Geospatial Relationship between Altitude and Mortality in India

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Abstract
High altitude environmental stressors have numerous and varied physiological effects on human health. Yet few analyses have investigated the influence of high altitude in resident populations over a large extent. In this study a preliminary analysis of the association between altitude and mortality in India was conducted. The assessment of mortality rates at different altitudes integrated geospatial concepts through a Geographic Information System (GIS) and Digital Elevation Model (DEM). Furthermore, surveyed health data was obtained from the Million Death Study (MDS) and the Special Fertility and Mortality Survey (SFMS) datasets. The statistical analysis reveals that all-cause mortality rate has no significant association with altitudes. However, it shows a positive correlation between altitude and prematurity and low birth weight mortality rate in neonates. Additionally, higher drinking rates for males were found at greater altitude. The preliminary results confirmed the relationship between particular mortality rate and altitude in India, but further investigations need to assess the total effect of altitude on mortality.

1. Introduction

1.1 Health and Altitude

High altitude environmental stressors have numerous and varied physiological effects on human health. The changing climate and reduced oxygen at high altitude can immediately result in hyperventilation, hypoxia, rapid dehydration, heart beat increment, high blood pressure in the lungs, and symptoms similar to a hangover for people traveling to high altitude on the short term (Bellis et al., 2005, Hackett and Roach, 1990 and Heber, 1921). Human adaptation to high altitude environments varies from one individual to another and depends on age, sex, and physical condition. Conversely, for people who reside at high altitude, the influence of altitude is different from that of travellers. Studies have revealed that many syndromes are related to high altitude, including cardiac, cardiovascular, pulmonary, as well as developmental issues in infants, pregnant women, and the elderly (Campbell, 1930, Balke, 1964, Hainsworth and Drinkhill, 2007, Johns et al., 2004, Tanrikulu et al., 2008, Tissot van Patot et al., 2009 and Wehby et al., 2010). Currently, many studies have illustrated the relationship between disease and high altitude, yet there are limited studies and suitable data that investigate the influence of altitude in resident populations over a large area.

1.2 Aims and Objective

High altitude reduces the oxygen density in air, which influences the regular functions of the body. Research on the effect of altitude on diseases has shown a variety of results for different countries. However, there is still insufficient research regarding the effect of altitude on mortality in India. The current study was aimed to fill this gap in knowledge with respect to resident populations in India. The aim of this study was to conduct a preliminary analysis of the relationship between altitude and mortality in India. More specifically, the objective of this research was to shed light on the question: Is altitude a health risk factor in India? This study used leading death causes in India to examine this question.

2. Data

2.1 Framework

In this study, the assessment of mortality in India at different altitudes integrated the concepts and datasets of Geographic Information Systems (GIS), Remote Sensing (RS), and epidemiology. Such technologies were utilized as they permit efficient processing and analyzing of data that covers large extents of the Indian territory, which is the 7th largest country in the world at approximately 3.3

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million km². In this case, GIS provided the spatial information; RS provided the environmental factor in the form of a digital elevation model (DEM), which supplies the altitude of the study sample locations; and finally, epidemiological data provided the distribution of demographics and deaths, as well as related socioeconomic/behavioural factors.

2.2 Dataset

This study included four datasets: the Million Deaths Study (MDS), the Special Fertility and Mortality Survey (SFMS), post office data, and DEM data. The MDS recorded well-validated verbal autopsy (VA) forms providing cause of death by gender and age for nearly 2.4 million nationally representative Indian households and 14 million human deaths (about 123,000 deaths recorded in this dataset were from 2001 to 2003). The current analysis extracted the number of deaths by cause, gender and age for the period of 2001 to 2003 from the MDS. The SFMS was conducted in 1998 and covered roughly 1.05 million households and 5.87 million individuals. The scheme of sample registration of births and deaths in India was used in the SFMS. This registration method is also known as the Sample Registration System (SRS) and is initiated by the office of the Registrar General, India. There were a total of 6434 SRS units that were utilized (4279 rural and 2155 urban). The SFMS provided socio-demographic and behavioural factors for the current study. Additional details regarding progress and results for the MDS and the SFMS have been published previously (Jha et al., 2006, RGI-CGHR and Collaborators, 2009 and SFMS, 1998). Post office data provided postal codes (also known as pin codes) in India as well as postal code areas and post office locations in the form of spatial geometry. Digital Elevation Model data was originally provided from the NASA Shuttle Radar Topographic Mission (SRTM). The raw data was post-processed as a hole filled DEM and mosaicked to provide seamless, nearly global coverage by Jarvis and Guevara (Jarvis et al., 2008). In the current study, the extraction of the altitude terrain parameters in India, (x, y, z), was performed through the DEM. The DEM, with a 500-metre resolution and an average vertical error of 5m, was used to obtain altitude data for the desired locations. The study sample provides wide geographic and socioeconomic diversity and is also the largest sample ever considered for India. The experiment employed proportional mortality from leading death causes according to the MDS as well as socioeconomic/behavioural factors, population and live births from the SFMS.

3. Methodology

3.1 Sample Measures

When integrating multiple datasets, the comprehension of data types and conditions is essential. In this study, the MDS data was divided into five age ranges: neonate, 1 to 4 years old, 5 to 14 years old, 15 to 29 years old, and 30 to 69 years old. The causes of death for each age group were selected by the primary death cause ranking (ICD 10) and extracted from the MDS data by age, gender, and death cause. Table 1 shows the top causes of death for each age group.

Table 1: Leading Causes of Death in Different Ages

Leading Causes of Death

Neo	0-4	5-14	15-29	30-69
Prematurity and low birthweight	Acute respiratory infections	Diarrheal diseases	Other unintentional injuries	Ischemic, hypertensive heart diseases (heart attack)
Neonatal infections	Diarrheal diseases	Respiratory infections	Suicide	Chronic pulmonary diseases (chronic lung)
Birth asphyxia and birth trauma	Measles	Injuries	Tuberculosis	Tuberculosis
	Other noncommunicable diseases			Cancer
	Injuries			Cerebrovascular disease (stroke)

Population and socioeconomic/behavioural factors were extracted from the SFMS. Five factors were selected: house quality, cooking fuel, illiteracy, smoking, and alcohol (drinking). House quality was quantified based on whether the roof, walls and floor were made of pucca (solid and permanent housing in India). Cooking fuel differentiated between households using liquefied petroleum gas (LPG) or electricity as the major cooking fuel. Resident members of households that were recorded as illiterate and within the age range of 15 to 70 years old were defined as illiterate for this study. Residents who had smoking habits (cigarette or bidi) and were 45 to 59 year-old males were considered as a smoking factor. Finally, alcohol was defined as a factor for 30 to 69 year-old males and females who drank daily. These factors were related to their altitude by SRS unit and examined to identify any relationships to altitude. Once the cause of death data (MDS) as well as the population and socioeconomic/behavioural factors (SFMS) were extracted, they were geo-located through post offices and had their altitudes determined from the DEM.

3.2 Age-Standardized Mortality Rate

Cause-specific mortality rates were calculated for 0 to 69 year old individuals, stratified into 5 year age groups, using death data from the MDS and population from the SFMS. In order to account for the effect of different sample sizes in the two datasets, the cause-specific mortality rates "r" were computed (equation 1). Additionally, age-standardized mortality rates (ASMRs) were calculated for each age group (5 to 14, 15 to 29, and 30 to 69 years old) using a direct method (equation 2). Essentially, the direct method accounts for the age distribution of the population by using the proportions of persons in the respective age group as weights. ASMRs were thus calculated by applying these weights to the cause-specific mortality rates. Population estimates for the weights were obtained from the WHO standard population sources (United Nation, 2008). All data was interpreted and calculated using SQL scripts through a PostgreSQL database.

$$r = \left(\frac{n_c}{N_M} \times \frac{n_s}{P_s} \right)$$

Equation 1

$$ASMR = \sum_{i}^{k} (r_i \times w_i); \quad w_i = \frac{p_i}{p_{total}}$$

Equation 2

Where:

I = Age group (every 5 years defines an age group)
r_i = Cause-specific mortality rate in age group i
n_C = Number of deaths for a specific cause of death in the MDS
N_M = Total number of deaths in the MDS
n_S = Number of deaths in the SFMS
P_S = Total Population in the SFMS
k = Maximum number of subgroups for each age group
W_i = Weight for age group i
P_i = Population in age group i
P_{total} = Total population in selected age range

Note that for ages under 5, live birth was used instead of population.

3.3 Altitude Extraction and Mapping Method

The key step in the study was to link mortality data to the location where the death occurred. This study assumes that deaths transpired within/nearby the recorded post office locations according to the datasets that recorded both death data and corresponding postal code. Within this condition, three cases were considered for obtaining the altitude at which a death occurred:

A. Only 1 post office within a postal code area.
B. More than 1 post office within a postal code area, and postal code area ≤ 10 km^2.
C. More than 1 post office within a postal code area, and postal code area > 10 km^2.

To extract more accurate altitude of mortality locations, the altitude of a death record in case A was extracted via the elevation of the post office location directly. In contrast, altitude of a death record in cases B and C were extracted via the elevation of the centroid of the post office area. After attaining the altitude for each dataset, the data was aggregated within every 50 m elevation range and mapped through the post office or centroid.

4. Results

4.1 Distribution of Population and Altitude in India

A 500 metre resolution DEM of India showed the two most northern regions of India (States of Jammu and Kashmir, Himachal Pradesh and Uttaranchal in the north of India; States of Sikkim and Arunachal Pradesh) have very high altitude with mean elevations of approximately 3,500 metres. Also, prominent on the DEM are the high lands that lie in the middle of India that are 700 metres above sea level (masl). The highest point in India is approximately 8,000 masl. More than 80% of population in India resides under 400 masl, especially along coastal regions, and are concentrated within only 60% of the entire country's area. Also, a total of 6,182 unique postal codes were applied to the study, of which altitude extraction from 4,477 post office points was performed directly by matching with the datasets (case A). Case B applied to 1692 postal codes and case C to 13, where the centroid of the geographic post office areas were used to obtain altitudes. This result showed that there were only 13 instances where a postal code area was larger than 10 km^2 and contained more than one post office; thus, the assumption that deaths occur nearby post offices is quite rational. Recall that extracted altitude estimated from a post office location has higher accuracy than that from the centroid of a post office area.

4.2 Age-Standardized Mortality Rate and Altitude Observations

A total of 19 age-standardized mortality rates were calculated with corresponding age by leading death causes. Statistical analysis was performed using Pearson correlation and linear regression. In addition to the primary analysis on altitude and age-standardized mortality rates, altitude and all cause mortality were examined as well. A summary of the study results is illustrated in Table 2 for both males and females. The results show there was no significant association with all cause mortality rate and altitude in India; however, there was a positive correlation between altitude and prematurity and low birth weight mortality rate in neonates (boys $r=0.72$, $p<0.03$; girls $r=0.89$, $p<0.00$). Additionally, higher drinking rates were found at greater altitude ($r=0.9$, $p<0.00$), as shown in Table 3. More general observations can be drawn from this study as well. For instance, the results indicate that a very small number of deaths occur at high altitudes in India; only 13% of deaths were recorded at higher than 500 metres and merely 461 of the examined deaths were found over 1,500 metres. Further analysis on more extensive data will undoubtedly reveal additional noteworthy trends regarding deaths and altitude in India.

Table 2: Association between altitude and ASMR (per 100, 000)

Altitude(m)		Prematurity & low birthweight	Neonatal infections	Birth asphyxia and birth trauma	Acute respiratory infections	Diarrhoeal diseases	Measles	Other noncom- diseases	injuries	Diarrheal diseases	Respiratory Infections	Injuries	Other unintentional injuries	Suicide	Tuberculosis	Heart attack	Chronic lung	Tuberculosis	Cancer	Stroke
Male																				
0-50	**ASMR	30.3	20.5	18.9	33.5	30.0	6.5	12.2	13.6	20.2	10.5	46.7	10.6	28.6	13.8	182.9	68.3	77.5	80.8	88.2
50-100	ASMR	37.7	38.8	25.6	56.1	43.4	12.3	16.2	15.5	39.4	19.9	48.8	7.3	19.9	18.8	156.0	92.4	118.2	73.8	74.8
100-150	ASMR	34.5	37.0	28.7	77.5	62.7	24.0	17.8	20.5	32.0	21.2	59.4	12.2	23.2	24.0	162.4	149.4	153.2	75.1	75.8
150-200	ASMR	37.7	34.0	31.4	83.2	74.9	22.3	14.9	20.2	65.9	21.8	54.6	7.7	37.6	29.8	167.7	145.4	153.4	78.9	61.9
200-250	ASMR	31.1	26.1	19.4	62.0	46.5	15.3	14.2	10.8	18.1	23.7	34.9	11.3	17.1	15.6	155.4	82.0	98.5	63.6	52.3
250-300	ASMR	48.3	29.3	17.1	54.1	30.5	9.1	11.7	8.6	45.4	24.9	96.6	11.8	37.0	24.6	165.2	102.9	117.5	71.7	61.6
300-350	ASMR	41.87	37.48	24.31	48.63	24.13	6.04	16.78	11.66	2.09	14.16	42.53	4.48	25.63	22.16	162.2	110	129.3	65.1	88.52
350-400	ASMR	40.8	25.9	21.0	51.8	38.3	17.3	15.0	9.8	19.0	32.2	42.9	12.4	28.6	19.3	146.7	100.9	114.0	58.5	66.1
>=400	ASMR	47.8	27.0	22.1	33.7	29.7	4.3	10.3	9.3	28.7	15.7	53.2	8.1	35.6	12.9	168.9	114.8	90.4	73.1	71.8
P-value		0.03	0.63	0.62	0.26	0.33	0.28	0.16	0.11	0.65	0.88	0.96	0.67	0.26	0.40	0.83	0.70	0.49	0.44	0.74
R		0.72	-0.18	-0.19	-0.42	-0.37	-0.41	-0.51	-0.57	-0.18	0.06	0.02	-0.17	0.42	-0.32	-0.09	0.15	-0.27	-0.30	-0.13
Female																				
0-50	**ASMR	31.1	25.1	18.4	39.2	32.0	8.0	12.0	13.5	53.3	26.4	36.7	2.5	45.2	14.4	79.1	47.5	39.1	80.1	72.1
50-100	ASMR	35.5	39.7	26.3	67.2	56.5	14.2	14.8	13.3	74.4	41.2	46.8	5.1	25.6	22.8	79.5	84.4	63.7	78.1	56.8
100-150	ASMR	39.4	42.6	33.1	85.5	68.7	25.8	18.3	11.4	65.4	58.5	58.6	5.0	43.4	35.2	71.5	76.2	64.5	85.2	42.9
150-200	ASMR	42.7	39.1	19.7	74.9	94.5	35.3	12.3	9.7	40.9	25.6	29.7	6.2	47.5	41.8	72.8	73.7	90.7	80.4	45.1
200-250	ASMR	38.5	32.5	15.6	72.1	64.0	20.8	11.9	10.1	49.6	26.4	31.2	5.2	16.3	30.6	75.6	57.0	60.6	71.2	45.4
250-300	ASMR	46.4	39.3	18.8	56.4	49.1	13.3	7.6	8.5	41.0	28.3	65.2	1.0	19.7	14.1	80.3	73.3	57.9	75.0	49.1
300-350	ASMR	45.4	35.9	16.0	52.8	27.2	6.8	9.1	14.1	33.1	22.4	17.9	6.4	51.1	21.6	57.5	45.9	41.3	64.8	78.1
350-400	ASMR	48.6	38.7	20.1	66.6	29.9	13.3	20.3	6.2	37.8	42.4	14.7	11.0	52.3	46.1	56.3	52.9	40.9	57.0	35.6
>=400	ASMR	53.8	30.1	22.4	43.1	29.0	6.7	13.1	7.9	33.9	15.6	45.1	3.6	35.8	18.2	80.9	65.9	40.5	81.7	54.2
P-value		0.00	0.62	0.71	0.31	0.33	0.30	0.96	-0.10	0.05	0.19	0.82	0.83	0.93	0.83	0.94	0.76	0.29	0.76	0.81
R		0.89	-0.19	-0.15	-0.38	-0.37	-0.39	-0.02	-0.58	-0.67	-0.49	-0.09	0.09	0.03	-0.08	-0.03	-0.12	-0.40	-0.12	-0.10

*Population of neonates and 1 to 4 year olds were calculated from live births in the SFMS dataset and Cause-specific mortality rate was calculated here instead of ASMR

**ASMR:Age-Standardized Mortality Rates (per 100,000 people) were calculated through UN estimated population in India 2008

Table 3: Association between altitude and other factors

Socioeconomic behaviour factors		House Quality	Cooking Fuel	Illiteracy		Smoking	Alcohol	
Altitude(m)				Male	Female	Male	Male	Female
0-50	n	82593	39818	94162	162169	36504	38431	1685
	*n_t	235226	198402	445835	436600	75272	218694	83368
	%	35.1	20.1	21.1	37.1	48.5	17.6	2.0
50-100	n	36756	13596	77813	136283	22805	24631	1519
	n_t	132957	104550	267512	263195	45741	129164	56238
	%	27.7	13.0	29.1	51.8	49.9	19.1	2.7
100-150	n	20440	8091	42964	66542	11163	12652	918
	n_t	66091	55079	132631	124597	22289	64864	21218
	%	30.9	14.7	32.4	53.4	50.1	19.5	4.3
150-200	n	20968	7200	42879	67819	9593	12289	651
	n_t	61179	49198	123806	111577	19791	61331	21680
	%	34.3	14.6	34.6	60.8	48.5	20.0	3.0
200-250	n	50959	26566	56554	92134	12586	18248	537
	n_t	95893	85329	190790	173944	27604	85574	32204
	%	53.1	31.1	29.6	53.0	45.6	21.3	1.7
250-300	n	19266	6579	26058	45365	6049	9080	992
	n_t	45404	39034	88744	83992	14293	43113	16474
	%	42.4	16.9	29.4	54.0	42.3	21.1	6.0
300-350	n	13380	5575	18040	32657	4265	6277	183
	n_t	31058	24034	61383	57530	9970	30848	12686
	%	43.1	23.2	29.4	56.8	42.8	20.4	1.4
350-400	n	9660	3351	17922	30860	4660	6306	354
	n_t	27360	21831	53673	51081	8780	27604	11717
	%	35.3	15.4	33.4	60.4	53.1	22.8	3.0
>=400	n	75142	37613	109566	188227	30658	54028	5282
	n_t	193932	176504	390053	379048	64810	203313	89619
	%	38.8	21.3	28.1	49.7	47.3	26.6	5.9
P-value		0.47	0.55	0.66	0.57	0.77	0.00	0.20
R		0.27	0.23	0.17	0.22	-0.11	0.92	0.47

*n_t: Total samples

5. Discussion

A review of previous studies reveals that altitude has different effects for the same disease in different regions. For instance, Jha et al., (2002) showed that long-term stay at high altitude is associated with higher risk of stroke; however, Faeh et al., (2009) demonstrated that coronary heart disease and stroke have lower mortality at higher altitude. These conflicting results warrant further research to determine if altitude is a risk factor for some diseases. The current study used India as the region of analysis and examined the relationship between mortality and altitude. There are some findings that were discovered but also some limitations that were confronted during this research. A main limitation of the study was that most of India's population is located at low altitudes in the datasets. For instance, more than 50% of the population lives at or below 200 masl. This also meant that the elevation classification was restricted according to the geographical distribution of the data. Therefore, it is challenging to explore relationships between very high altitudes (over 3,500 metre) and death rate because the MDS reports very few deaths at such altitudes. On the other hand, the datasets (MDS and SFMS) were recorded in 2001-2003 and 1998, respectively. Due to the different surveying frameworks employed for each study, not all data can be matched from MDS to SFMS via SRS unit. For this reason, unfortunately, approximately 10% of the data were matchless through both SRS unit and pin code and were correspondingly discarded. This study attempted to understand whether mortality is associated with altitude by examining the age-standardized mortality rate-altitude relationship in India. Historically, research on the effects of high altitude on health has focused on understanding the physiology of oxygen transport in the human body. Recent studies include the effect of low-high altitude on pre-existing illnesses, the effect of illnesses on altitude adaptation, and altitude effects on special populations such as infants, pregnant women and the elderly. The current study, encompassing a large range of different age groups and top causes of death in India, combines a GIS and RS implementation to explore the relationship between mortality and altitude. Although the results identified that all-cause mortality is not significantly correlated with altitude, a negative effect was observed between residence at altitude and prematurity and low birth weight in neonates. Several studies have found a similar outcome that altitude has an effect on low birth weight. For example, Wehby et al., (2010) identified negative altitude effects on birth weight in South America for both low (5-1,280 m) and high altitude (1854-3600 m). Additionally, Yip (1987) found that in the United States, birth weight averages 351 g less for populations living between 2500 and 3100 m above sea level as compared to those living between 0 and 500 m. Furthermore, an additional surprising result of the current study that has not been documented in the literature was that higher drinking rates were found at higher altitudes in India. The study suggests several questions for future research. These include finding additional datasets that could provide more residence data at high altitude. Another avenue of investigation would be to identify the role of healthcare centre distribution and corresponding quality of care, which also can contribute to altitude effects on health. In addition, incorporating the analyses of more environmental parameters, such as precipitation, temperature, vegetation, and proximity to water bodies could provide a better understanding of the environmental effects on health. Finally, evaluating altitude effects on health is critical for understanding the long-term altitude related consequences to humans. Once such an understanding is attained, methods for intervention can be deployed, where necessary, to avoid such negative effects. It is evident that many questions concerning the provision of health problems are related to the environment. However, people and health problems are not distributed evenly in the environment; as a result, services to meet those needs must be adapted accordingly. Effectively determining where and what health services should be provided in order to respond to the needs and solve the health problems for people in their unique circumstances is a challenge that still must be met in India and throughout the world. Combining GIS/RS and epidemiology studies can assist in resolving these problems. However, the first task that must be completed is that of developing a greater understanding of environmental-related health illnesses. This study achieved its goal of filling the gap of altitude-mortality association in India. To conclude, the study finds negative altitude effects on prematurity and birth weight and positive effects on drinking rate with altitude in India.

References

Balke, B., 1964, Cardiac Performance in Relation to Altitude. *The American Journal of Cardiology*, 14 (6), 796-810.

Bellis, F., Parris, R., Thake, D. and Richards, P., 2005, Difficult Decisions at Altitude: The Management of an Acutely Dyspneic Porter at 5000 Meters. *Wilderness & Environmental Medicine*, 16 (4), 212-218.

Campbell, J. A., 1930, Living at Very High Altitudes and Maintenance of Normal Health. *The Lancet*, 215 (5555), 370-373.

Faeh, D., Gutzwiller, F., Bopp, M. and For the Swiss National Cohort Study Group, 2009, Lower Mortality from Coronary Heart Disease and Stroke at Higher Altitudes in Switzerland. *Circulation*, 120, 495-501.

Hackett, P. H. and Roach, R. C., 1990, High Altitude Pulmonary Edema. *Journal of Wilderness Medicine*, 1 (1), 3-26.

Hainsworth, R. and Drinkhill, M. J., 2007, Cardiovascular Adjustments for Life at High Altitude. *Respiratory Physiology & Neurobiology*, 158 (2-3), 204-211.

Heber, A. R., 1921, Some Effects of Altitude on the Human Body. *The Lancet*, 197 (5100), 1148-1150.

Jarvis, A., Reuter, H. I., Nelson, A. and Guevara, E., 2008, Hole-Filled Seamless SRTM Data V4. *International Centre for Tropical Agriculture (CIAT)*, available from http://srtm.csi.cgiar.org. Retrived June 10, 2010.

Jha, P., Gajalakshmi, V., Gupta, P. C., Kumar, R., Mony, P., Dhingra, N. and Peto, R., 2006, Prospective Study of One Million Deaths in India: Rationale, Design, and Validation Results. *PLoS Medicine*, 3 (2), e18.

Jha, S. K., Anand, A. C., Sharma, V., Kumar, N. and Adya, C. M., 2002, Stroke at High Altitude: Indian Experience. *High Altitude Medicine & Biology*, 3 (1), 21-27.

Johns, D. P., Reid, D. W., Richard, H., Kent, E. P. and Charles, G. P., 2004, Influence of High Altitude on Lung Development and Function. In The Lung: Development, *Aging and the Environment*, 267-275, edited by R. Harding, K. Pinkerton, and C. Plopper (Oxford: Academic Press).

RGI-CGHR and Collaborators, 2009, Causes of death in India, 2001-03, edited by R. G. o. I. Sample Registration System. New Delhi: Ministry of Home Affairs, Govt. of India (forthcoming).

Registrar General of India, 2005, Special Fertility and Mortality Survey, 1998: A Report of 1.1 Million Households. New Delhi, India: Registrar General.

Tanrikulu, A. C., Acemoglu, H., Palanci, Y. and Eren Dagli, C., 2008, Tuberculosis in Turkey: High Altitude and Other Socio-Economic Risk Factors. *Public Health*, 122 (6), 613-619.

Tissot van Patot, M. C., Valdez, M., Becky, V., Cindrova-Davies, T., Johns, J., Zwerdling, L., Jauniaux, E. and Burton, G. J., 2009, Impact of Pregnancy at High Altitude on Placental Morphology in Non-native Women With and Without Preeclampsia. *Placenta*, 30 (6), 523-528.

Wehby, G. L., Castilla, E. E. and Lopez-Camelo, J., 2010, The Impact of Altitude on Infant Health in South America. *Economics & Human Biology*, 8 (2), 197-211.

United Nations, 2009, World Population Prospects – the 2008 Revision. New York: United Nations Population Division.

Yip, R., 1987, Altitude and Birth Weight. *The Journal of Pediatrics*, 111 (6, Part 1), 869-876.