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EFFECTS OF YOGIC INTERVENTIONS ON CARDIOPULMONARY AND ENDOTHELIAL HEALTH AT HIGH ALTITUDE: A PROSPECTIVE LONGITUDINAL INTERVENTIONAL STUDY

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ABSTRACT

High-altitude sojourn may lead to risk factors for high-altitude disorders and subsequent altitude sickness. This study was aimed to analyse the effects of sea-level yoga practices on individuals when they ascend to high altitudes (HAs). Healthy male subjects were randomly divided into two groups i) yoga group (n = 43) and ii) control group (n = 44). One month of yoga training was given to the yoga group for 30 min daily. The control group was provided daily routine for one month. Blood samples were collected when subjects were in fasting condition at sea level and at high altitude. The pulmonary function, blood pressure, cardiovascular and resting metabolic parameters and estimated markers of endothelial homeostasis were monitored at sea level and then at high altitude. The study revealed that yoga group had enhanced pulmonary functions ($p < 0.001$), maintained blood pressure, and increased endothelial homeostasis markers such as corin and ACE; and showed decrease in $VO_{2resting}$ and hypoxia-induced endothelial leak parameters such as Angptl4, sKDR. In control group, the blood pressure, VO_2, VCO_2, and Angptl4 increased, while ACE, corin, and sKDR decreased. Sea-level yogic intervention before ascending to high altitude was found helpful for individuals.

Keywords: Altitude, blood pressure, cardiopulmonary health, hypoxia, yoga

INTRODUCTION

People travel to high altitudes (HAs) for recreational sports (skiing, trekking, and climbing), tourism, and pilgrimage (Bärtsch and Swenson, 2013). Human movements in highly hostile environments such as HA are unavoidable for defence personnel, sojourners, miners, mountaineers, and guides (Farias *et al.*, 2013). HA has no precise definition, but physiologically it is considered an elevation of $\geq$ 3,000 m mean above sea level (masl) because most people develop some symptoms associated with the ascent of mountain areas at this elevation. Extreme altitude may be defined as one exceeding 5,500 m masl where a permanent residence is practically impossible. Overall, altitude is classified high (1500-3500 m masl), very high (3500-5500 m masl), and extreme (>5500 m masl) (Paralikar and Paralikar, 2010; Parati *et al.*, 2018). Ascending HA leads to the lowering of partial pressure of oxygen in blood, which is the manifestation of reduced barometric pressure at HA, and is subsequently related to changes in oxygen delivery in the system (West, 2004). Physical and environmental factors at HA are hypoxia, severe wind velocity, low relative humidity, high solar radiation, and difficult terrain. In addition, these areas are also arid with the scarcity of potable water, which represents an alien environment and causes problems for soldiers, travellers, and mountaineers (Imray *et al.*, 2010). Sudden exposure to the high-altitude hypoxic environment brings about some HA disorders affecting

an individual's physiological, biochemical, and cognitive responses. Synergic functioning of respiratory, cardiac, and hematological systems is required to enhance the bioavailability of oxygen at cellular level to adapt to hypoxic high-altitude conditions. Drugs with action mechanisms on organs such as kidneys, lungs, and brain and RBCs are recommended for individuals who encounter HA disorders. For early acclimatization to high-altitude acetazolamide, dexamethasone and nifedipine drugs are prescribed. Additionally, for symptomatic therapies, ibuprofen, and aspirin for headache and for nausea, promethazine are the recommended drugs. In some emergent situations like war or unavailability of suggested drugs, pre-yoga practice has been advised to rescue from high-altitude related disorders. Based on the anecdotes of sages living in high altitudes and surviving for a long time despite reduced food intake and oxygen, it may be the rationale for this. It has long been suggested that practicing yoga via voluntary and conscious respiration patterns can induce hypometabolic status and allow practitioners to tolerate hypoxia (Wallace *et al.*, 1971).

Yogic intervention (YI) is a five-thousand-year-old Indian science that includes physical postures (asanas), voluntarily regulated breathing (pranayamas), meditation (dhyana) and specific philosophical principles. The word yoga is derived from the Sanskrit root *yuj*, meaning "union" or bringing together (Iyenger, 2012). It is used as a promotive fitness practice all over the world due to its enormous health promotive benefits. Yoga can potentially reduce health care utilization (43%) significantly and is considered a key component in health system and health delivery system of any population (Stahl *et al.*, 2015). There is growing evidence to support the beneficial effects of yoga at high altitudes (Bernardi *et al*., 2006; Bernardi *et al*., 2007; Himashree *et al*. 2016). However, reports regarding the role of yoga in studying physiological and biochemical responses are scanty. In view of above, the present study was aimed to assess the impact of yogic intervention on physiological, cardiopulmonary, and biochemical responses of individuals at high altitudes or in hypoxic conditions.

MATERIALS AND METHODS

Study subjects

Eighty-seven healthy male subjects were recruited at sea level (SL) and were randomly divided into 2 groups i.e., control and yoga groups/intervention - physical characteristics were as under:

Physical characteristics	Yoga group	Control group
No. of subjects	43	44
Age (years)	30.08 ± 9.42	30.05 ± 6.80
Height (cm)	174.48 ± 3.66	174.52 ± 4.47
Body weight (kg)	71.93 ± 5.89	70.62 ± 6.77
BMI (kg m^{-2})	23.60 ± 4.39	23.20 ± 1.88

Data are given as the mean ± SEM

Control group performed routine daily activities during the study period. Yoga group underwent one-month yoga at SL. The study was approved by the Ethical Committee of Defence Institute of Physiology & Allied Sciences, DRDO and was conducted in strict compliance with the approved guidelines.

Study design

The study was conducted initially at SL in Chandigarh, India (321 m masl) in December 2018 for basal data. After one month, the subjects were shifted through road to a high altitude (HA) in a hilly region in Arunachal Pradesh, India (4633 m masl) in February 2019. At HA, a proper acclimatization schedule was followed before recording the data. Appropriate winter clothing was provided to all the subjects. The atmospheric temperature ranged from 28-35°C at SL and 5-20°C at HA; whereas inside the room, the temperature was maintained at 22±20°C. None of the subjects took psychotropic, psychoactive medication or other drugs. All the subjects were non-smokers, non-alcoholic and unexposed to a high-altitude environment. After explaining the study protocols and risk factors, a written informed consent was obtained from each subject for participation in the study.

Two yoga therapists taught both theoretical and practical aspects of yoga and its benefits to the subjects. The trainers took yoga practices (Plate 1)/sessions from therapists as under:

Asana (yogic postures) session = 10 min	Duration
1. Padmasana/ Sukhasana	1 min
2. Suptapavanmukktasana	30 sec x 3 times = 90 sec
3. Shavasana	1 min
4. Pavanmuktasana	15 sec x 3 times = 45 sec
5. Vajrasana	1 min
6. Gomukhasana	30 sec x 3 times = 90 sec
7. Makarasana	1 min
8. Bhujangasana	15 x 3 times = 45 sec
9. Shalvasana	30 sec x 3 times = 90 sec
Pranayama (breathing exercises): session = 6 min	
10. Kapalbhati Pranayama	30 sec x 4 times =120 sec
11. Anuloma - vilom Pranayama	30 sec x 4 rounds = 120 sec (pause 15 sec)
12. Bhramari Pranayama	30 sec x 4 rounds = 120 sec (pause 15 sec)
Meditation: session = 10-12 min	
13. Omkar meditation	30 sec x 4 rounds = 120 sec (pause 15 sec)
14. Guided meditation	8- 10 min

Plate 1: Various yoga postures practiced by the subjects during the yoga session

Body mass and height

Body mass was recorded after voiding between 6 and 8 AM before breakfast using a non-digital weighting machine (Virgo, India) in standing erect body posture with minimal clothing. For body mass index, the measurement of a person's weight to their height was calculated by working out the ratio of weight to height (kg m^{-2}).

Cardiorespiratory tests

Blood pressure: A digital blood pressure machine measured the subjects' blood pressure, both systolic and diastolic pressure. The subjects were in sitting or lying position during the test. The patients were instructed to calm for 10 min before the test. A hand strap was placed on left arm.

Breath-hold time (BHT) test: These measurements were performed in a sitting position with a nose clip in place. The experimenter visually controlled the subjects' breathing patterns to avoid

hyperventilation. The subjects were instructed to hold their breath for as long as they could. A minimum of three trials per subject were performed with a break between the trials for 2 min. The longest breath-hold time (in sec) was noted and used for analysis.

Pulmonary function test (PFT): A digital spirometer (Pony FX, COSMED, Italy) was used to assess the lung function. The subjects were asked to inhale one breath as deeply as possible and exhale as hard and fast as possible into the spirometer. Each participant was also instructed to ensure that no air leaked out of the side of their mouths as they blew out into the spirometer. Forced vital capacity (FVC), forced expiratory volume in one sec (FEV_1) and maximal voluntary ventilation (MVV) were measured following ATS/ERS standard procedures (Miller *et al.*, 2005).

Resting physiological parameters: Breathing frequency, VO_2, and VCO_2 were measured by portable computerized equipment (K5b2 COSMED, Italy). The standard gas mixture was used to calibrate the oxygen and carbon dioxide.

Peripheral oxygen saturation (SpO_2) measurement

Saturation of peripheral oxygen was measured using a pulse oximeter (Nonin Medical Inc., USA), which was used to assess the percentage of O_2 saturation in the blood via the infrared technique by placing it on the subject's index finger when they were resting.

Blood collection and analysis

Blood samples were collected between 6 and 8 AM from the antecubital vein after 12 h fasting. Gel and clot activator tubes were used for serum and ethylenediamine tetra acetic acid (EDTA) tubes for plasma collection. The plasma was separated instantly by centrifugation at 3000 rpm for 20 min at 40°C and stored in a deep freezer until assayed.

ELISA immunoassay

ELISA kits were used for human corin (Catalog No. DY2209), human ACE (Catalog No. DY929), human sVEGFR2/KDR Duo set ELISA (Catalog No. DY357), and human angiopoietin-like 4 (Catalog No. DY3485). The experiment was performed as per the instructions provided in manual. Briefly, the coating of a microliter plate was performed using an anti-antibody. The samples were added, and incubated for 2 h at room temperature. Washing was performed thrice with a buffer, then an anti-human (biotinylated) antibody added and incubated for 2 h. Again, washing was performed and peroxidase-conjugated streptavidin was added and incubated for 20 min at room temperature. The cells were washed with washing buffer, and a horseradish peroxidase substrate (3,3',5,5'-tetramethylbenzidine, TMB) was added and incubated for 20 min in dark. The reaction was stopped by adding 2 N H_2SO_4, and optical density measured (BioTek Eon™ High Performance Microplate Spectrophotometer, USA) at a wavelength of 450 nm.

Statistical analysis

A comparison of pre-intervention data at sea level and post-intervention data at high altitude in each group was analysed using a paired "t" test. For biochemical estimation, all analysis were nonparametric. Comparisons between continuous variables were performed using the Mann-Whitney U test with Bonferroni adjustment. Linear regression was carried out to evaluate the correlation between parameters. A significant level was set at a p value < 0.05. Statistical analysis was performed using GraphPad Prism v.6.04.

RESULTS AND DISCUSSION

The HA environment causes many numerous physiological and biochemical changes in humans, leading to increased sympathetic stimulation and autonomic activity. Medullary chemoreceptors sense oxygen depletion under hypoxia, which is reflected by increasing systemic and regional sympathetic

tone (Marshall, 1994). There is a compelling evidence about the role of sympathetic nervous system in hypoxic/HA environment (Koller *et al*., 1988). The plasma catecholamine content supports the concept of an elevation in sympathetic activity with time at altitude in both men (Mazzeo *et al*., 1994) and women (Passino *et al*., 1996).

Pulmonary function parameters

Pulmonary function (PF) parameter enhancements have been observed in individuals who practice yoga (Hakked *et al*., 2017, Bhagel *et al*., 2021; Bhagel *et al*., 2022). In our study spirometry measurements of participating subjects depicted significant enhancement in the PF values of FVC (increased 16.39%), $MEF_{75\%}$ (increased 15.17%), PEF (increased 9.79%), and $FEF_{25-75\%}$ (increased 16.52%) in the yoga group at high altitude ($p < 0.001$) revealing the effect of yogic training on pulmonary function parameters (Table 1). Yoga group showed more efficient lung emptying by increasing their different ranges of expiratory flows compared to their basal values; also, a higher FVC indicates that they might have higher respiratory muscle endurance. Thus, yoga group had a greater capacity to perform deep exhalation during altitude exposure. On the other hand, control group upon reaching HA showed mild increase in FVC, $MEF_{75\%}$, PEF, and $FEF_{25-75\%}$. It appears since control group had not undergone yogic intervention, they were not trained to use extra lung volumes therefore no significant improvement in their pulmonary functions was observed.

Table 1: Pulmonary function changes in yoga and control group at high altitude and sea level

Pulmonary function Parameter	Yoga group		Control group	
	Sea level	High-altitude	Sea level	High-altitude
FEV_1 (L min^{-1})	3.80 ± 0.56	3.87 ± 0.56	3.81 ± 0.55	3.82 ± 0.62
FVC (L)	4.27 ± 0.63	4.90 ± 0.55***	4.45 ± 0.86	4.47 ± 0.52
PEF	9.49 ± 1.77	10.42 ± 1.92***	9.48 ± 1.92	9.51 ± 1.70
$MEF_{25\%}$	1.85 ± 0.72	1.89 ± 0.58	1.87 ± 0.63	1.90 ± 0.69
$MEF_{50\%}$	4.40 ± 1.39	4.76 ± 1.30	4.37 ± 1.31	4.45 ± 1.48
$MEF_{75\%}$	7.51 ± 1.74	8.65 ± 1.95***	7.56 ± 1.69	7.62 ± 1.55
$FEF_{25-75\%}$	3.63 ± 0.96	4.23 ± 0.94***	3.72 ± 0.88	3.73 ± 1.05

Data presented as the mean ± SEM; Significance indicated for * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$, ns non-significant. Forced expiratory volume in one second (FEV_1), Forced vital capacity (FVC), peak expiratory flow rate (PEF), forced expiratory flow $FEF_{25-75\%}$, and maximal expiratory flow (MEF).

Table 2: The effect of altitudinal variation on cardiovascular parameters of yoga and control group

Parameters	Yoga group		Control group	
	Sea level	High altitude	Sea level	High altitude
SBP (mm Hg)	120.51 ± 6.56	122.74 ± 7.36	120.07 ± 4.78	129.02 ± 3.62***
DBP (mm Hg)	76.00 ± 4.52	71.79 ± 11.23	76.75 ± 9.52	86.55 ± 8.46***
Heart rate (bpm)	72.72 ± 8.06	80.19 ± 9.27	70.89 ± 7.82	107.26 ± 36.50***
MBP (mm Hg)	78.12 ± 4.03	76.35 ± 8.00	80.25 ± 6.71	88.62 ± 5.90***
SpO_2%	99.07 ± 0.26	93.77 ± 2.94***	99.25 ± 0.72	90.43 ± 4.58***
BHT (sec)	30.58 ± 8.88	43.05± 15.71***	33.39 ± 10.04	26.18 ± 6.78***

The values are expressed as the mean ± SEM; Significance indicated for *$p < 0.05$; **$p < 0.01$ ***$p < 0.001$; and ns non-significant; SBP - Systolic blood pressure, DBP - Diastolic blood pressure, MBP - Mean blood pressure; HR - Heart rate (HR); SpO_2 - Blood O_2 saturation), BTH - Breath-holding time.

HA exposure causes a mild to moderate increase in both systolic and diastolic blood pressure (West *et al*, 2013). Yoga practice can decrease blood pressure and can be associated with the sympatho-vagal balance shifting the individual towards parasympathetic dominance (Sarang *et al*., 2006), which was observed in the current study. Heart rate (HR) increases immediately upon arrival at HA, thereby increasing cardiac output to help restore systemic O_2 transport. We found that the control group HR increased by 51.30% while in YG it was increased by 10.27% at high altitudes. Cardiovascular parameters such as heart rate, systolic blood pressure (SBP), and diastolic blood

pressure (DBP), and blood pressure-derived parameters such as mean blood pressure (MBP) increased in CG at high altitudes as compared to the yoga group. SpO_2, or peripheral capillary oxygen saturation, measures the quantity of oxygen in the blood. For a healthy individual, SpO_2 ranges from 97-100% (Yanagisawa *et al.,* 1988). Due to a decrease in atmospheric pressure at high altitudes, the partial pressure of inspiring oxygen decreases. Hence, a decrement in the driving force for gaseous exchange in the lungs occurs. Low oxygen availability to tissues can cause problems in the digestive, neurological, and cardiac systems (Muthuraju *et al.*, 2014; Viscor *et al.,* 2018). Although blood O_2 saturation decreased in both groups at high altitudes, but the reduction in O_2 saturation was greater in the control group (8.88%) than in the yoga group (5.35%) from the baseline values. Breath-holding time decreased significantly ($p < 0.001$) from pre-intervention value of 33.39 sec to the post-intervention value of 26.18 sec (decreased by 21.59%) in control group. It is increased significantly from 30.58 sec to 43.05 sec (increased by 47.77%) in YG (Table 2). Increased breath-hold capacity values in the yoga group showed that individuals were able to reserve oxygen in their system compared to the control group. Increased breath hold capacity is an evident effect of yoga. The higher the BHT, the better because it signifies respiratory endurance and cardiopulmonary reserve (Bagavad *et al*., 2014).

Resting physiological parameters: Breathing frequency (BF), VO_2, and VCO_2 are shown in Table 3. Compared with sea-level measurements, an increase in breathing frequency, resting O_2 consumption VO_2, and resting CO_2 elimination was found in the control group at HA, showing that they are trying to catch more oxygen from the air when they reach high altitude. In contrast, the yoga group trained in breathing manoeuvres could sustain themselves in the hypoxic environment by breathing normally. The VO_2, resting CO_2 elimination, and BF decreased due to yogic intervention at sea level in the yoga group. Relaxation techniques decrease O_2 consumption, CO_2 elimination, and breathing frequency (Sood *et al*., 2010), in our study yoga is shown to have a beneficial role in calming down the body and mind, which reduces O_2 consumption as well as CO_2 elimination along with a relaxation response.

Table 3: The effect of altitudinal variation on resting physiological parameters of yoga and control groups

Parameters	Yoga group		Control group	
	Sea level	High altitude	Sea level	High altitude
Breathing rate (BR min^{-1})	14.24 ± 4.52	16.19 ± 4.12*	14.53 ± 1.70	20.50 ± 4.11***
VO_2 resting (L min^{-1})	0.25 ± 0.02	0.21 ±0.05**	0.24 ± 0.04	0.29 ± 0.08*
VCO_2 resting (L min^{-1})	0.22 ± 0.04	0.25 ± 0.07	0.23 ± 0.04	0.28 ± 0.09**

Data are given as the mean ± SEM; Significance is indicated for * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

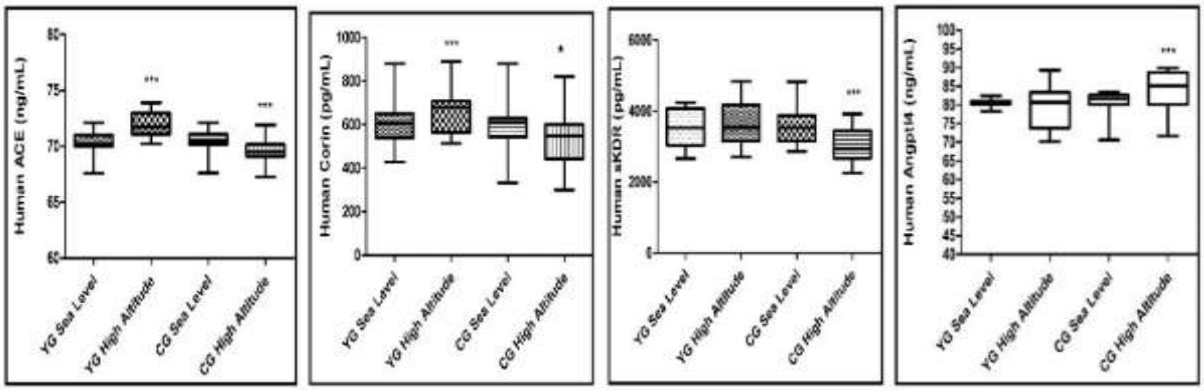
Estimation of markers of endothelial circulatory homeostasis

Two primary metabolisms that were targeted are the sympathetic-adrenal-medullary system (Mazzeo *et al*., 1994; Lahiri, 2000) and the renin-angiotensin-aldosterone system (RAAS) (Keynes *et al.*, 1982; Milledge *et al.,*1983) because of their intimate involvement in the regulation of BP even at altitude (Milledge *et al*., 1983). RAAS is a coordinated hormonal and proteolytic cascade that controls cardiovascular, renal, and adrenal functions that govern fluid and electrolyte balance and arterial pressure. RAAS role centrally in regulating blood pressure (BP) and sodium homeostasis. Evidence has shown that yogic practices can decrease sodium and potassium concentrations in the blood and decrease renin activity which causes a decrease BP towards normal in hypertensive patients (Selvamurthy *et al.,* 1998). For a more mechanistic understanding of this finding, we measured human corin and angiotensin-converting enzyme (ACE) in the subjects' blood. Corin converts hormones into activated forms such as pro-atrial natriuretic peptide (pro-ANP) and pro-brain natriuretic peptide (pro-BNP) to activate ANP and BNP. It is the long-sought physiological pro-ANP convertase (Yan *et al*., 2000). It is vital in maintaining normal blood pressure in vivo (Yan *et al.*, 2000). Active ANP is required to reduce sodium levels, lowering blood pressure (Burnett *et al*., 2007). Corin plays a vital role in cardio protection (Pang *et al*., 2015). The predominant effector peptide of the classic RAAS is

angiotensin II, whose synthesis begins with the cleavage of angiotensinogen into angiotensin I with the aid of renin, then angiotensin I is converted into angiotensin II with the aid of ACE. ACE is expressed in the kidney and lung epithelium.

Human ACE significantly increased from a pre-intervention value of 70.24 (ng mL^{-1}) to a post-intervention value of 71.99 ng mL^{-1} in the yoga group and decreased significantly ($p< 0.001$) to 69.54 (ng mL^{-1} from a baseline value of 70.49 (ng mL^{-1}) in the control group (Fig. 1A). Since ACE is involved in converting angiotensin 1 to angiotensin 2, this may be attributed to the increased fitness and decreased susceptibility to altitude sickness (Ashutosh *et al.*, 1976).

In our study human corin pg mL^{-1} increased significantly ($p<0.001$) from the pre-intervention value of 595.47 (pg mL^{-1}) to the post-intervention value of 662.98 (pg mL^{-1}) in the yoga group, whereas it decreased significantly to 556.68 (pg mL^{-1}) from the sea level (baseline) value of 597.52 (pg mL^{-1}) in the control group. (Fig. 1B). Our study showed a decreased level of corin in the control group, which is a suitable explanation for their increased BP. Studies have shown that reduced activity or expression of human corin is linked to an increased risk of hypertension or preeclampsia (Chen *et al*., 2010; Dong *et al*., 2010) .



A B C D

Fig. 1: Box and whisker plots showing the levels of (A), angiotensin-converting enzyme (ACE) (B), human corin (C), sKDR (D human Angptl4) markers of endothelial activation, vascular permeability and circulatory homeostasis levels in yoga and control groups from sea level to high altitude. Data are given as the mean ± SEM. Significance indicated for *p < 0.05; ** p< 0. 01 *** p< 0.001, ns = non-significant

Hypoxia-induced microvascular leak parameter

sKDR is a soluble variant of KDR expressed by endothelial cells. It is also known as vascular endothelial growth factor VEGF receptor 2. It binds to and inhibits vascular endothelial growth factor, a potent inducer of microvascular leakage (Millauer *et al*., 1993; Quinn *et al*, 1993). Human sKDR significantly increased from the pre-intervention value of 3530.60 (pg mL^{-1}) to the post-intervention value of 3638.66 (pg mL^{-1}) in the yoga group and decreased significantly ($p< 0.001$) 3009.24 (pg mL^{-1}) from the baseline value of 3569.58 (pg mL^{-1}) in the control group. (Fig. 1C).

Estimation of markers of endothelial activation and vascular permeability

Among the angiopoietin-like family of proteins, ANGPTL4 (Angiopoietin-related protein 4) induce their expression in endothelial cells under hypoxia. They act as regulators of angiogenesis, inhibitors of proliferation, migration, and tubule formation of endothelial cells, and reduce vascular leakage. They have an endocrine mechanism of action on endothelial cells (Paizis *et al*., 2005). Additionally, they are directly involved in regulating glucose homeostasis, lipid metabolism, and insulin sensitivity. In response to hypoxia, the unprocessed form of the protein accumulates in the sub-endothelial extracellular matrix. Human Angiopoietin-related protein-like 4 (Angptl4) significantly increased from a pre-intervention value of 80.33 (ng mL^{-1}) to a post-intervention value of 84.07 (ng mL^{-1}) in the

control group. It decreased non-significantly to 80.34 ng mL^{-1} from baseline value of 80.59 ng mL^{-1} in yoga group. In contrast, only a non-significant 0.31% decrease observed in yoga group (Fig. 1D).

Correlation between human corin and diastolic blood pressure (DBP)

DBP decreased in the yoga group after practicing yoga at sea level, while human corin increased significantly. This result shows a negative correlation between DBP in yoga group at high altitude (r = 0.3803, p = 0.0119) (Fig. 2).

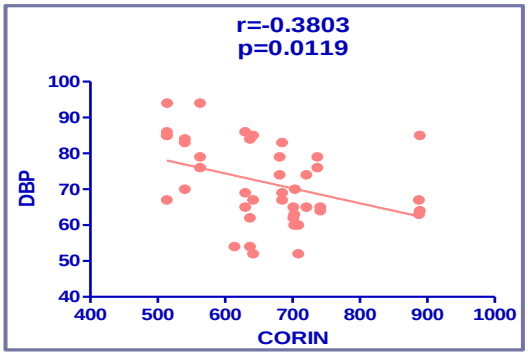


Fig. 2: Correlation between human corin and diastolic blood pressure (DBP) in yoga group at high altitude. r: shows the Pearson correlation coefficient. The significant correlation was p<0.05

During the last few decades, a significant amount of work has done to understand human biology concerning HA adaptation and disorders. But this study is one of its kind where we have tried to correlate physiological and biochemical parameters with the effect of yoga at high altitude. We observed five significant changes in yoga group which made subject's stay at HA comfortable as compared to the control; i) the enhanced pulmonary function parameters, especially FVC, PEF, $MEF_{75\%}$, and $FEF_{25-75\%}$, ii) maintained blood pressure, improved blood oxygen saturation, and increased breath holding capacity, iii) decreased breathing frequency and significantly reduced resting oxygen consumption (VO_2 resting) and carbon dioxide elimination (VCO_2); iv) decreased levels of human Angptl4 and soluble kinase domain receptor (sKDR) and the significant increase in the levels of human corin and human angiotensin-converting enzyme (ACE) and v) a negative correlation between human corin and DBP levels (r = 0.38, p = 0.012). Study's main findings are summarised in Fig. 3. The participants in our study were all young male individuals, which may limit the extrapolation of our results. This study is highly relevant to a significant workforce in high-altitude areas and could interest governments and policymakers who regulate work at high altitudes. The present study appraises the role of yoga in the context of cardiopulmonary health, endothelial functioning, and circulatory homeostasis at HA. It has greater applicability in scientific yoga research, traveling, and physical activity research.

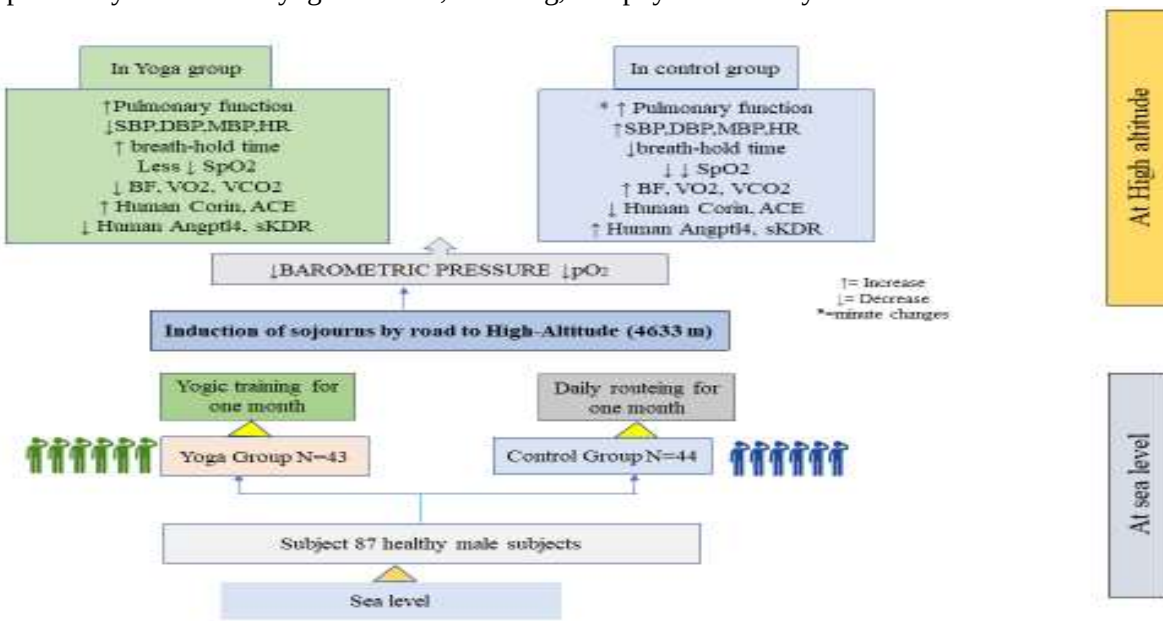


Fig. 3: Summary and main findings of the study

Conclusion: The yoga intervention at sea level before ascending to high altitudes may help individuals to combat hypoxic stress, and maintain cardiopulmonary health, endothelial functioning and circulatory homeostasis at HA.

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Disclosure statement: The authors have no potential conflicts of interest.

Ethical statement: The present work was approved by the Ethical Committee of Defence Institute of Physiology and Allied Sciences, DRDO, Delhi, India vide Ref No: IEC/DIPAS/A-4/2) and was carried out in strict compliance with the approved guidelines.

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