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Prevalence of hypertension at high altitude: cross-sectional survey in Ladakh, Northern India 2007–2011

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ABSTRACT

Objective: Prevalence of hypertension was examined in a widely dispersed (45 110 km^2) representative group of Ladakhi in Northern India. The influence of hypoxic environment of wide-ranged altitude (2600–4900 m) and lifestyle change on hypertension was studied.

Methods: 2800 participants (age 20–94 years) were enrolled. Systolic blood pressure ≥140 mm Hg and/or diastolic blood pressure of ≥90 mm Hg and/or taking current anti-hypertensive medicine was defined as hypertension. Height and weight for body mass index and SpO$_2$ were examined. The rural population comprised six subdivisions with a distinct altitude, dietary and occupational pattern. Participants in the urban area of Leh consist of two groups, that is, migrants settled in Leh from the Changthang nomadic area, and dwellers born in Leh. The prevalence of hypertension in the two groups was compared with that in the farmers and nomads in rural areas. The effects of ageing, hypoxia, dwelling at high altitude, obesity, modernised occupation, dwelling in an urban area, and rural-to-urban migration to hypertension were analysed by multiple logistic regression.

Results: The prevalence of hypertension was 37.0% in all participants and highest in migrants settled in Leh (48.3%), followed by dwellers born in Leh town (41.1%) compared with those in rural areas (33.5). The prevalence of hypertension in nomads (all: 27.7%, Tibetan/Ladakhi: 19.7/31.9%)) living at higher altitude (4000–4900 m) was relatively low. The associated factors with hypertension were ageing, overweight, dwelling at higher altitude, engagement in modernised sedentary occupations, dwelling in urban areas, and rural-to-urban migration. The effects of lifestyle change and dwelling at high altitude were independently associated with hypertension by multivariate analysis adjusted with confounding factors.

Conclusions: Socioeconomic and cultural factors play a big role with the effect of high altitude itself on high prevalence of hypertension in highlanders in Ladakh.

Strengths and limitations of this study

- This study examined most of the socioeconomic environmental factors known to influence hypertension in a population of different distinct geographical subdivisions of a high-altitude region. Though we did not carry out a nutritional survey in all the participants, overweight was a decisive factor for hypertension according to lifestyle change.
- This study showed the influence of ageing, overweight, modernised sedentary occupations, rural-to-urban migration and dwelling in urban areas to hypertension as well as the effect of altitude by multivariate analysis.
- This study did not look into the genetic factors, as environmental and genetic factors may contribute to regional and racial variations of blood pressure and the prevalence of hypertension.

INTRODUCTION

Systemic arterial hypertension at high altitude has evoked great interest among high-altitude researchers as well as in sojourners and natives. There have been conflicting reports with investigators generally reporting a slight increase in the blood pressure level soon after arrival at high altitude[1 2] and investigators reporting no such change[3 4] or a decrease followed by an increase.[5 6] There is no standard way of treating hypertension at high altitude for sojourners till now.[7 8] Similar contradictory views also exist between the investigators of the two high-altitude continents regarding the blood pressure status of the high-altitude natives. Studies done in Spiti India (4000 m) show a lower prevalence of hypertension.[9] Andean residents are reported to have low prevalence of hypertension[1 10 11] while the prevalence of hypertension in Tibet Lhasa was found to be higher than that of Han

migrants residing in Tibet.[12] Recent reports showed that the prevalence of hypertension was higher in Tibetan highlanders[13][14] than in Chinese lowlanders.[15]

The risk of developing hypertension may depend on socioeconomic factors, as well as geographic and racial differences. It is in the backdrop of this difference in opinion that we planned this study in Ladakh, one of the highest inhabited regions in the northernmost part of India. The population of the two districts of Ladakh (Leh and Kargil) was about 270 000 (Leh: 130 000, Kargil: 140 000) in 2011 by Census.[16] 77% of the population in Leh are Buddhists and 80% of the Kargil population are Muslims. Spread over 45 110 km^2, sandwiched between Karakoram in the north and Trans-Himalaya in the south and 80% comprising of a rural population with many villages high up in the mountains remaining inaccessible during winter, logistics for conducting a comprehensive epidemiological study representative of the whole population is formidable. The purpose of the study is twofold: first, to determine the prevalence of hypertension in different geographical subdivisions of this widely dispersed high-altitude district (from a median high 2500∼ to very high ∼4500 m), and second, which factors among the altitude, occupation, socio-economic and lifestyle play a predominant role in association with hypertension.

METHODS

This cross-sectional epidemiological study was carried out from 2007 to 2011. A total of 2800 participants aged between 20 and 94 years were examined. Figure 1 shows the map of Ladakh region showing all the villages in the subdivisions where the study was conducted. A two-stage stratified sampling method was used to select a representative sample of the adult population over 20 years of age. The population was first stratified as urban versus rural and then in the rural sector into six geographical areas (subdivisions). Each geographical subdivision has different characteristics in altitude, occupation, dietary habits and socioeconomic conditions as well as separate administrative blocks (table 1). Migrants from the rural
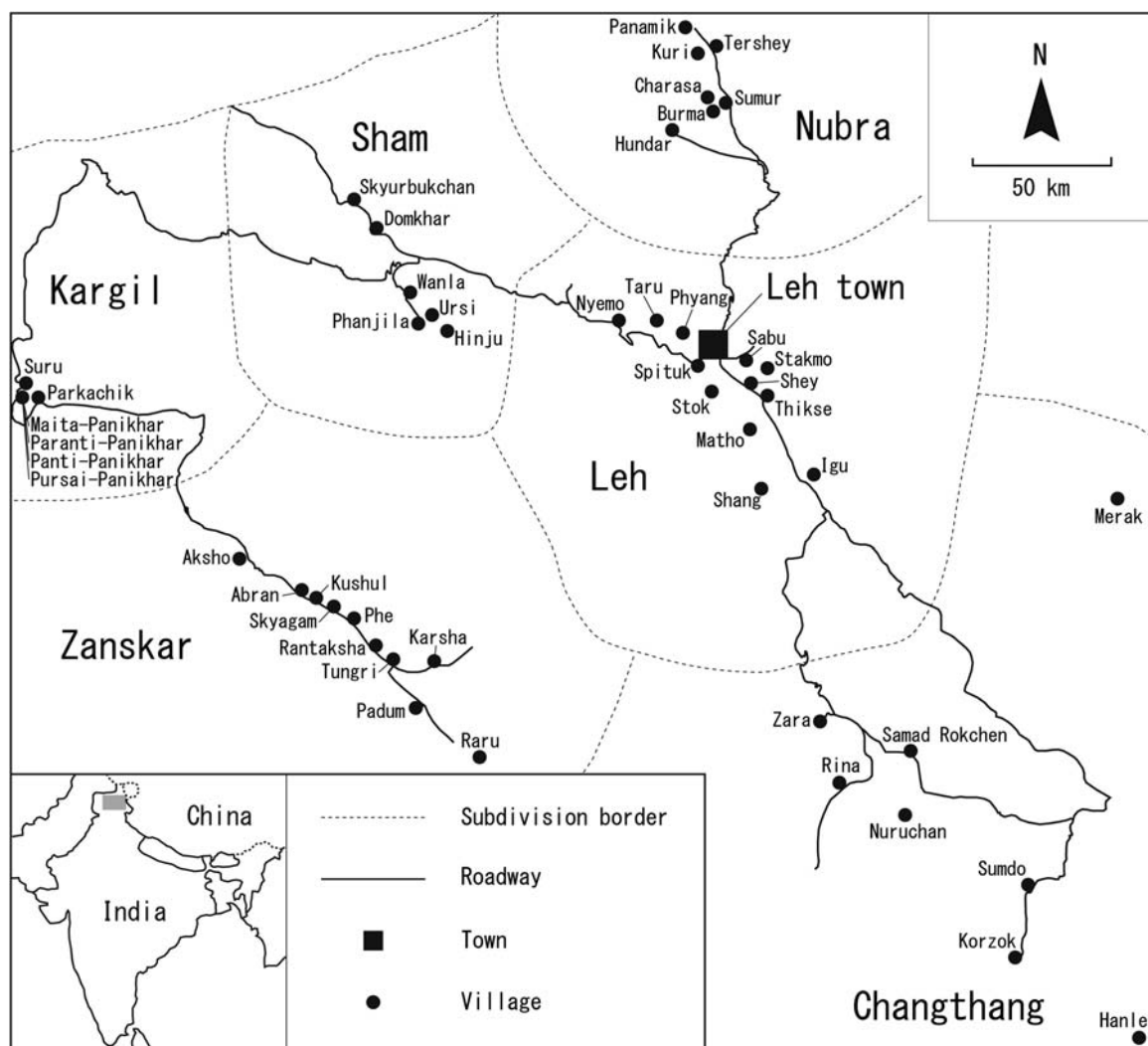

Figure 1 Map of Ladakh Region showing all the field sites. The map of Ladakh region showing all the villages in the subdivisions where the study was conducted.

Table 1 Characteristics of the subdivisions

Urban/rural	Subdivision	Altitude (metres above MSL)	Livelihood
Urban	Leh town (including colonies of migrants)	3300–3600	Urban lifestyle
Rural	Leh block villages	3000–3700	Farmer
	Nubra	2600–3000	Farmer
	Kargil (Panikhar and Parkachik)	2600–3100	Farmer
	Sham	2700–3900	Farmer
	Zanskar	3500–3900	Farmer and cattle rearing
	Changthang	4000–4900	Livestock rearing nomads

MSL, mean sea level.

population now settled in the Leh town subdivision since the 1970s were included in the urban population as they have adopted a lifestyle similar to the city dwellers. The Tata Institute of Social Sciences Mumbai (TISS) and Ladakh Autonomous hill development council (LAHDC) conducted a house-to-house survey of the total population of Leh (urban population) in 2007 for developing Ladakhi villages in the region.[17] Since the data from this census were the latest, we corrected and used this population survey list (age group 20–90 years) to draw our sample of urban population for the study. The list of 2000 eligible participants was representative of the age and gender structure of a Ladakhi family and they were invited as the volunteer participants to the research centre in Leh town. In the rural villages, all men and women aged 20 years or more were announced in the collaboration of health staff and village leaders. We carried out health checks on the volunteer participants in health centres or community halls in the rural villages.

There were no criteria for exclusion except absentees and critical and terminal illness patients who cannot report to the study centre to complete the study. Participants in *Leh town subdivision* were classified into two groups, that is, migrants settled in Leh town from Changthang area, and dwellers in Leh town. The former consisted of Tibetan and Ladakhi nomads. The latter consisted of Tibetans born in Leh, and other Ladakhi people, almost of whom were born in Leh, including some migrants from rural areas (non-Changthang).

The rural population was subdivided into six subdivisions as each subdivision had distinct characteristics which could influence the outcome.

Leh block subdivision comprises nearly 12 villages within 40 km of Leh town at an altitude varying between 3000 and 3700 m. The occupations of those living here are a mix of farming and modernised sedentary work. *Nubra subdivision* is in the north of Ladakh about 120 km from Leh after crossing Khardong Pass (5400 m), one of the highest motorable roads in the world. We studied the population of seven villages here. The subdivision is located on the banks of Shyok and Nubra rivers between the Karokoram and Ladakh ranges of mountains. People are predominantly farmers and the altitude of the valley generally is around 2600–3000 m. *Kargil subdivision (Panikhar and Parkachik)* is a green belt in Kargil district

and is a fertile farming area on the Suru river. However, fruit trees are not cultivated here. The population is mainly Muslim and the altitude is 2600–3100 m. We studied the population of six villages representative of this subdivision. *Sham (Khalse) subdivision* is wide-ranged in altitude (2700–3900 m), generally more fertile and many of the villages have fruit trees like apricot, apple and almond. We studied six representative villages in this subdivision. *Zanskar subdivision* is a remote region on the trans Himalayan range of mountain which remains closed from the rest of the world for 6 months in a year due to heavy snowfall. Though people do farming, yet the harsh weather is not conducive for productive farming. Fresh fruit and vegetables are very meagre here. People rear cattle, which forms their secondary source of income by selling dairy products. The altitude of the subdivision is 3500–3900 m. We studied 10 villages representative of this subdivision. *Changthang subdivision* is the biggest and highest plateau (Altitude 4000–4900 m). The population is generally nomadic, moving from pasture to pasture every 3 months along with their cattle and livestock and living in Yak wool woven tents. Life is very hard for them because of the high altitude and severe cold. Farming is not possible, and fresh fruit and vegetables fruits are not available to them throughout the year. Meat, barley flour and local tea are their staple diet. We studied six villages representative of the subdivision.

The occupation was interviewed from all the participants and classified into four groups: farmer, nomad, sedentary worker and others (housewife, manual labourer, monk, retired sedentary worker and no job). A full-time housewife was regarded as a housewife. A housewife who also worked as a nomad or farmer was classified as a nomad or farmer. People engaged in work closely associated with an urban lifestyle are classified into sedentary workers consisting of office worker, business person, shopkeeper, taxi driver, government officer, travel agent, teacher and so on.

The procedure for obtaining informed consent was approved by the Institutional review board of the Ladakh institute of prevention and the District ethical committee, Leh, Ladakh and Research Institute for Humanity and Nature, Kyoto, Japan. The participants attended the village medical aid centre or the village community centre. Anthropometric measurements including weight

and height were obtained using standard techniques. The body mass index (BMI) was calculated using the formula, $\text{weight(kg)}/(\text{height(m)})^2$. Blood pressure was measured in an arm using an automatic device (HEM 7000; OMRON Life Science Co. Ltd, Kyoto, Japan) based on the cuff oscillometric principle, and its accuracy has been validated in previous studies.[18–20] Oxyhaemoglobin saturation (SpO_2) was measured by a pulse oximeter (PULSOX-300; KONICA MINOLTA Co. Ltd, Tokyo, Japan). Blood pressure and SpO_2 were measured twice after taking at least a 5 min rest in a sitting position and the mean of systolic blood pressure (SBP), diastolic blood pressure (DBP) and SpO_2 was calculated. SBP ≥ 140 mm Hg and/or DBP of ≥ 90 mm Hg and/or taking current anti-hypertensive medicine was defined as hypertension.[21] The mean rate of current antihypertensive medication was 2.1%.

The age of the participants was confirmed with reference to a carefully prepared cross tabulation correlating their date of birth with the animal year, which the rural population always remembered, and to historical sentinel events in case of elderly participants.

Statistical analysis

χ^2 Test, Student's t-test and one-way analysis of variance were conducted for the analysis of the prevalence rate of hypertension or overweight (BMI ≥ 25), mean SBP, DBP, BMI and SpO_2. The associations of hypertension with the above confounding factors including altitude, ageing, sex, obesity, occupation and dwelling area were analysed by multiple logistic regression. Hypertension as the dependent variable was defined as SBP ≥ 140 mm Hg and/or DBP of ≥ 90 mm Hg and/or taking current anti-hypertensive medicine.[21] SPSS V.17.0 (SPSS Inc., Chicago, Illinois, USA) was used for the analysis. A statistically significant level was p<0.05.

RESULTS

A total of 2800 participants aged between 20 and 94 years were examined between 2007 and 2011.

Table 2 shows the characteristics of all variables and those associated with hypertension were overviewed. We found a 37.0% crude prevalence rate in the total Ladakhi population of both men and women. Male and older people, as well as those with overweight, had more prevalence of hypertension, but SpO_2 was not associated with hypertension. Dwelling at an altitude of 3000–3999 m had more prevalence of hypertension compared with altitude below 3000 or above 4000 m. People dwelling in urban areas had more prevalence of hypertension compared with those in rural areas. Nomads had lower prevalence of hypertension compared with farmers or sedentary workers.

Table 3 shows the participants surveyed and the prevalence rates of hypertension, mean SBP, DBP, BMI, rate of overweight (BMI ≥ 25) and mean SpO_2 according to sex and age groups in Ladakh region. Prevalence rates

of hypertension, mean SBP and DBP increased significantly with ageing in men and women. Up to the age of 60 years, men tend to have higher blood pressure than women; however, there were no significant differences between men and women aged 60 years or above. The prevalence of overweight was highest (28.5%) in the 40–59 age group and men had a higher prevalence rate of overweight than women up to 75 years. Mean SpO_2 decreased significantly with ageing in both men and women.

Table 4 shows the crude and age-standardised prevalence rates of hypertension, and overweight (%) in seven subdivisions in Ladakh region in each age group. As the mean age was different among the participants of the seven subdivisions (ANOVA, analysis of variance; p<0.0001), age-standardised prevalence rates were calculated.

Leh town subdivision, which is inhabited by an urban population, had a higher crude prevalence rate of hypertension (43.4%) with age-standardised prevalence rate (45.5%) than any other subdivisions comprising a rural population (crude; 24.3–39.1, age-standardised; 24.6–36.8) (ANOVA, p<0.0001). The prevalence of hypertension, especially in the younger age group of 40–59 years, was extremely high in Leh town (41.6%) compared with other rural subdivisions (19.6–30.7%) (ANOVA, p<0.0001). Also in the old population above 60 years, the prevalence of hypertension was highest in Leh town (61.7%) compared with other rural subdivisions (34.1–56.0%) (ANOVA, p=0.0001). There was no significant difference in prevalence of hypertension in the young age group of 20–39 among the seven subdivisions (ANOVA; ns, not significant). Prevalence rates of hypertension increased significantly with ageing in all subdivisions (ANOVA, p<0.01~ p<0.0001) except Kargil. Prevalence of overweight (BMI≥ 25) was highest in the middle age group of 40–59 in Leh town subdivision.

Table 5 shows the prevalence rate of hypertension at different altitude levels according to age and occupation group. Up to the altitude of 4000 m, the prevalence of hypertension rose with altitude and the participants surveyed at altitude ranging from 3500 to 3999 m had a higher prevalence rate of hypertension (40.8%) than the other altitude ranges in all participants (ANOVA, p<0.0001). In the age group of 20–59 years, people at altitude ranging from 3000 to 3499 m had a higher prevalence rate of hypertension than others, while in the age group of 60–74 years, up to the altitude of 4499 m, the prevalence rate of hypertension rose with altitude, and people at altitude ranging from 4000 to 4499 m had the highest prevalence rate of hypertension (55.8%) (ANOVA, p<0.05). In the age group of 75 years and more, the prevalence of hypertension was highest and there was no difference among altitude levels.

According to occupation group, the prevalence of hypertension rose closely with altitude remarkably in agriculture (p<0.001), mildly in sedentary workers (p=0.09) and insignificantly in nomads.

Table 2 Characteristics of all variables and those associated with hypertension in Ladakh region

	All	Hypertension (+)	Hypertension (−)	p Value
n	2800	1037	1763	
Per cent		37.0 (35.2 to 38.8)	63.0 (61.2 to 64.8)	
Male (%)	44.3 (41.8 to 46.8)	46.9 (43.9 to 49.9)	42.8 (40.5 to 45.1)	0.03
age (years)	53.8±15.0	60.1±13.8	50.1±14.4	<0.0001
weight (kg)	55.3±11.1	57.4±12.2	54.1±10.2	<0.0001
BMI	22.6±3.6	23.6±3.9	22.0±3.3	<0.0001
Overweight (BMI ≥25) (%)	24.4 (22.8 to 26.0)	34.9 (32.0 to 37.8)	18.2 (16.4 to 20.0)	<0.0001
SpO_2 (%)	89.7±5.2	89.5±5.4	89.8±5.2	ns
SpO_2 <89 (%)	32.5 (30.8 to 34.2)	32.1 (29.3 to 34.9)	32.7 (30.5 to 34.9)	ns
SBP (mm Hg)	130.9±23.2	153.8±19.9	117.5±11.7	<0.0001
DBP (mm Hg)	82.5±13.4	94.6±11.2	75.4±8.5	<0.0001
Altitude (m)	3514.4±432.2	3524.6±388.6	3508.3±455.9	ns
	n			
Altitude (n=2800), m		Per cent	Per cent	<0.0001
2500–2999	417	27.1 (22.8 to 31.4)	72.9 (68.6 to 77.2)	
3000–3499	428	37.4 (32.8 to 42.0)	62.6 (58.0 to 67.2)	
3500–3999	1604	40.8 (38.4 to 43.2)	59.2 (56.8 to 61.6)	
4000–4499	174	30.5 (23.7 to 37.3)	69.5 (62.7 to 76.3)	
4500–4999	177	32.2 (25.3 to 39.1)	67.8 (60.9 to 74.7)	
Dwelling area (n=2800)		Per cent	Per cent	<0.0001
Rural areas	1798	33.5 (31.3 to 35.7)	66.5 (64.3 to 68.7)	
Leh block (3000–3700 m)	349	33.0 (28.1 to 37.9)	67.0 (62.1 to 71.9)	
Nubra (2600–3000 m)	248	27.8 (22.2 to 33.4)	72.2 (66.6 to 77.8)	
Kargil (2600–3100 m)	115	24.3 (16.5 to 32.1)	75.7 (67.9 to 83.5)	
Sham (2700–3900 m)	451	39.2 (34.7 to 43.7)	60.8 (56.3 to 65.3)	
Zanskar (3500–3900 m)	284	36.3 (30.7 to 41.9)	63.7 (58.1 to 69.3)	
Changthang (4000–4900 m)	351	31.3 (26.4 to 36.2)	68.7 (63.8 to 73.6)	
Urban area: Leh town (3300–3600 m)	1002	43.4 (40.3 to 46.5)	56.6 (53.5 to 59.7)	
Dwellers in Leh town*	683	41.1 (37.4 to 44.8)	58.9 (55.2 to 62.6)	
Migrants from Changthang	319	48.3 (42.8 to 53.8)	51.7 (46.2 to 57.2)	
Occupation (n=2800)		Per cent	Per cent	<0.0001
Farmer	1247	36.6 (33.9 to 39.3)	63.4 (60.7 to 66.1)	
Nomad	220	27.7(21.8 to 33.6)	72.3 (66.4 to 78.2)	
Sedentary worker	549	37.3 (33.3 to 41.3)	62.7 (58.7 to 66.7)	
Others	784	40.2 (36.8 to 43.6)	59.8 (56.4 to 63.2)	
Housewife	325	42.5 (37.1 to 47.9)	57.5 (52.1 to 62.9)	
Manual labourer	63	14.3 (5.7 to 22.9)	85.7 (77.1 to 94.3)	
Monk	157	36.9 (29.4 to 44.4)	63.1 (55.6 to 70.6)	
No job	138	44.2 (35.9 to 52.5)	55.8 (47.5 to 64.1)	
Retired sedentary	101	48.5 (38.8 to 58.2)	51.5 (41.8 to 61.2)	

Mean±SD, % (95% CI).
p; χ^2 Test for the comparison of the rate of variables, and Student's t test for the comparison of the mean of variables between hypertension and non-hypertension.
*Almost born in Leh with some migrants from no-Changthang areas.
BMI, body mass index; DBP, diastolic blood pressure; ns, not significant; SBP, systolic blood pressure; SpO_2, oxyhaemoglobin saturation measured by a pulse oximeter.

Table 6 shows the prevalence rate of hypertension at different altitude levels in each subdivision. In the only Sham subdivision, where altitude ranging is as wide as 2700–3900 m, the prevalence rate of hypertension increased (29.1, 36.2, 46.4%, p=0.0067) in accord with the elevation of altitude (2500–2999, 3000–3499, 3500–3999 m) in spite of the decrease in overweight (23.3, 18.9, 12.6%, p=0.040) with the altitude. In the other subdivisions, there was no difference in the prevalence rate of hypertension among different altitudes.

Table 7 shows the prevalence rate of hypertension and overweight in people with different occupations. In the age group of 40–59 years, sedentary workers had the highest prevalence of hypertension (48.3%) and obesity (43.9%), while nomads (hypertension/obesity; 19.6%/22.5%) and manual labourers (11.3%/20.8%) had a lower prevalence of hypertension compared with other workers (27.3–36.1%/20.1–61.1%) (ANOVA, p<0.0001). In the other age groups, there was no or little significant difference in the prevalence of hypertension among different occupations.

Table 3 Prevalence of hypertension and related variables according to sex and age groups in Ladakh region

| | Age group (years) | | | | | |
	20–39	40–59	60–74	75–	All	p†
Male (n)	217	489	396	138	1240	
Female (n)	288	709	448	115	1560	
All (n)	505	1198	844	253	2800	
Hypertension (%)						
Male	18.4 (13.2–23.6)	34.2 (30.0–38.4)	48.2 (43.3–53.1)	63.8 (55.8–71.8)	39.2 (36.5–41.9)*	<0.0001
Female	12.5 (8.7–16.3)	29.9 (26.5–33.3)	50.4 (45.8–55.0)	67.0 (58.4–75.6)	35.3 (32.9–37.7)	<0.0001
All	15.1 (12.0–18.2)	31.6 (29.0–34.2)	49.4 (46.0–52.8)	65.2 (59.3–71.1)	37.0 (35.2–38.8)	<0.0001
SBP (mm Hg)						
Male	122.2±14.3****	127.7±18.0*	138.9±22.6	149.0±26.1	132.7±21.7***	<0.0001
Female	116.0±14.2	125.3±19.5	138.8±25.5	153.7±32.8	129.5±24.2	<0.0001
All	118.7±14.5	126.3±18.9	138.8±24.2	151.1±29.4	130.9±23.2	<0.0001
DBP (mm Hg)						
Male	78.5±11.4	83.4±12.5***	85.2±12.8	87.5±14.2	83.6±12.9***	<0.0001
Female	76.4±11.9	80.9±12.0	84.5±14.9	88.4±17.3	81.7±13.7	<0.0001
All	77.3±11.7	81.9±12.3	84.9±14.0	87.9±15.7	82.5±13.4	<0.0001
BMI						
Male	22.4±3.2***	23.3±3.6*	23.2±3.4****	22.4±3.4	23.0±3.5****	0.0017
Female	21.4±3.3	22.8±3.7	22.1±3.7	22.1±3.7	22.3±3.7	<0.0001
All	21.8±3.3	23.0±3.7	22.6±3.6	22.3±3.5	22.6±3.6	<0.0001
BMI ≥25 (%)						
Male	22.6 (17.0–28.2)*	31.7 (27.6–35.8)*	28.4 (24.0–32.8)**	19.6 (13.0–26.2)	27.7 (25.2–30.2)***	0.0098
Female	14.6 (10.5–18.7)	26.2 (23.0–29.4)	19.5 (15.8–23.2)	20.9 (13.5–28.3)	21.8 (19.8–23.8)	0.0003
All	18.0 (14.6–21.4)	28.5 (25.9–31.1)	23.6 (20.7–26.5)	20.2 (15.3–25.1)	24.4 (22.8–26.0)	<0.0001
SpO$_2$ (%)						
Male	90.8±4.4*	90.4±4.6	89.1±5.3**	89.0±5.4**	89.9±5.0	<0.0001
Female	91.6±3.6	90.3±4.8	87.7±6.4	86.6±6.5	89.5±5.0	<0.0001
All	91.2±4.0	90.4±4.7	88.3±5.9	87.9±6.0	89.7±5.2	<0.0001
SpO$_2$ <89 (%)						
Male	25.7 (19.9–31.5)*	29.0 (25.0–33.0)	37.1 (32.3–41.9)**	39.4 (31.2–47.6)*	32.2 (29.6–34.8)	0.0029
Female	17.7 (13.3–22.1)	27.2 (23.9–30.5)	46.3 (41.7–50.9)	52.2 (43.1–61.3)	32.8 (30.5–35.1)	<0.0001
All	21.1 (17.5–24.7)	27.9 (25.4–30.4)	42.0 (38.7–45.3)	45.2 (36.1–54.3)	32.5 (30.8–34.2)	<0.0001

p†; χ^2 Test for the comparison of the prevalence of hypertension and BMI ≥25 (%) among the 4 age groups in the whole population (n=2800);
*p<0.05, **p<0.01, ***p<0.001, ****p<0.0001: χ^2 test for the comparison of the prevalence of hypertension and BMI ≥25 (%) and SpO$_2$ <89 (%) between men and women, and Student's t test for the comparison of mean of SBP, DBP, BMI and SpO$_2$ between men and women in each age group.
ANOVA, analysis of variance; BMI, body mass index; DBP, diastolic blood pressure; SBP, systolic blood pressure; SpO$_2$, oxyhaemoglobin saturation measured by a pulse oximeter.

Table 4 Prevalence of hypertension and related variables in different age groups in each subdivision in Ladakh region

	Age group (years)				p Value	All
	20–39	40–59	60–74	75–		
Leh (n=1002) (mean 51.9±15.5 years)	n=223	n=447	n=245	n=87		
Hypertension, %	19.7 (14.5–24.9)	41.6 (37.0–46.2)	58.8 (52.6–65.0)	70.1 (60.5–79.7)	<0.0001	43.4 (40.3–46.5)
(Age-standardised prevalence rate, %)						45.5 (42.4–48.6)
BMI ≥25 (%)	20.6 (15.3–25.9)	40.7 (36.1–45.3)	34.8 (28.8–40.8)	26.4 (17.1–35.7)	<0.0001	33.6 (30.7–36.5)
Leh block (n=349) (mean 55.6±16.1 years)	n=60	n=127	n=123	n=39		
Hypertension,%	6.7 (0.4–13.0)	22.0 (14.8–29.2)	48.0 (39.2–56.8)	61.5 (46.2–76.8)	<0.0001	33.0 (28.1–37.9)
(Age-standardised prevalence rate,%)						30.7 (25.9–35.5)
BMI ≥25 (%)	30.0 (18.4–41.6)	34.6 (26.3–42.9)	35.0 (26.6–43.4)	23.1 (9.9–36.3)	ns	32.7 (27.8–37.6)
Nubra (n=248) (mean 50.5±15.5 years)	n=78	n=88	n=64	n=18		
Hypertension, %	11.5 (4.4–18.6)	29.5 (20.0–39.0)	37.5 (25.6–49.4)	55.6 (32.6–78.6)	0.0001	27.8 (22.2–33.4)
(Age-standardised prevalence rate,%)						31.0 (25.2–36.8)
BMI ≥25 (%)	9.0 (2.6–15.4)	17.0 (9.2–24.8)	14.1 (5.6–22.6)	16.7 (0–33.9)	ns	13.4 (9.2–17.6)
Kargil (n=115) (mean 51.9±13.5 years)	n=25	n=46	n=42	n=2		
Hypertension, %	16.0 (1.6–30.4)	19.6 (8.1–31.1)	33.3 (19.0–47.6)	50.0 (0–100)	ns	24.3 (16.5–32.1)
(Age-standardised prevalence rate, %)						24.6 (16.7–32.5)
BMI ≥25 (%)	16.0 (1.6–30.4)	2.2 (0–6.4)	9.5 (0.6–18.4)	0	ns	7.8 (2.9–12.7)
Sham (n=451) (mean 56.2±13.8 years)	n=62	n=189	n=150	n=50		
Hypertension, %	9.7 (2.3–17.1)	31.2 (24.6–37.8)	50.7 (42.7–58.7)	72.0 (59.6–84.4)	<0.0001	39.2 (34.7–43.7)
(Age-standardised prevalence rate, %)						36.9 (32.4–41.4)
BMI ≥25 (%)	11.3 (3.4–19.2)	19.6 (13.9–25.3)	17.5 (11.4–23.6)	14.0 (4.4–23.6)	ns	17.1 (13.6–20.6)
Zanskar (n=284) (mean 59.5±12.8 years)	n=10	n=115	n=127	n=32		
Hypertension, %	20.0 (0–44.8)	25.2 (17.3–33.1)	42.5 (33.9–51.1)	56.3 (39.1–73.5)	<0.01	36.3 (30.7–41.9)
(Age-standardised prevalence rate, %)						32.1 (26.7–37.5)
BMI ≥25 (%)	30.0 (1.6–58.4)	13.9 (7.6–20.2)	13.4 (7.5–19.3)	15.6 (3.0–28.2)	ns	14.4 (10.3–18.5)
Changthang (n=351) (mean 52.9±13.6 years)	n=47	n=186	n=93	n=25		
Hypertension,%	14.9 (4.7–25.1)	22.6 (16.6–28.6)	49.5 (39.3–59.72)	60.0 (40.8–79.2)	<0.0001	31.3 (26.4–36.2)
(Age-standardised prevalence rate, %)						32.6 (27.7–37.5)
BMI ≥25 (%)	12.8 (3.2–22.4)	24.7 (18.5–30.9)	16.1 (8.6–23.6)	16.0 (1.6–30.4)	ns	20.2 (16.0–24.4)

p; χ^2 Test for the comparison of the prevalence of hypertension and BMI >25 (%) among the four age groups in each subdivision.
BMI, body mass index; ns, not significant.

Table 5 Prevalence of hypertension and related variables according to altitude, age and occupation in Ladakh region

	Altitude (metres above MSL)					p Value
	2500–2999 m	3000–3499 m	3500–3999 m	4000–4499 m	4500–4999 m	
All	n=417	n=428	n=1604	n=174	n=177	
Hypertension (%)	27.1 (22.8–31.4)	37.4 (32.8–42.0)	40.8 (38.4–43.2)	30.5 (23.7–37.3)	32.2 (25.3–39.1)	<0.0001
SBP	126.3±21.6	128.9±19.9	132.8±24.0	129.7±23.9	130.9±23.8	<0.0001
DBP	80.8±12.2	83.5±13.1	83.3±13.7	80.0±13.7	79.2±12.8	<0.0001
BMI	21.8±3.1	22.7±3.7	22.8±3.6	22.4±3.6	22.6±3.7	<0.0001
BMI ≥25 (%)	16.6 (13.0–20.2)	25.0	27.1	20.1	20.3	<0.0001
SpO₂	90.2±4.7	90.6±4.2	90.0±5.2	86.1±5.8	86.7±5.7	<0.0001
SpO₂ <89 (%)	26.2 (22.0–30.4)	23.6 (19.6–27.6)	28.8 (26.6–31.0)	67.1 (60.1–74.1)	68.2 (61.3–75.1)	<0.0001
20–39 years	n=119	n=128	n=211	n=30	n=17	
Hypertension (%)	10.1 (4.7–15.5)	22.7 (15.4–30.0)	13.3 (8.7–17.9)	10.0 (0–20.7)	23.5 (3.3–43.7)	<0.05
BMI ≥25 (%)	11.8 (6.0–17.6)	17.2 (10.7–23.7)	23.2 (17.5–28.9)	6.7 (0–15.6)	23.5 (3.3–43.7)	<0.05
SpO₂ <89 (%)	15.4 (8.9–21.9)	16.4 (10.0–22.8)	14.5 (9.7–19.3)	69.0 (52.4–85.6)	100.0	<0.0001
40–59 years	n=155	n=197	n=660	n=77	n=109	
Hypertension (%)	27.1 (20.1–34.1)	41.1 (34.2–48.0)	32.4 (28.8–36.0)	15.6 (7.5–23.7)	27.5 (19.1–35.9)	<0.001
BMI ≥25 (%)	20.6 (14.2–27.0)	32.5 (26.0–39.0)	30.2 (26.7–33.7)	28.6 (18.5–38.7)	22.0 (14.2–29.8)	ns
SpO₂ <89 (%)	22.6 (16.0–29.2)	24.1 (18.1–30.1)	20.5 (17.4–23.6)	55.8 (44.7–66.9)	67.9 (59.1–76.7)	<0.0001
60–74 years	n=114	n=81	n=556	n=52	n=41	
Hypertension (%)	38.6 (29.7–47.5)	44.4 (33.6–55.2)	52.3 (48.1–56.5)	55.8 (42.3–69.3)	41.5 (26.4–56.6)	<0.05
BMI ≥25 (%)	15.9 (9.2–22.6)	23.5 (14.3–32.7)	26.5 (22.8–30.2)	15.4 (5.6–25.2)	17.1 (5.6–28.6)	ns
SpO₂ <89 (%)	36.6 (27.8–45.4)	30.4 (20.4–40.4)	40.2 (36.1–44.3)	78.8 (67.7–89.9)	56.1 (40.9–71.3)	<0.0001
75 years	n=29	n=22	n=177	n=15	n=10	
Hypertension (%)	51.7 (33.5–69.9)	63.6 (43.5–83.7)	68.4 (61.6–75.2)	60.0 (35.2–84.8)	60.0 (29.6–90.4)	ns
BMI ≥25 (%)	17.2 (3.5–30.9)	9.1 (0–21.1)	22.6 (16.4–28.8)	20.0 (0–40.2)	10.0 (0–28.6)	ns
SpO₂ <89 (%)	48.3 (30.1–66.5)	36.4 (16.3–56.5)	41.5 (34.2–48.8)	80.0 (59.8–100)	70.0 (41.6–98.4)	<0.05
Farmer	n=348	n=178	n=620	n=81	n=20	
Hypertension (%)	27.6 (22.9–32.3)	33.7 (26.8–40.6)	41.3 (37.4–45.2)	40.7 (30.0–51.4)	55.0 (33.2–76.8)	<0.001
BMI ≥25 (%)	14.7 (11.0–18.4)	12.4 (7.6–17.2)	15.6 (12.7–18.5)	19.8 (11.1–28.5)	20.0 (2.5–37.5)	ns
SpO₂ <89 (%)	23.8 (19.3–28.3)	24.4 (18.1–30.7)	41.5 (37.6–45.4)	85.0 (77.2–92.8)	94.7 (84.9–100)	<0.0001
Nomad				n=67	n=145	
Hypertension (%)				22.4 (12.4–32.4)	29.0 (21.6–36.4)	ns
BMI ≥25 (%)				25.4 (15.0–35.8)	17.9 (11.7–24.1)	ns
SpO₂ <89 (%)				46.3 (34.4–58.2)	63.9 (56.1–71.7)	<0.05
Sedentary worker	n=33	n=176	n=340			
Hypertension (%)	21.2 (7.3–5.1)	40.9 (33.6–48.2)	38.8 (33.6–44.0)			ns (0.09)
BMI ≥25 (%)	21.2 (7.3–5.1)	35.2 (28.1–42.3)	36.6 (31.5–41.7)			ns
SpO₂ <89 (%)	42.4 (25.5–59.3)	20.2 (14.3–26.1)	15.7 (11.8–19.6)			<0.001

p; χ^2 Test for the comparison of the prevalence of hypertension, BMI ≥25 (%) and SpO₂ <89 (%) among the five altitude groups.
BMI, body mass index; DBP, diastolic blood pressure; MSL, mean sea level; SBP, systolic blood pressure; SpO₂, oxyhaemoglobin saturation measured by a pulse oximeter.

Table 6 Prevalence of hypertension and overweight in different altitude levels in each subdivision in Ladakh region

	Altitude (metres above MSL)					p Value
	2500–2999 m	3000–3499 m	3500–3999 m	4000–4499 m	4500–4999 m	
Leh (3300–3600 m)						
n		189	813			
Hypertension (%)		42.9 (35.8–50.0)	43.5 (40.1–46.9)			ns
BMI ≥25 (%)		32.8 (26.1–39.5)	33.7 (30.5–36.9)			ns
Leh block (3000–3700 m)						
n		49	300			
Hypertension (%)		28.6 (15.9–41.3)	33.7 (28.4–39.0)			ns
BMI ≥25 (%)		40.8 (35.8–63.8)	31.3 (26.1–36.5)			ns
Nubra (2600–3000 m)						
n	248					
Hypertension (%)	27.8 (22.2–33.4)					
BMI ≥25 (%)	13.7 (9.4–18.0)					
Kargil (2600–3100 m)						
n	52	63				
Hypertension (%)	19.2 (8.5–29.9)	28.6 (17.4–39.8)				ns
BMI ≥25 (%)	15.4 (5.6–25.2)	1.6 (0–4.7)				<0.01
Sham (2700–3900 m)						
n	117	127	207			
Hypertension (%)	29.1 (20.9–37.3)	37.0 (28.6–45.4)	46.4 (39.6–53.2)			<0.01
BMI ≥25 (%)	23.3 (15.6–31.0)	18.9 (12.1–25.7)	12.6 (8.1–17.1)			<0.05
Zanskar (3500–3900 m)						
n			284			
Hypertension (%)			36.3 (30.7–41.9)			
BMI ≥25 (%)			14.4 (10.3–18.5)			
Changthang (4000–4900 m)						
n				174	177	
Hypertension (%)				30.5 (23.7–37.3)	32.2 (25.3–39.1)	ns
BMI ≥25 (%)				20.1 (14.1–26.1)	20.3 (14.4–26.2)	ns

p; χ^2 Test for the comparison of the prevalence of Hypertension and BMI ≥25 (%) among the altitude groups.
BMI, body mass index; MSL, mean sea level; ns, not significant.

Table 7 Prevalence of hypertension and overweight in people with different occupations in each age group in Ladakh region

	20–39 years			40–59 years			60–74 years			75 years		
	n	Hypertension	BMI ≥25	n	Hypertension	BMI ≥25	n	Hypertension	BMI ≥25	n	Hypertension	BMI ≥25
		Per cent	Per cent		Per cent	Per cent		Per cent	Per cent		Per cent	Per cent
Farmer	171	12.9 (7.9–17.9)	12.3 (7.4–17.2)	476	26.3 (22.3–30.3)	16.0 (12.7–19.3)	465	47.3 (42.8–51.8)	15.9 (12.6–19.2)	135	65.9 (57.9–73.9)	14.1 (8.2–20.0)
Nomad	4	0	25.0 (0–67.4)	146	19.9 (13.4–26.4)	23.3 (16.4–30.2)	54	40.7 (27.6–53.8)	11.1 (2.7–19.5)	16	62.5 (38.8–86.2)	25.0 (3.8–46.2)
Sedentary worker	204	19.5 (14.1–24.9)	19.1 (13.7–24.5)	277	48.0 (42.1–53.9)	44.0 (38.2–49.8)	61	45.9 (33.4–58.4)	39.3 (27.0–51.6)	7	42.9 (6.2–79.6)	42.9 (6.2–79.6)
Others	126	10.3 (5.0–15.6)	23.8 (16.4–31.2)	299	30.8 (25.6–36.0)	36.5 (23.2–36.0)	264	55.7 (49.7–61.7)	36.4 (30.6–42.2)	95	66.3 (56.8–75.8)	26.3 (17.4–35.2)
Housewife	44	13.6 (3.5–23.7)	25.0 (12.2–37.8)	157	29.0 (21.9–36.1)	36.3 (28.8–43.8)	98	57.1 (47.3–66.9)	25.5 (16.9–34.1)	26	84.6 (70.7–98.5)	23.1 (12.1–31.7)
Manual labourer	1	0	0	53	11.3 (2.8–19.8)	20.8 (9.9–31.7)	9	33.3 (2.5–64.1)	11.1 (0–31.6)	0	0	
Monk	43	4.7 (0–11.0)	30.2 (16.5–43.9)	36	36.1 (20.4–51.8)	61.1 (45.2–77.0)	57	56.1 (43.2–69.0)	52.6 (39.6–65.6)	21	52.4 (31.0–73.8)	38.1 (17.3–58.9)
No job	37	13.5 (2.5–24.5)	16.2 (4.3–28.1)	25	36.0 (17.2–54.8)	36.0 (17.2–54.8)	44	61.4 (47.0–75.8)	38.6 (24.2–53.0)	32	62.5 (45.7–79.3)	28.1 (12.5–43.7)
Retired sedentary	1	0	0	28	35.7 (18.0–53.4)	35.7 (18.0–53.4)	56	51.8 (38.7–64.9)	41.1 (28.2–54.0)	16	62.5 (38.8–86.2)	12.5 (0–28.7)
p Value		ns (0.05)	ns (0.07)		<0.0001	<0.0001		ns (0.07)	<0.0001		ns	<0.05

p; χ² Test for the comparison of the prevalence of hypertension and BMI ≥25 (%) among the four occupation groups: farmer, nomad, sedentary worker and others.
BMI, body mass index.

Table 8 shows the prevalence of hypertension and overweight comparing among dwellers in rural areas and Leh town and rural-to-urban migrants. The prevalence of hypertension and overweight was highest in migrants settled in Leh (hypertension/overweight; 48.3%/40.9%) followed by dwellers in Leh town (41.1%/30.2%) compared with those in rural areas (33.5%/15.3–19.3%). The percentage of engagement in occupations was shown in each participant group.

There was a difference in the prevalence of hypertension between Tibetan and Ladakhi nomads. The lowest prevalence of hypertension in spite of a higher prevalence of overweight was shown in Tibetan nomads (n=76) (hypertension/overweight; 19.7%/39.5%) compared with Ladakhi nomads (n=144) (31.9%/10.4%) living at higher altitude (4000–4900 m).

The effects of altitude, occupation and dwelling area on hypertension were analysed in all the participants by multiple logistic regression adjusted with age, sex and overweight in models 1–3 (table 9). In model 1, the altitude ranges of 3000–3499 (OR 1.78) and 3500–3999 (OR 1.42) were significantly associated with high prevalence of hypertension compared with 2500–2999 (m) adjusted with age, sex and obesity. However, the higher range of 4000–4499 or 4500– was not associated with hypertension. In model 2 with further adjustment by occupation, the altitude ranges of 3000–3499 (OR 1.62) and 3500–3999 (OR 1.34) and the highest range of 4500– (OR 2.57) became significantly associated with hypertension. Sedentary workers had a higher association (OR 1.56) compared with farmers, while nomads had a lower association (OR 0.42). In model 3, with further adjustment by dwelling area, the altitude range of 3000–3499 (OR 1.44) and the highest altitude range of 4500– (OR 2.69) kept significant association with hypertension independent of occupation and dwelling area. People dwelling in Leh town (OR 1.92) and migrants from Changthang (OR 1.70) were significantly associated with a high prevalence of hypertension compared with those dwelling in rural areas.

DISCUSSION

In the current study, we found that one-third of the population is at a higher risk of hypertension. As table 3 shows, the prevalence of hypertension tends to increase with age in both genders. Average SBP and DBP in men less than 60 years of age was found to be higher than in age-matched women. This is consistent with the prevalence of adult hypertension in a US population,[22] in a south Indian Chennai urban population study[23] and in rural and urban communities of Rajasthan.[24] The cause of lower blood pressure in women below 60 years may be due to hormonal effects in women during this age, that is, premenopausal women having a lower arterial blood pressure than age-matched men.[25] This may also be due to the effect of obesity, as the prevalence of overweight in men was higher in people under 75 years

Table 8 Prevalence of hypertension and related variables in different dwelling areas in Ladakh region

| | | Urban: Leh town | | |
| | Rural areas 1798 | Dwellers in Leh town 683 | Migrants from Changthang 319 | |
n				p Value
Age (years)	54.9±14.6	49.0±15.9	58.2±12.3	<0.0001
Hypertension (%)	33.5 (31.3–35.7)	41.1 (37.4–44.8)	48.3 (42.8–53.8)	<0.0001
BMI ≥25 (%)	19.3 (17.5–21.1)	30.2 (26.8–33.6)	40.9 (35.5–46.3)	<0.0001
SpO_2	88.8±5.6	90.7±4.2	92.3±3.2	<0.0001
SpO_2 <89 (%)	40.6 (38.3–42.9)	21.7 (18.6–24.8)	10.1 (6.8–13.4)	<0.0001
Altitude (m)	3543.2±534.1	3449.0±86.9	3491.9±39.6	<0.0001
Occupation (%)				
Farmer	66.8 (64.6–69.0)	6.3 (4.5–8.1)	0.9 (0–1.9)	
Nomad	12.0 (10.5–13.5)	0	1.3 (0.1–2.5)	
Sedentary	8.0 (6.7–9.3)	47.0 (43.3–50.7)	26.6 (21.8–31.4)	
Others	13.2 (11.6–14.8)	46.7 (43.0–50.4)	71.2 (66.2–76.2	
Housewife	2.6 (1.9–3.3)	27.2 (23.9–30.5)	28.8 (23.8–33.8)	
Manual labourer	0	0.9 (0.2–1.6)	17.9 (13.7–22.1)	
Monk	6.8 (5.6–8.0)	5.0 (3.4–6.6)	0.3 (0–0.9)	
No job	1.5 (0.9–2.1)	5.9 (4.1–7.7)	22.3 (17.7–26.9)	
Retired sedentary	2.3 (1.6–3.0)	7.8 (5.8–9.8)	1.9 (0.4–3.4)	

p; χ^2 Test for the comparison of the prevalence of hypertension and BMI≥25 (%) among the three groups, and ANOVA for the comparison of mean age among the three groups.
ANOVA, analysis of variance; BMI, body mass index; SpO_2, oxyhaemoglobin saturation measured by a pulse oximeter.

compared with women. The epidemiology of hypertension on the Tibetan plateau carried out by Sun and shinfu,[12] however, reports a higher prevalence of hypertension in women in all age groups. This difference in results might be influenced by there being more females in their cohort, as well as possible differences in obesity that are not shown in their report.

Though age-standardised prevalence of hypertension in Leh block (30.7%) was not high compared with other rural areas (24.6–36.8%), higher prevalence of hypertension in Leh town (45.5%) and higher prevalence of overweight in Leh block (32.7%) and Leh town (33.6%) were found compared with other rural areas (overweight; 7.8–20.2%). The high prevalence of overweight may be brought about because Leh block is somehow a more developed subdivision than the others in this study. Urbanisation can change the lifestyle of the people and their diet habits, which may result in obesity and high prevalence of hypertension. Dietary quantity intake as assessed by our nutritionist (Y.K) by a 24 h recall method showed that energy intake was higher in Leh town (2305 kcal in men and 1933 kcal in women) as compared to higher altitude at Changthang (2029 kcal in men and 1802 kcal in women). Variety of food intake as assessed by 11-item Food Diversity Score Kyoto (FDSK-11) was higher in Leh (6.7±1.8) as compared to higher altitude Changthang (6.1±1.5).[26–28] Economic conditions, traditional food culture and a harsh environment with limitation of resources affect energy intake and food diversity. In urban Leh and Leh block, the economic condition of the population is better. Bread, mutton, rice, pulses, vegetables, thukpa and eggs are the main dietary foods, with snacks of

sweet tea, biscuits, and fast food. Such a diet increases their calories, resulting in high BMI, and increases their salt intake, contributing to the higher prevalence of hypertension. One of the villages in Leh block, Stok, was a study centre in the Indian component of the Intersalt study,[29] an international study to determine the relationship of blood pressure with dietary ingredients, particularly sodium and potassium. Urinary sodium (means (and SD) calculated for men aged 20–39, men aged 40–59, women aged 20–39, and women aged 40–59 and then averaged over age and sex groups) was 203.7 mmol/24 h (75.0) and urinary potassium was 47.0 (19.2) mmol/24 h with a poor potassium sodium ratio. Although the data pertain to the year 1988, there is every reason to surmise that the situation which persists as a condition of socioeconomic improvement without parallel improvement in health awareness prevails even today. There is a recent report on the effect of using a low-sodium, high-potassium salt substitute for Tibetan highlanders with hypertension.[30]

Domkhar valley in Sham subdivision situated along the Domkhar stream is about 25 km long and divided into three hamlets of different altitudinal contour and diversified environment. Paba, rice, bread, thukpa, sku, kholak and the local beverage chang are the main diets. Meat is rarely available. Fresh fruit is available in plenty in lower Domkhar and at some places in middle Domkhar, but none in upper Domkhar due to its high-altitude location (Altitude 3800 m). Prevalence of hypertension is very high here (39.1%) among the rural subdivisions. The prevalence of hypertension, especially in Sham subdivision, was as high as that in Leh town in the old age group above 60 years (Sham: 56.0% vs Leh town:

Table 9 The effect of altitude, occupation and dwelling area on hypertension adjusted with age, sex and overweight by multiple logistic regression analysis

	n	Model-1			Model-2			Model-3		
		OR	CI	p Value	OR	CI	p Value	OR	CI	p Value
Age (year)										
20–39	505	1.00			1.00			1.00		
40–59	1198	2.43	1.84 to 3.22	<0.0001	2.78	2.08 to 3.71	<0.0001	2.85	2.12 to 3.83	<0.0001
60–74	844	5.66	4.24 to 7.55	<0.0001	6.93	5.09 to 9.43	<0.0001	7.20	5.26 to 9.86	<0.0001
75–	253	11.40	7.89 to 16.46	<0.0001	14.45	9.82 to 21.26	<0.0001	14.71	9.93 to 21.79	<0.0001
Male (vs female)	1240 (1560)	1.02	0.86 to 1.21	ns	0.95	0.80 to 1.13	ns	1.00	0.84 to 1.20	ns
BMI ≥25 (vs BMI <25)	683 (2117)	2.60	2.14 to 3.13	<0.0001	2.51	2.07 to 3.05	<0.0001	2.52	2.08 to 3.06	<0.0001
Altitude (m)										
2500–2999	417	1.00			1.00			1.00		
3000–3499	428	1.78	1.30 to 2.44	<0.001	1.62	1.17 to 2.23	<0.01	1.44	1.04 to 2.01	<0.05
3500–3999	1604	1.42	1.10 to 1.83	<0.01	1.34	1.02 to 1.75	<0.05	1.16	0.88 to 1.54	ns
4000–4499	174	1.01	0.67 to 1.53	ns	1.37	0.87 to 2.15	ns	1.40	0.88 to 2.20	ns
4500–	177	1.19	0.79 to 1.79	ns	2.57	1.41 to 4.68	<0.01	2.69	1.48 to 4.90	<0.01
Occupation										
Farmer	1247				1.00			1.00		
Nomad	220				0.42	0.24 to 0.72	<0.01	0.37	0.22 to 0.64	<0.001
Sedentary worker	549				1.56	1.20 to 2.02	<0.001	1.02	0.74 to 1.40	ns
Others	784				0.99	0.80 to 1.23	ns	0.68	0.52 to 0.90	<0.01
Dwelling area										
Rural areas	1798							1.00		
Dwellers in Leh town	683							1.92	1.45 to 2.55	<0.0001
Migrants from Changthang	319							1.70	1.21 to 2.38	<0.01

Model-1: The effect of altitude on hypertension adjusted with age, sex and overweight.
Model-2: The effect of altitude and occupation on hypertension adjusted with age, sex and overweight.
Model-3: The effect of altitude, occupation and dwelling area on hypertension adjusted with age, sex and overweight.
BMI, body mass index; ns, not significant.

61.7%) and in the higher altitude level of 3500–3999 (Sham: 46.4%, Leh town: 43.5%) in spite of a much lower rate of overweight in Sham (17.1%) compared with Leh town (33.6%). Different from people in the Leh block subdivision, people in Sham had much poorer availability of foods for a long time until recently and they may have vulnerability to the recent quick change of dietary habits, especially in older people and those dwelling in remote areas at higher altitude. We showed the high prevalence of impaired glucose tolerance (35%) in old people in Domkhar compared with Tibetan people in Qinghai, China in the previous report. We also suggested that there may be a vulnerability to glucose intolerance brought on by recent changes in lifestyle in people with long-term backgrounds of economically traditional lifestyles with limited food resources.[31]

Mutton, rice, momo (mutton), thukpa (comprising of Atta, vegetable mostly dry and dry cheese), kholak (Barley flour with local tea) and paba (a mix of barley flour, wheat flour and grounded pea cooked in plain water with salt added to taste) are the main diets of the Changthang population in both Ladakhis and Tibetans. Taking snacks is not in their food culture, and nor are modern snack items available at that remote high-altitude region. A relatively lower prevalence of hypertension was observed in Changthang Tibetan natives (19.7%) and Changthang Ladakhis (31.9%) living at higher altitude (4000–4900 m).

Zanskar subdivision, located at an intermediate high altitude (3500–3900 m), has a population mainly concerned with farming and cattle rearing. Butter tea, local beverage chang, thukpa, barley flour kholak, rice and pulses are the main dietary foods; meat is rarely eaten. Fresh fruit and vegetables are usually not available in Zanskar and Changthang. The crude prevalence of hypertension in Zanskar appears to be high (36.3%) but age-standardised prevalence (32.1%) was the same as in other rural areas, as the mean age was highest in Zanskar (table 4).

Modernised sedentary workers, rural-to-urban migrants, and dwelling in urban area population (Altitude 3300–3600 m) had a higher prevalence of hypertension and increased BMI as compared to the rural population. Previous reports support our hypothesis of highlanders' vulnerability to hypertension by socioeconomic globalisation.[12–14 31–34] A higher prevalence of hypertension was reported in Tibetans compared with immigrant Hans in the Tibetan plateau, with the prevalence being greater in the urban population around Lhasa than in the rural population.[12] In another report, a longitudinal survey was carried out in the prevalence of hypertension in people over 15 years in different ethnic groups in China in 1991 and 2002. The prevalence of hypertension in Tibetan people increased from 17.8% (in 1991) to 24.7% (in 2002), which was the highest compared with the other seven ethnic groups including Han (from 11.3% to 16.2%).[32] A recent report showed that the prevalence of hypertension (SBP≥140 or DBP ≥90 or treatment) in 1289 Tibetan highlanders (Lhasa and suburbs; 3700–4200 m) aged 18 and more was 39%.[13] Another report showed that the prevalence of hypertension in 692 Tibetan highlanders (rural area of Lhasa; 3700 m) aged 30–80 years was 37% (SBP≥130 or DBP ≥85 or treatment).[14] The prevalence of hypertension was close to our result of 37% and higher than that of Chinese lowlanders aged 20 years and more (27% in 2007–2008).[15] Blood pressure in 332 highlanders in Leh (13–81 years old, mean 50 years) was compared with those in U town, Hokkaido, Japan (24–79 years, mean 56.8) in 2004. Higher DBP and a larger increase in blood pressure with age were observed in people living at a high altitude, as compared with Japanese living at a low altitude.[35] Younger people, but not adults and elderly people, among Tibetan immigrants from Leh to the lowlands in India were reported to have higher blood pressure compared with those living in the highlands. Measurements of adiposity had a significant effect on BP.[33] The prevalence of hypertension was higher (72.7%) in Tibetan highlanders in Shangrila (Altitude: 3300 m) compared with lowlanders in Jing Hong (57.0%) and Tosa (59.9%). There was a significant association between living in an urban area with a higher prevalence of hypertension and obesity in younger people under 60 years compared with those living in a rural area.[34] Younger people may be more vulnerable to hypertension by a quick modernised lifestyle change. Also in our report, a higher prevalence of hypertension in Leh town (44.7%) was observed, especially in the middle-aged group of 40–59 years, compared with other areas (19.6–30.7%).

A higher OR of altitudes from 3000 to 3999 m compared with an altitude below 3000 m was observed after adjustment with age, sex and overweight. One reason may be socioeconomic factor, as this altitude level was compatible with that of the urban area of Leh town and urban dwellers had a higher rate of hypertension and obesity by lifestyle change compared with rural dwellers. Another reason may be the effect of high altitude itself, as the dwellers in Sham subdivision at the altitude of 3000–3999 m had a higher prevalence of hypertension in spite of a lower prevalence of overweight compared with those dwelling below 3000 m. The highest prevalence in older people was shown at a higher altitude over 4000 m. Moreover, the prevalence of hypertension rose closely with altitude remarkably in farmers (p<0.001), mildly in sedentary workers (p=0.09) and insignificantly in nomads (table 5). That is the reason why the higher altitude range of 3000–3999 and 4500– (OR 2.18) kept significant association with hypertension after adjustment with age, occupation or dwelling area by the multivariate analysis, which also supports the effect of high altitude itself to hypertension.

The limitation of this paper is that it did not look into the genetic factors, as environmental and genetic factors may contribute to regional and racial variations of blood pressure and prevalence of hypertension. Genetic

evidence for high-altitude adaptation in Tibetan people was reported recently.[36][37] A relatively lower prevalence of hypertension in spite of a higher one of overweight in Changthang Tibetan natives (hypertension/overweight; 19.7% vs 31.9%/39.5% vs 10.4%) compared with Changthang Ladakhi living at higher altitude (4000–4900 m) was observed in our report. The association between the hypoxic adaptation gene and hypertension should be studied further. The strength of this study is that it looked into most of the environmental factors known to influence hypertension in the population of different distinct geographical subdivisions of a high-altitude region. This study showed the influence of ageing, overweight, modernised sedentary occupations and rural-to-urban migration and dwelling in urban areas to hypertension as well as the effect of high altitude on hypertension by multivariate analysis.

The conclusion reached is that like everywhere else in the world, hypertension prevalence in a high-altitude population has multifactorial aetiology. Our study shows that age, gender, socioeconomic factors, culture, race and changing lifestyle play a big role with the effect of high altitude itself on the high prevalence of hypertension.

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