Respiration and Reproduction on the Roof of the World:

Cultural and Physiological Adaptations to Chronic Hypoxia
In a High-Altitude Kyrgyz Nomadic Population

Ted Callahan, Boston University
Visiting Research Fellow, Social Research Center
American University – Central Asia

Introduction

> "And when you leave this little country, and ride three days north-east, always among mountains, you get to such a height that 'tis said to be the highest place in the world! And when you have got to this height you find a fine river running through a plain clothed with the finest pasture in the world; insomuch that a lean beast there will fatten to your heart's content in ten days…The plain is called Pamier, and you ride across it for twelve days together, finding nothing but a desert without habitations or any green thing, so that travelers are obliged to carry with them whatever they have need of. The region is so lofty and cold that you do not even see any birds flying. And I must notice that because of this great cold, fire does not burn so brightly, nor give out so much heat as usual, nor does it cook food so effectually" - Marco Polo, *The Travels of Marco Polo*

In this famous description, Marco Polo captures the barren and forbidding nature of the *Bam-i Dunya*, the "Roof of the World", Afghanistan's Wakhan Corridor. Yet, for the very reason that Polo notes in this passage – its lush pasturage - the Wakhan has been the seasonal home of nomads for thousands of years. More recent travelers than Polo are still told legends concerning the fabled Pamir pasture lands: "A single blade of Pamir grass is as good as a haystack" (Michaud, 1972: 458). The inhabitants of this remote corner of Central Asia are the Kyrgyz, who had traditionally roamed the vast grasslands and river valleys of what was, until fairly recent geopolitical events divided it into nations, simply known as Turkestan. First Russian colonial expansion, then the Bolshevik revolution of 1917 and finally the Chinese Communist Revolution of 1949 forced the

various Central Asian pastoral nomadic groups to either settle or move into increasingly marginal, isolated areas, delimited in a way that made no sense from a pastoralist's perspective. As the international borders of the Soviet Union, China, Pakistan, and Afghanistan became more clearly defined – and politically sensitive – during the twentieth century, one small population of Kyrgyz nomadic pastoralists found themselves confined to living on the Roof of the World.

The closing of these frontiers created "different ecological conditions and impose[d] constraints" to which the Kyrgyz adapted through what anthropologist Nazif Shahrani calls "pastoral nomadic involution" (Shahrani, 2002: xl-xli). By this he means an "ecological adaptive process" in which "greater development and specialization within the existing adaptive pattern is pursued without radical transformation to a new form of subsistence system or accompanying cultural change" (Shahrani, 2002: xli). The new ecological conditions were twofold: a decrease in the amount of available pasture, necessitating a new pastoral production strategy, and year-round residence in a high altitude (HA – defined as 2500 meters or higher) environment characterized by hypoxia (reduced partial pressure of oxygen due to low barometric pressure) and a cold climate. The "constraints" that the Kyrgyz faced were the "severance of social, economic, and cultural ties" that their isolation produced (2002: xli) and which demanded to varying degrees a reorganization and reorientation of their economy and society.

In this paper, I will discuss the physiological stresses to which the Kyrgyz were subjected to in this new environment: cold and altitude. Whereas previously they were able to over-winter in lower pasturages in what are now Xinjiang, China and Tajikistan, following the closure of the Soviet and Chinese borders, the Kyrgyz were forced to

subsist year-round at elevations above 4000 meters. However, unlike other highland populations, who in the course of living at high elevations for thousands of years have evolved genetic adaptations for coping with hypoxia, Kyrgyz adaptations to high altitude were - and remain - primarily cultural.

In the first part, I will provide a basic overview of the pastoral production strategies adopted or modified by the Kyrgyz in response to their confinement in the Wakhan, as described by Nazif Shahrani in his monograph, *The Kirghiz and Wakhi of Afghanistan*. However, because Shahrani's fieldwork was conducted between 1972-74, the many significant events which have occurred in the 30 years since – the out-migration of 1,300 Kyrgyz from the Wakhan in 1978, the Soviet invasion in 1979 and the decade-long Afghan-Soviet war which followed, the civil war in Afghanistan from 1989-2001, the dissolution of the USSR and the independence of the five Soviet Central Asian nations in 1991, and the American-led invasion of Afghanistan in 2001 – render his description of the Kyrgyz quite dated. Aside from various reports by NGOs active in the region and the work of a German geographer, Hermann Kreutzmann (2000, 2003; Kreutzmann and Felmy, 2003), no serious ethnographic study of the Kyrgyz has been attempted since Shahrani's 1970s fieldwork. Here I include what little current information is available from the few reliable reports on this region, as well as my own observations based on two trips to the Wakhan[1].

In the second part, I will describe the physiological adaptations that occur as a result of permanent and generational residence at high altitude. Using data from studies

[1] May-June, 2006 (via Kabul) and September-October, 2006 (via Tajikistan – Ishkashim border crossing). Funding was provided by a grant from the Central Asia Institute and their support is gratefully acknowledged here.

of both indigenous and migrant highland populations in Tibet, the Andes, and Ethiopia, I will discuss whether the Kyrgyz, as a result of continual residence at high altitude, show any indication of either developmental or genetic adaptation to hypoxia. My model for this is the developmental adaptation hypothesis (DAH), which "reasons that highland populations are distinctive due to hypoxic exposure during development that causes structural and functional modifications" of normal oxygen (O_2) delivery processes (Beall and Steegmann, 2000: 211-212).

I conclude that, compared to tests of the DAH with Han Chinese populations in Tibet and residents of European ancestry living in the Andes and in Colorado, the Kyrgyz show few of the developmental and none of the genetic adaptations that have been suggested to exist among indigenous highland populations. The likely reason for this lack of adaptation is the fact that the Kyrgyz have resided year-round in the Afghan Pamirs for a relatively short period – less than 100 years. Lacking any evolutionary adaptations, the Kyrgyz response to the problem of chronic hypoxia has been essentially cultural and despite "hypoxia, cold, exposure, and other high-altitude-specific factors influencing population dynamics" (Shahrani, 2002: 124-125), as well as staggering mortality rates, the Kyrgyz have been able to maintain a balanced demographic trend. This suggests that cultural responses to environmental stresses can, in the evolutionary short term, serve as a substitute for either developmental or genetic adaptations.

The Kyrgyz of the Afghan Pamir

The Kyrgyz who inhabit the Wakhan Corridor have managed to subsist in one of the most challenging environments imaginable. 82.9% of Wakhan District (part of

Badakhshan Province) is above 3000 meters and 17.1% is between 1,800 and 3,000 meters (Dupree, 1980: 6). During the winter (early November to late May), temperatures can plummet to -50^{o}C. The area is exceedingly remote and access is restricted to certain times of the year. Both flora and fauna are sparse. The Wakhan-Pamir area consists of two high valleys, known as *öröön* (plural, *örööndör*). The higher *öröön* is called the Big (*Zor*) Pamir, runs east-west for nearly sixty kilometers, and is bounded by the Alichur and Wakhan ranges on the north and south, respectively. The Little (*Kechek*) Pamir also runs east-west, for one-hundred kilometers. It is separated from the Big Pamir, lying to the west, by the Wakhan range and is bordered on the south by the Hindu Kush, which forms the border between Afghanistan and Pakistan. The mountains surrounding these *örööndör* average 5,450 meters in height.

The precipitation and wind patterns of the Pamir valleys are dictated by the mountainous topography of the region. Average precipitation is between six and 12 centimeters, mostly in the form of snow. The prevailing wind direction is from the northwest, which has the effect of scouring the windward and northern ends of the valleys: “the winter pastures are thus left clear of snow, but the continuous wind adds to the extreme harshness of the winter” (Shahrani, 2002: 13). Permanent snow cover is found above 5000 meters.

The Kyrgyz are Turkic Muslim pastoralists, who practice a form of modified semi-nomadism in their respective *örööndör*, depending on the season. Summers (June to early September) are spent in the southern parts of the *örööndör*, called *tersky*, while winters are spent in the northern parts of the valleys, referred to as *kongey*. *Tersky* are north-facing, shady and, because much of the snow carried by the northwesterly winds is

deposited there, are suitable only for summer pasturage. *Kongey* are south-facing, sunny, and, for reasons mentioned above, receive less wind-blown snow during the winter

The annual Kyrgyz migrations in the Afghan Pamirs are as follows: around June, they move south to the *jailoo*, their summer pasture and camping grounds. In mid-October, as the temperatures become colder and snow falls on the higher mountain slopes, they move north to their *kështoo*, the winter pasture and camping ground. Because this area is inhabited for the longest continuous period and the forage resources are subjected to greater stress, the camps (*aël*), consisting of several households (*üy*), are smaller and more dispersed than during other times of the year. Accordingly, with more abundant forage, the summer camps are more populous than the winter ones, with up to 12 *üy* living together in a single *aël* (Shahrani, 2002: 147).

Shahrani, describing the tempo of a typical *jailoo*, writes:

> "Summer in the Pamirs is a time of plenty, relaxation, feasting, and visiting among relatives and friends. There is little or no friction about the use of pasturage and most summer pastures are either public property or corporately owned by kinship groups.
>
> Aggregation of larger numbers of *oey* units during the summer is important, not only for social but also for economic reasons. Many people are required at this time of the year to help with the daily milking routine, and the feeding of the lambs and kids. A large number of men are also needed to help shear the animals during the summer season while a good many men and women are needed to help in the making of felt. Yet another activity during the summer is the preparation for the long winter months. A large labor force is needed for the cutting, collecting, and storing of winter fodder, as well as peat for fuel. Some of these tasks are carried out with the help of hired labor (either Kirghiz or Wakhi) but many are accomplished through cooperation between members of each camp" (Shahrani, 2002: 147).

Shahrani's census of the Kyrgyz, taken between 1972 and 1974, found a total of population of 1,825 people and 333 households[2]. Of these, 1,380 members of 246

[2] A previous census, taken by the Afghan government in 1921, estimated that 2,000 Kyrgyz lived in the Wakhan Corridor. However, in 1921, the borders with what would become Tajikistan, Pakistan, and China were still largely theoretical and cross-border seasonal migration makes this figure, at best, speculative.

households lived in the Little Pamir and 445 members of 87 households lived in the Big Pamir (Shahrani, 2002: 49). Both populations were largely stable and generally free from either in- or out-migration; Shahrani explicitly refutes the suggestion that high bridewealth (*qalyn*) led some of the more impoverished Kyrgyz men to marry Wakhi[3] women (Michaud, 1972: 462). Sectarian differences between the Sunni Kyrgyz and Ismaili Wakhi meant that "feelings of contempt were mutual", with the result that the "exchange of women, or even the suggestion of sexual relations with Wakhi women, outrages Kirgiz males; giving a Kirgiz woman to a Wakhi is unthinkable" (Shahrani, 1979: 187). There were some instances of Uzbek and Tajik lowland traders marrying Kyrgyz women (though not the reverse), although a scene in the ethnographic film *The Kirghiz of Afghanistan* poignantly demonstrated the horror that Kyrgyz women held at the prospect of having to live in the "heat" outside of the Wakhan (cf. Shahrani, 1978: 243-4). Even today, there are relatively few cases of intermarriage between Kyrgyz and other ethnic groups.

At present, the total population of the Afghan Pamir is largely speculative and, as can be seen below in Table 1, current estimates of the total Kyrgyz population and household structure vary considerably. For the purposes of this report, I have assumed a total population of 1,500 individuals (600 in the Big Pamir and 900 in the Little Pamir) living in 250 households (100 in the Big Pamir and 150 in the Little Pamir), with an average of six persons per household.

[3] The Wakhi are an Indo-European people found throughout northeastern Afghanistan, southern Tajikistan, western China, and northern Pakistan. In Afghan Wakhan, the Wakhi subsist through a combination of seasonal transhumance and agriculture in alluvial areas. In contrast to predominately Sunni Badakhshan, the Wakhi are Ismaili, a sectarian branch of Shiites who follow the Aga Khan.

Table 1. Kyrgyz Population and Number of Households

	Shahrani (1979)	Fitzherbert (2003)	Kreutzmann (2003)	Duncan (2006)	WFP (2006)	Abdul Rashid (2006)
Total Population	1825	1400-1600	~1334	N/A	N/A	1600-1700
Total Households	333	210-240	250	N/A	338	418
Average per H/H	5.5	6.7	~5.3	N/A	N/A	3.8-4.1
Big Pamir:						
Population	445	~938	~587	690-740	N/A	403-435
Households	87	140	110	100-108	100	106
Average per H/H	5.1	6.7	~5.3	6.9	N/A	3.8-4.1
Little Pamir:						
Population	1380	~600	~747	N/A	N/A	1186-1280
Households	246	100	140	N/A	238	312
Average per H/H	5.6	6.7	~5.3	N/A	N/A	3.8-4.1

Note: In a 1999 report, Kreutzmann and Felmy claimed a total population of 1,264, divided into 237 households, giving an average of 5.3 per H/H. This would suggest a total population of 1,334 in 2003 (587 in the Big Pamir and 747 in the Little Pamir).
Sources: Shahrani 2002; Fitzherbert 2003; Duncan and Duncan 2006; Kreutzmann and Felmy 2003; author's interviews with World Food Programme (2006) and Abdul Rashid Khan (2006)

The discrepancies in the older versus the more recent data are attributable to the out-migration of 1,300 Kyrgyz in 1978, following a Marxist coup in Afghanistan backed by the Soviet Union. Fearful of Soviet reprisals, all of the Kyrgyz living in the Little Pamir save for 10 households (50 individuals), described by Shahrani as "very poor and disgruntled" (2002: 231), fled into Pakistan, led by their khan, Rahman Qul. For reasons that are not entirely clear, the nearly 500 Kyrgyz living in the Big Pamir remained

behind[4]. During the summer of 1979, 100 of these Kyrgyz refugees, living in Gilgit, Pakistan, died, mostly from illness. High mortality, combined with dissatisfaction over Rahman Qul Khan's authoritarian style of leadership and a guarantee of safe passage from Soviet forces, prompted fifty-four families (about 250 individuals) to return to the Little Pamir in October 1979. Eventually, with the cooperation of the Turkish government, in 1982 the remaining 1,129 Kyrgyz refugees were allowed to resettle in eastern Turkey, near Lake Van, where, in 2001, they numbered about 2,200 individuals (Shahrani, 2002: 264).

Kyrgyz Social Organization and Pastoral Production

At the time of Shahrani's fieldwork, the size of the average *üy* ranged from two to 14 individuals, with an average of 5.5 persons per household (Shahrani, 2002: 139). The majority (79.5% or 265) of the *üy* consisted of a married couple and their children, "often augmented by a parent, occasionally a widowed uncle or aunt or unmarried siblings of the husband and wife" (ibid). 13.5%, or 45, *üy* were "patrilineal extended families consisting of two or more monogamous conjugal units of siblings (horizontal) or of different generations (vertical)" (ibid). Finally, 7%, or 23, *üy* were "made up of composite or polygynous (two or three wives) families of either the nuclear or extended type" (ibid).

Shahrani notes two "main constraints that influence the *oey* composition and size" (2002: 142). The first, seen in the seasonal aggregations of the Kyrgyz, concerns the

[4] Shahrani claims that the decisive factors were the distance and difficulty of the terrain separating them from the Pakistani border (1984: 232). However, my interviews with Afghan Kyrgyz suggest that there were political and economic considerations involved as well.

"access of domestic groups to productive, and thereby to reproductive, resources" and the other involves "the uncertainty of human reproduction in the high-altitude conditions" (ibid). Kyrgyz social organization in the Wakhan is based mainly on individual herding units (the *üy*) and cooperative herding units (the *aël*), which Shahrani calls "ecologically adaptive herd management institutions" (2002: 149). These institutions are a logical and necessary response to the intricacies of finding sufficient pasturage and to meeting seasonal labor needs. As such, they show little variation from similar arrangements found in any pastoral society seeking to exploit seasonally distributed resources, the main difference being that the Kyrgyz are limited to a relatively confined area. Therefore, it does not seem likely that hypoxia and its effect upon reproduction significantly influence *üy* composition and size.

Because the Pamir portion of the Wakhan is too high to support agriculture, the Kyrgyz rely almost entirely upon their herds for subsistence, either directly or by providing some tradable commodity. Fat-tailed sheep, long-haired goats, yaks, Bactrian camels, and horses are the primary domesticated species, with sheep, goats and yaks comprising the mainstay of the Kyrgyz herding economy. Sheep and goats, both of which "fatten very quickly during the short Pamir summer, a time of relatively abundant pasturage" and "achieve good physical condition over a short period of time and to sustain fat and meat over a long cold winter" (Shahrani, 2002: 92), provide the basic subsistence requirements of the Kyrgyz. They are slaughtered for their meat, usually in late summer and fall, and the hides are used for "clothing, bedding, containers, and in exchange for other goods" (Shahrani, 2002: 94). Yak cows provide the bulk of the milk that the Kyrgyz process into *ayran* (sour milk), *jughrat* (yoghurt), *qurut* (hard cheese),

and *qaymaq* (cream). In contrast to sheep and goats, which are milch for only four to five months of the year, yak cows produce milk six to nine months of the year (Shahrani, 2002: 102). Yak milk also has a higher fat content in comparison to that of other milk animals. Dung (*tizak*), as well as peat and a *Ceratoides* shrub (*teresken*), are collected, dried, and then used as fuel for cooking and heating.

Like most nomadic groups, the Kyrgyz depend on nearby sedentary societies to furnish both agricultural and manufactured goods. The bulk of the Kyrgyz diet, especially during the winter, consists of cereal grains (wheat and barley), pulses (peas, lentils, and horsebeans), and rice acquired both from Wakhi agro-pastoralists living at the western end of the Wakhan Corridor and itinerant Tajik traders from lowland Badakhshan who come to the Pamir in the summer to trade. The Kyrgyz barter their pastoral goods for these products[5] and in this situation they benefit from living at high altitudes, since the "reproductivity of Kirghiz sheep and goats is, to a large extent, limited to the Pamirs. They lose vigor and fertility when taken to 'hot' lowland towns and villages" (Shahrani, 2002: 92). Over the past 10 years, food relief provided by Focus International and the World Food Programme has become an important source of subsistence, helping make up grain shortfalls and cushioning the aftershocks following large livestock die-offs.

Life at High Altitude

The Kyrgyz only began to live year-round at high altitude in the Pamirs during the early part of the twentieth century. Describing the annual migrations of the Kyrgyz prior to this period, Shahrani writes:

[5] A significant portion of Kyrgyz commodities are also traded for opium and other luxury goods including tea, sugar, and tobacco.

> "Before the 1930s the Afghan Pamirs were frequented by only about thirty Kirghiz *oey* units during the summer months. These Kirghiz were extensive pasturage users, with a vertical pattern of migration oscillating between the high Pamirs and the lower altitudes in their winter pasturage grounds, in what is now the Soviet territory of Tajik S.S.R. The Kirghiz did not remain in the Afghan Pamirs during the winter months except when they had to avoid trouble with local and state authorities, or a confrontation with other feuding Kirghiz groups" (2002: 171).

Kyrgyz reluctance to continuously inhabit the Wakhan stemmed from the extreme cold and high elevation of this region. The plateau regions suitable for pastoralism range from 3,000-5,000 meters, with temperatures below 0^0C most of the year and, during winter, dropping as low as -50^0C. Given such harsh conditions, it is no surprise to find that the first recorded instance of altitude illness comes from the description of a Chinese military expedition to what is assumed to have been the Pamirs: "Again, on passing the Great Headache Mountain, the Little Headache Mountain, the Red Land, and the Fever Slope, men's bodies become feverish, they lose colour, and are attacked with headache and vomiting; the asses and cattle being all in like condition" (Wiley, 1881: 57).

In contrast to most pastoral areas, the main limiting factor of the Wakhan is altitude, not precipitation (Shahrani, 1978: 240-241). Altitude determines not only the limit of pastoral production, but also of human habitation; no permanent human settlements are found above 5,300 meters, although this figure has varied over time and is "determined partly by economic factors, rather than solely by human tolerance to hypoxia" (West, 2002: 401). Hypoxia is the limiting factor for human habitation in HA regions and those populations that live at or near this upper limit have had to adapt to lower than normal O_2 levels. Adaptation, in a biological sense, is defined as "any response designed to allow an organism or a species to survive" and thus occurs in one of

two ways: physiological adaptations of individuals and genetic adaptations of populations (Piantadosi, 2003: 16).

Genetic Adaptation to High Altitude

Physiological adaptations are short-term and involve "functional, structural or molecular change that occurs in an individual as a result of exposure to change in the environment" (Piantadosi, 2003: 16). In contrast, genetic adaptation is a "structural or functional change built into the molecular genetic code of a species…that favors survival in a particular environment" (ibid). Genetic adaptations are heritable because they are a result of changes in reproductive (germ) cells (genotypic), rather than in somatic cells (phenotypic), but require many generations to become established and spread throughout a population. Adaptation to hypoxia at both the individual and population levels therefore depends on the duration of exposure, which is classed four ways: acute (hours), chronic (hours to years), life-long (including the period of fetal development), and generational (Ward, et al, 1989: 67).

Genetic adaptations produced by generational exposure to hypoxia have been discovered among three different HA populations living in the Andean Altiplano (4,000 meters), on the Tibetan Plateau (4,000 meters) and on the Semien Plateau in Ethiopia (3,500 meters). Archaeological data indicate that these areas have been continuously inhabited for 11,000 years, 23,000 years and 50,000 years, respectively (Beall and Steegmann, 2000: 209-210; Beall, et al., 2002: 17215) and among such populations "gene pools have had time to be modified by natural selection to increase the frequency of traits enhancing oxygen transport" (Beall and Steegmann, 2000: 209). What is especially

interesting is that despite having the same selective pressure - hypoxia - these populations "have evolved three distinctly different biological adaptations" (Mayell, 2004). Andeans have a higher blood hemoglobin concentration [Hb] but do not hyperventilate whereas Tibetans do essentially the reverse: "Andeans go the hematological route, Tibetans the respiratory route" (ibid). In addition, Tibetans seem to be able to synthesize larger amounts of nitric oxide, a vasodilator, from inspired air, offsetting comparatively low blood O_2 levels with increased blood flow (Beall and Goldstein, 2001: 411). The nature of the Ethiopian population's adaptation is something of a mystery, as they have normal [Hb] levels, do not hyperventilate, and don't seem to more effectively synthesize nitric oxide (Beall, et al, 2002: 17217).

Physiological Adaptation to High Altitude

Because the Kyrgyz have only recently begun to have generational exposure to hypoxia, we can almost be certain that they lack any significant population-level genetic adaptations to HA. Despite strong selective pressures[6] favoring the development of adaptations such as those found in the South American, East African, and Tibetan cases, insufficient generational exposure to HA residence means that the Kyrgyz are limited to physiological adaptations resulting from either chronic or life-long hypoxia. The former adaptation occurs via two processes, acclimatization and acclimation. Acclimatization is the short-term (days or weeks) physiological adaptation to changes in the natural environment involving two or more environmental factors (stressors), whereas acclimation refers to the changes that "occur in physiological systems or in an entire

[6] See the discussion on maternal, infant, and child mortality below.

organism" in response to a single stressor over a period of weeks or months (Piantadosi, 2003: 18-19). Together, these processes encompass respiratory (the hypoxic ventilatory response or HVR: an increase in the rate and depth of breathing triggered by exposure to hypoxia) and biochemical changes which are generally complete after six weeks of residence at HA.

There are also developmental adaptations acquired during prenatal growth that are believed to influence the acquisition of a high altitude phenotype (Rupert and Hochachka, 2001: 235). This developmental adaptation hypothesis (DAH) has been tested in a number of studies looking at the performance of migrant and second or third generation residents at HA. In one study comparing European children "from a population without ancestral exposure to high-altitude" living at high and low altitude in Bolivia, both oxygen acquisition by vital lung capacity and maximal physical work capacity were discovered to be higher in the high altitude samples, "providing some support for DAH in that it found changes in the direction of similarity to Andean highlanders and offered evidence that adolescence is a critical period for attaining full adaptation" (Beall and Steegman, 2000: 212).

Another study compared lifelong Tibetan high altitude residents and long-term Han Chinese residents with lifelong Han-Tibetan residents of Lhasa (3,658 meters) to assess the differences in ventilation and HVR (Curran, et al., 1997: 2098). An increase in HVR and a rise in ventilation are two ways that acclimatization improves oxygen transport under hypoxic conditions (Beall and Steegmann, 2000: 213). A blunted HVR has been reported for "Colorado high altitude natives and long-term residents of European descent after 20-25 years of exposure" and it seems that "this is the usual

human response to chronic hypoxic stress" (Beall and Steegmann, 2000: 211). The Lhasa study found that the Han-Tibetans had a blunted HVR but ventilation resembling that of the Tibetans, leading the authors to conclude that though HVR is progressively blunted with long duration of high altitude residence, "their [the Han-Tibetans] Tibetan ancestry appears protective in their maintenance of high resting ventilation" (Curran, et al., 1997: 2099). The authors' results did not support the hypothesis that "the development of peripheral chemoreceptor response to hypoxia is prompted by increased O_2 availability in the transition from intrauterine to extrauterine life, and if the Han-Tibetans resembled the Han subjects in having poorer neonatal oxygenation, this might have led to decreased ventilatory sensitivity to hypoxia from birth" (Curran, et al., 1997: 2103).

Shahrani makes no mention of either HVR or ventilation regarding the Kyrgyz, though he does provide anecdotal evidence of a decreased maximal physical work capacity:

> "The Kirghiz acknowledge temporary hypoxic discomfort during activities that demand added physical exertion (shoveling snow, for example). This discomfort is felt especially when a person engages in physical activity after consuming large quantities of fatty food…The Kirghiz are fully aware of the debilitating effects upon both people and animals of altitude sickness, or *tutak* (literally, 'being choked'). Kirghiz cultural response to alleviate hypoxic discomfort, as well as to prevent attacks, is based on simple dietary prescriptions and advice. The afflicted are advised to rest and avoid rich and fatty foods" (Shahrani, 2002: 118-119).

Although the above description is hardly evidence that the Kyrgyz lack any developmental adaptations, nothing in Shahrani's account or those of others who have visited the Kyrgyz (cf. Michaud, 1972; Shor, 1950) provides support for the idea that the Kyrgyz were anything other than very well acclimated to the altitude of the Wakhan-Pamir area. The likely reason for this absence of developmental adaptations is the fact that the Kyrgyz have resided year-round in the Afghan Pamirs for only three generations

or less. Lacking any biological adaptations, the Kyrgyz response to the problem of living under conditions of chronic hypoxia has been essentially cultural. One way in which this can be seen is in terms of demographic data, particularly fertility and mortality rates.

Kyrgyz Demography

The Afghan Kyrgyz have demonstrated consistently high rates of both mortality and fertility. According to Shahrani's data from the 1970s, the average fertility rate was 4.4 children per woman[7] and the maternal mortality rate (MMR) was 1,300 maternal deaths for every 100,000 live births. The mortality rates for infants (0-1 year; IMR) and children (1-5 years; U5MR) were 140 and 467 deaths per 1,000 live births, respectively (Shahrani, 2002: 122-124).

Today, the figures are similarly stark, only worse. Province-wide, Badakhshan has 6,500 maternal deaths for every 100,000 live births – the highest MMR ever recorded (IRIN, 2007) and more than seven times the 890/100,000 average for the "least developed countries"[8] (UNICEF, 2000). According to UNICEF, Afghanistan's current IMR and U5MR – 165/1,000 and 257/1,000 – are also among the highest in the world and well-above the IMR and U5MR averages for "least developed countries" of 97/1,000 and 161/1,000 (UNICEF, 2005). Surveys by a Western doctor active in the Wakhan for the past five years indicate that U5MR among the Kyrgyz of the Big Pamir is

[7] Since only 160 of the 380 women who had given birth in Shahrani's sample size were post-menopausal, the total fertility rate was likely higher than the 4.4 average fertility rate would suggest.

[8] To put these numbers into perspective, Afghanistan's average MMR – the second highest in the world – is 1,600 /100,000, far above the world average of 400/100,000. The average MMR for "industrial countries" is 13/100,000 (UNICEF, 2000)

approximately 520 deaths per 1,000 live births (Duncan and Duncan, 2006: 7), meaning that more than half of all children born die before reaching age five.

No definite correlation has been proven to exist between hypoxia and maternal, infant and child mortality, in part because of the difficulty in disaggregating other contributing factors, such as "poor diet for both mothers and offspring during the winter, lack of any kind of medical help, and unsanitary conditions" (Shahrani, 2002: 123). However, "the main known determinant of infant mortality" is that of low birthweight (LBW) (Bortman, 1998: 314). While Shahrani does not provide any data on birthweight, he did note "From my own observations I found Kirghiz newborns consistently smaller than the infants in the lower altitudes of Badakhshan" (Shahrani, 2002: 122).

Many factors influence LBW, though the primary risk factors associated with it – and almost all of these are true for the Kyrgyz - include "inadequate prenatal care, in women over the age of 40, women under 20, single women, smoking mothers[9], women with an intergenesic interval of less that 18 months, and women with a body mass index of less than 20" (Bortman, 1998: 314). One study, however, concluded that "high altitude acts independently from other factors to reduce birthweight" rather than as "an exacerbation of other risk factors" (Jensen and Moore, 1997: 1003).

This study, conducted in Colorado, found that "birthweight declined an average of 102 g per 3300 ft (1000 m) elevation when the other characteristics were taken into account, increasing the percentage of low birthweight by 54% from the lowest [915 to 1523 meters] to the highest [greater than or equal to 2744 meters] elevations in Colorado" (ibid). A similar study found that "in comparison with neonates born at sea level,

[9] "During the winter a fire is kept going on the floor in the center of the yurt for most of the day from sunrise to late in the evening…women spend most of their time in the yurt" (Shahrani, 2002: 127-128).

neonates born at higher altitudes (greater than 2000 meters) had a twofold to threefold increase in LBW rate, mainly related to a higher incidence of intrauterine growth retardation[10]. Comparison of the LBW rate on the basis of small geographic divisions in the mountain states show a positive correlation between the LBW rate and high altitude" (Yip, 1987: 869).

Kyrgyz women do not demonstrate any of the developmental adaptations – increased "hypoxic ventilatory sensitivity and higher levels of ventilation and arterial O_2 content" (Moore, 2003: 145) – that, among Tibetan women native to 3658 meters, appear to produce infants with higher birth weights, higher arterial oxygen saturation and less frequent signs of hypoxemia compared to children born at high altitude to non-natives (Niermeyer, et al., 1995). Other neonatal and maternal adaptations found among high altitude natives in the Andes and Tibet but lacking in "acclimatized newcomers" to altitude include "less intrauterine growth retardation, better neonatal oxygenation, and more complete neonatal cardiopulmonary transition, enlarged lung volumes, decreased alveolar-arterial oxygen diffusion gradients, and higher maximal exercise capacity" (Moore, et al., 1998: 25).

Lacking such adaptations, Kyrgyz women respond to the challenge posed by hypoxia to pregnancy and childbirth in a purely cultural manner: they attempt to have as many children as possible, knowing that one-in-two offspring will die before reaching reproductive age. Shahrani relates being told by one Kyrgyz woman that "she had twenty-one pregnancies, nineteen live births, but only one child survived. Many women

[10] Intrauterine growth restriction, a contributing factor in LBW among HA pregnancies, is a "consequence of reduced fetal O_2 supply, whether due to maternal, placental, or fetal causes. However, the exact mechanisms by which hypoxia retards fetal growth are unclear" (Moore, 2003: 143).

had given birth to more than eight and up to sixteen children" (2002: 124). By attempting to maintain high levels of fertility, Kyrgyz women of reproductive age[11] are also subject to the numerous dangers associated with childbearing, with the result that a Kyrgyz woman's lifetime risk of maternal death is greater than one-in-three and pregnant women face "almost 600 times the risk of dying in childbirth than do [their] counterparts living in North America" (Leidl, 2007). However, despite these formidable obstacles, all of which are compounded by the total absence of medical care, the Kyrgyz have been able to maintain a stable population without any appreciable in-migration.

Conclusion

All of the genetic and developmental adaptations to hypoxia that I have discussed in this paper require long-term residence under hypoxic conditions. Migrants to these regions who lack either ancestral or generational exposure enjoy only the limited possibilities offered by physiological adaptation to environmental stresses such as hypoxia. At elevations approaching the upper limit of this adaptability, their primarily means of survival is cultural. This is as true today for the Kyrgyz living in the Wakhan Corridor as it was for the prehistoric ancestors of the Andeans, Tibetans, and Ethiopians who took up life in the highlands. These three populations and the genetic adaptations they possess are living proof that their ancestors successfully employed whatever cultural devices they had at their disposal in survive in a stressful environment:

"Suddenly it gets really cold. Biomass declines precipitously. It becomes very arid because of wind-flow patterns. The landscape becomes one of very patchy vegetation, rocky. And the huge herds of gazelle, antelope, and sheep wax and wane. What happens?

[11] According to the UN Population Fund (UNFPA), more than 40% of women in Badakhshan province are married before age 15 and "girls under the age of 15 are five times more likely to die in childbirth than women in their twenties" (Leidl, 2007).

Do the people adapt and tough it out? Did they abandon the highlands? Or do these early populations more or less go extinct? There's no evidence yet. But finding biological differences suggests they toughed it out and adapted" (Mayell, 2004).

This narrative continues to play itself out today among a small population of nomads living in one of the earth's most remote places. They offer us a unique window into both the adaptability of culture and perhaps, given enough time, of biological evolution. Life on the Roof of the World is, for the Kyrgyz who continue to reside there, a bittersweet compromise between their desire to adhere the ways of their forebears and the harsh reality of dwelling at the limit of their physiology. Despite the extreme weather – the biting cold and the unrelenting *Bad-i Wakhan*, as the westerly winds are called – and the incredible labor required to live a pastoral life at over 4,000 meters, the Kyrgyz who migrated to Turkey still wistfully remember their former home. When I visited their village in 1999, the older men, who could still recall their days as nomads, expressed their desire to return to *Bam-i Dunya*, the finest pasturage in the world, where "a lean beast there will fatten to your heart's content in ten days."

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