

## High Altitude Hypoxia, Culture, and Human Fecundity/Fertility: A Comparative Study

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*This paper presents new demographic findings for a high altitude Himalayan population residing in Ladakh, India, and reviews problematic issues regarding the hypothesized relationship between fertility/fecundity and altitude in the Himalayas in light of these findings. It concludes that the low completed fertility ratio reported for the Sherpas of Khumbu, Nepal, is not caused by hypoxia-induced low fecundity, but is the product of cultural factors affecting the exposure of females to the risk of intercourse, a critical confounding factor that has not received adequate consideration in previous studies. Contrary to earlier reports, the present study demonstrates that all high altitude Himalayan populations for which published data exist exhibit moderately high fertility and fecundity, and do not differ significantly in their fertility levels. Furthermore, it argues that the claims for a statistically significant difference in fertility between high, moderate, and low altitude Himalayan populations are groundless, and suggests that a parallel reevaluation of Andean findings is required. [fertility, fecundity, hypoxia, Himalayas, Andes]*

### INTRODUCTION

THE RELATIONSHIP BETWEEN HIGH ALTITUDE AND REPRODUCTION has been a topic of interest since the Spanish Conquest of the Andes (Monge 1948). Following the lead of a body of anecdotal information reporting the reproductive difficulties experienced by Spanish women at high altitude in Latin America and of experimental work with animals, researchers undertook systematic studies of Andean populations to test the hypothesis that high altitude hypoxia reduces fecundity.

Since it is extremely difficult to measure fecundity directly in a "field" situation, most studies have measured instead the fertility of high altitude natives under the assumption that in populations not consciously controlling fertility, differences in fertility reflect differences in fecundity. From these studies it has been widely reported that high altitude has a depressing effect on fecundity and fertility (Baker 1978; Abelson 1972; Abelson et

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al. 1974; Hoff and Abelson 1976; Clegg 1981; Weitz 1981b). As Hoff and Abelson (1976:144) wrote: "Hypoxia, which acts to reduce fecundity, appears to be the major component of reduced fertility at high altitude."

More recently, attention turned to another major high altitude zone, the Himalayas. The first reports from this area dealt with Khumbu Sherpas of Nepal. These depicted extremely low fertility (Weitz et al. 1978; Gupta 1978, 1980) and appeared to corroborate Andean findings of a hypoxic effect (Gupta 1978, 1980; Bangham and Sacherer 1980; Weitz 1981b). However, subsequent research in Limi, another high altitude area in Nepal (Goldstein 1981b), reported contrary findings and questioned the validity of these reports. This paper presents new demographic findings for a third high altitude Himalayan population living in Ladakh, India, and reviews problematic issues regarding the relationship between fertility/fecundity and altitude in the Himalayas and Andes in light of these findings.

## BACKGROUND

### *The Initial Case for an Altitude Hypoxic Effect in the Himalayas*

The first serious research on the fertility of high altitude Himalayan populations was conducted in 1970-1971 among the Sherpas of the Khumbu area of Eastern Nepal (see Figure 1) (Weitz et al. 1978). Residing at altitudes of over 3400 m, these Sherpas are the descendants of Tibetans who migrated to the area some 300-400 years ago (Haimendorf 1964). They still speak a dialect of Tibetan and adhere to Tibetan Buddhism. A very low fertility was reported for this group, namely a completed family size (completed fertility ratio - CFR) of 4.8 for all women aged 50 or older. This level of fertility is extremely low for a population which claimed not to be using contraception, and puts the Khumbu Sherpas on a par with the hunting and gathering !Kung San of the Kalahari desert who are known widely as one of the world's societies with the lowest "natural fertility." These findings supported informal observations of very low fertility among Tibetans in Chinghai Province, China (Ekvall 1972).

A second fertility survey conducted with the same population of Sherpas in Khumbu reported an even lower completed fertility ratio ( $CFR_{45+}$ ) of 4.5 births for all *married* women aged 45 or over (Gupta 1978, 1980). Presumably this CFR would be even lower if, as in the case of Weitz et al. (1978), *all* women, married and unmarried, were included. This fertility was indicated to be significantly lower than the  $CFR_{45+}$  of 7.4 reported for Sherpas living at low altitude (900-1800 m) in the Kalimpong area of India. The study concluded that

there is a suggestion of reduced fertility in the high altitude sample in several of the measures employed. Besides the significant reduction in the mean completed family size and the number of live births per married woman, trends in the same direction are seen in the number of live births per mother over 30, the average number of live births, and the total fertility rate. . . . Our findings agree with those obtained in the Andean studies, in which, while mortality does not seem to be related to altitude, fecundity in general shows a negative relationship [Gupta 1980:113]

A third study compared Sherpas at high altitude (using the Gupta and Weitz CFR figures) with four Sherpa populations living at moderate altitude (220 m-2600 m) (Bangham and Sacherer 1980). It reports a "much higher completed fertility rate" ( $CFR_{45+} = 7.8$ ) at moderate altitude and states that the low fertility of Khumbu "is mostly attributable to lower fecundity" (ibid.:323).

### *Contradictory Evidence*

Research conducted with other high altitude Himalayan populations subsequent to the Sherpa studies produced very different results. We shall first present this newer and con-

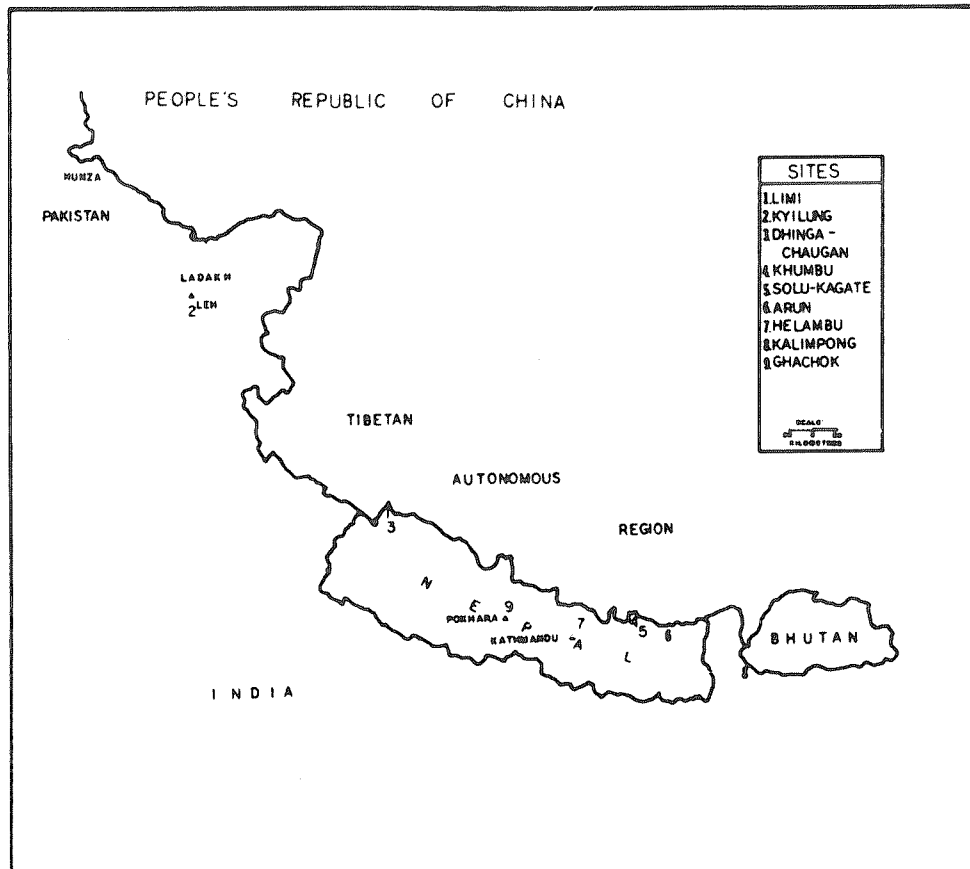


Figure 1. Map of main research sites in the Himalayas.

tradictory evidence, examine the reasons underlying the different results, and then criticize the validity of the Sherpa studies.

Goldstein (1981a, b) presented demographic data from Tsang village (3900m) in Limi, a remote high altitude Tibetan speaking valley in northwest Nepal on the Tibeto-Nepalese border (see Figure 1). Based on field research conducted in 1974, 1976, and 1977, and based on the entire population rather than a sample, he reported a  $CFR_{45+}$  of 7.4 for married females. This CFR is significantly higher than that reported for the Sherpas by either Gupta (1978, 1980) or Weitz et al. (1978) ( $P < 0.05$ ).

These stories (Goldstein 1976, 1981a, b) argued that the low fertility of the Khumbu Sherpas is not typical of high altitude Tibetan populations and, after comparing Limi with other Tibetan populations living at moderate altitude in the Himalayas, suggested that contrary to common belief, Tibetan populations generally have moderately high fertility. Thus, at one point in time, there was completely contradictory evidence from two high altitude Himalayan study areas.

The papers on Limi emphasized the importance of considering how sociocultural factors act to reduce fertility, particularly the impact of mating systems such as fraternal polyandry, the marital union wherein two brothers share one wife. Fraternal polyandry was shown to relegate a substantial proportion of females to a life outside marital union and therein markedly reduced overall fertility (Goldstein 1976). In Limi, 19% of the

females over 45 were unmarried and had a CFR of 1.8, as compared with 7.4 for married females of the same age (Goldstein 1981b). Because of this, the overall CFR<sub>45+</sub> was only 6.3.

Given this, it is obvious that as more females are relegated to the status of never-married and therein excluded from regular or frequent sexual intercourse, the population CFR will decrease. The importance of considering sociocultural factors which might produce such an effect cannot be overemphasized. The initial series of papers were testing the hypothesis that hypoxia, a physical environmental stress not mediated by cultural means, acts to reduce fecundity as measured by fertility. It is, therefore, essential to control for confounding factors that affect fertility such as exclusion from exposure to intercourse (Davis and Blake 1956; Little and Baker 1976) so as to isolate the effects of hypoxia alone. A sociocultural factor that lowers fertility will, if not taken into consideration, leave the erroneous impression that the low fertility observed is reflective of underlying low fecundity. The Limi data mentioned above demonstrate a difference of over one birth between the CFR<sub>45+</sub> for "all women" and for only "married" women (i.e., for women at risk).

But even grouping females into the categories "ever" and "never" married may be inadequate because the category of "ever-married" can include females who have not been exposed to the risk of intercourse for a substantial portion of their reproductive years. For example, in many Tibetan groups it is not uncommon for some females to marry early but then get divorced after a year or two and remain unmarried (i.e., not "at-risk" of pregnancy) for the rest of their lives. Since these females have at most only one or two children, when they are included with "ever-married" females the overall fertility rate drops. While these intramarital type factors were not relevant in the Limi analysis, their importance will be seen below in the Ladakh data.

Thus, in order to investigate the effect of hypoxia on fecundity (as measured by fertility), comparable "controlled" samples must be established in each population. As will be demonstrated below, this can be done by controlling for factors which may influence fertility apart from hypoxia, and by focusing on the CFR of what we call "fully married" women, i.e., women who have been exposed to the risk of conception for almost all of their biological reproductive span, given, of course, the normal age at first marriage. Focusing on such a category of women avoids the possibility that two populations exhibiting very different CFRs do so because they contain very different proportions of women with culturally reduced fertility. We shall refer to this measure as CFR-FM.

Demographic research that attempts to isolate the effects of social factors on reproduction, however, is complicated by other pitfalls. Depending on the society, it may be very difficult to accurately determine these confounding factors since people are often suspicious of strangers asking personal questions and since many statuses associated with reduced reproduction (e.g., "divorced") carry pejorative connotations which may motivate subjects to conceal their "lower" status. Consequently, it is methodologically essential to go beyond a simple one-time interview schedule and utilize intensive community based research in which the investigator resides in the community for an extended period of time and develops rapport and mechanisms for cross-checking questionnaire/census information (Chen and Murray 1976; Campbell et al. 1979). This checking and rechecking is necessary not only for the demographic vital statistics but also for the critical sociomaterial history of females in the study.

Using this perspective, this paper expands the corpus of Himalayan high altitude fertility data by presenting new demographic information collected by Goldstein and Tsarong in Ladakh, a high altitude Tibetan speaking district of Jammu-Kashmir State in India.

## THE DEMOGRAPHIC STRUCTURE OF KYILUNG VILLAGE, LADAKH

*Location and Methods*

The demographic data presented below were collected during the course of a 16-month period from May 1980 to September 1981, as part of a larger study on the sociocultural and economic organization of monasticism in the area. During the summer of 1980 a household census was collected by a local research assistant. At that time reliable information could not be collected for some questions, for example, the number of deceased children. Over the next year, as rapport developed, a second household census-fertility survey of the entire village was conducted by the investigators with the assistance of a locally born monk from the Kyilung (pseudonym) monastery. At this point, preliminary analysis was made and questionable items, for example, women who reported *low or no births*, were checked by reinterviewing subjects and via conversations with relatives, neighbors, and knowledgeable local monks. Similarly, the marital-demographic history of each household in the village was discussed with key informants to ascertain unusual marriage patterns that might affect fertility levels.

Using this methodology, a number of very serious errors among the initial reports were discovered, for example, an older female reporting only one or two births who in fact had borne more children but had divorced and left the children with the husband. We also found several women who had married late (in their mid-30s) and had not, therefore, been exposed to the risk of conception for the same length of time as had other "normally" married females. Thus, care was taken to identify and classify women whose reproductively active years had been constrained by cultural factors that lessened their exposure to the risk of conception. Ten different "socio-marital reproductive types" of women aged 45 + were abstracted on the basis of relevance to the issue of reduced risk of conception.

## A. "Fully Married"

1. Women who married at or before 24 are still married, and have had no intervening divorce. These women have had maximal exposure to risk of conception in this society. (1A) Women recently deceased (within past 5 years) but whose age at death was 45 + and whose marital status was category No. 1. Their fertility data were reported by a spouse and cross-checked with siblings, relatives, offspring, and/or neighbors.
2. Women who married at or before the age of 24, were widowed, but only late in life after the age of 40. Their exposure to risk of conception was reduced for only a small proportion of their reproductively active years.
3. Women married at or before the age of 24 who had been divorced early but had remarried within a few years. Exposure to the risk of conception was reduced for only a small portion of their reproductive span.

## B. "Never Married"

4. Women who never married. These females represent the category with the greatest loss of reproductive potential since they were never in a culturally sanctioned marriage union. While sexual activity is certainly not limited to sanctioned marriage unions and these women do have children, exposure to sexual intercourse is restricted and their fertility is low.
5. Women who married at or before 24 years of age but divorced after a year or two and then remained unmarried.

## C. "Reduced Fertility"

6. Women who married at or before 24 years of age but widowed early, before 33.
7. Women who married late in life, after 33.

8. Women who divorced early and remarried only late in life, after 33.
9. Women who divorced late in life (after 33) and did not remarry.<sup>1</sup>
10. Women who were widowed late in life (over 40), but who were also married late in life (in their 30s).

Throughout this research, ages were collected using the traditional 60-year Tibetan "animal-element year" system which allows translation to the Western calendar with an error of only  $\pm 0.5$  years.

Kyilung itself is a high altitude valley laid out along both sides of a tributary of the Indus River which is located near Leh, the capital of Ladakh. The lowest part of the valley is about 3560 m in altitude and the highest section of the village is about 4085 m although animals are herded and maintained for part of the summer at altitudes up to almost 4950 m. The village contains 214 households and over 1000 persons belonging to two different ethnic groups: Buddhists (the original inhabitants) and Muslims (who began to settle there hundreds of years ago, and who themselves are divided between Kashmiris and Baltis). For all practical purposes, the Buddhists are endogamous although the Muslims do sometimes take Buddhist brides. Thirty-one percent of the households are Muslim and 69% Buddhist. All inhabitants speak Ladakhi, a Tibetan dialect.

#### KYILUNG FERTILITY

Table I presents fertility data as measured by the average number of births for the entire female population of Kyilung village that is over 40 years of age. Completed fertility for all women 45-69 (married, never-married, etc.) is 6.1.<sup>2</sup> However, when potentially confounding social factors are taken into account, a different picture emerges.

Table I illustrates the considerable difference in fertility associated with the different sociomartial reproductive categories. Since the amount of fertility reduction in categories 2 and 3 is slight, we have grouped them together with categories 1 and 1A to form the larger category termed "fully" married women. The remaining categories form two groups: one of "never-married women" (categories 4 and 5) and one of women with reduced exposure (categories 6 through 10). When the data are aggregated in this manner, the CFR<sub>45-69</sub> for "fully" married women is 6.6, while the CFR<sub>45-69</sub> is only 2.0 for "unmarried women" and 3.9 for women with "reduced fertility."

Given the tremendous disparity in fertility associated with differential exposure to the risk of conception, the ideal technique to control for this critical factor would be to calculate for each woman the precise number of years "at-risk" and the part of the reproductive span when these "at-risk" years occurred. With this, any two populations, regardless of social practices, could be compared with respect to the number of births in relation to the number of years "at risk." However, this level of detail was not possible and a less precise, but still highly effective and accurate strategy was developed which isolates and focuses on the group of women who have *not* experienced substantial loss of reproductive time, i.e., the category of "fully married" women. By focusing on this category, one controls for the confounding effect of reduced exposure to the risk of pregnancy and thus makes fertility levels reflect fecundity more closely. It also permits construction and analysis of comparable samples in populations having different social practices and patterns. The 6.6 CRF-FM<sub>45-69</sub> of these "fully" married females in Kyilung is not significantly different from the 7.4 CFR<sub>45+</sub> of the equivalent fully married Limi females (ANOVA,  $P > 0.05$ ).

Table I also indicates that there is a substantial difference in fertility between Muslims and Buddhists in all age categories over the age of 40. For *married* females 45-69, the 0.8 difference in fertility (6.4 compared to 7.2) is not statistically significant ( $P > 0.05$ ). However, Table I further demonstrates a basic difference in the marital patterns of Bud-

TABLE 1. KYILUNG FERTILITY BY AGE, RELIGION, AND SOCIO-MARITAL TYPE.

Age	Religion	Mean no. births for "fully" married women	N	Mean no. births for "never-married" women	N	Mean no. births for "reduced fertility" women	N	Mean no. births for all women	N	
60-69	Buddhist	6.5 SD 2.99	24	5.0 SD	00	1	6.5 SD 2.12	2	6.4 SD 2.86	27
	Muslim	7.2 SD 2.39	9						7.2 SD 2.39	9
	Both	6.7 SD 2.82	33						6.6 SD 2.74	36
50-59	Buddhist	6.2 SD 3.15	29	1.5 SD	.71	2	3.0 SD 2.0	5	5.5 SD 3.26	36
	Muslim	7.0 SD 3.58	6						7.0 SD 3.58	6
	Both	6.4 SD 3.18	35						5.7 SD 3.31	42
45-49	Buddhist	6.4 SD 2.6	17	1.5 SD	1.73	1	3.8 SD 2.5	4	5.2 SD 3.04	25
	Muslim	7.2 SD 2.36	14						7.2 SD 2.4	14
	Both	6.7 SD 2.49	31						5.9 SD 2.95	39
45-69	Buddhist	6.4 SD 2.93	70	2.0 SD	1.83	7	3.9 SD 2.39	11	5.7 SD 3.09	88
	Muslim	7.2 SD 2.55	29						7.2 SD 2.55	29
	Both	6.6 SD 2.84	99						6.1 SD 3.02	117
40-44	Buddhist	6.3 SD 2.55	21	1.3 SD	1.21	6	2.0 SD 0	1	5.1 SD 3.11	28
	Muslim	7.3 SD 1.98	8						7.3 SD 1.98	8
	Both	6.6 SD 2.41	29						5.6 SD 3.02	36

dhists and Muslims. All Muslim women are in the "fully married" category. Because of this, the difference in fertility between Buddhists and Muslims (the CFR<sub>45-69</sub>) almost doubles to 1.5 births (5.7 to 7.2) when all females 45-69 are considered. This difference is statistically significant (t test,  $P < 0.05$ ).

Table II compares the Kyilung fertility data with that of Khumbu and Limi. It illustrates the relatively high completed fertility of "fully" married females in both Limi and Kyilung (7.4 and 6.6) in contrast to that reported for Khumbu. Gupta's CFR<sub>45+</sub> of 4.5 is over two births lower per married female than Kyilung, and almost three births lower than Limi.

The statistical significance of these differences was tested utilizing ANOVA and the Student-Neuman-Keuls Multiple Range Test (SNK). The Student-Neuman-Keuls Test determines both the presence of statistically significant differences between a multiplicity of populations and the precise point where this difference exists, for example, which populations differ significantly (Sokal and Rohlf 1969; Zar 1974).<sup>3</sup>

The SNK Test was used to compare the CFRs of married women from Limi, Kyilung Buddhist, Kyilung Muslim, and Khumbu.<sup>4</sup> The ANOVA test showed a significant difference among these means ( $P < 0.05$ ) and the SNK Test showed that the Sherpas CFRs (Gupta 1978; Weitz et al. 1978) are not consistent with data from the other high altitude populations, that is, they are significantly lower.

Thus, while on the one hand there is a very strong concordance between the Gupta (1978) and Weitz et al. (1978) data for the Sherpas of Khumbu, there is also an equally strong concordance between the Limi and Kyilung data and a statistical difference between the two sets. Although it is possible that there is some very different biological pattern underlying this difference, we contend that this discrepancy is not the result of environmental-biological differences (e.g., hypoxia, hypothyroidism) but rather is an artifact of the Khumbu-Sherpa data and analysis. The Sherpa studies suffer in varying degrees from serious problems which raise questions about the reliability and validity of their findings, the generalizability and significance of their conclusions, and the conclusions of others using their findings. In particular, the Khumbu studies failed to take into account the possibility that some women had been excluded from the risk of intercourse for substantial amounts of their reproductive period.

TABLE II. COMPLETED FERTILITY RATIOS FOR LIMI, KYILUNG, AND KHUMBU.

Group	Source	Altitude	Age	CFR, married women <sup>a</sup>	N	CFR, all women	N
Limi	Goldstein 1981b	3900 m	45 +	7.4 (SD 3.16)	17	6.3 (SD 3.69)	21
Kyilung:							
Buddhist		3500 m		6.4 (SD 2.93)	70	5.7 (SD 3.09)	88
Muslim		to	45-69	7.2 (SD 2.55)	29	7.2 (SD 2.55)	29
Both		4000 m		6.6 (SD 2.86)	99	6.1 (SD 3.02)	117
	Weitz et al. 1978		50 +			4.8 (SD 3.44)	110
Khumbu	Gupta 1978, 1980	3500 + m	45 +	4.5 (SD 2.48)	19		
	Weitz 1981c		50 +	6.3 (SD NA)	44	4.8 (SD 3.44)	110

<sup>a</sup> All but Gupta's CFR reflect roughly equivalent "fully married" women.



## CRITIQUE OF SHERPA FINDINGS

Gupta (1978, 1980) published results of a fertility survey conducted in Khumbu and Kalimpong sometime in the early to mid-1970s. The data from this survey, however, are suspect. Table 5 of that paper lists the number of live births by the age of married women. For Khumbu women 45-49, a CFR of 5.7 is cited. But for those 50-54 a CFR of 1 is reported and for those 55 and over, a CFR of only 3.3 is reported. The latter figure is more than two births lower than the CFR for women 45-49. This strongly suggests that the overall low CFR of 4.5 is the result of underreporting of births by the older women in the sample, due either to faculty memory or outright informant misinformation. If this very low fertility for older women reflects some idiosyncratic historical process or event affecting the older women, it is not discussed in the paper.

Moreover, the sample size of the study is very small and appears not to have been selected by a random or systematic sampling method. For example, the study is based on 14 Khumbu women 45 years and over (Gupta 1978, Table 5). Weitz et al. (1978:183) however, in their Table 1, list the total Khumbu area as having 260 women over the age of 50. Given this figure, the Gupta sample comprises only 5% of the total women over 50 and thus even less of the total women over 45. With this small and nonrandom sample, these CFR figures are unlikely to be representative of the total Khumbu population. Furthermore, this Khumbu sample apparently does not exclude Tibetan refugees who fled from Tibet and settled in Khumbu in the early 1960s.

Research by Goldstein and Beall among Tibetan refugees in Pokhara and Kathmandu (Nepal) suggested that among Tibetan refugees there are a disproportionate number of nulliparous and low-fertility females. On questioning, these Tibetan refugees corroborated this, indicating that families with many children, particularly young ones, disproportionately decided to remain behind in Tibet. The difficulties of the flight to exile and the belief that their exile would be short as it had been earlier in this century, kept many females with large families in Tibet. The Tibetan refugees, therefore, represent a skewed sample and should have been excluded (or separated out) from the analysis.

Finally, and most critically, the Gupta study made no attempt to take into account varying exposure to the risk of intercourse within the category of ever-married women.

The low altitude Kalimpong Sherpa data reported in this study are also seriously flawed. The study does not indicate when or from where these migrants came and the CFR data reported again are inconsistent. For example, while the  $CFR_{45+}$  is 7.4, the  $CFR_{40-44}$  is only 5.4. It is highly improbable that Kalimpong women average 2 births during the 5-year age interval 40-44, but less than 1 birth during each of the two immediately prior 5-year intervals (30-34 and 35-39) and only 1.5 births during the 25-29 interval (Gupta 1980:109).

The data reported by the Weitz et al. (1978) study are also problematic. First, this study lumped Tibetan refugees with indigenous Sherpas. When Weitz (personal communication) recalculated his figures eliminating the refugees, the  $CFR_{50+}$  for all women increased from the original 4.8 to 5.2.

But a  $CFR_{50+}$  of 5.2 was still low relative to the CFRs reported for Limi and Kyilung, and the question of how to account for this anomalously low fertility still remained.

Weitz has argued for both a hypoxic effect and a further social and biological effect which reduced Khumbu fertility even lower than that of high altitude native Andean populations, for example:

both fertility and birth weights appear to be lower at high altitudes.

Although reduced, fertility in the *altiplano* [Andes] is still high. Completed family size . . . averages 6.7 births in Nuñoa [Peru] and is similar in other areas of the *altiplano*. In comparison, completed family size in one well-studied area of low-altitude Peru was 8.3.

Sherpa fertility is much lower—completed family size is about 5.1. Part of the difference [between this and the Nunoan CFR] may be explained by various cultural factors that seem to lower Sherpa fertility. In the past, low iodine intake caused . . . hypothyroidism, which is known to result in an extremely high level of spontaneous abortions [thus lowering the no. live births]. [Weitz 1981b:82]

We contend that if exclusion from exposure to intercourse were taken into account and a comparable category of "fully married" Sherpa women constructed, Khumbu Sherpa fertility would *not* be unusually low, i.e., when a Khumbu Sherpa sample population roughly approximating the Limi and Kyilung "fully married" samples is isolated, Sherpa fertility is equivalent to that of Limi and Kyilung.

However, the data reported in Weitz et al. (1978) do not directly permit such recalculation. First, as indicated earlier, the low fertility Tibetan refugees are included with Sherpas in all calculations. Second, there is no breakdown of women in the sample by virtue of present and past marital status (e.g., divorced, widowed, separated) or even a clear ever-married/never-married dichotomy. Third, no fertility figures are presented for "ever" and "never" married women as distinct categories. Instead, the data are presented (broken down) only with reference to socioeconomic strata and degree of village acculturation. Because these socioeconomic categories and village types contain different but unspecified proportions of Tibetan refugees and potential differences with regard to divorce, etc., it is not possible to recalculate the data to construct a category of "fully married" or even "ever-married" women. However, there *is* evidence suggesting that if a category of "fully married" women could be constructed, it would show relatively high fertility. For example, this study cited a  $CFR_{50+}$  of 6.2 for married females in the higher socioeconomic category which included fewest Tibetan refugees.

Recently, these Khumbu fertility data were reorganized to segregate out Tibetan refugees and take into account different types of marital statuses (Weitz personal communication). While this goes a long way toward addressing the issue of exclusion from the risk of intercourse and thus conception, it still does not take into account reduced fertility *within* marital categories, for example, monogamous women who married only later in life. Nonetheless, the new breakdown provides additional insight into what Khumbu Sherpa completed fertility would be if a "fully married" category could be constructed. For example, the  $CFR_{50+}$  for Sherpa women married monogamously was 6.5, a figure almost identical to that of Kyilung Buddhists (ibid.). Calculation of a weighted  $CFR_{50+}$  for a composite category consisting of monogamously, polyandrously, and polygynously married women (weighting for proportion of total population) resulted in a  $CFR_{50+}$  of 6.3. Our experience suggests that in-depth anthropological research on family and marital history would further increase this relatively high CFR by identifying and excluding females within the marital types who have had reduced exposure to the risk of intercourse and thus conception (analogous to the Kyilung analysis).

When these new CFRs of 6.3 and 6.5 were compared with the CFRs of Limi and Kyilung, the initial statistically significant difference mentioned earlier (associated with the 4.8 figure) vanishes ( $P > 0.05$ ). And when the CFRs of all of these are then compared (using the Student-Neuman-Keuls Multiple Range Test) with Gupta's 4.5  $CFR_{45+}$ , Gupta's figure is statistically different from the others [Khumbu (Gupta) < Khumbu (recalculated Weitz) = Kyilung (Buddhist) = Kyilung (Muslim) = Limi]. In other words, when even a roughly comparable subsample of Khumbu females was isolated which excluded all Tibetan refugees and women who have been divorced, widowed, never-married, and so forth, Khumbu fertility is *not statistically different* from that of the other high altitude Himalayan populations studied by Goldstein.

In the end, then, the unusually low fertility reported for high altitude Sherpas (Weitz et al. 1978; Gupta 1978, 1980) and utilized by Bangham and Sacherer (1980) does not

reflect low fecundity produced by high altitude hypoxia or other biological-environmental factors such as hypothyroidism. Rather it reflects a failure of these studies to control for critical confounding factors affecting fertility.

#### *A Comparison of the Fertility of High and Low Altitude Himalayan Populations*

While the issue of the anomalously low fertility reported for Khumbu Sherpas appears to be resolved, the more fundamental issue of whether the fertility (and fecundity) of these high altitude Himalayan populations is significantly different from that of low and moderate altitude Himalayan populations must be examined. As indicated earlier, both Bangham and Sacherer (1980) and Gupta (1978, 1980) have concluded that there is a significant difference in fertility between low-moderate and high altitude Himalayan populations that is caused by hypoxia produced low fecundity at high altitude. Weitz (1981a) suggested that this difference between Khumbu Sherpas and the moderate altitude Solu, Arun, Helambu, Kagate Sherpas may be explained by factors other than hypoxia such as by husband absenteeism and hypothyroidism. We contend again that when exposure to the risk of conception is controlled for, the current evidence does not support the conclusion that high altitude Himalayan populations have lower fertility than *comparable* lowlander populations.

The serious shortcomings of Gupta's high and low altitude data have been discussed above. The Bangham and Sacherer study (1980) suffers from equally fundamental shortcomings. The sample of 75 women comes from 15 moderate altitude Sherpa villages in Helambu, Solu, and the Upper Arun River (see Figure 1) located at altitudes between 2200 m and 2600 m. As indicated in Table III, they report a  $CFR_{45+}$  of 7.6 for Helambu, 8.5 for Solu-Arun, and 5.3 for Kagate (a subpopulation in Solu comprised of migrants from Helambu). The joint  $CFR_{45+}$  for these three populations is 7.8, a figure they report to be significantly higher than the completed fertility of the high altitude Khumbu Sherpas (using the 4.5 and 4.8 CFRs). However, because of the size and character of the samples and the methods of data collection, the findings reported cannot be considered valid.

This study indicated that villages were visited for only a few days and interviews were conducted with whomever came to see them and would cooperate (Bangham 1978). In no case was the size of the universe from which their sample came indicated and it is, therefore, impossible to determine the percent of the total that their sample represents. However, we know it must be extremely small because it averages out to less than five women per village studied. Because these five women were not selected by any random or systematic methodology (i.e., were self-selected) their reported data cannot be treated as representative of the larger populations. In fact, in one of their sites (Kagate), the entire sample of women aged 45+ consisted of only 4 individuals.

These very serious shortcomings are compounded by the fact that the misleadingly low fertility figures cited by Gupta (1978, 1980) (4.5) and Weitz et al. (1978) (4.8) are used for the high altitude contrast population. Thus, the finding of a statistically significant difference between high and moderate altitude Sherpas has no validity. In fact, when our recalculation of Weitz's marital fertility (6.3) is used for the high altitude Sherpa population, there is no statistically significant difference between the CFR reported by Bangham and Sacherer for the moderate altitude Sherpas (7.8) and the CFRs of Limi, Kyilung (Buddhist and Muslim), and Khumbu ( $P > 0.05$ ).

Nonetheless, this does not mean that valid comparisons of fertility cannot be made across altitude zones in the Himalayas. To the contrary, a number of new and excellent cultural-demographic indepth studies make such a comparison feasible. Before discussing these, a comment must be made on how we shall operationally define "altitude" in

this paper. We shall use 3400 m as demarcating a high altitude zone and 2000 m a moderate altitude zone. Table III presents the currently available fertility data for the Himalayas.

An 18-month in-depth, cultural-demographic study of two contiguous villages at "moderate altitude," one Hindu (2300 m) and one Tibetan (2500 m), was conducted in Humla, a remote district in northwest Nepal (Ross 1981). It included all females in the village and reported a  $CFR_{45+}$  for all Tibetan females of 6.0, and a  $CFR_{45+}$  of 6.7 for ever-married females. However, when women widowed before the age of 45 were excluded, the CFR-FM increased to 7.0 (ibid.). A parallel effect is reported for the Hindu populations. Here the  $CFR_{45+}$  for ever-married is 6.2 (all females were ever-married). This increases to 7.4 when women widowed before the age of 45 are eliminated.

Another detailed long-term cultural-demographic study was conducted in 1979-1980 in the "low altitude" Nepalese hill village of Ghachok (1400 m) located north of Pokhara (Folmar 1983). It also included all females in the village and reported a relatively low  $CFR_{45+}$  of 5.5 for ever-married Caste Hindu women. However, excluding all women widowed before the age of 45 from the computation increased the  $CFR_{45+}$  to 6.6. When women who married after the age of 25 were also excluded, the CFR (i.e., CFR-FM) increased still further to 7.2 ( $N = 48$ ). In turn, this breaks down into a  $CFR-FM_{45+}$  of 6.9 ( $N = 22$ ) for high caste (Brahmin-Chetri) women and 7.4 (26) for low caste women.

Other more fragmentary fertility data exist (see Table III) for moderate and low altitude Himalayan populations (Macfarlane 1976; Levine 1977; Goldstein and Beall, unpublished observation) but because these do not permit isolation of a "fully married" category, our comparative cross-altitude analysis is limited to the Folmar and Ross data. Two techniques were used to test the relationship between the fertility of these high, low, and moderate altitude populations. Figure 2 presents a bar graph of altitude and CFR-FM for the seven populations listed in Table III for which such data exist (i.e., Ladakh Buddhist, Ladakh Muslim, Sherpa Khumbu, Dzinga, Chaugan, Ghachok high caste, Ghachok low caste). It illustrates clearly the absence of any altitude related pattern. Correlation-regression analysis also revealed no significant relationship between altitude and completed fertility rate ( $P > 0.05$ ).

The Student-Neuman-Keuls Multiple Range Test was also used to compare the CFRs of the nine populations in Table III for which standard deviations are published (with the exception of Gupta's Khumbu data). It also found no statistically significant difference between the high, moderate, and low altitude populations. Further SNK tests excluding first Gupta's data and then Gupta's and Bangham and Sacherer's data were run, but there was still no statistically significant difference between the high, low, and moderate altitude populations.

Consequently, while Gupta's and Bangham and Sacherer's findings of a statistically significant difference between low and high altitude populations in the Himalayas were technically correct, they are scientifically invalid due to the manner in which the data on which their computations were based was collected, analyzed, and compared. Based on new cultural-demographic data and the recalculation of existing data, we found that the fertility of high altitude Himalayan women of post-reproduction age is moderately high and is *not* statistically different from the fertility of women residing at moderate and low altitudes once comparable "controlled" samples are constructed.

#### *Hypoxia and Fertility in the Andes*

All of this raises the question of whether there are major population differences between the Andes and Himalayas with respect to the effect of high altitude hypoxia on

TABLE III. COMPLETED FERTILITY RATIOS FOR HIMALAYAN POPULATIONS RESIDING AT HIGH, MODERATE AND LOW ALTITUDE.

	Group	Source	Altitude	Ethnicity	Age	CFR for married women	N
High altitude	Limi	Goldstein 1981a, b	3900 m	Tibetan	45 +	7.4	17
	Kyilung <sup>1</sup>		3800 m	Ladakhi- Buddhist	45-69	6.4	70
	Kyilung <sup>2</sup>		3800 m	Ladakhi- Muslim	45-69	7.2	29
	Khumbu All of the above	Weitz 1981c	3400 + m	Sherpa	50 +	6.3	44
	Khumbu	Gupta 1978, 1980	3400 + m			6.8	
Moderate altitude	Dhinga	Ross 1981	2500 m <sup>a</sup>	Tibetan	45 +	7.0	13
	Chaugan	Ross 1981	2300 m	High caste Hindu	45 +	7.4	11
	Nyinba	Levine 1977	2900 m	Tibetan	43 +	6.3	19
	Helambu	Goldstein and Beall	2600 m	Sherpa	45 +	7.2	20
	All of the above					7.0	
	Solu-Arun	Bangham and Sacherer 1980	2400 m	Sherpa	45 +	8.5	26
	Helambu	Bangham and Sacherer 1980	2600 m	Sherpa	45 +	7.6	40
	Kagate	Bangham and Sacherer 1980	2400 m	Sherpa	45 +	5.3	4

Low altitude	Ghachok	Folmar Ms.	1400 m	Hindu — high caste	45 +	6.9	22
	Ghachok	Folmar Ms.	1400 m	Hindu — low caste	45 +	7.4	26
	Thak	Macfarlane 1976	1700 m	Tibeto- Burman: Gurung	40 +	5.6	12
	All of the above						
	Kalimong (Gupta)	Gupta 1978, 1980	1400 m	Sherpa	45 +	6.2 7.4	69

<sup>a</sup> In cases where villages have a main and summer location, we use the altitude of the main village. In cases where a village or sample is spread out over a substantial altitude gradient, we use the average altitude.

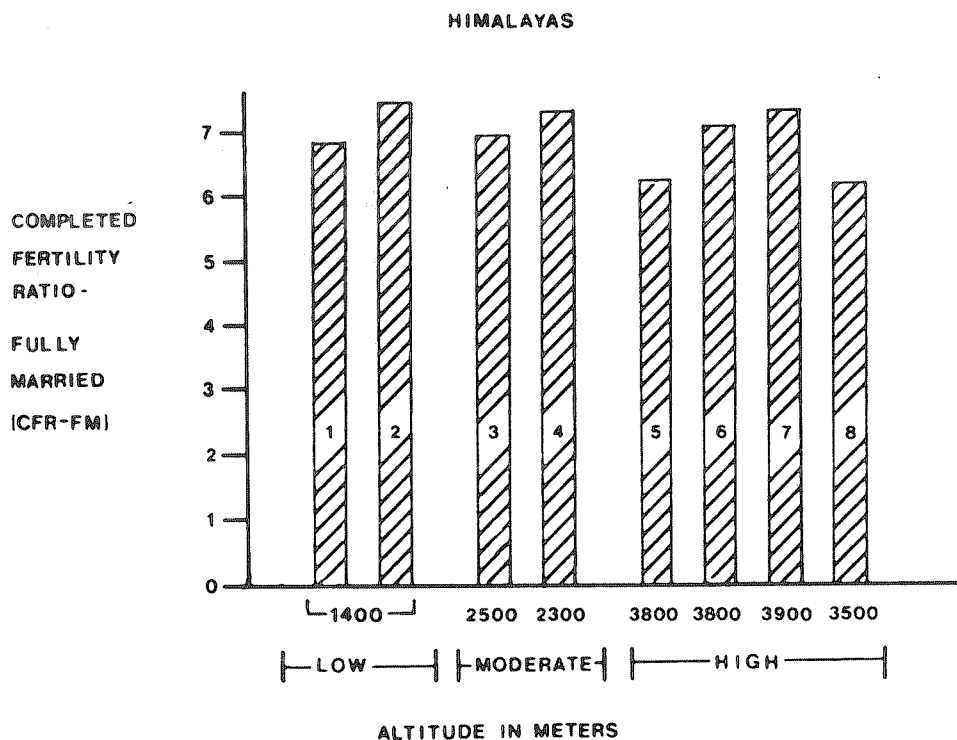


Figure 2. This compares the completed fertility of fully married (CFR-CM) women for eight populations residing at different altitudes in the Nepal and Indian Himalayas. Population 1 = Ghachok (Nepal), high caste Hindu (Folmar ms.); population 2 = Ghachok (Nepal), low caste Hindu (Folmar ms.); population 3 = Dhinga (Nepal), Tibetan (Ross 1981); population 4 = Chaugan (Nepal), high caste Hindu (Ross 1981); population 5 = Kyilung (Ladakh, India), Ladakhi-Tibetan; population 6 = Kyilung (Ladakh, India), Balti Muslim; population 7 = Limi (Nepal), Tibetan (Goldstein 1981b); population 8 = Khumbu (Nepal), Sherpa-Tibetan (Weitz 1981c).

fecundity/fertility or, alternatively, whether some of the same confounding social factors shown for the Himalayas may also exist in the Andean literature.

Examination of this literature finds no reports of extremely low fertility such as we have seen regarding the Khumbu Sherpas but nonetheless finds that the evidence for a hypoxic effect on fertility in the Andes is equally flawed by contradictory findings, methodological shortcomings, and conceptual oversimplification, particularly the lack of comparability of samples. In reality, the evidence in support of a hypoxic effect on fertility in the Andes is no more persuasive than what we have seen for the Himalayas. Only brief examples of the problems will be explicated here.

Table IV presents the CFRs for Andean populations for which microdemographic, i.e., community level<sup>5</sup> data exist and from which the claim for an hypoxic effect is derived. As is readily evident, there *does not* appear to be any altitude-related pattern. For example, the high altitude Aymara studied by Cruz-Coke et al. (1966) and Dutt (1976, 1980) have CFRs ranging from 5.8 to 8.5 whereas the low and middle altitude Aymara have CFRs ranging from 5.4 to only 7.2. Furthermore, Dutt (1976, 1980) reported *no* statistically significant difference in the fertility of the high, middle, and low altitude

TABLE IV. COMPLETED FERTILITY RATIO FOR SELECTED ANDEAN POPULATIONS.

Group	Source	High altitude CFR <sub>45+</sub>	N	Moderate altitude CFR <sub>45+</sub>	N	Low altitude CFR <sub>45+</sub>	N
Chilean Aymara	Cruz-Coke 1966	7.3 (SD 3.14)	Na	—	—	6.4 (SD 2.89)	Na
		8.5 (SD 2.37)	Na	—	—	7.2 (SD 3.45)	Na
		5.8 (SD 2.64)	Na	—	—	—	—
Bolivian Aymara	Dutt 1976, 1980	5.9 (SD 3.05) <sup>a</sup>	28	7.2 (SD 2.31)	20	6.9 (SD 3.01)	13
		5.9 (SD 3.24) <sup>b</sup>	78	5.3 (SD 2.67)	64	5.4 (SD 3.92)	17
Peruvian Quechua and Mestizos	Hoff 1968	6.7 (SD 3.00)	31	—	—	—	—
	Way 1972 Abelson 1972	9.1 (SD 1.67) <sup>c</sup>	7	—	—	8.0 (SD 4.85) 8.3 (SD 1.25)	3 14

<sup>a</sup> urban<sup>b</sup> rural<sup>c</sup> refers to pregnancies



Bolivian samples he studied. However, when the SNK test was computed for Dutt's (1976, 1980), Abelson's (1972, 1976) and Hoff's (1968) data (we were unable to determine precise sample size and thus could not use Cruz-Coke's data), there was *no* statistical difference between the high, middle, and low altitude groups. Figure 3 illustrates this. Ironically, there was a statistical difference between Dutt's *low* altitude rural Bolivian populations and Abelson's *low* altitude Peruvian population.

Despite this lack of significant correlation between altitude and completed fertility, the proponents of a hypoxic effect in the Andes contend that the evidence supports such a conclusion (Abelson 1972, 1976; Abelson et al. 1974; Clegg 1981; Donayre 1966; Hoff and Abelson 1976; Weitz 1981b). The case is based primarily on a comparison of the fertility of Peruvian high altitude natives (HAN) studied by Hoff (1968) and Peruvian low altitude natives (LAN) studied by Abelson (1972). As one recent paper comments: "when care is taken [as in the case of Hoff and Abelson] to compare groups differing only in their altitude residence . . . significant differences [referring to hypoxia and fertility]

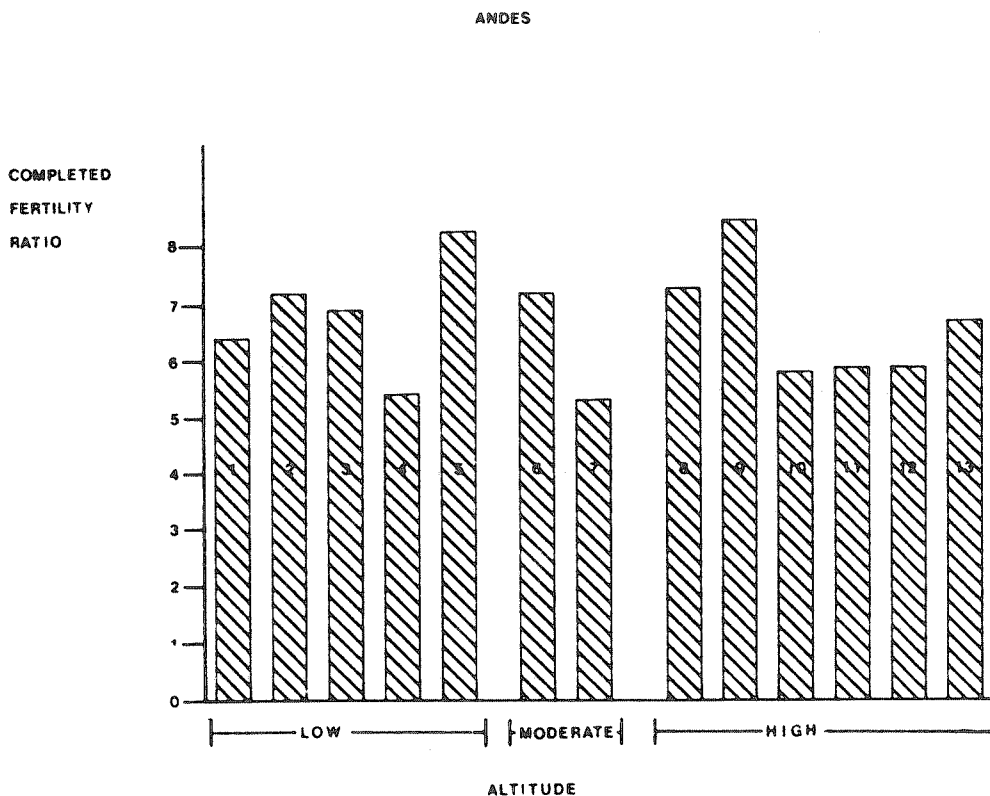


Figure 3. This compares the completed fertility ratios for women aged 45+ in thirteen populations residing at different altitudes in the Andes. Population 1 = Aymara, Chile (Cruz-Coke 1966); population 2 = Aymara, Chile (ibid.); population 3 = Aymara, Bolivia (Dutt 1980); population 4 = Aymara, Bolivia (ibid.); population 5 = Quechua-Mestizos-Aymara, Peru (Abelson 1972); population 6 = Aymara, Bolivia (Dutt 1980); population 7 = Aymara, Bolivia (ibid.); population 8 = Aymara, Chile (Cruz-Coke 1966); population 9 = Aymara, Chile (ibid.); population 10 = Aymara, Chile (ibid.); population 11 = Aymara, Bolivia (Dutt 1980); population 12 = Aymara, Bolivia (ibid.); population 13 = Quechua, Peru (Hoff 1968).

can be demonstrated" (Clegg 1981:149). We suggest, to the contrary, that what is striking about the Andean studies (and most of the Himalayan ones) is precisely that none of them attempted to control for the critical confounding social variables, despite the investigators' apparent awareness of this issue.

Hoff conducted his research among Quechua Indians in Nuñoa (4000 m) on the Peruvian plateau (*altiplano*) as part of a large biocultural project. Abelson also conducted his study as part of this ongoing project. His research was conducted at sea level in the Tambo valley in southern Peru. His subject population included migrants from high altitude (mostly Quechua and Aymara), nonmigrant lowlanders (mestizos, i.e., Peruvians with European admixture, Quechua and Aymara) and low altitude migrants (mestizos, Quechua, and Aymara).

Both studies utilized a lengthy fertility-sociocultural questionnaire but whereas Abelson's study interviewed women, Hoff's study interviewed predominately the *male* heads of households. Given the high frequency of serial monogamy among Quechuas, current husbands may not be aware of infant mortality experienced by current wives in a prior union and thus may well have inadvertently underreported female fertility. Moreover, both studies interviewed small samples that do not appear to have been randomly or systematically drawn. Hoff's included 31 women over the age of 45, and Abelson's study included only 14 women over the age of 45 (less than 3 women per research site). Thus, methodologically, both studies have small samples given the universe from which they could select and there is reason to doubt their representativeness.

Abelson's case for the presence of a substantial hypoxic effect on fertility in the Andes is mainly based on the claim that there is: (1) greater fertility for nonmigrant, low-altitude natives (LAN) than nonmigrant, high-altitude natives (HAN), and (2) an increase in the fertility of HAN migrating downward to low altitude. He concluded that "the stress of hypoxia can act to reduce fertility, and this effect is measurable at the population level. The size of the effect is between 1 and 2 births per woman" (Abelson 1976:89). However, this interpretation is inconsistent with the evidence cited.

There are several ways to compare fertility. Perhaps the most common way is to compare the fertility of women assumed to have completed their reproduction, that is, women 45 years or over. Another way is to compare the age-specific fertility of women at all ages, for example, 15-19, 20-24. This is particularly important when migrant fertility is being considered since their reproductive years are spent in at least two different environments.

The Abelson study attempted to use both approaches but could not do so directly because the high altitude Nuñoa study (Hoff 1968) did not report age-specific fertility rates for HAN women under 45 years of age. Therefore, the pre-45 fertility of nonmigrant HAN was obtained indirectly by using the premigration fertility experience of high-to-low altitude migrants to represent the reproductive experience of all nonmigrant high altitude inhabitants (Abelson 1972). Premigration fertility data were calculated from these high altitude migrants for three age categories: 15-19.9; 20-24.9; 25-29.9.

The validity of such a comparison clearly rests upon the degree to which this group of women who subsequently emigrated to low altitudes are representative of *all* high altitude resident (i.e., nonmigrant) women. Abelson's Figure 1 (1972:43) intends to establish this by comparing the age-specific cumulative fertility of a group of high altitude resident women in Nuñoa with those of the group of women who subsequently emigrated to low altitude. The age-specific rates of the two groups are said to be comparable since the migrant data points are "close to the curve for the Nuñoa population" (ibid:47). Yet, Figure 1 in a later paper (Abelson et al. 1974) depicts the fertility of the downward migrants as *lower* than that of nonmigrant high altitude natives. Moreover, since the Nuñoa study did not report age-specific fertility rates, the origins of the curve are

unclear. The study merely states: "These figures [the age-specific fertility rates] were not available for the high altitude population of Nuñoa, but from the data that Hoff presents it is possible to draw a graph of their cumulative fertility (Figure 1)" (Abelson 1972:41).

Ignoring for a moment the problem of this unspecified extrapolation, this study reported significantly lower fertility for HAN women aged 15-19.9 and 20-24.9 (prior to migration) than for LAN nonmigrants. However, it also reported no significant difference for the third age category examined, women 20-24.9. We interpret these findings as indeterminate.

This study also reported on the completed fertility ratio (CFR) for the HAN and LAN nonmigrant populations. Comparing the 6.7 CFR<sub>45+</sub> of Hoff's HAN Nuñoa sample (N = 31) with the LAN CFR<sub>45+</sub> of 8.3 (N = 14), it concluded: "The completed fertility of the two populations shows that 8.29 children are born to the low altitude population during their reproductive life compared to 6.7 for the high altitude population. The results show that more children are born to the low altitude population" (ibid:40). However, our t-tests reveal *no statistically significant difference* in these two CFR's ( $P > 0.05$ ).

The case for a hypoxic effect is further challenged by contradictory data reported in another study conducted in the same two areas (Way 1972:94). Reporting numbers of pregnancies rather than live births, this study reported that HAN women 45+ had *more* pregnancies (9.1, N = 7) than a LAN sample of women 45+ (8.0, N = 3) although this difference was not statistically significant. Similarly, the differences in the number of pregnancies for HAN and LAN women at younger ages (24-45) were also not statistically significant. This study, however, used a small, apparently self-selected sample and, like the other Peruvian studies mentioned above, did not take into account and control for exclusion of women from the risk of intercourse.

Given the sensitivity of fertility to such social and cultural factors, until women whose fertility has been culturally reduced are excluded from computations, it is not possible to determine whether the reported CFRs of different Andean populations are dissimilar because of different fecundity levels or because of confounding cultural factors such as different proportions of women excluded from the risk of conception for substantial amounts of time. Unfortunately, *none* of the Andean studies have done this. Hoff (1968:109), in fact, states that he could not assess the effect of marital instability on net fertility. The impact of this shortcoming is likely to be exaggerated because of the very small samples utilized in these studies. For example, if we argue hypothetically that 3 (of the 31) women in Hoff's sample had been excluded for a substantial period of time from the risk of pregnancy and thus had borne only 2 children each, the CFR<sub>45+</sub> would increase substantially from 6.7 to 7.2 when they are excluded from the computation.

For these and other reasons, we suggest that the data and analyses presented in support of the hypothesis that high altitude hypoxia reduces fecundity and fertility in the Andes are inconclusive. When the wide range of CFRs at both high and low altitude were examined there was *no* altitude related pattern (see Figure 3). Similarly, when the findings of Andean village-level surveys were examined, the results also failed to support the hypoxia hypothesis. The maze of contradictory findings is, as was seen in the Himalayas, in all likelihood an artifact of the failure to take account of and control for cultural factors such as exposure to the risk of conception.

Based on the reexamination of the Andean and Himalayan data, it is concluded that the case for the presence of a hypoxic effect acting to reduce fertility and fecundity in long-term resident native populations in the Andes and Himalayas is scientifically unproven, despite its widespread acceptance. Of course, this does not imply that such an effect does not exist; it means only that new research taking into account the methodological and conceptual factors discussed in this paper is necessary. To test the effects of

altitude on fecundity and fertility, the effects of confounding factors must be controlled. Until this is done, the evidence for a hypoxic effect is primarily anecdotal.

#### NOTES

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<sup>1</sup> In none of these cases was barrenness the precipitatory factor; the mean number of live births for the three Ladakhi women 45-69 in this category is 1.33.

<sup>2</sup> Women over 70 ( $N = 13$ ) have been excluded from these computations because there is very definite evidence that their replies underreport fertility and because it was virtually impossible to obtain corroborative information for them on infant mortality, exclusion from the risk of conception, etc. For example, the self-reported number of births for married women over 70 is 3.9 (SD 3.84), a figure almost 3 births lower than that of married women 45-69. There is no historical event (cohort effect) that would account for this. We believe that this report of untypically low fertility is the result of an underenumeration of births ending in infant mortality. For example, whereas married women 45-69 reported that 2.2 ( $N = 99$ ) of their births resulted in deaths, the married women 70+ reported only 0.6 ( $N = 10$ ) of their births resulted in death. There was also a higher percentage of nulliparous women in 70+ category, again indicating underreporting of births.

<sup>3</sup> A special interactive computer program was written in Fortran for this study. This program requires only means, standard deviations and sample sizes for input and first computes an analysis of variance (ANOVA). If the ANOVA test reveals statistically significant differences, then the program branches into the Student-Neuman-Keuls procedure to pinpoint where the differences exist. John Blangero, a Ph.D. candidate in physical and medical anthropology in the Department of Anthropology, Case Western Reserve University, wrote the computer program for the SNK test.

<sup>4</sup> The lower CFR of 6.3 was used in his computation. Since Weitz (personal communication) did not provide S.D. figures, we used the ones cited in his 1978 paper for the 4.77 and 6.2 CRFs.

<sup>5</sup> The term "micro-demographic study" is used in the Andean literature (Baker and Dutt 1972) to distinguish studies in which investigators actually administered questionnaires locally from those based on national and regional census data. However, it should be noted that none of the Andean "micro-demographic" studies are equivalent to the intensive, long-term, community based micro-demographic studies conducted by Goldstein (1976, 1981a), Ross (1981), and Folmar (1983).

#### REFERENCES CITED

- Abelson, A. E.  
 1972 Altitude, Migration and Fertility. M.A. thesis, Department of Anthropology, Pennsylvania State University.  
 1976 Altitude and Fertility. *Human Biology* 48(1):83-91.
- Abelson, A. E., T. S. Baker, and P. T. Baker  
 1974 Altitude, Migration, and Fertility in the Andes. *Social Biology* 21:12-27.
- Baker, P. T.  
 1978 The Adaptive Fitness of High-Altitude Populations. *In The Biology of High Altitude Peoples*. P. T. Baker, ed. pp. 317-350. Cambridge, Eng.: Cambridge University Press.
- Baker, P. T., and J. S. Dutt  
 1972 Demographic Variables as Measures of Biological Adaptation: A Case Study of High Altitude Human Populations. *In The Structure of Human Populations*. G. A. Harrison and A. J. Boyce, eds. pp. 352-378. Oxford: Clarendon Press.

- Bangham, C. R. M.  
1978 Nepal Valleys are Fertile. *Geographical Magazine* 50:681-687.
- Bangham, C. R. M., and J. M. Sacherer  
1980 Fertility of Nepalese Sherpas at Moderate Altitudes: Comparison with High-Altitude Data. *Annals of Human Biology* 7(4):323-330.  
1981a Reply to Weitz. *Annals of Human Biology* 8(4):385-386.
- Campbell, J. G., R. Shrestha, and L. Stone  
1979 The Use and Misuse of Social Science Research in Nepal. Kathmandu: Research Center for Nepal and Asian Studies.
- Chen, K.-H., and G. F. Murray  
1976 Truths and Untruths in Village Haiti: An Experiment in Third World Survey Research. In *Culture, Natalty and Family Planning*. John F. Marshall and S. Polgar, eds. pp. 241-262. Chapel Hill, N.C.: Carolina Population Center.
- Clegg, E. J.  
1981 Some Approaches to Methodology to High-Altitude Research. In *Environmental and Human Population Problems at High Altitude*. pp. 147-150. Paris: Centre National de la Recherche Scientifique.
- Cruz-Coke, R., A. P. Christoffanini, M. Aspillaga, and F. Bancani  
1966 Evolutionary Forces in Human Populations in an Environmental Gradient in Arica, Chile. *Human Biology* 38:421-438.
- Davis, K., and J. Blake  
1956 Social Structure and Fertility: An Analytic Framework. *Economic Development and Culture Change* 4:211-235.
- Donayre, J.  
1966 Population Growth and Fertility at High Altitude. In *Life at High Altitudes*. PAHO. pp. 74-79. Sci. Pub. No. 140. Washington, D.C.
- Dutt, J. S.  
1976 Altitude and Fertility: The Bolivian Case. Ph.D. dissertation, Department of Anthropology, Pennsylvania State University.  
1980 Altitude and Fertility: The Confounding Effect of Childhood Mortality—A Bolivian Example. *Social Biology* 27(2):101-114.
- Ekvall, R. B.  
1972 Demographic Aspects of Tibetan Nomadic Pastoralism. In *Population Growth: Anthropological Implications*. Brian Spooner, ed. pp. 265-286. Cambridge: MIT Press.
- Folmar, S. J.  
1983 Fertility and the Economic Value of Children in Pokhara Valley, Nepal. Ph.D. dissertation, Department of Anthropology, Case Western Reserve University.
- Goldstein, M. C.  
1976 Fraternal Polyandry and Fertility in a High Himalayan Valley in Northwest Nepal. *Human Ecology* 4:223-233.  
1981a High Altitude Tibetan Populations in the Remote Himalaya: Social Transformation and Its Demographic, Economic, and Ecological Consequences. *Mountain Research and Development* 1(1):5-18.  
1981b New Perspectives on Tibetan Fertility and Population Decline. *American Ethnologist* 8(4):721-729.
- Gupta, R.  
1978 A Comparative Demographic Study of the Sherpas of Upper Khumbu (above 10,000 ft.), Darjeeling District, West Bengal, Calcutta: Biological Sciences Division of the Indian Statistical Institute.  
1980 Altitude and Demography Among the Sherpas. *Journal of Biosocial Science* 12:103-114.
- Haimendorf, C. von Furer  
1964 The Sherpas of Nepal. London: J. Murray, Ltd.
- Hoff, C. J.  
1968 Reproduction and Viability in a Highland Peruvian Indian Population. In *High Altitude Adaptation in a Peruvian Community*. P. T. Baker, ed. pp. 85-152. University Park, Pa.: Occasional Papers in Anthropology, The Pennsylvania State University.

- Hoff, C. J., and A. E. Abelson  
1976 Fertility. *In* Man in the Andes. P. T. Baker and M. A. Little, eds. pp. 138-146. Stroudsburg, Pa.: Dowden, Hutchinson and Ross.
- Levine, N.  
1977 The Nyinba: Population and Social Structure in Polyandrous Society. Ph.D. dissertation, Department of Anthropology, University of Rochester.
- Little, M. A., and P. T. Baker  
1976 Environmental Adaptations and Perspectives. *In* Man in the Andes. P. T. Baker and M. A. Little, eds. pp. 405-428. Stroudsburg: Dowden, Hutchinson and Ross.
- MacFarlane, A.  
1976 Resources and Population. Cambridge, Eng.: Cambridge University Press.
- Monge, C.  
1948 Acclimatization in the Andes. Baltimore: The Johns Hopkins University Press.
- Ross, J. L.  
1981 Hindu and Tibetan Reproduction and Fertility in Northwestern Nepal: A Study of Population, Ecology and Economics. Ph.D. dissertation, Department of Anthropology, Case Western Reserve University.
- Sokal, R. R., and F. J. Rohlf  
1969 Biometry. San Francisco: Freeman.
- Way, A. B.  
1972 Health, Exercise Capacity and Effective Fertility Aspects of Migration to Sea Level by High Altitude Peruvian Quechua Indians. Ph.D. dissertation, University of Wisconsin.
- Weitz, C. A.  
1981a Fertility of Nepalese Sherpas at Moderate Altitudes: Comparisons with High-Altitude Data. *Annals of Human Biology* 8(4):383-385.  
1981b Weathering Heights. *Natural History* 90(11):72-84.
- Weitz, C. A., I. G. Pawson, M. V. Weitz, S. D. R. Lang, and A. Lang  
1978 Cultural Factors Affecting the Demographic Structure of a High Altitude Nepalese Population. *Social Biology* 25(3):179-195.
- Zar, J. H.  
1974 Biostatistical Analysis. Englewood Cliffs, N.J.: Prentice-Hall.