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LUNG FUNCTIONS AND THEIR CORRELATIONS WITH HEIGHT, WEIGHT AND BODY SURFACE AREA AMONG THE HIGH AND LOW ALTITUDE MONPAS OF ARUNACHAL PRADESH, INDIA

ABSTRACT: Background and objectives: Generally highlanders show altitudinal stresses on biological traits than their lowland counterparts. This study examines lung functions and their correlations with height, weight and body surface area in two Monpas groups namely, the Dirang and Tawang Monpas residing in low and high altitude area of Arunachal Pradesh.
Methods: Anthropometric measurements were taken and lung functions tests were conducted among the adults aged 18–55 years.
Results: Tawang Monpas are taller than Dirang Monpas, while Dirang Monpas are heavier than Tawang Mnpas. Values of lung function tests are higher in Dirang males than Tawang males. But in females no such trend emerges. In contrary to other Indian studies lung function values are more related to stature than body weight in these populations.
Interpretation and Conclusion: Pearson coefficient of correlation ('r') between anthropometric and respiratory parameters shows statistically significant association in 3 cases (out of 24 cases) in Dirang Monpas and in 13 cases (out of 24 cases) in Tawang Monpas. This is indicative of altitudinal stresses on biological traits in highlander Tawang Monpas.

KEY WORDS: Anthropometric traits - Respiratory parameters - Correlation - Monpas - Altitudinal difference

INTRODUCTION

Men have been familiar since long with the fact that the conditions of life are usually harder and breathing is more difficult in high altitude areas than in low altitude ones, and that striking functional and morphological differences exist between high and low altitude populations. An appreciable proportion of the

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world population live permanently at elevations of 3000 m or higher and are exposed to a harsh environment, known as "high altitude", which in reality comprises a constellation of stresses, namely, hypobaric hypoxia, cold, rugged terrain, high dosage of ultraviolet radiation, iodine deficiency, limited natural resources etc. (Gupta *et al.* 1989).

There are good numbers of studies on the effects of altitudinal stresses on human biological traits in Latin America, East Africa and Tien Shan (Harrison *et al.* 1969, Baker, Dutt 1972, Hoff 1974, Mazess 1975, Frisancho 1976, Cruz-Coke 1977, Schull, Rothhammer 1978). Systematic and comprehensive studies of high altitude human biology are few in South Asia and more precisely in India. To mention, Gupta and Basu (1981) conducted a comparative biomedical survey of fertility, mortality, body dimensions, dietary intakes, intestinal parasitic load, haematological status etc. among the Sherpas of Upper Khumbu (3500–4500 m), Nepal, and Kalimpong subdivision (1000–1500 m), West Bengal, India. Physical growth among Tibetans at high and low altitudes in India was studied by Tripathy and Gupta (2007). While, Malik and Singh (1978) examined the growth trends among Bods (male) highlanders of Ladakh, Bhasin and Singh (1992) studied physical growth and respiratory functions in two high altitude populations namely, Bodhs and Baltis of Ladakh. In an another study Tyagi *et al.* (2008) conducted a study on an endogamous population of the Rajput caste group staying in the Sirmaur district (2438 m - 3048 m) of Himachal Pradesh. High altitude populations namely, Spitian of Spiti valley (Himachal Pradesh), Rajput Bhotia of Mana valley of Chamoli district (Uttarakhand) and Kinnaura male Rajputs of Himachal Pradesh were studied by Singh *et al.* (1986), Sidhu *et al.* (1985) and Malhotra (1975) respectively. However, no such study on human biology of highland populations is reported from North-East India in general and Arunachal Pradesh in particular. This paper deals with lung functions and their correlations with height, weight and body surface area in two Monpa groups namely, the Dirang and Tawang Monpas residing in low and high altitude of Arunachal Pradesh.

MATERIAL AND METHODS

To conduct this study, healthy, 303 adult Dirang (Male: 164, Female: 139) and 454 Tawang (Male: 239, Female: 215) Monpas were selected in the age group of 18–55 years. Dirang Monpa data were collected during April-May in 2014, while Tawang Monpa data were collected during May-June, 2015. The subjects were categorized in five groups:

Group A: –20 years;
Group B: 20–29 years;
Group C: 30–39 years;
Group D: 40–49 years and
Group E: 50+ years.

Dirang Monpa: Dirang Monpas are Buddhist by religion, who is one of the sub-groups of Monpa tribe. They inhabit the hilly terrain (1600 m) of West Kameng district of Arunachal Pradesh. This district experiences moderate to heavy rainfall and in the winter it experiences severe cold. Dirang Monpas residing in Dirang town and its surrounding areas were selected for study.

Tawang Monpa: Tawang Monpas are also Buddhist. Like Dirang Monpa they are also one of the sub-groups of the Monpa tribe, who are high altitude (3048 m) people. They inhabit the hilly terrain of Tawang district. This district experiences moderate to heavy rainfall and in the winter it experiences frost and snowfall. For present study Tawang Monpas residing in Tawang town and its surrounding areas were selected.

Pulmonary function tests

Pulmonary function tests were carried out with the help of Helios 702 Spirometer (manufacturer: Recorders and Medicare Systems P Ltd.). Before conducting the tests, subjects were asked whether they have any respiratory problems or not. Subjects with any kind of respiratory problems were excluded from pulmonary function tests. Four readings like, forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1/FVC ratio and peak expiratory flow rate (PEFR) were recorded. Tests were carried out in morning in post absorptive phase. Readings were taken in standing position. Best of the three test readings was considered. Age, height and body weight were recorded in years, centimeters and kilograms respectively. Anthropometric measurements were taken following standard techniques (Weiner, Lourie 1969).

Body surface area (BSA): For BSA, the following formula as suggested by Lee *et al.* (2008) was used:

$BSA\ (cm^2) = 73.31\ Height\ (cm)^{0.725} \times Body\ weight\ (kg)^{0.425}$

Pearson correlation values were obtained using SPSS Statistical Package (Version: 16.0).

RESULTS

Mean and S.D. of age, height (cm), weight (kg) and body surface area (cm^2) are set out in Tables 1a and 1b for Dirang and Tawang Monpas respectively. Mean age of Dirang Monpas (males: 35.57 years; females: 36.59 years) is comparatively higher than Tawang Monpas (males: 31.07 years; females: 31.78 years) in this study. Mean stature is higher in Tawang Monpas (males: 166.16 cm; females: 156.80 cm) than Dirang Monpas (males: 163.24 cm; females: 153.46 cm) when total population is considered. But mean body weight is higher in Dirang Monpas (males: 64.63 kg; females: 60.59 kg) than Tawang Monpas (males: 62.06 kg; females: 55.63 kg). A similar trend is perceptible in case of BSA too i.e. mean BSA is higher in Dirang Monpas (males: 17287.50 cm^2; females: 16079.78 cm^2) than Tawang Monpas (males: 17164.28 cm^2; females: 15727.58 cm^2). However, when these parameters are examined in different age groups it is noticed that though mean stature is higher in different age groups in Tawang than that of the Dirang Monpas for both the sexes, in case of body weight, higher mean is observed in Tawang Monpa males in age group A (-20 years), D (40-49 years) and E (50+ years), and in Tawang Monpa females in age group E. It can be mentioned

TABLE 1a: Mean and standard deviation of anthropometric measurements: Dirang Monpa.

Group	Sex	No.	Age (in years)		Height (cm)		Weight (kg)		Body surface area (cm^2)	
			Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
A	Male	9	18.44	0.52	163.33	5.04	55.22	3.03	16213.93	560.67
(-20 years)	Female	5	18.40	0.54	154.80	8.64	54.0	7.35	15436.50	1361.73
B	Male	50	24.92	3.05	163.46	5.24	61.92	9.95	16994.37	1388.22
(20-29 years)	Female	47	25.04	2.47	153.32	3.93	56.45	9.07	15598.09	1182.77
C	Male	43	34.23	2.88	163.23	5.65	66.21	11.70	17468.82	1578.77
(30-39 years)	Female	35	34.40	3.17	153.63	4.91	62.86	10.88	16350.38	1417.46
D	Male	43	44.0	2.80	163.46	4.77	67.0	10.86	17575.19	1425.72
(40-49 years)	Female	28	43.96	3.25	153.86	6.38	65.14	9.16	16633.32	1239.04
E (50+ years)	Male	19	55.68	3.42	162.16	4.68	67.32	11.09	17506.70	1449.96
	Female	24	57.58	5.81	152.75	4.32	61.46	11.36	16116.67	1389.18
Total	Male	164	35.57	11.21	163.24	5.11	64.63	10.93	17287.50	1455.68
	Female	139	36.59	12.59	153.46	4.95	60.59	10.44	16079.78	1346.13

TABLE 1b: Mean and standard deviation of anthropometric measurements: Tawang Monpa.

Group	Sex	No.	Age (in years)		Height (cm)		Weight (kg)		Body surface area (cm^2)	
			Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
A	Male	82	17.56	1.20	165.50	6.40	59.12	13.12	16783.47	1971.30
(-20 years)	Female	46	16.96	1.09	157.15	6.14	51.26	9.37	15229.02	1444.95
B	Male	52	23.38	3.09	167.19	7.37	57.79	12.0	16742.60	1763.21
(20-29 years)	Female	69	24.12	2.61	157.55	5.73	50.01	7.98	15104.06	1036.54
C	Male	39	33.67	2.93	168.97	8.79	63.64	9.83	17616.85	1492.79
(30-39 years)	Female	49	33.59	2.75	156.77	5.93	56.98	8.93	15916.92	1299.92
D	Male	30	43.93	3.34	164.37	6.91	68.37	11.31	17797.43	1562.32
(40-49 years)	Female	17	44.65	3.14	155.23	4.75	64.06	7.15	16622.01	779.53
E (50+ years)	Male	36	59.42	7.09	164.64	6.76	67.95	13.44	17622.87	2529.84
	Female	34	58.32	5.69	155.65	5.13	66.76	8.86	16947.37	1135.24
Total	Male	239	31.07	15.23	166.16	7.27	62.06	12.83	17164.28	1946.24
	Female	215	31.78	14.21	156.80	5.71	55.63	10.57	15727.58	1374.98

that mean body weight for both the total males and females are higher in Dirang than the Tawang Monpas. Side by side, mean BSA is higher in Tawang Monpa males in age group of A (-20 years), C (30-39 years), D (40-49 years) and E (50+ years), and in Tawang Monpa females in E (50+ years) age group. Similarly, mean BSA is considerably higher in age group A (-20 years), C (30-39 years) and D (40-49 years) in Tawang males, and in E age group (50+ years) in Tawang females.

Tables 2a and 2b show the distribution of Dirang and Tawang Monpa males and females according to lung function tests in different age groups. In males, mean FVC (Dirang: 2.96: Tawang: 2.84), FEV_1 (Dirang: 2.81: Tawang: 2.74) and PEFR (Dirang: 6.82: Tawang: 6.09) are higher in Dirang than the Tawang Monpas, while FEV_1/FVC (Dirang: 95.11: Tawang: 96.84) is higher in Tawang than Dirang Monpas. Means of FVC (Dirang: 2.43: Tawang: 2.43) and FEV1 (Dirang: 2.32: Tawang: 2.34) are more or less same in both Dirang and Tawang Monpa females, while PEFR (Dirang: 5.53: Tawang: 4.37) is higher in Dirang Monpa females and FEV_1/FVC (Dirang: 94.68: Tawang: 96.34) is higher in Tawang Monpa females than their counterpart. Though mean value of FVC, FEV_1, and PEFR gradually decreases with increase in

TABLE 2a: Mean and standard deviation of lung function tests: Dirang Monpa.

Group	Sex	FVC		FEV_1		FEV_1/FVC		PEFR	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
A	Male	2.76	0.77	2.62	0.76	94.51	2.87	7.43	1.62
(-20 years)	Female	2.77	0.61	2.71	0.66	97.02	4.34	5.82	1.55
B (20-29 years)	Male	3.09	0.69	2.93	0.65	94.62	4.82	7.18	1.62
	Female	2.57	0.51	2.48	0.54	96.12	4.65	6.05	1.55
C (30-39 years)	Male	2.99	0.51	2.90	0.46	97.17	4.17	6.97	1.35
	Female	2.43	0.54	2.33	0.61	95.32	5.37	5.70	1.57
D (40-49 years)	Male	2.92	0.57	2.76	0.56	94.65	5.98	6.51	1.75
	Female	2.42	0.58	2.31	0.63	94.61	5.78	5.48	1.59
E (50+ years)	Male	2.72	0.48	2.51	0.46	93.08	9.90	5.91	1.70
	Female	2.08	0.46	1.90	0.49	90.54	5.37	4.29	1.50
Total	Male	2.96	0.60	2.81	0.58	95.11	5.80	6.82	1.64
	Female	2.43	0.55	2.32	0.60	94.68	5.50	5.53	1.65

TABLE 2b: Mean and standard deviation of lung function tests: Tawang Monpa.

Group	Sex	FVC		FEV_1		FEV_1/FVC		PEFR	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
A	Male	3.10	0.67	2.91	0.62	93.97	6.90	6.22	1.86
(-20 years)	Female	2.34	0.40	2.24	0.37	96.21	5.07	4.55	0.98
B (20-29 years)	Male	2.94	0.59	2.87	0.51	98.06	3.62	6.96	1.86
	Female	2.50	0.26	2.44	0.27	97.54	4.56	4.65	1.09
C (30-39 years)	Male	2.68	0.45	2.65	0.45	99.10	2.47	6.91	1.90
	Female	2.47	0.41	2.38	0.42	96.07	7.94	4.22	0.88
D (40-49 years)	Male	2.62	0.41	2.57	0.34	98.59	0.34	5.35	1.41
	Female	2.37	0.36	2.28	0.37	96.25	5.55	4.51	0.94
E (50+ years)	Male	2.45	0.38	2.40	0.37	97.72	3.52	4.29	1.11
	Female	2.37	0.33	2.24	0.35	94.50	8.37	3.73	0.82
Total	Male	2.84	0.60	2.74	0.54	96.84	5.27	6.09	1.94
	Female	2.43	0.35	2.34	0.36	96.34	6.35	4.37	1.01

age in Dirang males as well as females, in case of FEV_1/FVC no such trend of decrease according to age is noticed in males. Mean of FVC and FEV_1 decreases with increase in age in Tawang males. But in Tawang females no such trend is perceptible. In case of FEV_1/FVC also no such trend of increase or decrease according to age is noticed in both the gender.

Comparison between various anthropometric parameters between Dirang and Tawang Monpas is shown in *Table 3a*, while in *Table 3b* comparison between various respiratory parameters between Dirang and Tawang Monpas is shown. The 't' values show statistically significant difference between Dirang and Tawang Monpa males and females in height in B (20–29 years) and C (30–39 years) age groups, and between total populations, while the same is evident between two populations in females in age group E (50+ years). In body weight, the total populations of Dirang and Tawang Monpa differ significantly in both the sexes. The males in age group A (–20 years) and females in age group B show significant difference in terms of body weight and BSA between two populations. However, Dirang females differ significantly with Tawang females in age group E and in case of total populations in BSA (*Table 3a*).

In case of FEV_1/FVC and PEFR the total populations of Dirang and Tawang Monpa differ significantly in both the sexes. But in case of FVC and FEV_1 the 't' value shows no difference between two populations in both the sexes. Statistically significant difference is noticed between Dirang and Tawang Monpa males and females in FVC in age group E. The males in age group D (40–49 years) and females in age group E show significant difference between two populations in FVC and FEV_1 respectively. In FEV_1/FVC, in age group B, C and D the Dirang and Tawang Monpa males and in age group E the Dirang and Tawang Monpa females differ significantly. However, in PEFR, in age group A, D and E males of these two populations and in age group B, C and D females of the two populations differ significantly (*Table 3b*).

Pearson co-efficient of correlation is performed between anthropometric and lung function tests and the 'r' values are furnished in Table 4a for Dirang and Table 4b for Tawang Monpas respectively. It is

TABLE 3a: Comparison (t values) of anthropometric measurements between Dirang and Tawang Monpa. *Significant at 5% level of probability.

Group	Height (cm)		Weight (kg)		Body surface area (cm^2)	
	Male	Female	Male	Female	Male	Female
A (–20 years)	1.19	0.59	2.20*	0.77	1.98*	0.32
B (20–29 years)	2.96*	4.75*	1.89	3.97*	0.80	2.79*
C (30–39 years)	2.10*	2.64*	1.08	1.18	0.44	1.43
D (40–49 years)	0.62	0.82	0.52	0.44	0.62	0.04
E (50+ years)	1.59	2.34*	0.18	1.92	0.22	2.41*
Total	4.71*	5.86*	2.16*	4.35*	0.73	2.38*

TABLE 3b: Comparison (t values) of lung function tests between Dirang and Tawang Monpa. *Significant at 5% level of probability.

Group	FVC		FEV_1		FEV_1/FVC		PEFR	
	Male	Female	Male	Female	Male	Female	Male	Female
A (–20 years)	1.21	1.65	1.12	1.68	0.44	0.39	2.12*	1.79
B (20–29 years)	1.07	0.70	0.43	0.40	4.09*	1.63	0.63	5.38*
C (30–39 years)	0.38	0.40	1.79	0.50	2.61*	0.52	0.17	5.29*
D (40–49 years)	2.14*	0.36	1.90	0.21	4.33*	0.95	3.13*	2.62*
E (50+ years)	2.70*	2.90*	1.10	3.40*	1.98	2.77*	3.86*	1.60
Total	0.00	0.00	0.00	0.00	3.16*	2.63*	4.29*	8.29*

interesting to note that while the 'r' value is statistically significant in 3 parameters only in Dirang Monpas, this value is statistically significant in 13 parameters in Tawang Monpas. Significant correlation is noted in Dirang males between height and FVC, height and FEV_1 and height and PEFR (*Table 4a*), while in Tawang males significant correlation is noticed between height and FVC, height and FEV_1, height and PEFR, weight and FVC, weight and FEV_1/FVC, BSA and FVC, BSA and FEV_1, and BSA and FEV_1/FVC. In Tawang Females correlation is significant between height and FVC, height and FEV_1, height and PEFR, weight and FEV_1/FVC and BSA and FEV_1/FVC (*Table 4b*).

DISCUSSION

Among various investigating modalities available, pulmonary function tests are an invaluable tool for assessment of lung function (Vijayasekaran *et al.* 2003). Pulmonary functions are influenced by anthropometric, environmental, genetic, ethnic, socio-economic and technological variations (Anudhakar *et al.* 1985). Generally, highlanders have been found to be smaller in body size and mass and larger in chest circumference compared with the lowlanders (Gupta *et al.* 1989). In the present study 't values show statistically significant difference between Dirang and Tawang Monpa males and Dirang and Tawang Monpa females in stature, body weight, BSA, FEV_1/FVC and PEFR excepting BSA in males. However, in FVC and FEV_1 no such difference is noticed.

Values obtained from Tawang Monpa, the highlander and Dirang Monpa, the lowlander of Arunachal Pradesh show Tawang Monpas are taller than Dirang Monpas, But body weight is higher in Dirang Monpas than their counterpart. Malik and Singh (1978) observed that the male Bods of Ladakh in the Western Himalaya grew faster than plains dwelling Indians and were taller and heavier than their lowland counterparts. In males, with regard to absolute measurements the high altitude Sherpas had higher values of stature, sitting height and weight compared to the low altitude Sherpas (Gupta, Basu 1981).

Bhasin and Singh (1990) in a study of lung functions and their correlation with height and weight among Dogras of Jammu and Kashmir reported that different pattern of growth observed for stature and body weight may be due to "localized morphological adaptations". Since the Dogra population groups are living in the same physical environment for a quite long time; these differences may also be due to their genetic make-up. Thus, higher value of body height and lower value of body weight among Tawang Monpas than their counterpart is the results of localized morphological

Table 4a: Co-efficient of correlation "r" for height, weight, body surface area and lung function tests: Dirang Monpa. *Significant at 0.05 level (2- tailed); ** Significant at 0.01 level (2- tailed).

Measurements	FVC		FEV_1		FEV_1/FVC		PEFR	
	Male	Female	Male	Female	Male	Female	Male	Female
Height (cm)	0.291**	0.008	0.275**	-0.011	-0.031	-0.088	0.189*	-0.055
Weight (kg)	0.720	0.073	0.102	0.065	0.109	0.000	0.107	-0.043
Body surface area (cm^2)	0.135	0.062	0.158	0.050	0.090	-0.027	0.134	-0.051

Table 4b: Co-efficient of correlation "r" for height, weight, body surface area and lung function tests: Tawang Monpa. *Significant at 0.05 level (2- tailed); ** Significant at 0.01 level (2- tailed).

Measurements	FVC		FEV_1		FEV_1/FVC		PEFR	
	Male	Female	Male	Female	Male	Female	Male	Female
Height (cm)	0.233**	0.233**	0.234**	0.271**	-0.045	0.131	0.215**	0.200**
Weight (kg)	0.133**	0.028	0.089	-0.081	-0.139*	-0.249**	-0.022	-0.103
Body surface area (cm^2)	0.185**	0.105	0.151*	0.016	-0.130*	-0.189**	0.055	-0.035

adaptation as well as genetic make-up in both Tawang and Dirang Monpas.

Body surface area (BSA) is the total area of a human's skin. Physiological phenomena are more closely related to BSA than body weight or height (Lee *et al.* 2008). Rothhammer and Spielman (1972) studied anthropometric variations among high and low altitude Aymara of Chile and found anthropometric distance to closely correspond altitude differences; the high altitude groups had smaller body size and body mass compared to low altitude. Gupta and Basu (1981) in a study of high and low altitude Sherpas found higher value of surface area in the highland Sherpa than their counterpart. In contrary, in Monpas, BSA is found to be higher in lowland Monpas (i.e. Dirang Monpas) than highland Monpas (i.e. Tawang Monpas). This again justified the results of localized morphological adaptation as well as genetic make-up in the studied populations.

Present study reveals higher values of lung function tests in males as compared to females. Though Dirang Monpa males show higher values than Tawang Monpa males, in females no such trend is evident. Various studies in Indian region show that lung functions are positively correlated with body measurements (Bhattacharya 1963, Malik 1975, 1979, Malik, Singh 1979, Singh, Bhasin 1983, Bhasin, Singh, 1990, 1991, 1992). In most of these studies, it has been reported that lung functions are more related to body weight than stature. Contrary to Indian data, lung functions in Dirang and Tawang Monpas are more related to stature than body weight. In Dirang Monpa, none of the lung functions value is correlated with weight, while in Tawang Monpa, FVC is related with weight in males and FEV_1/FVC is related with weight in males and females both. It can also be recapitulated that while the 'r' value is statistically significant in 3 cases (out of 24 cases) only in Dirang Monpas, this value is statistically significant in 13 cases (out of 24 cases) in Tawang Monpas. This signifies altitudinal stresses on biological traits in highlander Tawang Monpas. In fine, it can be said that this study will help us in deriving predictive equations for lung function from healthy Dirang and Tawang Monpa adults.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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