Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 14, Issue 21s (2025)
https://www.jneonatalsurg.com

Ethnic Variations in Spirometric Parameters A Comparative Study

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Cite this paper as: Varsha. M. Shindhe, Fareedabanu. A. Balikai , Amit Magadum , Jyoti. M. Benni , Sudha Ambiger , Maheshkumar. M. Shindhe (2025 Ethnic Variations in Spirometric Parameters A Comparative Study. *Journal of Neonatal Surgery*, 14 (21s),20-28.

ABSTRACT

Objective:
High-altitude adaptation is a multifaceted process involving various physiological adjustments. Tibetans, having inhabited high-altitude regions for centuries, have developed distinctive physiological adaptations to thrive in hypoxic environments. This study aimed to investigate whether Tibetans exhibit superior lung function adaptations compared to the Indian population, and whether these adaptations are innate, enabling them to excel in high-altitude environments.

Material and Methods:

A comparative analysis was performed on 100 male youths, comprising 50 Tibetans and 50 Indians, carefully matched for age, sex, and anthropometric characteristics. Utilizing the Spiroanalyser SPL 95, a comprehensive assessment of lung function was conducted, encompassing vital capacity (VC), expiratory reserve volume (ERV), inspiratory reserve volume (IRV), inspiratory capacity (IC), and tidal volume (TV).

Results:

Tibetan youths demonstrated significantly superior lung function, with notably higher values for vital capacity (VC), expiratory reserve volume (ERV), inspiratory reserve volume (IRV), inspiratory capacity (IC), and tidal volume (TV), compared to their Indian counterparts.

Conclusion:

The marked differences in lung function parameters observed in this study indicate that Tibetans possess unique physiological adaptations, likely rooted in genetic factors, which confer enhanced lung function capabilities. These adaptations enable Tibetans to excel in high-altitude environments, underscoring their remarkable ability to thrive in hypoxic conditions.

Keyword: *genetic inheritance, high altitude adaptation, lung functions, Tibetan population*

1. INTRODUCTION

Lung function is a critical sign of physiological integrity and possible illness, making respiratory health the foundation of overall wellbeing1.

Lung size is influenced by an individual's genetic composition.Additional variance is also influencedby other environmental factors, including selective migration, diet, and regular activity. When combined, these factors lead to ethnic variations in various lung volumes and their related indices2.

Research suggest that besides the significant predictors of pulmonary function, such as age, gender, ethnicity or height, altitude above the sea level serves as an important determinant for lung volumes 3, 4.

Of the various parameters used to assess lung function, slow vital capacity is a key indicator, providing essential information on pulmonary performance1. Inspiratory capacity and vital capacity are crucial parameters of lung function that are significantly impacted by high-altitude adaptation5. Vital capacity is defined as the volume change occurring between maximum inspiration and maximum expiration. The VC can be divided into three subdivisions: tidal volume (TV), inspiratory reserve volume (IRV) and expiratory reserve volume (ERV) 5. Slow Vital Capacity measures maximum volume of the air which can be slowly and fully exhaled following a maximal inhalation, integrating the effects of lung compliance as well as respiratory muscle strength1.

Scientists who study altitude adaptation have been fascinated by the anecdotal exceptional physical performance of Sherpas and Tibetans at high altitudes from the dawn of the Himalayan climbing era. Compared to lowlanders, Tibetans have larger lungs, improved lung function, a larger lung diffusing capacity, and greater hypoxic and hypercapnic ventilatory response. The idea that a potential evolutionary genetic mediated adaptation to high altitude makes sense as these ethnic groups might have lived at high elevations for prolonged duration than any other community 6.

Native Tibetans have inhabited Tibetan Plateau, with an average elevation of about 3000-5000 meters, for approximately 25,000 years7. Over time, they have developed unique genetic adaptations that enable them to thrive in this high-altitude, low-oxygen environment8,9. These adaptations have allowed Tibetans to maintain adequate oxygen delivery to their bodies, despite the reduced oxygen availability at high elevations 6 .

Despite the fact that numerous studies have compared the lung function tests of Tibetans with those of Han, Chinese, Sherpas, and other ethnic groups, studies comparing the lung function tests of Tibetans and Indians are scarcely available. These factors have prompted us to investigate how young Tibetans' respiratory systems function. We aim to determine whether the genetic makeup of these young Tibetans still confer excellent respiratory parameters, similar to those of their ancestors, or if environmental factors have led to a diminution of these effects over time.

Material and Methods

Our study was a comparative case control study, accounting 10 months study time duration. In this study we examined the pulmonary functions of 50 healthy Tibetan male young adults aged 20-30 years residing in a Tibetan resettlement camp, Karnataka , southern part of India. For comparison, we included same number of Indian male adults who served as controls. This study was conducted in Mundgod at the Doeguling Tibetan Resettlement, with formal approval from hospital administration. To facilitate effective communication and ensure participant cooperation, the research team conducted three preliminary visits to the Tibetan camp in Mundgod. These visits enabled the team to explain the study's goals , test protocol methods, and benefits to the Tibetan participants in their native language, with the assistance of local doctors, medical professionals and technicians.

For the current study, 50 Indian students from a medical institute in north kannada district ,southern India who were matched for height, weight and age served as controls.

Participants were selected randomly according to predetermined inclusion and exclusion criteria.

Inclusion Criteria

Healthy Tibetan and Indian young males aged between 20-30years willing to actively participate in the study.

Exclusion Criteria

Participants not willing to participate in the study

Age outside the range of 20-30 years

H/O Smoking

H/O Occupational exposure to particulate matter and dust

H/O Tuberculosis or Chronic Obstructive Lung Disease

H/O Obstructive Sleep Apnea , Cardiopulmonary diseases

H/O Diabetes Mellitus , Hypertension

Current or past history of Chest and spine bone deformities

Allergies or Use of Narcotics

The Institutional research and ethics committee approved the study and its methodology. Prior authorization from subjects and controls was obtained before the tests were actually conducted, and a written informed consent from all study participants was obtained. Both subjects and controls completed a comprehensive proforma, and each subject underwent a detailed clinical examination to rule out any noteworthy findings that would fall within the exclusion criteria. Participants received a demonstration of the test and practiced the procedures until they were comfortable with the techniques.

Each subject's weight and height were noted.The Dubois nomogram was used to calculate body surface area (BSA). The formula used to calculate BMI was Weight in kg/Ht in m2. Vital signs such as pulse rate, blood pressure and respiratory rate were recorded.

A detailed clinical examination was performed to evaluate cardiovascular, respiratory and central nervous system.

For assessing the pulmonary functions, the instrument Spirolyser SPL-95 was used. Every day, the device was calibrated using a two-liter calibration syringe.

Recording of Slow Vital Capacity parameters

Prior to testing, all participants received a detailed explanation and demonstration of the maneuver from the technician, the test was performed in a seated position. The subject's mouth is fitted with a pneumotachograph mouthpiece, which they seal firmly with their lips. After applying a nose clip , the test is initiated by pressing the start button .

The subject is instructed to first breathe normally for 3 cycles, then Perform maximum inspiration followed by maximum expiration for 1-2 times and then resume normal breathing.

The test automatically terminates after 50 seconds. The system displays the following values:

Vital Capacity (VC), Inspiratory Reserve Volume (IRV) , Expiratory Reserve Volume (ERV) and Tidal Volume (TV).

A second VC test is conducted in the same manner. The system stores two readings, and the best result is selected for printing.

The collected data was compiled, analyzed, and presented in a descriptive statistical format, expressing results as mean ± standard deviation (mean ± "S.D."), to facilitate comparison of anthropometric, vital, as well as pulmonary function test parameters between Tibetan and Indian populations. Unpaired Student's t-test was employed to determine significant differences in pulmonary function parameters between the two groups using SPSS version 20.

A "p-value"of less than 0.05 was considered statistically significant, with a confidence interval of 95%

Results

Anthropometric data:

The Anthropometric parameters of Tibetan and Indian youths were compared, revealing no statistically significant differences between the two groups. The mean age in Tibetan population was 25.6 ± 4.1 years, while that in Indian population was 24.4± 3.0 years. Similarly, the mean height in Tibetan population was 169.7 ± 6.6 cm, compared to 169.0 ± 6.1cm in Indians. The mean weight in Tibetan population was 66.3 ± 11.6 kg, while that in Indian population was 65.0± 9.0 kg. Additionally, mean body mass index in Tibetan population was 23 ± 3.6 kg/m2, compared to 22.7 ± 2.4 kg/m2 in Indians. Finally, the mean body surface area (BSA) of Tibetans was 1.7 ± 0.2 sq.m, while that of Indians was 1.7 ± 0.2 sq.m. Overall, these findings indicate that the two groups were well-matched in terms of anthropometric parameters .

The anthropometric characteristics of the Tibetan population are summarized in Table 1.

Table 1: Comparison of Anthropometric data between Tibetan and Indian groups

Variables	No. of subjects	Age (Years) Mean±"S.D."	Height (cm) Mean±"S.D."	Weight (kg) Mean±"S.D"	BMI (kg/m^2) Mean±"S.D"	BSA (sq.m) Mean ±"S.D"
Tibetans	50	25.6± 4.1	169.7± 6.6	66.3± 11.6	23± 3.6	1.7± 0.2
Indians	50	24.4± 3.0	169.0 ± 6.1	65.0± 9.0	22.7 ± 2.4	1.7± 0.2
"p-value"		> 0.05	> 0.05	> 0.05	> 0.05	> 0.05

"p-value": < 0.001 (HS) Highly significant,

"p-value": 0.01 to 0.05 (S) Significant,

"p-value": > 0.05 (NS) Not significant

"S.D." : Standartd Deviation

(cm): centimetres

(kg): kilograms

BMI (kg/m2): Body Mass Index in Kilogram per Meter Square

BSA (sq.m): Body Surface Area in Square Meter

2. Vitals data:

The vitals data revealed significant differences between Tibetan and Indian groups in certain parameters. The mean respiratory rate was significantly higher in Tibetans (16.6 ± 2.8 breaths/min) compared to Indians (15.9 ± 2.4 breaths/min). Similarly, Tibetans had a significantly higher mean pulse rate (78.3 ± 4.8 beats/min) at rest compared to Indians (75.2 ± 3.9 beats/min).

In terms of blood pressure, Tibetans had a slightly higher mean systolic blood pressure (122.6 ± 5.3 mmHg) compared to Indians (120.7± 6.0mmHg), although the difference was not statistically significant. However, the mean diastolic blood pressure was significantly lower in Tibetans (77.5 ± 4.5 mmHg) compared to Indians (79.7 ± 5.5 mmHg) . The vital parameters of the Tibetan and Indian populations are presented in Table 2.

Table 2: Comparison of Vitals data between Tibetan and Indian groups

Variables	No. of Subjects	RR/ min Mean±"S.D."	PR /min Mean±"S.D."	SBP (mmHg) Mean±"S.D."	DBP (mmHg) Mean ±"S.D."
Tibetans	50	16.6± 2.8	78.3± 4.8	122.6± 5.3	77.5 ± 4.5
Indians	50	15.9 ± 2.4	75.2± 3.9	120.7± 6.0	79.7± 5.5
"p-value"		< 0.01	< 0.001	> 0.05	< 0.05

"p-value": < 0.001 (HS) Highly significant,

"p-value": 0.01 to 0.05 (S) Significant,

"p-value": > 0.05 (NS) Not significant

"S.D." : Standartd Deviation

PR (Beats/minute):Pulse Rate as Beats per Minute.

RR: Respiratory Rate per Minute

SBP (mmHg):Systolic Blood Pressure in millimetres Mercury

DBP (mmHg) Diastolic Blood Pressure in millimetres Mercury

Slow Vital Capacity Parameters:

Tibetans demonstrated a higher Vital Capacity of 4.7 ± 0.4 L, compared to Indians who had a VC of 3.8 ± 0.2 L ("p-value" < 0.001).

Similarly, Tibetans had a higher Expiratory Reserve Volume (ERV) of 1.3 ± 0.4 L, whereas Indians had an ERV of 0.9 ± 0.2 L ("p-value" < 0.001).

The Inspiratory Reserve Volume (IRV) was also higher in Tibetans, measuring 2.7 ± 0.4 L, compared to 2.2 ± 0.2 L in Indians ("p-value"< 0.001).

Additionally, Tibetans had a higher Inspiratory Capacity (IC) of 3.4 ± 0.4 L, whereas Indians had an IC of 2.8 ± 0.2 L ("p-value" < 0.001).

Lastly, Tibetans demonstrated a higher Tidal Volume (TV) of 0.6 ± 0.1 L, compared to 0.5 L in Indians ("p-value"< 0.001).

These results collectively indicate that Tibetans possess better lung function adaptations compared to Indians. Table 3 presents the Slow Vital Capacity (SVC) parameters for both Tibetan and Indian populations.

Table 3: Comparison of Slow Vital Capacity parameters between Tibetan and Indian groups

riables	Tibetans	Indians	‘t’ value	“p-value”
No. of Subject	50	50		
VC in Litres Mean±“S.D.”	4.7 ± 0.4	3.8 ± 0.2	1.4	< 0.001 HS
ERV in Litres Mean±“S.D.”	1.3 ± 0.4	0.9 ± 0.2	5.38	< 0.001 HS
IRV in Litres Mean±“S.D.”	2.7 ± 0.4	2.2 ± 0.2	8.12	< 0.001 HS
IC in Litres Mean±“S.D.”	3.4 ± 0.4	2.8 ± 0.2	9.66	< 0.001 HS
TV in Litres Mean±“S.D.”	0.6± 0.1	0.5	5.35	< 0.001 HS

“p-value”: < 0.001 (HS) Highly significant,

“p-value”: 0.01 to 0.05 (S) Significant,

“p-value”: > 0.05 (NS) Not significant

“S.D.” : Standartd Deviation

Vital Capacity (VC), Expiratory Reserve Volume (ERV), Inspiratory Reserve Volume (IRV), Inspiratory Capacity (IC), and Tidal Volume (TV)

2. DISCUSSION

The present study revealed statistically highly significant differences in various lung function parameters between Tibetan and Indian youths, despite matching for age, gender and anthropometric parameters. Specifically, Tibetan youths exhibited higher values for: Tidal Volume, Inspiratory Reserve Volume, Expiratory Reserve Volume, Inspiratory Capacity as well as Vital Capacity. These differences may be attributed to several factors, including: Stronger contraction forces of respiratory muscles, Higher thoracic compliance, favorable thoracic mechanical properties, combined with significantly improved lung parenchymal function 10.

These results indicate that Tibetan youths have evolved distinct physiological adaptations that confer superior lung function, setting them apart from their Indian peers.

In the present study, Vital Capacity was significantly higher in Tibetans (4.7 ± 0.4 L) compared to Indians (3.8 ± 0.2 L) (“p-value” < 0.001), indicating a substantial difference in lung function between the two groups. Vital Capacity assessment evaluates maximum inspiratory and expiratory efforts, providing insight into respiratory muscle strength 11.

Chen et al. (1997) conducted a comparative study on Tibetan and Han adolescents living at high altitudes (3417m and 4300m). The results showed that: Tibetan adolescents exhibited significantly higher vital capacity and maximal voluntary ventilation at rest compared to their Han counterparts. These findings indicate that Tibetans have developed remarkable physiological adaptations, optimizing their oxygen uptake and transport, thereby enabling them to thrive in the oxygen-depleted high-altitude environment 12.

Likewise another study by Droma T., McCullough R. G., "et al", reported that Tibetans had increased vital capacity and total lung capacity compared to Han residents. Additionally, the study found that Tibetans had a greater chest circumference than Han subjects 13.

Our study found that Tibetan youths had a significantly higher Expiratory Reserve Volume (ERV) of 1.3 ± 0.4L compared to Indian controls at 0.9 ± 0.2L ("p-value" < 0.001). This difference may be attributed to stronger contraction forces of expiratory muscles, including the anterior abdominal wall muscles and internal intercostal muscles, in the Tibetan population 14.

In our study, Tibetans had a significantly higher Inspiratory Reserve Volume (IRV) of 2.7 ± 0.4 liters compared to Indians at 2.2 ± 0.2 liters ("p-value" < 0.001), indicating a notable difference in lung function between the two groups. The Tibetan group had a significantly higher Inspiratory Capacity (IC) of 3.4 ± 0.4 liters compared to the Indian group at 2.8 ± 0.2 liters, with a highly significant statistical difference ("p-value" < 0.001). The observed differences in lung function may be attributed to several factors, including stronger inspiratory muscle contractions, increased activity of the dorsal respiratory group (DRG) neurons, and potentially greater transpulmonary pressure 15.

Tibetans had a significantly higher Tidal Volume (TV) of 0.6 ± 0.1 liters compared to Indians at 0.5 liters, with a highly significant statistical difference ("p-value"< 0.001).

Similar to our study, a 1990 study by Sun S.F. "et al". found that Tibetans' greater tidal volumes resulted in increased minute ventilation. Additionally, a positive correlation was observed between maximal tidal volume and resting vital capacity 16.

A 1993 study by Zhuang J. "et al". found that Tibetan young men had higher minute ventilation compared to Han young men, which was attributed to an increased respiratory frequency 17.

Research conducted by Beall C. M., Strohl K. P, "et al". revealed that Tibetans' resting ventilation was approximately 1.5 times higher compared to other populations, highlighting a distinct physiological adaptation 18.

A study by Ge, R. L., Chen Q. H., "et al". found that Tibetans had significantly lower minute ventilation at maximal exercise compared to Han individuals. This difference may be attributed to genetic or peripheral adaptation factors unique to the Tibetan population 19.

A 2002 study by Weitz C.A., Garruto R.M., "et al". found that growing up at high altitude results in small to moderate increases in lung volumes (approximately 6%) compared to genetically similar groups raised at low altitude 20.

The Tibetan youths in this study had ancestors who lived at high altitude from birth, whereas the Indian youths were born at sea level. Lung function is shaped by various factors, including anatomy of chest wall, thoracic mechanical properties, parenchymal lung development, and body mass index10 .

Comparative studies have investigated the physiological adaptations of Tibetans in relation to other high-altitude populations. A notable study by Beall "et al". (1997a) compared ventilation and hypoxic ventilatory response (HVR) between Tibetans and Bolivian Aymara living at similar elevations. The results showed that Tibetans exhibited significantly higher resting ventilation (approximately 1.5 times greater) and HVR (approximately double) compared to the Aymara 18. A notable difference was observed between Tibetans and Aymara, with 35% of the variation in resting ventilation among Tibetans attributed to genetic differences. In contrast, no such genetic influence was detected in the Aymara. This suggests that Tibetans possess a greater genetic potential for evolutionary adaptation in traits related to high-altitude ventilation6,18.

Another study done by Marconi C, Marzorati M, Grassi B, Tibetan lowlanders, having inherited genetic adaptations from their ancestors, are likely to exhibit enhanced cardiorespiratory performance. Notably, they have smaller muscle fiber cross-sectional areas, which may facilitate a shorter diffusion path for oxygen at the muscular level, potentially contributing to improved oxygen delivery and utilization 21.

Further research is necessary to elucidate the specific genetic factors that influence the characteristics of ventilatory functions in Tibetan youths 6.

CONCLUSION

Our study reveals that despite facing similar environmental conditions, Tibetan youths exhibit better lung function compared to Indian youths, suggesting a genetic basis for this difference and hence our study supports the notion that Tibetans have evolved unique physiological adaptations to thrive in high-altitude environments. These adaptations encompass changes in lung function, oxygen transport, and utilization, enabling Tibetans to cope with hypoxic conditions. The Tibetans in our study retained superior lung function, likely due to the inheritance of genetic factors that favor high-altitude adaptation. In contrast, Tibetan youths in this study had lower pulmonary function test values compared to their counterparts residing in Tibet. Further studies are needed to clarify the genetic mechanisms that contribute to the distinctive ventilatory functions observed in Tibetan youths. Elucidating the genetic mechanisms driving high-altitude adaptation in Tibetans will provide valuable insights into the evolution of human physiology.

Acknowledgement

We extend our sincere gratitude to the Head of the Department of Physiology and the Institution's Research Committee for their approval and support in conducting this study. We also appreciate the enthusiastic participation and cooperation of all the volunteers who made this study possible. Special thanks to the Incharge Doctor and the Lab Technician at the Doeguling Tibetan Resettlement Hospital, Mundgod, Karnataka, for their invaluable assistance and facilitation throughout the study.

Funding sources: Self funded.

Conflict of Interest

Nil.

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