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A decade of rapid change: Biocultural influences on child growth in highland Peru

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Abstract

Objectives: In the past decade many areas of Peru have been undergoing extreme environmental, economic, and cultural change. In the highland hamlet of Chugurpampa, La Libertad, climate change has ruined harvests and led to frequent periods of migration to the coast in search of livelihood. This biocultural research examines how the changes could be affecting the growth of children who maintain residence in the highlands.

Methods: Clinical records from the early 2000s were compared to those from the early 2010s. Charts were randomly selected to record anthropometric data, netting a sample of 75 children ages 0-60 months of age. Analysis of covariance was run to compare mean stature, weight, and BMI between cohorts. Percentage of children who fall below the −2 threshold for z-scores for height and weight were compared by age and cohort.

Results: A significant secular trend in growth was found, with children born more recently larger than those born a decade before. The effect is most notable in the first year of life, with the growth advantage attenuated by the age of 3 for height and age 4 for weight. While children were unlikely to be stunted from 0 to 3 years of age, 44% of the later cohort were stunted and 11% were underweight from 4 to 5 years of age.

Conclusions: Three possible explanations for the rapid shift are entertained: more time spent on the coast during gestation and early childhood, which may attenuate the effect of hypoxia on child growth; dietary change; and increased use of biomedicine.

1 | INTRODUCTION

Over the past decade, many areas of Peru have undergone dramatic economic, social, cultural and climate changes that have disrupted long-established life ways (Adams, 2012; Lennox & Gowdy, 2014; Lennox, 2015; Mitchell, 2010). This includes the highland hamlet of Chugurpampa in the northern Department of La Libertad. The effects of such changes on childhood growth and development have not been adequately studied. The aim of this research is to assess secular patterns of change in anthropometrics in Chugurpampa over a relatively short period of time. Chugurpampa, in the western cordillera, covers an altitude range of 2875 to 3750 m, with houses arrayed over more than 700 hectares of mountainous terrain. The principal occupation is potato agriculture, produced for subsistence as well as for the market. The first author, upon visiting the hamlet for the first time in over 20 years to conduct a restudy of medical tradition and health outcomes, noticed an apparent increase in people's body size. This led to further inquiry into patterns of growth in infants and young children.

To examine this secular shift, a brief review of the cultural and historical context of the region is first necessary. In the 1980s, Chugurpampa was a large, vibrant peasant community. Three fundamental events have occurred that are driving other changes in Chugurpampa: the conversion of

TABLE 1 Significant changes over time in Chugurpampa

	Late 1980s	Early 2010s
Primary changes:		
Environment	Occasional droughts, but largely stable	Drastic climate change
Social Organization	*Comunidad campesina*; communal land	Private property, alienable land
Mobility	7–14 hour trip to coast	2–3 hour trip; roads enhanced for mining
Corollary changes:		
Population	$n = 932$	$\sim n = 600$
Community Size	~1000 hectares	~700 hectares, upper part has fissioned off
Demographics	Vibrant large age-balanced community	Children/whole families migrated to coast
Economy	Bumper potato and other harvests	Crop variety decreased, loss of heirlooms
Diet	Mostly locally produced	More rice, noodles, processed foods
Health Care	Traditional; district capital health clinic	Few healers; health post since 1999
Health	Generally very good	Apparently very good
Political	Communal association, cargo-like posts	Very weak association, many posts gone
Feasting	Annual patron feast, small & mostly local	*Mayordomo* often from coast, huge crowds
Religion	90% Catholic, 10% Evangelical	~60% Catholic, 40% Evangelical
Orientation	Local; somewhat to coastal Peru	Local; coastal Peru; world
Technology	Occasional, brief TV viewing	Consistent TV, cell phone
Aspirations	Local status	Starting to adopt cosmopolitan ideals

the community from a *comunidad campesina*, or communal village with usufruct rights, to private property in 1993; successive years of drastic environmental instability since 2005 including drought, deluge, unseasonable temperatures, and invasive flora and fauna; and increased mobility from road improvements primarily made to facilitate mining activity since the mid-2000s (Table 1). Due to the erratic climate and the loss of communal integrity, the peasant economy is in disastrous shape. Recent harvests have been variably productive, with the actual size as well as total yield of potatoes shrinking.

While migration from Chugurpampa to the coast grew slowly and incrementally since the first pioneer settled in Trujillo in 1960, it spiked between 2000 to 2012 due to the interaction during that period of crop failure, mobility, and the pull of the burgeoning community of migrants already established in Trujillo, such that 47% of all outmigration over the past 55 years has occurred during that period (from original census data by the first author and recent re-census and network analysis by MS). At this point at least one-third of the population has abandoned their fields and migrated permanently to the coast, aided by the ability to sell one's land that was formerly held communally. A mining boom occurred in the highlands around 2005, disrupting rural livelihoods while it raised the country's overall GDP (Bebbington & Bury, 2009; Ponce & McClintock, 2014). This included a major expansion of the mining center of Huamachuco that incentivized state road improvements to the sole transport artery in the zone. Chugurpampa lies along that route.

Due to the disruptions, traditional healer availability has diminished (Lazo, Oths, & Stein, 2013). A health post established in the community in 1999 was used sporadically by the population until 2007 when the government initiated Programa JUNTOS, a cash-transfer welfare program that creates tremendous incentive for children to attend school regularly and to frequent the health post for wellness checkups; benefits may be suspended if either is not done (Huber, Zárate, Durand, Madalengoitia, & Morel, 2009).

The years of ruined harvests have led to either permanent or repeated periodic migration to coastal cities in search of livelihood. Those who maintain residence in the highlands frequently visit family who have become full-time coastal residents. The highland-coastal migration, a sort of modern transhumance without the livestock, has brought with it an orientation to mainstream society and an introduction to new technology, aspirations, and diet. This research suggests how these shifts could be affecting the health of children in the highland hamlet of Chugurpampa. In contrast, conditions that have *not* changed since the 1980s are high altitude hypoxia and poverty.

While positive secular trends, or an increase in growth over time, have been seen worldwide since the mid-20th century within and between populations, it has been less well-documented in indigenous Latin American populations (Dittmar, 1998; Gonzales, Crespo-Retes, & Guerra-García, 1982; Gonzales, Valera, Rodriguez, Vega, & Guerra-Garcia, 1984; Leatherman, Carey, & Thomas, 1995), and often not found when looked for (Carey, 1988; Leonard, 1989; Pawson & Huicho, 2010).

TABLE 2 Age range and other characteristics of studies of highland Andean child growth and development

Source	Year	Ages	Area	Sample	Location	Altitude
present study	2017	0 - 5	rural	indigenous	Chugurpampa, Peru	2875–3750
Berti & Leonard	1998	1.5 - 50	rural	mestizo	near Salcedo, Ecuador	3300–3600
Berti et al.	1998	1 - 20	rural	mestizo	near Salcedo, Ecuador	3300–3600
Carey	1990	1 - 70	rural	Quechua	Nuñoa, Peru	3960–4543
de Meer et al.	1993	0 - 14	rural	Quechua, Aymara	Lake Titicaca Basin, Peru	3810–3840
Dittmar	1998	6 - 29	rural	Aymara,	Putre, Chile	3530
Frisancho & Baker	1970	2 - 22	rural	Quechua	Nuñoa, Peru	4000–5500
Gonzales et al.	1982	7 - 20	urban	indigenous	Puno, Peru	3800
Gonzales et al.	1984	6 - 30	urban	indigenous	Huancayo, Peru	3280
Graham	1997	1 - 6	rural	Quechua	Ura Ayllu, Peru	3400
Greksa et al.	1984	10 - 20	urban	Aymara	La Paz, Bolivia	3750
Haas et al.	1982	0 - 1	urban	indigenous, mestizo	La Paz, Bolivia	3600
Jones	2014	.5 - 2	rural	(Quechua)	Potosí, Bolivia	2700–4200
Leatherman et al.	1995	3 - 22	semi-urban/ rural	(Quechua, mestizo)	Nuñoa, Puno	3850–5000
Leonard	1989	1 - 70	rural	Quechua	Nuñoa, Puno	4000
Leonard et al.	1990	2 - 21	rural	Quechua	Nuñoa, Puno	4000
Leonard et al.	1995	0 - 5	rural	Quichua, European	Salcedo, Ecuador	3000–3500
Leonard et al.	2000	0 - 5	rural	(Quichua, European)	Salcedo, Ecuador	3000–5000
Obert et al.	1994	10 - 11.5	urban	Aymara, Spanish	La Paz, Bolivia	3600
Pawson et al.	2001	4 - 18	mining	Quechua, Spanish, mestizo	Tintaya & Marquiri, Peru	4100
Pawson & Huicho	2010	3 - 18	(rural)	Quechua, mestizo	Nuñoa, Peru	4100
Pomeroy et al.	2014	3 - 8.5	rural	indigenous, mestizo	Santillana & Vinchos districts, Peru	3100–4400
Pomeroy et al.	2015	.5 - 8.5	rural	indigenous, mestizo	Santillana & Vinchos districts, Peru	3100–4400
Roman et al.	2015	1 - 5	rural	mostly indigenous	Jujuy, Argentina	>2500
Stinson	1980	6 - 21	rural	Aymara	Ancoraimes, Bolivia	3800–4000
Stinson	1982	8 - 14	urban	European	La Paz, Bolivia	3200–3600

(-) = deduced from context or previous studies.

Secular change in infant and child growth has long been assumed to be mostly a consequence of modernization, specifically due to improvement in parental education, nutrition, and/or socioeconomic status (Dittmar, 1998), better hygiene and health care, and even genetic admixture (Gonzalez, 1984). Across Peru in general, healthy child stature is shorter and weight is lighter relative to WHO international growth standards, while growth trajectories are comparable (Bustamante, Freitas, Pan, Katzmarzyk, & Maia, 2015). Nonetheless, mean anthropometric measures for Peruvian children have increased across the past century (Uauy, Albala, & Kain, 2001), with secular trends occurring primarily in coastal and some highland urban areas. In the few cases where secular trends have been discovered in the rural Andes, they take place over several generations in one population (Gonzales et al., 1982, 1984; Leatherman et al., 1995;

Leonard, Leatherman, Carey, & Thomas, 1990). In Puno (Gonzales et al., 1982) and Nuñoa (Leatherman et al., 1995; Leonard, et al., 1990), no secular gain was found in adult stature, whereas a significant increase was noted for children, with Leonard et al.'s gain predominantly in the upper income groups. In contrast, Dittmar (1998), found significant increases across a 15 year span in measures for adults and children over 6 years of age in highland northern Chile, which was attributed to better nutrition. Eveleth and Tanner (1990) credited the overall lack of secular growth trends among indigenous American groups to the fact that little had changed in their environmental conditions.

Previous research has varied in terms of when the developmental delay in child growth is thought to occur at high altitude. It has been posited to occur in utero (Beall, 1981; Haas et al., 1982), during the first year of life (Leonard, DeWalt, Stansbury, & McCaston, 2000), after 1 year (de Meer, Bergman, Kusner, & Voorhoeve, 1993; cf. Román, Bejarano, Alfaro, Abdo, & Dipierri, 2015, pp. 434), and after 20 months (Andrissi, Mottini, Sebastiani, Boldrini, & Giuliani, 2013, pp. 345). Leonard, DeWalt, Stansbury, and McCaston (1995) found delays at 2 years, Beaton (1992) at 3 years, and others around age 4 (Bustamante et al., 2015; Picón-Reátegui, 1976). Lamentably, only three previous studies include children from birth to 5 years (de Meer et al., 1993; Leonard et al., 1995, 2000) (see Table 2); *none* of the studies investigating secular change include this age range. Therefore, despite the first two years of life being the time when the greatest effects of the familial environment occur (see Eveleth & Tanner, 1990), little data on highland growth for this age exist. If acclimatization to hypoxia begins early on, then it is possible that highland babies spending more time at sea level may acclimatize somewhat less, resulting in an increased body size. Thus, in contrast to most highland research on growth, which focuses on older children and adolescents, this research also includes children from birth to 2 years of age in an effort to add to the sparse information on the determinants of growth during infancy and early childhood, a goal Leonard et al. (2000) has championed.

Conventional physiological explanations of developmental delay during childhood include malnutrition (Leonard, 1989; Obert et al., 1994), infectious disease (Martorell, 1980), and genetics (Greksa, 1996; Pomeroy et al., 2015). Research in the Andes has perforce needed to also focus on the altitude at which a child lives because of the physiological effects of high altitude hypoxia such as slowed fetal growth (Carter, 2015) and shorter stature (Frisancho, 1976; Román et al., 2015; Stinson, 1980). These effects are strongest when a child has lived permanently at high altitude (de Meer, Heymans, & Zijlstra, 1995; Tarazona-Santos, Lavine, Pastor, Fiori, & Pettener, 2000), with infancy appearing to be the most labile age (Greksa, 2006).

When mobility was more limited, altitude was far outweighed in significance by other factors in growth (Leonard et al., 1990; Obert et al., 1994). Indeed, bioculturally oriented anthropologists have spent decades showing there are other more vital, complex, and remediable ecological, political-economic, and sociocultural influences on growth such as diet, land tenure, oppression, and climate change; that is, a biology of poverty is at play in differentiating health statuses of children in poor communities (Thomas, 1998). For instance, Greksa, Spielvogel, Paredes-Fernandez, Paz-Zamora, and Caceres (1984) noted larger heights in children in the urban Andes with better access to health care and resources, while Carey's (1990) fine-grained analysis of three distinct villages in Southern Peru found the village with the lowest heights and weights to be that with the *lowest* altitude due to its social marginalization. Now, with the numerous shifts that have occurred, altitude—a seemingly fixed trait—requires a new perspective, one that views stature as a "cultural-biological," to follow Goodman (2013). Thus, renewed attention to hypoxia is merited, given the recent unprecedented level of highland-coastal mobility.

We seek to extend the work of Thomas, Leatherman, Leonard, and others, who have documented the effects of poverty on growth while making it clear that being small is not a viable adaptation to scarcity (Goodman & Leatherman, 1998). Socio-economic conditions such as poverty are strongly correlated with failure to thrive (Graham, 1997; Tanner, 1987; Wachs, Creed-Kanashiro, Cueto, & Jacoby, 2005), yet the precise mechanisms are largely left unexplained; that is, how poverty gets under the skin and creates growth differential, beyond merely limiting consumption, is a more complicated matter (Thomas, 1998). As Carey (1990, pp. 268) held, models of health "should more thoroughly examine how broader macrolevel social forces affect the local system by shaping social structure and/or access patterns to critical material and social resources."

2 | METHODS

2.1 | Sample

Data were recorded in August of 2012 from a random sample drawn from the Chugurpampa Health Post clinical files from 1993 to 2012 (all but 4 cases were from 1999 or later) in which patients are organized by family. All families in the Spanish-speaking indigenous community are represented with few if any exceptions. This can be attributed to the JUNTOS program that expects routine medical check-ups of pregnant women and children from birth until 18 years of age as a precondition for receipt of a monthly stipend per child (Huaman Ayala, Blumenthal, & Sarnquist, 2013). A systematic interval of two was used to select 50% of the files

TABLE 3 Gender distribution of sample by time period

		Gender		
		Female	Male	Total
COHORT	≤2005	21	18	39
	≥2011	13	23	36
Total		34	41	75

to record anthropometric data on all family members. Under our supervision, the clinic technician located and recited the data points, which we recorded anonymously by unique identification numbers to maintain confidentiality. For the purposes of this analysis, cases from the 5-year eco-socio-cultural transition period from 2006 to 2010 were omitted to enhance the contrast between the earlier (cohort 1) and later (cohort 2) time periods, resulting in a sample of 75 children aged 0 to 60 months. While cohort 2 can be considered random, cohort 1 cannot (a high bar rarely achieved in comparable studies), though we can be fairly confident of its representativeness. Of the 80 families in the total sample, 51 had children under 5 at any point during the data collection period. Of the 51, 63% used the clinic prior to 2007 and 98% used it from 2007 on. The percentage for the early cohort is a conservative estimate, given the addition of newly formed families over time, and the retirement of families from the active clinical charts as they relocated.

Whether cohort 1 could be weighted toward the wealthier or the sicker is impossible to ascertain, though little such bias would be suggested based on clinic attendance by the majority, minimal socioeconomic status (SES) variability (no mestizos live in the hamlet [Oths, 1998]), and the custom of measuring infants during the first year—conditioned by the longstanding efforts by the Ministry of Health and NGOs to get mothers to do so. Comprehensive Health Insurance, or SIS, (Seguro Integral de Salud) was begun by the Peruvian Ministry of Health in 2001 as the public sector of the health care system designed to provide health care to the, especially rural, poor. Thus, families would have had free clinic visits throughout the majority of time covered by data collection (two-thirds of cohort 1 are from 2001 on). At no point in the clinic's existence were families charged a fee to have their children's height and weight measured. Furthermore, physical access is not an issue; the health post is centrally located at the "five corners" where the schools, storefront homes, and chapel are located, and where all meetings and events are held, resulting in the area being visited constantly by all community members.

Therefore, it appears that while a majority of families made use of the clinic prior to 2007, the JUNTOS program mandate clearly increased the frequency of clinical visits per child and increased the percent of families using the clinic to near 100%. During the earlier period, mothers appeared to mostly take their children to be weighed once during the first year, and to only take them for monthly well-baby checkups once JUNTOS began, thus explaining the skew towards younger children in the earlier cohort.

The research received IRB approval from the University of Alabama, the Pontifical Catholic University of Peru (PUCP), and written permission from the Director of the La Libertad Regional Ministry of Health (DIRESA).

2.2 | Measurement

Stature was measured to the nearest 0.1 cm. Infants up to 2 years of age were measured using a recumbent length board (built by Ministry of Health, Peru). Older children who could stand were measured for height in bare feet with a stadiometer built by El Antropometrista (Lima, Peru) prior to 2006, and after that, by Greetmed (Model GT131-200, China). Weight was measured to the nearest 0.05 kg. Infants were assessed with a Seca scale (Germany) Model 745, for data prior to 2006 and for later data a digital Model 354. Older children were weighed using a Greetmed scale (Model GT131-200, China). The scale for weighing older children prior to 2006 was not on the premises for inspection. Age was coded to the nearest day. Ministry of Health nurses and technicians took all measurements, and have used the same methods of measurement across the period represented by the data.

2.3 | Analysis

Statistical data were analyzed using SPSS v. 20 and z-scores calculated using the NHANES calculator based on WHO (2009) standards. For descriptive purposes given the modest sample size, we deemed it preferable to plot actual data against the CDC growth charts rather than smooth the data by creating a curve of the data points (cf. Dittmar, 1998; Pawson, Huicho, Muro, & Pacheco, 2001). Mean and z-scores of height and weight as well as BMI of children from 2005 and earlier were compared to those from 2011 to 2012. To assess secular changes between time periods, analysis of covariance was run to compare stature and weight between cohorts controlling for gender and age, and for 0–12 month olds controlling for gender. Numbers in other age categories were too low for individual statistical testing. Due to small sample sizes, as there was no main effect of gender or interaction effect of cohort and gender, all children were pooled for presentation, with gender then controlled for due to the known systematic differences in size between male and female newborns and children. The percentage of children who fell below the −2 threshold for z-scores of height and weight were compared by age category and cohort.

TABLE 4 Comparison of mean stature and weight by age category and cohort

	Age (mo)	≤2005 $\bar{x}$ ± SD (n)	≥2011 $\bar{x}$ ± SD (n)	p
Stature (cm)	Total[a]	70.4 ± .90 (38)	73.4 ± .95 (35)	.04
	0–11.9[b]	54.9 ± 1.1 (31)	60.9 ± 2.3 (6)	.025
	12–23.9	76.7 ± 2.4 (3)	75.9 ± 1.5 (8)	
	24–35.9	78.9 ± 3.7 (1)	87.4 ± 2.1 (3)	
	36–47.9	94.2 ± 3.2 (1)	92.2 ± 0.9 (11)	
	48–60.9	104.9 ± 6.3 (2)	97.5 ± 3.3 (7)	
Weight (kg)	Total[a]	8.6 ± .24 (39)	9.4 ± .25 (36)	.036
	0–11.99[b]	4.9 ± .28 (32)	6.4 ± .65 (6)	.048
	12–23.99	9.6 ± .66 (3)	10.0 ± .40 (8)	
	24–35.99	9.5 ± 1.1 (1)	12.5 ± .53 (4)	
	36–47.99	13.4 ± .60 (1)	14.0 ± .17 (11)	
	48–60.99	17.9 ± 1.4 (2)	15.6 ± .75 (7)	

[a]ANCOVA of total sample statures and weights controlling for gender and age.
[b]ANCOVA of 0-<12 month olds controlling for gender.

3 | RESULTS

The clinical sample consisted of 34 girls and 41 boys, 39 from the earlier cohort and 36 from the later (Table 3). The earlier cohort skewed towards the more recently born and those of the later cohort were distributed more evenly across the age categories for the reasons noted above.

Table 4 provides the mean statures and weights by cohort for the total sample and 1-year age intervals. A significant secular trend was found, with children born more recently in the northern Peruvian highlands larger than those from as few as 6 years previously. The effect was most notable in the first year of life, with the growth advantage attenuated by the age of 3 for height and age 4 for weight. Comparing BMI

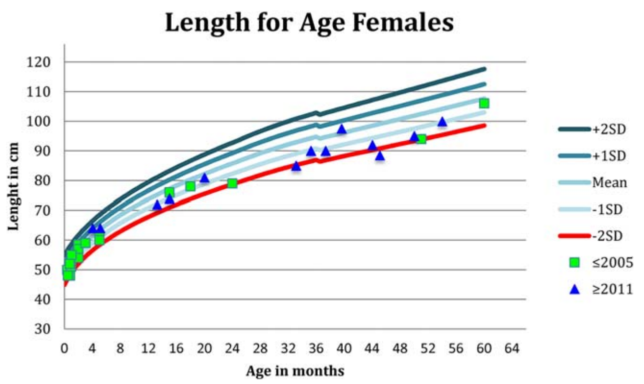

FIGURE 1 Length for Age in Girls from 0 to 60 months

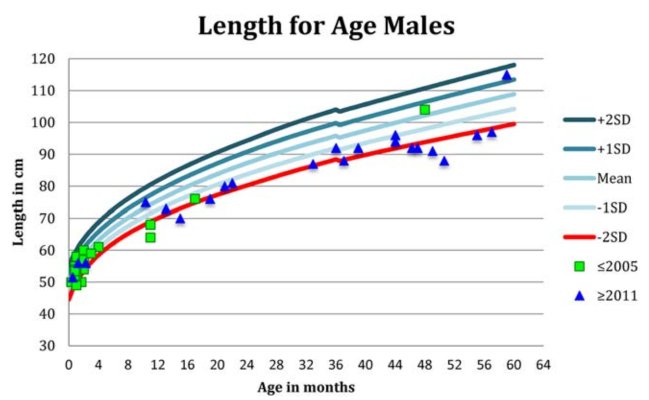

FIGURE 2 Length for Age in Boys from 0 to 60 months

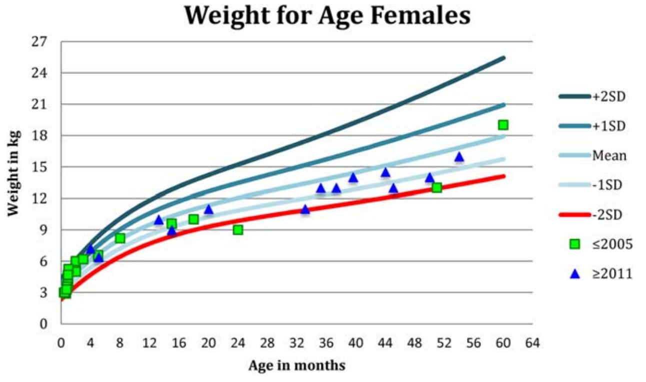

FIGURE 3 Weight for Age in Girls from 0 to 60 months

between the cohorts also revealed a secular increase, with the later group exhibiting a higher mean ($x_1 = 15.71$, $n = 38$; $x_2 = 16.51$, $n = 35$; $t = -2.07$, $P = .043$).

When size data are plotted by gender on CDC growth charts (Figures 1–4), data fall around the low normal range with few cases above the mean, and relatively few below the −2SD threshold. Despite this, the collective trajectory indicates a normal rate of growth for most children until about 3 or 4 years of age, when the curve for the recent cohort begins to flatten. The trend can be seen most clearly in boy's height. Also, keeping in mind these charts are normed to other populations with larger children, fewer Andean children fall below the critical −2 SDs below the mean, demarcated by the red line, than might be expected.

Table 5 compares the z-scores of children by cohort in terms of the percentages who fall below the −2SD threshold. While those from 2011 to 2012 fared better from ages 0 to 3—only 2 fell below the threshold for height and only 1 for weight—they fared worse after that, especially with regard to height. While the later cohort of children were less likely than the earlier children to be stunted or underweight from 0 to 3 years of age, after 3 years of age a full 44% were stunted and 11% were underweight compared to none for the earlier cohort. Sample size for this age range for the earlier cohort was insufficient to make comparisons. Based on International

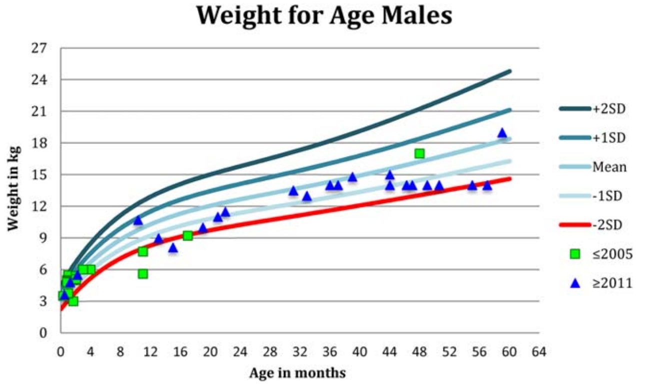

FIGURE 4 Weight for Age in Boys from 0–60 months

TABLE 5 Stunting and Underweight: Comparison of percentage of children who fall below the −2 threshold for z-scores of height and weight by age category and cohort

	Age (yr)	≤2005 % (n)	≥2011 % (n)
Stature			
	0–2.9	14.3 (5/35)	11.8 (2/17)
	3–5	0.0 (0/3)	44.4 (8/18)
Weight			
	0–2.9	13.9 (5/36)	5.6 (1/18)
	3–5	0.0 (0/3)	11.1 (2/18)

Obesity Task Force standards for children 5 and under, no child was overweight.

4 | DISCUSSION

The handful of Andean growth studies of secular change primarily focus on adolescents and adults, and either assess differences over several generations or compare different locales or regions. Our study measured children, including infants, in one population and across a brief time span. While the sample is small, convergent lines of evidence, such as ethnographic observation, mean height, weight, BMI, and the percentage falling below international standards, support the finding of a positive secular growth trend. Without the hypothesis of increased coastal travel, it would otherwise seem counterintuitive that a significant secular growth increase coincided with a moment of environmental and, consequently, economic crisis for highlanders. Our data provide an intriguing contrast with recent data emerging from Nuñoa where a secular increase in growth parallels a burgeoning dairy industry, and for the first time overweight children are found (Hoke, Leatherman, & Leonard, 2016, pp. 175). This underscores the need to account for local variation in socio-economic conditions.

While overall there is little stunting or underweight up to 3 years of age, a collective flattening of the growth curve is evident after that. The 2011–2012 cohort appears to be losing some ground despite their above average beginnings; though the early cohort does not seem to falter equally, their few numbers at this age do not allow us to say this definitively. Of the numerous studies on the age at faltering, our data are most in accord with that of Beaton (1992) and Bustamante et al. (2015). The finding is also consistent with Haas et al.'s (1982) longitudinal data that show high-altitude infants to be shorter and lighter than low-altitude infants only through the first year of life. Here, our later cohort approximates his low-altitude group, which we are hypothesizing may be due to transhumance. We suspect an increase in early weights due to frequent travel between altitudes, and a later loss of amplitude in the growth curve due to diet and metabolism.

Chugurpampa differs in some respects from other locales in the Andean highlands where seminal research on growth and development has been carried out. While high in altitude, it is on the lower end of the range studied (see Table 2), and in being closer to the Equator enjoys a more temperate climate (snow is rare) than sites in southern Peru and Bolivia. While people are poor, they are less so than those in Nuñoa, for instance. The region has historically been quite productive agriculturally, and commonly considered the nation's breadbasket. This, along with a clean water supply, results in generally good health and a low infant mortality rate (Oths, 1998). As Carey (1990) noted, poverty leads to sickness and death in Nuñoa. There, McGarvey (1974, pp. 273) recorded a 26% infant mortality rate (IMR) over a 6-year period for the lower SES, compared to 0% for those in the upper strata. In contrast, the overall IMR in Chugurpampa in 1988 mirrored that of Nuñoa's wealthiest (Oths, 1998). That said, the recognition that being poor and politically disadvantaged can have numerous effects on health has been amply documented and is not in dispute. The local social environment and the struggles that come along with life as a highland peasant have clearly and importantly been shown to affect body size. However, Chugurpampans were poor and politically disadvantaged in the past, and they remain so today. Thus, elements of their highland lifeways are changing without a concomitant improvement in SES. Regardless of the differences between Chugurpampa and other study sites, the point to underline is the recent dramatic secular change and to try to understand what may be driving it.

Given the anonymous nature of the data collected, we were not able to document number of days spent at low altitude during gestation and early life, diet, or medical care. Based on our long term knowledge of the community and recent observations, we examine in turn the plausibility of these three explanations for the recent changes in body composition.

4.1 | Mobility and transhumance

Andeans have long been a mobile people, noted by the earliest chroniclers like Garcilaso de la Vega (1973 [orig. 1609]) as well as by later researchers (e.g., Picón-Reátegui, 1976), and monumentally evidenced in the still extant Incan trail. Nonetheless, hypermobility is a quite recent phenomenon. While internal migration from sierra to coast has occurred for decades in Peru (Fehren-Schmitz et al., 2014), the frequency, rapidity, and number of persons engaging in it are at a level never previously possible. Travel has accelerated immensely with paved roads, more and better transportation, and hard times that send people in search of livelihood. Before the road improvements, a highlander would spend from 7 to 14 hours of arduous journey to reach the coast, beginning with a trek along foot trails to reach narrow one lane unpaved roads along vertiginous mountainsides to then hope to catch a bumpy ride in the back of an intermittent potato truck. Or one could wait until Sunday market to make the somewhat more direct trip in a commercial bus. In the past few years, buses have begun to run hourly between Trujillo and Julcan, the nearest market town, a journey of just 2 hours along two-lane paved roads (see Bury, 2008 on recent road construction). Highlanders' travel is further facilitated by their expanded social networks on the coast, now at a mature stage compared to earlier decades when they consisted of only a few pioneer migrants (de Haas, 2010).

The effects of growth faltering due to hypoxia are strongest when a child has lived *permanently* at high altitude, being a function of the point of the life cycle at which it starts and the amount of time of exposure (de Meer et al., 1995; Tarazona-Santos et al., 2000). Infancy seems to be the most labile stage for hypoxia's effects (Greksa, 2006), and the first year of life is where our data show the largest difference between cohorts. Nowadays in Chugurpampa, permanence is rare; few spend all their infancy and childhood at high altitude, even though they live there. For contrast, Pawson and Huicho (2010) commented that in 1999, "only three children in our entire sample [of 361] could remember visiting sea level for any length of time." While this mobility is evident to the casual observer, more studies are needed to operationalize the precise degree of variability in travel.

The amount of time spent at high altitude over the lifetime can confound growth data, though this variable has seldom been considered, with two exceptions. Pawson et al. (2001) in comparing the growth of children living in two southern Peruvian communities, Marquiri and Tintaya, controlled for time lived at high altitude and speculated that higher SES families were able to travel to lower altitudes to visit relatives more frequently. Stinson (1982) in assessing growth in children of European descent in La Paz asked about any trips the child had made to low altitude in addition to residence, finding time at low altitude positively associated with greater growth. Neither was looking at secular changes, but rather at cross-sectional differences. Many studies have documented growth differentials between highland and lowland groups of the same ancestry; it is possible that previous findings of rural-urban differences in growth where both sites are highland may have overlooked the extent of mobility in the urban groups, besides the accounted for nutritional, wealth, and other factors (see for example, Leonard et al., 1990). While wealthier Tintayans may have traveled more, this is not necessarily the case in Chugurpampa, where in recent years desperation necessitates travel as often as does wealth. As Adams (2012) found, environmental degradation and financial strain are often the precursors of mobility in highland Peru. Thus, pre- and post-natally, trips to the lowlands may represent opportunities for episodes of catch-up growth, or what might be glossed as place-induced saltations (borrowing Lampl et al.'s [1992] notion).

4.2 | Diet as a competing hypothesis

The youngest children show the clearest secular gain. With respect to potential dietary change as an explanation for the noted secular trend, the level of food intake would have the least effect as an explanatory variable at this age due to exclusive breastfeeding, which is standard practice in rural areas. Bottle feeding was never observed, which accords with Vitzthum (1989) who found it only in exceptional cases. While duration of breastfeeding was not measured individually, ethnographic observation and interviews put age at weaning at around 2 years of age in Chugurpampa, with little supplemental feeding in the first year. This accords with Leonard et al. (2000) in the Bolivian highlands (24.7 mo ± 3.4) and Andrissi et al. (2013), de Meer et al. (1993), and Vitzthum (1989) in southern Peru, all of whom found the age of weaning to be 2 years. One might suspect supplementary feeding of solid foods (beyond water and broth, which is typical to maintain hydration) to be a contributing factor. However, if supplemental feeding occurs along with breastfeeding, it is unlikely to account for the secular increase in growth based on Leonard et al.'s (2000) observation that it correlated *negatively* with infant weight due to the lower nutrient density of foods given. Furthermore, mother's diet has little effect on the composition, either in quality or quantity, of breast milk (Dettwyler & Fishman, 1992). As for dietary factors, then, it is unlikely that age at weaning or breastmilk quality differs now from the recent past.

Whereas refined, high calorie-low nutrient foods such as noodles, white rice, snacks, and soda were known and available in the past, there is no question that improved roads, increased travel, and the failure of agriculture due to climate change have facilitated an increased consumption of them. Though, as Urke, Bull, and Mittelmark (2013) noted, rural highlanders are well-aware of the poor quality of such "city foods" and often boast of the broad range and higher quality of the native foods they produce and consume. In any event, weight gain due to a recent switch to consumption of higher fat, lower quality foods would not be affecting those under 2 years of age.

How then to account for the flattening of the growth trajectories after age 3 or 4 for the recent cohort? Some have conjectured that the lower nutrient density of adult foods is the culprit, which consists mainly of tubers and grains instead of fats and proteins (Andrissi et al., 2013; Berti & Leonard, 1998). However, there is evidence that highland natives rely more upon glucose than fat for fuel and absorb protein more slowly than lowlanders (West, Schoene, & Milledge, 2007, pp. 197, 201), which makes their diet consisting in large part of potatoes, corn, and wheat more adequate than often acknowledged. (Of note, while meat consumption may be sporadic, the protein of beans and quinoa in the diet is rarely mentioned.) The growth slowdown in mid-childhood does not go unrecognized by highland parents, who explain it as a result of children no longer being able to snack at will when they begin school—Graham found this as well (1997)—which is necessary, especially at an age when there is a high energy demand for growth and expenditure. Berti and Leonard (1998) allude to this in noting that children may not be able to consume enough calories. In Chugurpampa, preschool (*PRONOEI*) begins at age 3 and grade school attendance is highly monitored in recent years due to JUNTOS.

Rarely mentioned in the literature is the increased physiological demand at high altitude resulting in a higher basal metabolic rate, for which adults, and presumably children more so, require an estimated 10 to 100% more kilocalories than the amount needed at low altitude to maintain body weight (Butterfield et al., 1992; Holden et al., 1995: Picón-Reátegui, 1978; West et al., 2007). Thus, when explaining slowed growth after 3 or 4, attention must be paid to the inherent higher metabolism, and thus caloric need, that results from the synergistic effects of physical activity and labor (Pomeroy et al., 2014)—children begin to contribute to household tasks around age four (Oths, 1998)—and high altitude pressures such as oxygen saturation, colder climate, and dehydration (Andrissi et al., 2013; West et al., 2007). In other words, the higher the altitude (the effects of which are exponential) the more difficult it is for well-fed children to carry out a normal daily routine and still eat enough to achieve full growth potential on a standard timeline. The elongated period of skeletal and sexual maturation into the early 20s found among highlanders may be a compensatory adaptation (Frisancho, 1976; Greksa, 2006).

4.3 | Is medical care making the difference?

Another competing hypothesis about what is driving the secular growth trend is a higher level of biomedical care. Immunization coverage is unlikely a factor as it has been high in Chugurpampa since the late 1980s (Oths, 1998). More biomedical prenatal care during pregnancy for mothers, delivery in a hospital setting, and checkups for children is fairly universal since JUNTOS began in 2007, a time frame that corresponds with the later cohort. These days, mothers perceive they have little choice but to get prenatal care from a health post and deliver in a hospital if they wish to collect state benefits (Huaman Ayala et al., 2013). Hospitals attended are typically at the same altitude in the district and provincial capitals, though may include the hospital in coastal cities such as Trujillo. As a result of the policy change, midwives are seldom used for birth, though sometimes still for prenatal care. Higher clinic attendance notwithstanding, a comprehensive WHO study of the JUNTOS program found it had no effect on malnutrition levels, nor heights and weights of children under 5 (Perova & Vakis, 2009).

In general, the effects of biomedical prenatal care and delivery on infant size are not clear. Prenatal vitamins, if taken, will not affect birth weight, though they may affect birth length (Prawirohartono, Nyström, Nurdiati, Hakimi, & Lind, 2013), though there was little evidence of consistent vitamin consumption in the hamlet. An increased use of biomedicine may involve greater antibiotic use, which is believed to promote growth in livestock as well as humans (Teillant & Laxminarayan, 2015; Ternak, 2005). While no evidence for this was gathered, it would seem logical that an illness serious enough to require antibiotics in infants would wipe out any weight gains the antibiotic would engender. The occasional well-child check-up at the local health post is unlikely to affect growth.

Beyond diet and health care, other alternative, though less plausible, explanations for the increase in growth that cannot as yet be ruled out are a decrease in exposure to organic compounds such as insecticides and herbicides, which may have been reduced due to poor growing conditions, or higher average temperatures due to climate change (see Schell, Knutsen, & Bailey, 2012). An intriguing new hypothesis on secular trends in stature suggests strategic growth adjustments among lower income are a social signal to achieve higher status; again, this is unlikely to apply to infants (Hermanussen & Scheffler, 2016).

4.4 | Limitations

Positive features of this data are the 0 to 5 age range of the sample. Another advantage is that the data represent a systematic sample of the community rather than the commonly employed convenience sample. The lead author's long term residence in and trust by the community aids considerably in terms of supplying ethnographic insights. Similar to nearly all studies of very young children in rural highland areas, our sample numbers are low, which leaves open the possibility that findings are due to sampling error. While it would have been ideal for us to collect measurements ourselves rather than relying on clinical records, that could not have been achieved without residing full time in the community for a decade. The clinic data provided the rare opportunity to gather data on 0–2 year olds, which can be extremely difficult to gather in isolated hamlets where house are spread out across several hours walking distance, in contrast to nucleated villages and towns.

What cannot be known is if the secular trend noted is temporary or permanent. The secular increase of earlier decades in Nuñoa found by Leatherman et al. (1995) was not apparent when Pawson and Huicho (2010) restudied the population 15 years later. And Leatherman noted that within the population, while children had become larger over time, the adults had not, indicating that growth advantages may have been lost by adulthood. Recent research in the area has again detected a secular trend upward in height and weight (Hoke et al., 2016, pp. 175). Whatever the future trends, they will certainly be dependent upon the various socio-cultural, economic, and environmental conditions of the specific place and time period.

Future research might profitably explore intracultural diversity in growth due to religious faith (many have converted to Protestantism), aspirations and life goals, occupation, harvest quality, education level, and other ecological, economic, sociocultural and demographic dimensions. Data on the diet, prenatal care, and living patterns of the mothers and infants also should be collected in the future along with anthropometric measures. The mobility history of each child also needs to be specified, as our hypothesis can only be confirmed by examining the relationship between linear growth and the amount of the growth period spent at low altitude. In a sample of residents, we found over 60% of households have at least one family member living on the coast now, in addition to a dense network of kin, so the role of remittances as a buffer against economic stress could be measured. There are no doubt effects of, and perhaps interactions among, all these variables.

5 | CONCLUSIONS

In the Andean highlands, child growth is a complex and multifactorial phenomenon. Numerous stressors, many of them interacting, shape body size, with no one factor providing complete explanatory power. In Chugurpampa, stature and weight have shifted upwards in less than a generation. There is an overall significant increase in the weight and height of babies now compared to a decade ago, likely due to the effects of tremendous environmental and social upheaval. A focus on altitude was rightly superseded in the 80s and 90s by more intriguing and variable phenomena such as microclimates, socioeconomics, land tenure, diet and other factors (Carey, 1990; de Meer et al., 1993; Leatherman et al., 1995; Leonard et al., 1995). The contribution of this study is to suggest that altitude be reintroduced to the mix in a novel biocultural way, to more comprehensively assess a very complicated scenario.

Above other potential explanations, we suspect an increase in early weights may be due the recent accelerated travel between sierra and coast, with a later loss of amplitude in the growth curve due to diet and metabolism. Ruined harvests because of climate change push people to seek work in the city, or frequently visit relatives relocated there. Widened and paved roads to facilitate mining in the region make frequent trips feasible. Hypoxia's dampening effect on child growth might be lifted during episodic coastal stays, including while in utero. An association between greater travel and the secular growth trend remains to be tested.

CONFLICTS OF INTEREST

None.

AUTHOR CONTRIBUTIONS

KO and HS analyzed the data and drafted the manuscript. KO, MS and RL designed the study, and directed implementation and data collection. KO, MS and RL collected the data, and KO and RL provided necessary logistical support. KO, HS, and MS edited the manuscript for intellectual content and provided critical comments.

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