Birth Weight among Tibetans at Different Altitudes in India: Are Tibetans Better Protected from IUGR?

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ABSTRACT We report the variation in birth weight among the Tibetans at different altitudes in India to test the hypothesis of greater protection from intrauterine growth retardation (IUGR) among Tibetan compared with other high-altitude native populations. We found that the birth weight of Tibetans at Leh (3521 m, high altitude) is quite similar to what has been reported previously for Tibetans at similar altitudes and is significantly higher than the low-altitude native populations living at similar altitudes. Tibetan birth weights are greater than those of other ethnic groups, both at high and low altitudes. Compared with Tibetans at high altitude (Leh, India; 3521 m), Tibetans at low altitudes (Bylakuppe, India; 800 m and Chandragiri, India; 970 m) have heavier birth weights. This finding is similar to what has been observed previously for other high-altitude native populations. Greater protection from IUGR is not observed for Tibetans compared with other high-altitude native populations as was reported previously. Genetic potential for birth weight is seemingly manifested only at low altitude. Am. J. Hum. Biol. 17:442–450, 2005.

Birth weight is an integrated measure of prenatal growth and is regularly used by clinicians and public health workers as an indicator of newborn viability. Considerable variation in newborn size exists within and between populations. Birth weight is multifactorial and sensitive to the large variety of environmental stresses, which the fetus experiences from conception until delivery.

Investigations in North and South American highlands showed that high-altitude populations tend to have low birth weights. Lichty (1957) showed this relationship in 1957. Frisancho (1970) in a review showed that at high altitude, there is an 18% reduction in birth weight. Maternal residence at high altitude left shifts the entire distribution of birth weights (Yip, 1987; Wilcox, 2001). One of the best-documented effects of the high altitude is a progressive reduction of birth weight (Moore et. al. 1998; 2001). A review by Moore et al. (1998) of studies conducted over a 40-year period showed that birth weights decline an average of 100 g per 1000 m altitude gain. Similar results were shown by Jenson and Moore (1997) for U. S. populations in Colorado. Babies are both lighter and shorter for gestational age, conforming to a model of growth retardation throughout pregnancy. In addition to the lower mean birth weight, the percentage of low-birth-weight babies is four times greater at high than at low altitudes in a U. S. population-based study (Yip, 1987).

At high altitude, women of high-altitude ancestry give birth to heavier babies compared with high-altitude residents who were born and raised at low altitude or with women born and raised at high altitude but descended from populations of low-altitude ancestry (Haas et al., 1980; Zamudio et al., 1993; Niermeyer et al., 1995). The longest resident populations at high altitude experience the least decline and the shortest resident groups the most reduction in birth weight (Haas et al., 1977; Haas, 1981; Moore et al., 1998). This protection from altitude-associated reduction in the birth weights for the longest resident population may be due to a genetic adaptation of these population at high altitude; natural selection may have acted to protect the fetus from the stress of hypoxia and permit normal fetal growth, although a decline in birth weight is observed with increase in altitude within each population.

Tibetans are believed to have lived at high altitudes for longer than other high-altitude populations of the world. Controversy exists as to when the high-altitude areas were first inhabited by humans in evolutionary history. According to Cruz-Coke (1978), the present highlanders likely invaded the highlands after the last glaciation ended approximately 12,000 years ago. High-altitude occupation may have begun earlier, because stone tools and rock paintings have been found on the Tibetan plateau that are datable to a period between 20,000 and 50,000 years ago based on comparison of the artifacts (Gupta and Ramchandran, 1995; Bellezza, 2001; Weiwen, 2001; Aldenderfer and Yinong, 2004). An absolute date available for a find of hand prints and footprints in 1995 by Zang and Li at a site, Chusang, using Optical luminescence dating for the hearth-like structure found near one concentration of prints gave dates between 21,000 and 22,000 years ago. These dates suggest that people arrived on the Tibetan Plateau sometime between 50,000 and 25,000 years ago (Aldenderfer, 2003). Analysis of the Y-chromosome haplotypes by Su et al. (2000) show that the present Himalayan populations diverged from a population in the upper yellow river basin not before 6,000 years ago. If this date is to be believed, the present Tibetan population has a recent history in the highlands comparable to that of the Andeans.

Heavier birth weights are generally seen in Tibetans than Andean or Rocky mountain residents of the same altitude (Moore, 1990). In the only study comparing birth weights of Tibetans at high and low altitude, Zamudio et al. (1993) found almost similar average birth weight among Tibetans in Lhasa (3658 m) compared with a sample of Tibetans in Kathmandu (1200 m). They found that the altitude-associated difference in birth weight is least among the Tibetans compared with the North American and South American populations. They conclude that this supports the hypothesis that Tibetans are better protected from intrauterine growth retardation (IUGR), and selection toward optimization of birth weight has occurred. Similar results were seen in a study comparing larger numbers of Tibetan and Han residents of a 2700–4700-m altitude range in Tibet (Moore et al., 2001). Smith (1997) observed a similar kind of protection for Nepalese Sherpa. Sherpa is a mongoloid group culturally, as well as biologically, related to Tibetans (Furer-Haimendorf 1975, 1984; Gupta 1981). In contrast, Wiley (1994a, 1994b) did not find such a protection for Ladakhis based on the lesser birth weights at high altitude compared with other high-altitude native populations. Wiley's sample was of heterogeneous ancestry, largely composed of people identifiable with the Tibetan culture and language.

In this study, we report birth weights for Tibetans at different altitudes in India to see whether similar variation is observed as reported previously for Tibetans by Zamudio et al. (1993) and Moore et al. (2001). We considered that such a comparison between Tibetans at high altitude and low altitude might help to shed light on whether the Tibetan population is, indeed, better adapted to high altitude than other high-altitude native populations. We have also compared the birth weights of some neighboring populations with the Tibetans.

MATERIALS AND METHODS

Tibetans are a predominantly Mongoloid population inhabiting the central Tibetan Plateau. The central Tibetan Plateau is land locked and bounded on all sides by huge mountains ranges. The Tibetan Plateau represents the world's largest and highest landmass, with an average elevation of more than 4500 m and supporting human populations up to 5000 m.

The present Dalai Lama with many of his followers fled Tibet in 1959 and entered India. The government of India gave them asylum, and they were settled in different parts of the country. In total, 35 agricultural-based settlements were established. Today, the Tibetan population is approximately 85,147 according to the Tibetan Demographic survey (1998) or more than 110,000 according to the estimates of United States Committee for Refugees and Immigrants (USCRI, 1999). The different parts of India offer them different climatic and cultural environments compared with those in which they lived in Tibet (web page of department of Home, The Government of Tibet in Exile, 1996). The environment of Leh, Ladakh is more or less similar to the cold, low-humidity, and hypoxic environment of Tibet. In contrast, the settlements in Himachal Pradesh, Arunachal Pradesh, Karnataka, Orissa, Delhi, and elsewhere are located at low to moderate altitudes and have a range of climates quite different from that of Tibet.

Three Tibetan settlements (Table 1, Fig. 1) in India with different ecological settings have been selected for study. Settlements at Bylakuppe (800 m) (Mysore, Karnataka) and Chandragiri (970 m) (Gajapati, Orissa) have been selected at low altitude. These two places differ in their ecological and cultural settings. Chandragiri is on the Eastern Ghats, nearer to coast and away from urban centers. It is also infested with malaria. In contrast, Bylakuppe is on the Indian peninsular plateau, away from the seacoast and is nearer to urban centers. The settlement at Choglamsar, Leh (3521 m) is at high altitude and provides a control group for the effects of migration, because it is located at high altitude.

Data collection

Data were collected from the birth registers of respective state government district hospitals at Leh and Chandragiri, Tso Jhe Khangsar Hospital Bylakuppe, and Menlha

TABLE 1. Physical features of the settlements under study

Sl. no.	Place of residence	District and State	Altitude above sea level (m)	Average annual rainfall (cm)	Humidity level	Temperature range (degrees Celsius)
1	Bylakuppe	Mysore, Karnataka	800	75–85	Medium	25–32
2	Chandragiri	Gajapati, Orissa	970	230	High	10–38, cold winters, hot summers
3	Choglamsar	Leh, Jammu and Kashmir	3521	15	Very low	Summer: days are warm, nights cold (10–30). Winter: extreme cold with snowfall (−5–−20)

Fig. 1. Map of India showing the three places under study: Choglamsar, Chandragiri, and Bylakuppe.

Hospital Chandragiri. Except for the hospital at Leh, the other hospitals were in the vicinity of the Tibetan settlements. The district hospital at Leh is 7 km from Tibetan settlements. We also collected data for neighboring Hindu populations at Chandragiri; and Ladakhi Bods, Muslims, Indian Hindus, and Nepali Hindus at Leh. Ladakhi Bods are said to be related to the Tibetan population and show similarity with Tibetans in the socioreligious sphere. It is estimated that the Ladakhi Bods emigrated from Tibet approximately 1000 years ago (Kaul and Kaul, 1992). Most Muslims at Leh are called Arghuns who came from the west (Pakistan and Afghanistan) after the 14th century (Kaul and Kaul, 1992). The physiognomic similarity some Muslims show with the Bods may be due to admixture with the Bods, and some may have been converts from the Bods. Indian and Nepali Hindus are ethnically different from Tibetans and have migrated to Leh in past couple of decades or are there on temporary government or private postings.

Data were collected for the period of April 1, 2000, to October 11, 2003, at Bylakuppe and May 4, 1995, to June 19, 2003, at Chandragiri. At Leh, the Tibetan data were collected for the period from December 28, 2002, to August 4, 2004, and data for other ethnic groups for the months January, February, June, and July of 2004. Information was collected for birth weight, sex of the infant, date of delivery (DOD), mother's age, ethnicity of the mother, and nature of birth (single, multiple; live birth, stillbirth). Data for the first day of the last menstrual period (LMP) could be collected only for 105 Tibetan births from Tso Jhe Khangsar and Menlha Hospital at Bylakuppe and Chandragiri, respectively. Only live singleton births were considered for the study. Statistical analysis was done with the help of MS Excel 2000 and SPSS 7.5. ANCOVA (general linear model) was used to assess the effect of covariates for different categories.

RESULTS

The sample size, mean birth weight, and standard deviation according to place and sex are given in Tables 2a and 2b for Tibetan and neighboring populations, respectively. Mean maternal age for the total Tibetan data is 28.73 ± 5.35 (SD) years, with not much variation between the three places of residence. Maternal age correlated with birth weight both within the Tibetans and all groups

TABLE 2a. Birth weight sample size (N), *mean, standard deviation (SD), and percentage low birth weight for Tibetans*

Place of residence	Sex	*N*	Mean (g)	SD	Percent low birth weight
Bylakuppe	Males	58	3493.1	483.7	3.0
	Females	60	3445.0	603.6	3.1
	Total	118	3468.6	546.2	3.1
Chandragiri	Males	27	3488.9	508.6	3.4
	Females	19	3407.9	464.4	0.0
	Total	46	3445.4	487.2	2.1
Leh	Males	21	3285.7	432.8	4.8
	Females	10	3000.0	294.4	0.0
	Total	31	3193.5	411.4	3.2

TABLE 2b. Birth weight sample size (N), *mean, standard deviation (SD), and percentage low birth weight for neighboring populations*

Place of residence	Ethnicity	*N*	Mean (g)	SD	Percent low birth weight
Chandragiri	Indian Hindus	92	2524.7	538.0	31.5
Bylakuppe	Indian Hindus	4	3012.5	347.3	0.0
Leh	Indian Hindus	16	2768.8	359.1	6.3
	Nepali Hindus	15	2373.3	606.5	53.3
	Muslims	49	3083.7	570.9	8.0
	Ladakhi Bods	301	3052.8	414.0	5.7

combined ($r_{tibetan} = 0.187$, $P = 0.009$; $r_{total} = 0.222$, $P = 0.000$).

The frequency of preterm birth (less than 37 weeks) was 4.8% and of the five preterm births four were more than 35 weeks. The mean gestational age, calculated as DOD − LMP in days, for the available data for the Tibetans is 283.05 ± 5.35 and is unrelated to birth weight in the Tibetans ($r = 0.092$, $P = 0.352$). So we assumed that inclusion of gestational age would not have affected the adjusted birth weights much.

Analysis of covariance (ANCOVA) for the Tibetan data (Table 3) using maternal age as a covariate and place of residence and sex as fixed factors (categories) showed that place of residence ($P = 0.023$) but not infant sex ($P = 0.129$) altered birth weight. Maternal age influenced birth weight even after place of residence and sex were controlled ($P = 0.019$). After adjusting for maternal age, place of residence, and sex, the average birth weight at low altitudes was 3460 g ± 47 (SE) at Bylakuppe and 3456 g ± 76 at Chandragiri, and 3166 g ± 98 at high altitude (Leh) for the Tibetans. Both low-altitude values were greater than the high-altitude mean ($\Delta_{loC\ -\ hiL} = 290$ g, $P = 0.020$; $\Delta_{loB\ -\ hiL} = 295$ g, $P = 0.008$; Fig. 2). The Tibetans birth weight was similar at the two low altitudes ($\Delta_{loB\ -\ loC} = 13$ g, $P = 0.962$). Birth weight averaged 294 g lower at high altitude ($P = 0.006$) when ANCOVA was performed again after combining the data for the two low-altitude places, Chandragiri and Bylakuppe.

Males were heavier than females at each of the three places of residence, the maximum difference being at Leh, but none of these differences was significant ($P_B = 0.451$, $P_C = 0.617$, $P_L = 0.07$).

At both low and high altitudes, Tibetans have higher birth weights compared with other populations at the same locale. Birth weights differed significantly for ethnicity ($P = 0.000$) when maternal age was used as a covariate and place of residence, ethnicity, and infant sex were used as fixed factors (Table 4) for the entire data set (considering Tibetan and other ethnic groups).

The percentage of low birth weight (<2500 g) (Table 2) was very low among Tibetans (3.1% at Bylakuppe, 2% at Chandragiri, 3.2% at Leh, and 2.9% for the overall Tibetan data). The difference in low birth weight at the three places and the two sexes is not significant. At Leh, the percentage of low birth weight is the lowest for

TABLE 3. Result for ANCOVA for birth weight taking maternal age, place of residence, and sex as covariates among Tibetans

Source	Type III sum of squares	Df	Mean square	F	Sig.
Corrected model	4054069[a]	6	675678.25	2.62	0.02
Intercept	54117375	1	54117374.97	209.64	0.00
Maternal age	1433636	1	1433635.81	5.55	0.02
Place of residence	1977044	2	988522.15	3.83	0.02
Sex	601158.1	1	601158.08	2.33	0.13
Place of residence*Sex	333412.6	2	166706.31	0.65	0.53
Error	48530802	188	258142.57		
Total	2.34E+09	195			
Corrected total	52584872	194			

[a] $R^2 = .077$ (Adjusted $R^2 = .048$).

Pairwise comparison between place of residence for adjusted mean birth weight among Tibetans

		Mean difference (I-J)	SE	Sig.	95% Confidence interval	
Place (I)	Place (J)				Lower Bound	Upper Bound
Bylakuppe(3460.37)	Chandragiri	4.33	89.57	0.96	−212.04	220.70
	Leh	294.66*	109.06	0.01	31.22	558.10
Chandragiri (3456.04)	Leh	290.33*	123.92	0.02	−9.00	589.66
	Bylakuppe	−4.33	89.57	0.96	−220.70	212.04
Leh (3165.71)	Chandragiri	−290.33*	123.92	0.02	−589.66	9.00
	Bylakuppe	−294.66*	109.06	0.01	−558.10	−31.22

Mean difference based on estimated marginal means (given within parenthesis under place I).
*The mean difference is significant at the 0.05 level.

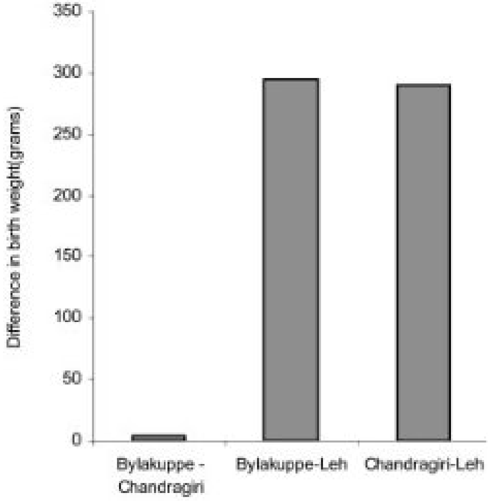

Fig. 2. Difference in birth weight between place of residence.

Tibetans (3.2%) and greatest for the Nepali Hindu (53.3%), with intermediate values found in the other groups (e.g., Muslims, Ladakhi Bods, and Indian Hindus).

The frequency of low birth weight varied among places of residence and ethnicity (for place of residence $X^2 = 31.470$, $P = 0.000$; for ethnicity $X^2 = 90.024$, $P = 0.000$). No difference in percentage of low birth weight is observed between the two sexes ($X^2 = 0.353$, $P = 0.552$). Only ethnicity significantly influenced the occurrence of low birth weight when logistic regression using place of residence, ethnicity, sex, and maternal age as independent variables was performed.

DISCUSSION

The difference in birth weight between low and high altitude is inversely proportional to the protection from IUGR at high altitudes. Groups that have migrated from low to high altitude relatively recently have a greater decline in birth weight than groups that have been long residents at high altitudes. Among high-altitude native populations, a lesser birth weight difference has been reported for Tibetans compared with North and South American native highlanders. Two studies have compared the effect of altitude on birth weight in Tibetans and other groups. The first by Zamudio et al. (1993) studied Tibetans at two altitudes, Lhasa (3658 m) and Kathmandu (1200 m). They found a very small nonsignificant increase in birth weight at Kathmandu even after controlling for parity, gestational age, and infant sex. In the second study, Moore et al. (2001) studied the variation in birth weight with respect to altitude among the Tibetan living at 2700–4700 m in Tibet. Those living at extreme altitudes of more than 4000 m showed a significant decline in birth weight. But the decline was not as sharp as for the Han, a low-altitude group living at the same altitudes as the Tibetans. They did not have any sample of Tibetans at low altitude. Table 5 compares the results of studies on Tibetan birth weights at different altitudes among the various studies.

Our study shows that Tibetan birth weights at each of the three settlements were more than that of groups with low-altitude ancestry who were living at the same altitudes. The difference is greater for

TABLE 4. Result for ANCOVA for birth weight taking maternal age, place of residence, ethnicity, and sex as covariates for the total data

Source	Type III sum of squares	*Df*	Mean square	F	Sig.
Corrected model	66255103.72[a]	10.00	6625510.37	29.69	0.00
Intercept	145200530.42	1.00	145200530.42	650.61	0.00
Maternal age	1853126.16	1.00	1853126.16	8.30	0.00
Place	885762.16	2.00	442881.08	1.98	0.14
Ethnicity	12886867.54	4.00	3221716.89	14.44	0.00
Sex	1751909.38	1.00	1751909.38	7.85	0.01
Place of residence * Ethnicity	2568829.68	2.00	1284414.84	5.76	0.00
Error	147519928.28	661.00	223176.90		
Total	6537671700.00	672.00			
Corrected total	213775031.99	671.00			

[a] $R^2 = .310$ (adjusted $R^2 = .299$).
Terms with insignificant interaction left out from analysis.

TABLE 5. Results from birth weight studies in Tibetans at different altitudes

Place	Altitude (m)	*N*	Birth weight (g)	SD	Ref.
Lhasa, Tibet	3658	34	3222	400.0	Zamudio et al., 1993
Kathmandu, Nepal	1200	45	3313	322.6	Zamudio et al., 1993
Tibet	>4000	96	2860		Moore et al., 2001
Tibet	3000–4000	165	3140		Moore et al., 2001
Tibet	>3000	116	3110		Moore et al., 2001
Leh, India	3521	31	3194	411.4	Present study
Chandragiri, India	970	46	3445	487.2	Present study
Bylakuppe, India	800	118	3469	546.2	Present study

the Nepali and Indian Hindu population than for the Ladakhi Bods and Muslims, who may have some genetic affinity with the Tibetans or have a longer duration of residence at high altitudes. The birth weight for Tibetans at Leh is quite similar to what has been reported earlier at similar altitudes by Zamudio et al. (1993) in Lhasa and by Moore et al. (2001) in Tibet. A new finding in this study is that Tibetan birth weights are higher in the Tibetans living at low altitudes than the Tibetans living at high altitudes, such that the increase in birth weight with decreasing altitude among Tibetans ($\Delta_{(lo\ -\ hi)} = 294$ g, $P = 0.006$) is similar to what was observed for Andeans in Peru ($\Delta = 270$ g) by Beall (1981); in Bolivia ($\Delta = 282$ g) by Haas et al. (1980); and in North America ($\Delta = 352$ g) by Yip (1987) (Fig. 3).

A problem with the high-altitude data from Tibetans in this study, as well as most of the other studies, is its small sample size, mainly because most of the births take place at home and hence birth weight data are unavailable. However, this likely means that those delivering at hospitals are from higher economic status. Income from the flourishing and emergent tourism industry in Ladakh compensates for the higher cost of living at Leh. So lower economic status cannot be held responsible for the lower birth weight at Leh compared with Bylakuppe or Chandragiri. Moreover, the birth weight of Tibetans at high altitude in this study is similar to what has been reported in previous studies at similar altitudes. As was the case for Tibetans living at Kathmandu studied by Zamudio, the settlements in India

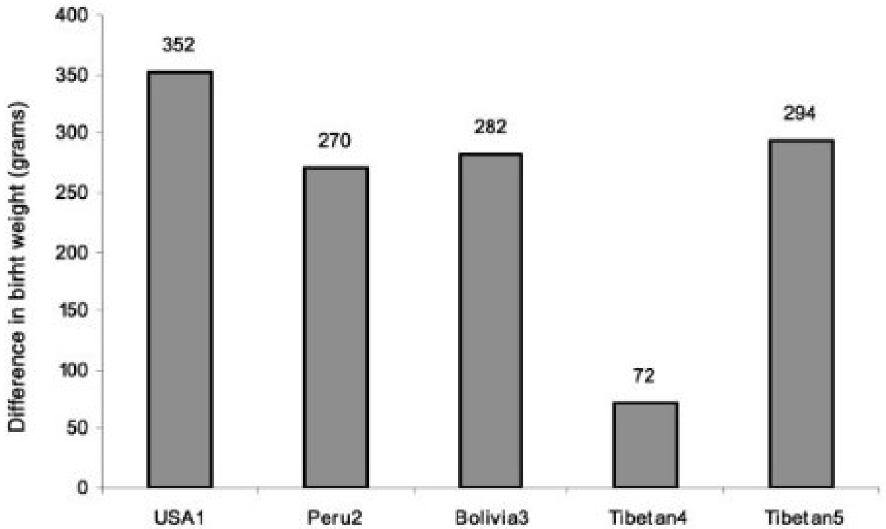

Fig. 3. Difference in birth weight between low and high altitude in different studies (1, Yip [1987]; 2, Beall [1981]; 3, Haas et al. [1980]; 4, Zamudio et al. [1993]; 5, -this study).

are also refugee settlements. Nevertheless, we observed that the Tibetan population is performing better than the local populations in the economic activities with which they are involved. However, compared with the settlements in India, the Kathmandu settlement may have been less well off in terms of economic conditions, which may be the reason why higher birth weights were not seen in Kathmandu.

Data available for the Himalayan populations related to Tibetans (in terms of culture, language, and historical facts) like Sherpa (Smith 1997) and Ladakhi Bod (Wiley 1994a, this study) show that Tibetans have greater birth weights than Sherpas and Bods. This may indicate either their shallower antiquity at high altitude as suggested by Wiley (1994a) for Ladakhis or poor nutritional status (low hemoglobin percentage, low body mass index, and consumption of alcohol) for Sherpas as suggested by Smith (1997) as the possible reasons for their lower birth weights. A striking feature of Table 2b is the low average birth weight and higher incidence of low birth weight in Indians even at low altitudes. Indian Hindus are a heterogeneous group divided in many endogamous caste groups. Our sample at low altitude is composed of Indian Hindu populations from a rural area in Chandragiri. The figures for birth weight and percentage of low birth weight we got for this group is similar to what has been reported previously for India in many different studies (Ulijaszek et al., 1998; UNICEF, 2001; Park, 2002; WHO, 2002). Factors identified for these lower birth weights in India and other developing countries point to poor nutritional status of the mother and ethnicity.

When low birth weight is taken as an indicator of health status of the newborn, Tibetans show a very low percentage of low birth weights at both low and high altitudes compared with the other populations. The incidence of low birth weight is comparable or lower than the lowest figures available for the most developed countries and populations (Ulijaszek et al., 1998), who are likely advantaged in terms of nutritional status. Higher birth weights and a lower frequency of low birth weights at high altitudes among Tibetans compared with groups of low-altitude ancestry may be due to better adaptation attributable to long duration of residence at high altitudes or to genetic factors independent of environment.

Heavier birth weights are observed at both low altitudes compared with high-altitude settlements, even though the two low-altitude settlements had distinct socioeconomic and environmental characteristics. The Tibetans' heavier birth weights at high altitude compared with persons living at the same altitudes but of low-altitude ancestry may indicate better adaptation compared with the low-altitude native population, or it may be due to genetic factors influencing birth weight irrespective of altitude. The Tibetans' heavier birth weights at low altitudes indicate that fetal growth does not achieve its potential even among Tibetans at high altitude. Genetic potential for birth weight is seemingly manifested only at low altitude. Findings of this study suggest that Tibetans do not have a uniquely greater protection from IUGR compared with other high-altitude native populations. This similarity in the protection from IUGR between the Tibetan and Andean population may suggest as well that these two populations may have occupied the highlands in the comparable time period in the human evolutionary history.

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