evidence for the biological manifestation of environmental stress. Most importantly, these results demonstrate a relationship between environmental stress and Mexican migration push factors.

U.S. Resident Group

The U.S. resident group was compared to both migrant groups to provide a base measure of SES and environmental stress. While the results of the One-Way ANOVA showed a significant difference in levels of FA between the U.S. residences and Mexican

migrants, there was no significant difference between U.S. residences and Central American migrants. Weisensee and Spradley (2018) indicate that the majority of individuals consisting of the U.S. resident group were likely of lower SES – donating their remains due to their inability to cover funeral costs. However, the authors further note that within the last seven years, the BDC has transitioned to only accepting remains with prior arrangements, increasing demographic (i.e., SES) variation within the BDC. The ANOVA results suggest that the U.S. resident group and Central American group may be of similar SES's, experiencing similar environmental stress during physical development.

Central American Group

By 2013, Central Americans from the Northern Triangle surpassed the number of Mexicans apprehended at the U.S.-Mexico border (U.S. Customs and Border Protection, 2019) – the majority citing violence, avoiding recruitment into gangs, exploitation, and poverty as reasons for fleeing to the U.S. (Hiskey et al., 2018). Since the 1980s, the Northern Triangle has experienced high levels of crime and violence due to civil wars and political unrest. It is estimated that 75,000 people died during the El Salvadorian Civil War, while 200,000 are estimated to have died during the Guatemalan Civil War (Hiskey et al., 2018). These numbers do not account for the unknown number of the "disappeared". Due to its proximity to both El Salvador and Guatemala, thousands of civilians and combatants fled to Honduras during the civil wars. Coupled with Honduras's involvement in the U.S. anti-communist campaign and its inability to accommodate the larger workforce, crime and violence began to rise. During the late1990s and 2000s, the escalation of gang violence after the implementation of the

IIRIRA in 1996 began driving people out of Central America and into the U.S., despite the risk of violence and death throughout the journey. In conjunction with the high levels of violence due to the drug cartel operations, particularly in El Salvador and Honduras, it is undisputable that the majority of Central Americans migrate to the U.S due to widespread violence.

The results from the One-way ANOVA suggest that the Central American migrant group maybe of higher SES compared to the Mexican migrant group, experiencing lower levels of environmental stress. This is not to say that Central Americans do not experience environmental stress associated with low SES (Figures 9 and 10). The results likely reflect how violence in Central America affects people from all SES's. Those with the means to pay the costs of migrating north (coyotes, extortions, etc.) but die of exposure, for instance, may compose the Central American group under study.

Figure 4 illustrates the temporal relationship between identified El Salvadorian developmental periods, the El Salvadorian Civil War, and the period following the IIRIRA. Of the 10 developmental periods examined, four coincided significantly or partially with the civil war, four coincided significantly with the period following the IIRIRA, and eight coincided with both events. All seven individuals included in the craniometric analysis had developmental periods that coincided significantly with at least one event. Of the seven individuals included in the craniometric analysis, FA scores for individuals designated as ME14-508, OpID 373, OpID 387, OpID 439 fell below the Central American group mean of 4.75 (Table 4**;** Figure 11). Although there is a distinct period between both events, the lack of police presence throughout the country after the

war contributed to the violence between 1992 and 1996 (Figure 8).

Similarly, the developmental period of the 11 identified Guatemalan individuals show a temporal relationship with either the Guatemalan Civil War, the period following the IIRIRA, or both (Figure 5). Eight individuals' developmental periods coincided significantly with the Guatemalan Civil War, while three individuals' developmental periods coincided significantly with the period following the IIRIRA. Of the six individuals included in the craniometric analysis, three individuals' developmental periods coincided significantly with both events. Additionally, of the six individuals included in the craniometric analysis, FA scores for individuals designated as ME 13-483, OpID 0405, OpID 0454, OpID 0461 fell below the Central American group mean of 4.75 (Table 4; Figure 11).

While there were no major events like a civil war in Honduras, the country has met with economic and political instability throughout its history. After 1996, when the IIRIRA resulted in the deportation of young gang-affiliated individuals, crime and violence largely associated with the drug trade rose sharply to levels never before seen outside of war. As Hiskey et al. (2018) research has shown, the daily high-violence context in Honduras has heavily contributed to the decision to leave, outweighing the risks of traveling north. Of the three identified Honduran developmental periods, one coincided significantly with the period following the implementation of IIRIRA and two fell between 1969 and 1989 (Figure 6). Of the two individuals included in the craniometric analysis, the FA score of individual designated as OpID 0425 fell below the Central American group mean of 4.75 (Table 4; Figure 11). With a small sample size, it is difficult to make any inferences. Considering Honduras's high poverty rates since at

least the early1990s (Figure 10), high homicide rates since the late 1990s (Figure 8), and results from the Hiskey et al. (2018) study, Hondurans more than likely migrate to the U.S. due to both violence and poverty.

While a significant amount of research associate's economic migrants to Mexico, the economic migrant narrative cannot be applied to Central Americans, due to Central Americas political and economic past (Hiskey et al., 2018). Using data collected during the 2014 AmericasBarometer survey, Hiskey et al. (2018) carried out an individual-level analysis to examine the connection between crime victimization and the intention to emigrate, which showed that Salvadorians and Hondurans who experienced multiple instances of crime victimization within a year were more likely to migrate to the U.S., while economic factors were more of an influence for Guatemalans. Hiskey et al. (2018) further showed that armed robbery and extortion/blackmail were types of crime victimization experienced more by Salvadorians, Hondurans, and Guatemalan compared to other Central Americans.

Research regarding individual migrant SES is limited, however, the following factors should be considered when making inferences about migrant SES. First, it takes a considerable amount of resources to migrate to the U.S. Households making enough income to make emigration possible are more than likely to consider emigrating (Hiskey et al, 2018). Given this factor, the further away the country of origin is from the U.S., the necessity for more resources increases. Second, the primary source of income for Central American gangs is monthly extortion ("*la renta*") of small to large businesses (i.e., barbershops, grocery stores, Coke and Pepsi distributors, etc.) (Beaubien, 2009; Zaidi, 2019). It can be inferred that shop owners and workers of larger businesses likely have

steady incomes and are of relatively higher SES compared to the population living below poverty levels. Given the results of the Hiskey et al. (2018) study, shop owners and workers**,** targeted by extortionists, are more likely to consider emigrating to the U.S. along with individuals (i.e., women and adolescents) experiencing other types of crime victimization and economic insecurities.

The results of the present study showed that the relationship between environmental stress and craniofacial FA was lower in the Central American group compared to the Mexican group. War and gangs have contributed to the high levels of violence in the Northern Triangle. The lower levels of FA in the Central American group likely reflect how violence affects the overall population, driving individuals from all SES's to flee from Northern Triangle countries. These results further show that violence has and continues to act as a decisive and forceful factor for U.S. bound migration.

Sex Differences in FA

Statistical analysis did not show significant differences between combined males and females. The high representation of males (N= 520) to females (N=158) may explain why no differences in sex were observed. The female buffering hypothesis, which suggests that females are better suited to cope with environmental stress (Frayer & Wolpoff, 1985; Stinson, 1985), may explain the lack of difference, even with the high representation of males. A more even distribution of males to females is needed to strengthen the current analysis of combined males and females, but also by individual group.

U.S. Policy and Intervention

The ANOVA results and developmental timelines suggest that the civil wars, economic crisis, and immigration reform are at least partially responsible for the environmental stressors and violence in Central America and Mexico. Deeply rooted in political and economic interests, U.S. policy and intervention has contributed to the instability and violence that fuels migration today. U.S. funding to stop the spread of communism throughout the 1980s helped create dire social, economic, and political conditions that still exist in the Northern Triangle. Seeking refuge from the violent conditions created by war, thousands of Central Americans fled to the U.S., many resettling in inner cities. In Los Angeles's inner city, young migrant Salvadorians formed MS-13 for protection from other gangs. When immigration reform made more people eligible for deportation, thousands of MS-13 gang members were sent back to Central America, who would later establish gang networks and initiate widespread violence. In Mexico, major beneficiaries of NAFTA were U.S. companies and Mexico's upper classes, while the lower classes struggled with the loss of agricultural jobs, exploitation, and worsening work conditions. The drive to continue the unsuccessful war on drugs is complicated and beyond the scoop of the current research. However, the U.S. government has used its objectives to justify building the wall along the U.S southern border. U.S. demand for drugs fuels supply routes throughout Latin America. Seeking opportunities, corrupt local governments and gangs work with drug cartels, who maintain drug routes, extending from the Caribbean coast to the U.S.-Mexico border.

Structural Violence

Farmer (2003) proposes that the relationship between inequality and health

outcomes is a socially produced phenomenon and are “biological reflections of social fault lines”. Drawing from Farmer’s (2003) work, the present study suggests that high levels of Mexican group FA represent the manifestation of structural violence in the human body, which speaks to the forces working to limit the distribution of resources. While a lesser relationship is indicated between environmental stress and FA in the Central American group compared to the Mexican groups, it is evident that Central Americans experience a different degree of structural violence. Criminal violence is the legacy of war and power inequality in Central America. Faced with immediate danger, civilian populations have no choice but to seek asylum in the U.S. Migration is the response to the lack of resources and power in Latin America. U.S. influence over Latin America has contributed to mass migration, while also preventing their movement to obtain their basic human rights. The invisibility of structural violence acts to limit life chances in migrant home countries and is the cause of the massive loss of life along the U.S.-Mexico border, which continues to go unnoticed.

V. CONCLUSION

Analyses of variance (ANOVA), developmental timelines, and PAHO health indicator data from 1990-2010 were used to better understand skeletal manifestations of environmental stress and its relationship with Central American and Mexican migration. The Mexican group had significantly higher levels of craniofacial FA compared to both Central American and the U.S. resident groups, suggesting that that Mexican group were of lower SES, experiencing more environmental instability during the critical period of physical development. Lower levels of craniofacial FA in the Central American group likely reflect the high levels of widespread violence in Central America, affecting all SES's.

Since the 1980s, civil wars, economic crises, and immigration reform created conditions that sparked major migration waves. The economic and social fallout of the 1980s economic crisis and NAFTA in the 1990s likely contributed to high levels of craniofacial FA in the Mexican group. While more data is needed to strengthen this study, the results suggest that the social and economic costs of neoliberalism in Mexico created environmental stressors that also push migration from Mexico to the U.S. While also impacted by environmental stressors, violence has shown to be a greater driving force for Central American migration. With increases in gang- and drug-related violence since 1996, Central Americans face constant danger, forcing families out of their home counties in staggering numbers.

The present study has documented the biological consequences of environmental stress and has shown that economic factors and violence are still major migration push factors. The results align with historic trends (U.S. Customs and Border Patrol, 2019),

previous research (Birkby, Fenton, & Anderson, 2008; Weisensee & Spradley, 2018), and narratives of lived experiences (Hiskey et al., 2018). To better understand the causes of migration, it is important to recognize historic and current U.S. influence over Latin America. The destabilization of Latin America was at least partially driven by U.S. policy and intervention. Seeking a way out from deteriorating conditions in their home countries, migrants are met with barriers that limit their movement. U.S. Immigration reform, of which criminalizes migrants, has created conditions that allow the massive loss of life at the U.S-Mexico border and the invisibility of this humanitarian crisis (Klinenberg, 2002). The present study contributes to the mounting evidence of the deteriorating conditions in Latin America that fuel migration. The U.S. has the responsibility to modify immigration reform and redefine asylum criteria to include protections from criminal violence in the Northern Triangle.

APPENDIX SECTION: CRANIOFACIAL LANDMARK DEFINITIONS

Table 1: Craniofacial Landmark Definitions

Landmark	Abbreviation	Midline of right/left	Definition
Alare	alar	R/L	The most lateral point on the margin of the nasal aperture taken on the anterior surface.
Asterion	ast	R/L	The point where the lambdoidal, parietomastoid, and occipitomastoid sutures meet.
Basion	bas	M	Midline point at the anterior margin of the foramen magnum.
Bregma	brg	M	Point where the coronal and sagittal sutures intersect.
Dacryon	dac	R/L	Anterior border of the junction of the lacrimal and frontal. Apex of lacrimal fossa on the frontal bone.
Ectoconchion	ect	R/L	The intersection of the most anterior surface of the lateral border of the orbit and a line bisecting the orbit along its long axis.
Frontomalare anterior	fma	R/L	Point where the frontozygomatic suture intersects with the orbit. Point is taken anterior.
Lambda	lam	M	Point where the sagittal and lambdoidal sutures meet.
Nasion	nas	M	Point of intersection of the nasofrontal suture and the mid-sagittal plane, on the frontal bone.
Nasale inferius	nlhi	R/L	The most superior point where the nasal touches the maxilla
Opisthion	ops	M	Midline point at the posterior margin of the foramen magnum.
Porion	por	R/L	Point at the most superior aspect of the EAM
Prosthion-Howells	pro	M	Midline point at the most anterior point on the alveolar process of the maxillae.
Zygion	zyg	R/L	Maximum lateral extent of the zygomatic arch.

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