https://ijpp.com

ScientificScholar® Knowledge is power
Publisher of Scientific Journals

Indian Journal of Physiology and Pharmacology

Original Article

Visuospatial attention at high altitude in two ethnically distinct groups of soldiers

Debojyoti Bhattacharyya[1], Koushik Ray[2], Krishna Kishore[2], Praveen Vats[3], Meerim Sartmyrzaeva[4], Almaz Akunov[4], Abdirashit Maripov[4], Akpay Sarybaev[4]

Departments of [1]Ergonomics, [2]Neurophysiology, [3]High Altitude Physiology, Defence Institute of Physiology and Allied Sciences, Defence Research and Development Organization, New Delhi, India, [4]High Altitude Physiology and Cardiology, Kyrgyz-Indian Mountain Biomedical Research Centre, Bishkek, Kyrgyzstan.

***Corresponding author:**
Debojyoti Bhattacharyya, Department of Ergonomics, Defense Institute of Physiology and Allied Science, Defence Research and Development Organization, New Delhi, India.

rajdeb8206@gmail.com

Received: 01 August 2023
Accepted: 10 November 2024
Published: 27 December 2024

DOI
10.25259/IJPP_421_2023

Quick Response Code:

ABSTRACT

Objectives: For strategic purposes, soldiers of different ethnicities are deployed in high-altitude (HA) areas from time to time. During their operations, hypoxia may influence visuospatial attention. Therefore, assessment of visuospatial attention is of paramount importance during HA tenure.

Materials and Methods: Two distinct ethnic groups, composed of Indian and Kyrgyz lowland soldiers, were ascended to 3,200 m to assess visuospatial attention. Visual search experiments were conducted for a target in the presence of distractors while simultaneously recording the eye movements. The target present correct reaction time (RTP), target absent correct reaction time (RTA), slopes and intercept of reaction time X set size, fixation duration and saccade latency were measured at baseline, as well as on days 3, 7, 14 and 21 of the HA stay and day 3 of the return from HA.

Results: At HA, most of the parameters were significantly changed. Kyrgyz soldiers had higher RTP (e.g. 2179.99 ± 992.21ms for Indian, and 2641.78 ± 142.28 ms for Kyrgyz, with 12 set size, on day 3 at HA) and RTA values, as well as a higher intercept of the visual search than Indian soldiers. Kyrgyz soldiers had higher fixation duration (e.g. 291.75 ± 7.40 ms for Indians, and 303.78 ± 18.93 ms for Kyrgyz, with 16 set size, on Day 3 at HA) and saccade latency (e.g. 326.21 ± 34.88 ms for Indian, and 356.67 ± 67.48 ms for Kyrgyz, with 12 set size, on day 3 at HA) values than Indian soldiers from day 3 onward.

Conclusion: The task performance of Indian soldiers improved after day 3 at HA, whereas Kyrgyz soldiers struggled to adapt throughout their stay. The ethnogenetic diversity, life experience variables and demographic characteristics of Indian and Kyrgyz soldiers could all be contributing causes to differences in their visuospatial attention. The hypobaric and hypoxic environment further interacted with all these variations.

Keywords: Hypoxia, Acclimatisation, Visual search, Eye movement, Reaction time

INTRODUCTION

Many nations have a strategic requirement for the deployment of armed forces at high altitudes (HAs). The soldiers are typically lowland indigenous who have ascended to HA from sea level. Soldiers must be vigilant and cognitively active in such scenarios to make the best decision for the situation. Acclimatisation is therefore crucial following ascent to HA for optimal physical and mental performance in a low barometric pressure environment. Among the various domains of cognitive performance, visuospatial attention and reaction time are critical for soldiers to identify the spatial details of potential threats and respond appropriately as quickly as possible.[1-4] Therefore, it is imperative to assess the soldiers' cognitive performance during every stage of an expedition to HAs.

Previous research found ethnic differences in cognitive performance.[5] Boivin (1991)[6] found that Scottish children outperformed Zairian children on the visual-spatial task. Non-Hispanic white elderly performed better than Mexican Americans across a battery of screening tests based on the functionality of the domains associated with frontal/executive parts.[7] However, none of the aforementioned investigations looked into how ethnic diversity and HA interacted.[8] Compared the cognitive performance of highlanders and lowlanders with similar socioeconomic and genetic ancestry across the lifespan in a sample ranging in age from 4 to 84 years. They found that highlanders were consistently slower than lowlanders in processing speed while performing tasks for memory components (Quality of Episodic Secondary Memory, Quality of Working Memory and speed of memory), attention (speed and accuracy) and psychomotor speed (simple motor speed and cognitive, psychomotor speed). Ethnogenetic analysis revealed that highlanders had a slightly higher percentage of native Andean ancestry than low-altitude participants, which was not associated with cognitive performance Yu *et al.* (2022).[9] Investigated the cognitive performance among two groups of Tibetan highlanders and Han lowlanders from different socioeconomic backgrounds in relation to changes in cerebral oxygenation. Tibetan highlanders had significantly lower cognitive scores than Han lowlanders, and cognitive scores were significantly correlated with gross domestic product rather than altitude.

Visual search experiments represent the established method for investigating visuospatial attention, wherein individuals locate a target amid various distractors. Response time is documented based on the target's presence or absence, revealing a search slope that indicates the efficiency of the search process, influenced by the number of distractors and set size. The conventional way to register response time is by pressing the key on the keyboard/or clicking the mouse/or touching the screen, as soon as the participant sees the target or decides that the target is absent.[10-13] Set size refers to the total number of visual stimuli that appear on the screen. Eye movement recording has already proven useful in interpreting visuospatial attention, which is concerned with the visual search for a target.[14,15] Soldiers from various ethnic backgrounds are required to collaborate together in a variety of critical situations, which may take place at HA. Many factors may impact the decision-making process of joint operations. Therefore, in the present study, visuospatial attention was assessed by a simple visual search task with a simultaneous recording of eye movement activities between two different ethnic groups (Indian and Kyrgyz soldiers) from different geographical locations. Evaluations were conducted under similar conditions of HA exposure. Ethnically Indians are mixed of Indo-Aryan and Dravidian; on the other hand, the Kyrgyz population is a combination of Huns and Mongolians.

MATERIALS AND METHODS

Subjects and study protocol

The minimum sample size identified for the statistical analysis was 15 from each group with an effect size of f = 0.25 (this indicates a medium effect) and power, b = 0.95. However, due to certain logistics and administrative issues, we could only recruit 10 participants from each group. Therefore, the study was conducted on 20 participants (ten Indian [Age – 23.11 ± 2.0 years, height – 173 ± 3.0 cm, weight – 66.15 ± 5.17 kg and body mass index (BMI) – 22 ± 1.81 kg/m^2] and ten Kyrgyz [Age – 20.60 ± 3.0 years, height – 176.10 ± 4.0 cm, weight – 72 ± 6 kg and BMI – 23 ± 1.60 kg/m^2] soldiers) with an educational qualification of higher secondary level. All participants were lowlanders with no history of HA exposure, 6/6 visual acuity without corrective lenses and no recent eye infection, history of eye surgery or discomfort or pain in the eyes while using digital display media. The term 'lowlanders' essentially depicts the natives of the sea levels. The average terrestrial elevation of Indian lowlanders and Kyrgyz lowlanders is 235 m. and 800 m, respectively. The participants did not undergo any altitude training. They provided informed consent to participate in the study. The study protocol was approved by the Institutional Ethics Committee on the use of humans as the experimental subjects and the experiment conforms to the principles outlined by the deceleration of the Helsinki protocol. Indian soldiers were flown to Bishkek, Kyrgyzstan, by 4 h of a direct flight. There is a time difference of half an hour between India and Kyrgyzstan (the Kyrgyz time zone is advanced by half an hour). To counteract the effects of jet lag (if any), baseline recording was carried out on day 3 at Bishkek (800 m above sea level) in both Indian and Kyrgyz soldiers, and both groups of soldiers were then ascended by road to HA, Tuya Ashu (3,200 m above sea level) by road. After a stay of 21 days, soldiers were returned to Bishkek, where the study was conducted on day 3 [Figure 1]. Atmospheric temperature was ranging from 28°C to35°C at Bishkek and from 9°C to 25°C at Tuya Ashu, whereas inside the rooms, the temperature was maintained at 22°C ± 2°C.

Saturation of peripheral oxygen (SpO_2) was measured using a finger pulse oximeter (Model No. 3230, M/s, Nonin Medical, Inc.).

Visual search tasks

Based on the principles outlined by Wolfe (2010)[10] and Wolfe (2015),[16] a visual search task was designed in the

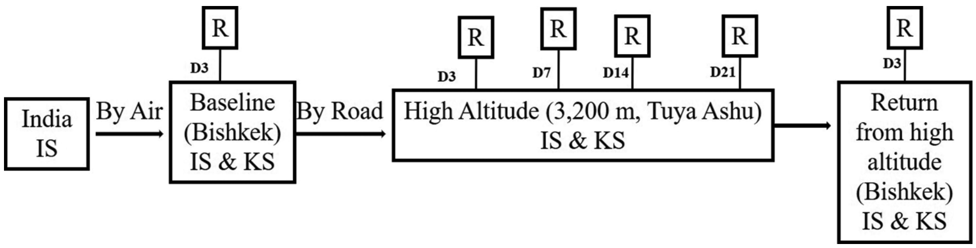

Figure 1: Schematic diagram of the experimental protocol. Indian soldiers (IS) reached Bishkek by air, and baseline recordings (R) were performed on both IS and Kyrgyz soldiers (KS) on day 3 (D3). Soldiers were transported by road from Bishkek to 3,200 m altitude (Tuya Ashu) where they stayed for 21 days. High-altitude R's were carried out on day 3 (D3), day 7 (D7), day 14 (D14), and day 21 (D21). After that, soldiers were returned from high altitude to Bishkek by road and all the parameters were recorded on day 3.

Java™ platform in which participants had to search for a target in the presence of many distractors. For the present study,  (A circle with a right cut) and  (Circle with a left cut) were selected as the stimuli for 'Target' and 'Distractors', respectively. The 'Target' and 'Distractors' are mirror images of each other with a minute feature of discretion, which creates a strong conflict in the brain toward accurate identification. Target and distractors had similar dimensions during presentation mode, extending a visual angle of 1.2°–1° for a distance ranging from 60 cm to 70 cm between the screen and the participant's eye. The opening space of the target and distractors extended a visual angle of 0.6°–0.5° for a distance ranging from 60 cm to 70 cm between the screen and the participant's eye. With a set size of 12 and 16 stimuli, two types of search displays were generated. There were 1 target and 11 distractors, and 1 target and 15 distractors under 12 and 16 stimuli conditions, respectively. A total of 16 trials were conducted, with eight trials presenting the presence of targets and the remaining eight trials presenting the absence of targets. The stimuli were randomly distributed in the search matrix with a jittering of 100 pixels. The participants were instructed to register their responses by pressing the key 'F' in the presence of the target and the key 'J' during the absence of the target. The manoeuvre of key pressing had to be accomplished as early as possible, followed by a self-decision on the presence or absence of the target. The 'target present' and 'target absent' trials appeared randomly, followed by the registering of the responses by pressing a relevant key. The trials started with an eye fixation of 500 ms on a black 'X' in the middle of the screen on a white background. Immediately after that, the search matrices started appearing by pressing either key 'F' or key 'J'. The next search matrix appeared with a delay of 3000 ms. The details of the experimental protocol are shown in Figure 2. Both groups of participants received a clear demonstration of the entire procedure of task performance. In the case of Kyrgyz soldiers, the detailed procedure of task performance was first vividly demonstrated to a native senior researcher (who had good proficiency in English) in English. The native senior researcher then instructed and showed the task to their soldiers in the Kyrgyz language, ensuring that they understood how to complete it. Before the start of the main experiment, each participant completed at least three practice sessions to become familiar with the task-performance hardware, software and experimental guidelines.

Recording of eye movements and experimental setup

Volunteers were instructed to put on headset with the eye tracking optics (Sensomotoric Instruments [SMI] iViewX Eye Tracker, M/s SMIs, Germany) ensuring the ease of wearing for an optimum calibration condition. Followed by this '5' point, calibration was performed by standard protocol. The recording software 'iViewX' (M/s SMI) was run at a sampling rate of 250 Hz. Stimuli were delivered in a 17-inch Liquid Crystal Display (LCD) monitor (M/s Hewlett-Packard, Model No. L1710) with a 5:4 aspect ratio and 160° × 160° Horizontal × Vertical Viewing Angle. Participants' chins were supported by a chinrest to stabilise the redundant movement of the head. The illumination level of the experiment room was maintained at 450 lux. Recording started with the onset of the search task and stopped immediately with the termination of all search trials. The recorded files of eye movement data were analysed in 'BeGaze' software (M/s SMI).

Parameters

The correct reaction time of 'target present' (RTP) and reaction time of 'target absent' (RTA) were registered at the end of each trial for individual soldiers. Slopes (search efficiency), that is, time spent/item and intercepts of the visual search, were calculated from 'set size 12' to 'set size 16' for all the experimental sessions. In the case of eye movement parameters, average fixation duration (AFD) and saccade latency were considered to interpret the visuospatial attention while performing the visual search.

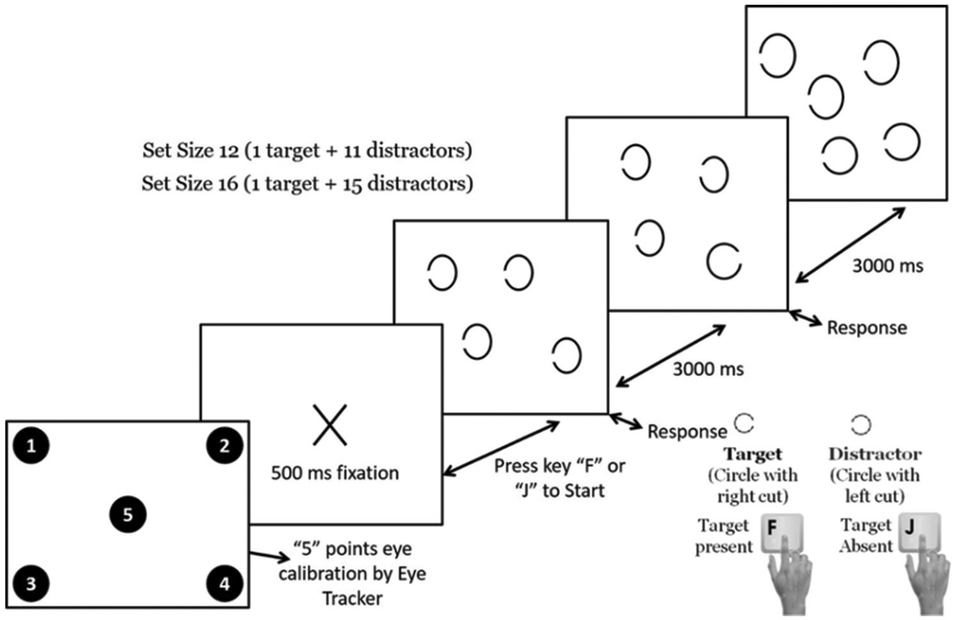

Figure 2: Schematic presentation of Visual search experiment which started with '5' points eye calibration followed by a 500 ms fixation on 'X.' The experiment started by pressing of keys 'F' or 'J' and the matrix with set sizes '12' and '16' started appearing, response time was registered by pressing the 'F' and 'J' keys for the target present and absent respectively.

Statistical analysis

All the parameters were checked for normal distribution by Shapiro–Wilk test. A two-way mixed-design analysis of variance (ANOVA) was conducted to observe any significant effect of experimental independent variables on the dependent variables. The between-measure independent factor was the group of soldiers, that is Indian and Kyrgyz soldiers. There were two within-measure independent factors, (1) various days of experiments (DE), that is, Baseline, on day 3 (Day 3 at HA [HA_D3]), day 7 (Day 7 at HA [HA_D7]), day 14 (Day 14 at HA [HA_D14]) and day 21 (Day 21 at HA [HA_D21]) at HA and return from HA, and (2) set size, that is 12 stimuli and 16 stimuli at which both groups of soldiers were repeatedly measured. The individual and interaction effects of independent variables were observed on the dependent variables' fixation duration and saccade latency. In the case of reaction time, there was another within-measure independent factor, that is, Target present/absent. Bonferroni *post hoc* test was also applied to compare the individual pairs followed by the overall significant effect of an independent variable. A Two-sample *t-test* (Assuming Unequal Variances) was also carried out to observe the significance difference between Indian and Kyrgyz soldiers of mean changes for all the variables at baseline. All the tests were conducted on the Statistical Package for the Social Sciences (Version 16). The significance of the test was confirmed when $P \leq 0.05$.

RESULTS

Results of Shapiro–Wilk's test revealed that 75% of the dependent variables are normally distributed ($P > 0.05$), and the remaining 25% showed very close to significance ($\approx P > 0.05$) level. Values are graphically presented as mean ± standard error of the mean.

Reaction time

There was no significant difference for RTP under set size 12 ($t_{18} = 1.80$, $P = 0.087$) and 16 ($t_{15} = 1.32$, $P = 0.206$) at baseline, respectively. Similarly, in the case of RTA, the difference was found non-significant under set size 12 ($t_{18} = 1.51$, $P = 0.147$). Whereas, under 16 set size conditions, the mean difference in RTA was found significant ($t_{16} = 3.11$, $P = 0.006$) at baseline. Results [Table 1] of mixed-design ANOVA revealed an overall significant effect of DE ($F_{[3.78,64.56]} = 68$, $P < 0.05$), set size ($F_{[1,17]} = 26.20$, $P < 0.05$) and presence/absence of target ($F_{[1,17]} = 104.71$, $P < 0.05$) on reaction time of visual search. Interaction effects of DE X set size ($F_{[2.47,42.05]} = 19.12$, $P < 0.05$), DE X Target ($F_{[2.20,37.41]} = 12.50$, $P < 0.05$) also produced significant effects on reaction time. When the ethnicity interacted with DE, that is, DE X Group ($F_{[5,85]} = 7.20$, $P < 0.05$) and the presence/absence of target, that is, Target X Group ($F_{[1,17]} = 7.50$, $P < 0.05$) significant effects were observed on reaction time.

In the present study, it was observed that target present slopes ranged from 54 to 440 ms/item [Table 2] in both groups of

Table 1: Effects of various independent variables on target present/absent correct reaction time.

	F-value	df	*P*-value
DE	67.99*	3.78, 64.56	0.000
Set size	26.20*	1, 17	0.000
Target	104.71*	1, 17	0.000
DE×Set size	19.12*	2.47, 42.05	0.000
DE×Target	12.50*	2.20, 37.41	0.000
Set size×Target	2.16^{NS}	1, 17	0.159
DE×Set size×Target	1.44^{NS}	3.38, 57.51	0.236
Group	2.67^{NS}	1, 17	0.120
DE×Group	7.20*	5, 85	0.000
Set size×Group	0.38^{NS}	1, 17	0.54
Target×Group	7.50*	1, 17	0.014
DE×Set size×Group	0.781^{NS}	5, 85	0.56
DE×Target×Group	1.53^{NS}	5, 85	0.187
Set size×Target×Group	0.005^{NS}	1, 17	0.94
DE×Set size×Target×Group	0.29^{NS}	5, 85	0.91

DE: Days of experiments, ANOVA: Analysis of variance, and Target: Presence/absence of target. df: Degree of freedom. Results of three-way mixed design ANOVA (within/repeated-between measure) presented by F, df and *P*-values to show the significant effects of various individual independent variables as well as interactions among them, where Group is the between measure factor and DE, set size and Target are within measure factors. * indicates the effects are significant (*P*<0.05), NS indicates the effects are not significant (*P*>0.05).

soldiers, irrespective of DEs. The same fact is observed in the case of target-absent slopes, which range from 430 to 1131 ms/item [Table 2]. Graphical presentation of the slope of reaction time X set size function revealed slight steepness during target-present and target-absent trials, with a negative slope in HA_D3 in both Indian and Kyrgyz soldiers ([Figures 3 and 4], except for Kyrgyz soldiers during target-absent trials). The details of pair wise comparison has been reported in Table 3 by conducting Bonferroni post hoc analysis.

Average Fixation Duration (AFD)

The mean difference in AFD was neither found to be significant under the 12 set size (t14 = 1.41, P = 0.180) nor under the 16 set size ($t_{16} = 0.68$, $P = 0.504$) at baseline. DE produced a significant effect ($F_{[2.63,44.75]} = 6.18$, $P < 0.05$) on the changes in fixation duration [Table 4]. Interaction between DE X set size imposed a significant effect ($F_{[5,85]} = 1.16$, $P < 0.05$) on fixation duration. When Group separately interacted with DE, that is, DE X Group, significant effect was observed ($F_{[5,85]} = 2.76$, $P < 0.05$). The details of pair wise comparison has been reported in Table 5 by conducting Bonferroni post hoc analysis

Saccade latency

No significant changes were observed in saccade latency, neither under 12 set size ($t_{12} = 0.19$, $P = 0.851$) nor under 16 set size ($t_{13} = 0.01$, $P = 0.984$) at baseline. DE produced a significant effect ($F_{[4.19,71.33]} = 5.14$, $P < 0.05$) on the changes in saccade latency [Table 4]. The individual effect between group factors was found significant ($F_{[1,17]} = 11.00$, $P < 0.05$). When the group interacted with DE, that is, DE X Group a significant effect was observed ($F_{[5,85]} = 2.55$, $P < 0.05$). The details of pair wise comparison has been reported in Table 6 by conducting Bonferroni post hoc analysis.

Arterial oxygen saturation

Results of repeated measure ANOVA revealed significant changes ($F_{[4,45]} = 39.97$, $P < 0.05$) in SpO_2 in Kyrgyz soldiers. SpO_2 was significantly decreased after 3 days (96 ± 0.88; $P < 0.001$) of ascent to HA than baseline (baseline, 98 ± 0.16). On days 7 and 14, SpO2 remained the same as on day 3, 96 ± 0.40 ($P < 0.001$ than baseline) and 96 ± 0.86 ($P < 0.01$ than baseline), respectively, which further increased to 97 ± 0.65 on day 21 ($P < 0.05$ than baseline) on days. In Indian, soldiers significant changes ($F_{[4,45]} = 24.9$, $P < 0.05$) were also observed. SpO_2 was significantly decreased after 3 days (96 ± 0.73; $P < 0.001$) of ascent to HA than baseline (98 ± 0.16). On days 7, 14 and 21, SpO_2 remained the same as on day 3, 96 ± 0.90 ($P < 0.01$ than baseline), 96 ± 1.08 ($P < 0.01$ than baseline) and 96 ± 1.08 ($P < 0.01$ than baseline), respectively.

DISCUSSION

The findings of the study indicate that visuospatial attention is influenced by ethnic variability during the process of acclimatisation following acute exposure to 3,200 m. The RTP and RTA showed a similar pattern of changes during exposure to HA in both groups of soldiers [Figure 5]. It indicated that on HA_D3, the ongoing cognitive acclimatisation in the domain of visuospatial attention imposes difficulty in judging the presence or absence of the target, which improved with the progression of the acclimatisation process. Higher values of RTP and RTA were observed for Kyrgyz soldiers under both set size conditions throughout various DE compared to Indian soldiers, revealing that Kyrgyz soldiers encountered a slowdown in cognitive processing during visual search. Furthermore, an interaction effect of DE X Group and Target X Group causes significant changes in reaction time, indicating a distinct ethnic component in visuospatial attention [Table 1].

The slope of the *reaction time X set size* function reflects the search efficiency, that is ms/items, deploying serial attention from item to item.[17] Literature depicts that target-present slopes of 20–40 ms/item range represent an inefficient range.[18] The target present and target absent slopes [Table 3] indicated a thorough search across various DEs which also demanded attention. Results of *reaction time X set size* indicate a decline in search efficiency on day 3 of HA exposure

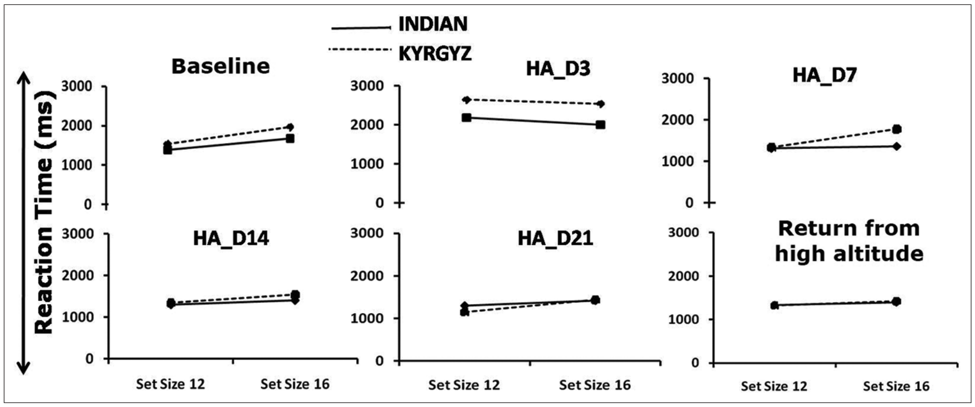

Figure 3: Target present correct reaction time are plotted as a function of set size at baseline, high altitude day 3 (HA_D3), day 7 (HA_D7), day 14 (HA_D14), day 21 (HA_D21) and return from high altitude for both Indian and Kyrgyz soldiers.

Table 2: Slope and intercept of target present and target absent correct reaction time between set size 12 and 16 on various days of experiments for Indian and Kyrgyz soldiers.

Condition	Participants	Target present		Target absent	
		Slope (ms/Item)	Intercept (ms)	Slope (ms/Item)	Intercept (ms)
Baseline	Indian	292.80	1091	594.40	1910
	Kyrgyz	433.60	1093	1131.00	2395
HA_D3	Indian	-178.10	2358	-430.00	4448
	Kyrgyz	-102.30	2744	491.20	4547
HA_D7	Indian	54.56	1257	791.70	1582
	Kyrgyz	440.30	900	706.40	2249
HA_D14	Indian	104.40	1191	540.00	1745
	Kyrgyz	197.10	1146	773.50	2129
HA_D21	Indian	113.40	1186	471.00	1608
	Kyrgyz	281.20	872	587.70	2423
Return from high	Indian	56.89	1278	592.40	1591
altitude	Kyrgyz	95.00	1231	531.10	2431

Note: HA_D3: Day 3 at high altitude, HA_D7: Day 7 at high altitude, HA_D14: Day 14 at high altitude, HA_D21: Day 21 at high altitude

Table 3: Post hoc analysis for changes in reaction time:

Individual pair of days of experiment	Level of significance
BL versus Day_03	**0.000**
BL versus Day_07	**0.000**
BL versus Day_14	**0.007**
BL versus Day_21	**0.009**
BL versus RFH	**0.000**
Day_03 versus Day_07	1.000
Day_03 versus Day_14	**0.000**
Day_03 versus Day_21	**0.000**
Day_03 versus RFH	**0.036**
Day_07 versus Day_14	**0.000**
Day_07 versus Day_21	**0.000**
Day_07 versus RFH	**0.001**
Day_14 versus Day_21	**0.000**
Day_14 versus RFH	**0.000**
Day_21 versus RFH	0.304

Bold pairs show a significant change in the dependent variables. Baseline (BL) and Return from high altitude (RFH)

during the acclimatisation process [Figures 3 and 4]. The intercept reflects sensory processing, decision-making, and motor response.[19] The intercept, that is decision-making by key pressing, took longer time at HA compared to baseline in both groups of soldiers (except for target-present trials in Kyrgyz on HA_D7 and HA_D21) [Table 1]. Decision-making on target absence took more time than for the target present. A higher intercept value (except on HA_D7 and HA_D21 for the target present) throughout the DEs in Kyrgyz soldiers indicated an overall delay in sensory processing, decision-making, and motor response than in Indian soldiers.

Fixation duration and saccade latency provide a quantitative measure of brain function and are considered more robust and reproducible than neuropsychological testing.[20,21] In Indian soldiers, changes in fixation duration and saccade latency showed a similar pattern during exposure to HA which increased on HA_D3; thereafter, a gradual decrease till HA_D14, again an increase on HA_D21 and finally returned

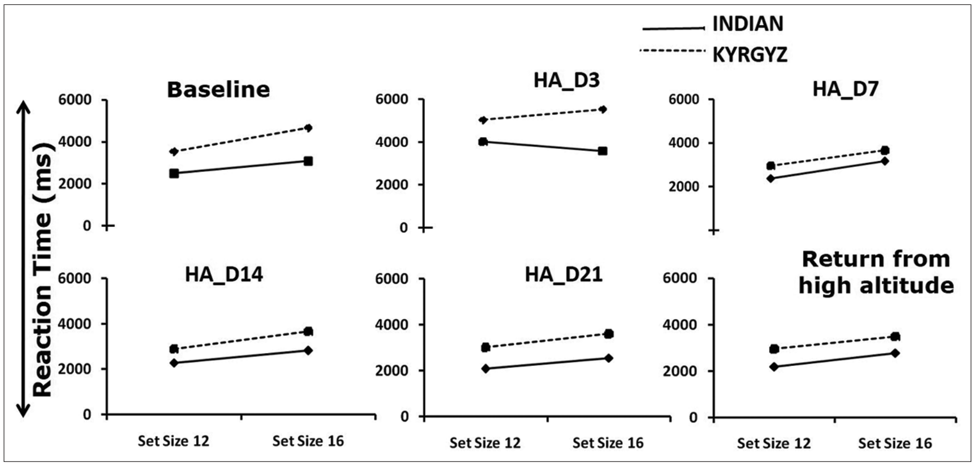

Figure 4: Target absent correct reaction time are plotted as a function of set size at baseline (BL), high altitude day 3 (HA_D3), day 7 (HA_D7), day 14 (HA_D14), day 21 (HA_D21) and return from high altitude (RFH) for both Indian and Kyrgyz soldiers.

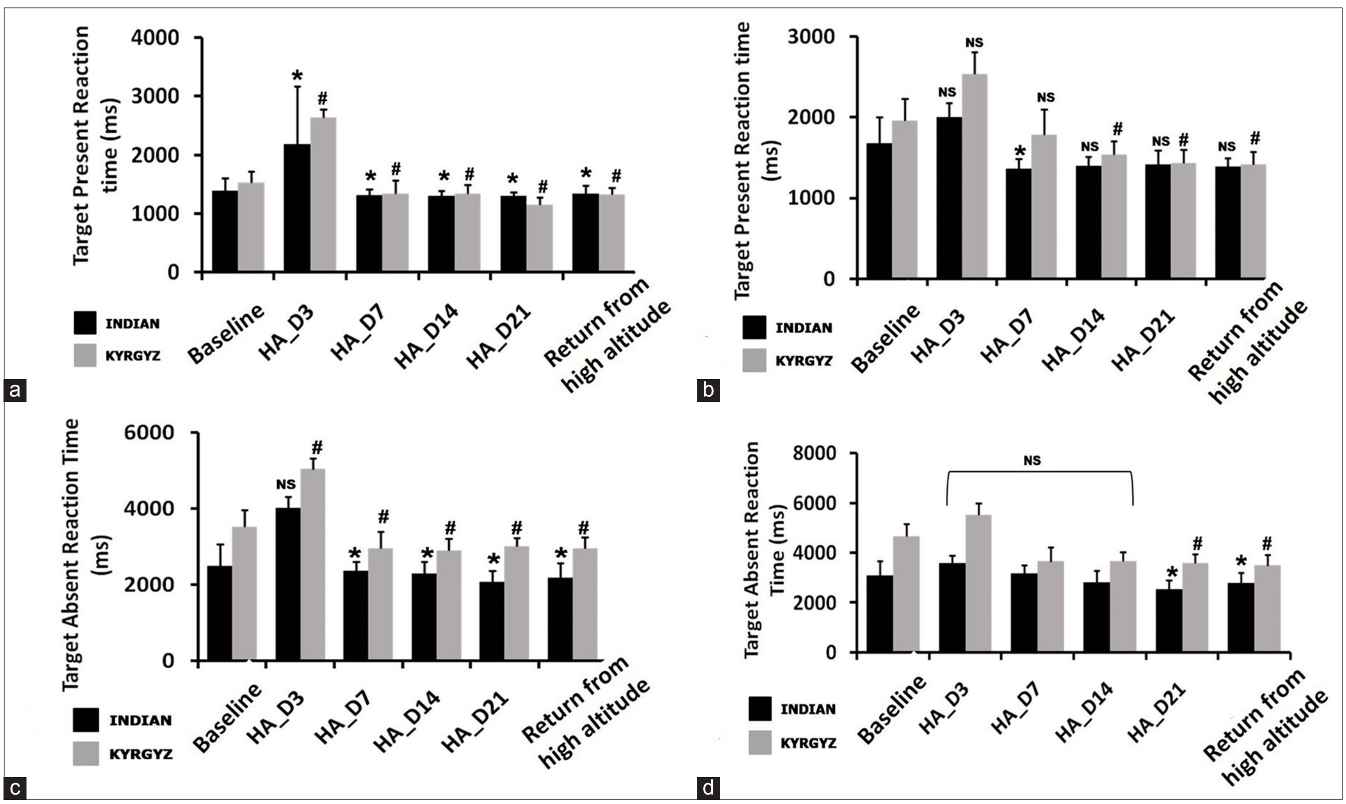

Figure 5: (a) and (b) Represent the effect of high altitude on the target present correct reaction time under set size 12 and 16 respectively. (c) and (d) represent target absent correct reaction time under set size 12 and 16 respectively. Values are plotted as Mean ± SEM. * denotes significant ($P < 0.05$) changes in Indian soldiers compared to baseline. # denotes significant ($P < 0.05$) changes in Kyrgyz soldiers compared to the baseline. NS denotes non-significant ($P > 0.05$) changes in both groups of soldiers compared to the baseline. HA_D3: Day 3 at high altitude, HA_D7: Day 7 at high altitude, HA_D14: Day 14 at high altitude, HA_D21: Day 21 at high altitude.

to very close to baseline values [Figure 6]. Therefore, it can be postulated that for Indian soldiers, visuospatial attention got acclimatised with a synchronised pattern of changes in fixation duration and saccade latency from HA_D3 onward.

In Kyrgyz soldiers, changes in fixation duration and saccade latency also showed similar patterns during exposure to HA which first increased on HA_D3, decreased on HA_D7, and then progressively increased until they returned to baseline

[Figure 6]. Thus, in the case of Kyrgyz soldiers, visuospatial attention did not level off till day 21 at HA. Therefore, it can be depicted that acclimatisation of visuospatial attention in association with fixation duration and saccade latency might require more than a period of 21 days at 3200 m for Kyrgyz soldiers. Thus, the effect of HA exposure might have persisted till day 3 on return to baseline. The decrease in fixation duration and saccade latency on HA_D7 may be explained as an increased cognitive effort to cope with the demand of the task, which might not succeed on the successive DEs where the effect of HA or task difficulty and/or a combination of both took the upper hand. Higher values of fixation duration and saccade latency in Kyrgyz soldiers reflect slow processing after fixing an object and consequent delay in initiating saccade.

Although both groups of soldiers maintained a good level of peripheral oxygen saturation, that is 96–97% on exposure to 3,200 m, a delay was observed in RTP, RTA, fixation duration, and saccade latency compared to baseline in both groups of participants. This might be due to the difference that exists between peripheral and cerebral saturation.[22] Observed that although the peripheral saturation improved from day 2 (81.2%) to day 7 (85.9%), the cerebral saturation continued to decline from day 2 (65.4%) to day 7 (62.9%) on exposure to 4,559 m. Thus, poor cerebral saturation may cause a delay in the cognitive processing of visuospatial attention. Besides this, other studies reported impairment in hand-eye coordination even for the well-known task at 3,048 m.[23,24]

Ray *et al*., 2019 reported a decrease in cognitive performance in Kyrgyz soldiers than in Indian soldiers followed by an acute exposure at 4,111 m for 21 days.[25] There are other studies where it is also observed that Indians and Kyrgyz have shown different patterns of acclimatisation in the domain of cardiorespiratory,[26-28] body composition,[29] haematological[27] and global gene expression profile changes.[30] Therefore, it can be stated that there may be a strong influence of ethnogenetic factors which result in a wide range of physiological and cognitive variabilities between these two groups.

Limitations of the study

The present study was limited by several factors, which could be improved in future research. A lower statistical power may be expected due to the small sample size. Initiation of the assessment earlier, for example immediately after 24 h of arrival at HA may also be helpful for stronger interpretation. Integration of more advanced neurological techniques such

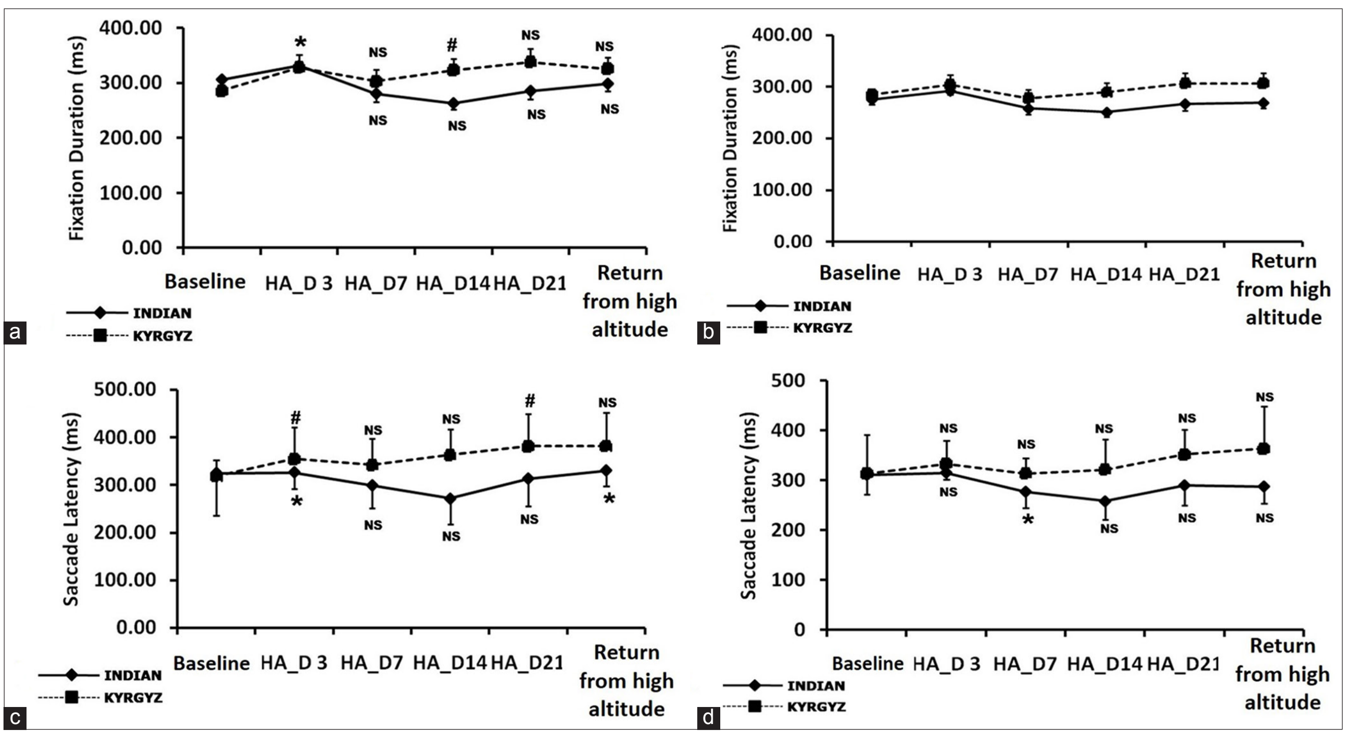

Figure 6: (a) and (b) Represent effect of high altitude on the fixation duration under set sizes 12 and 16 respectively. (c) and (d) represent saccade latency under set sizes 12 and 16 respectively. Values are plotted as Mean ± SEM. * denotes significant ($P < 0.05$) changes in Indian soldiers compared to baseline. # denotes significant ($P < 0.05$) changes in Kyrgyz soldiers compared to the baseline. NS denotes non-significant ($P > 0.05$) changes in both groups of soldiers compared to the baseline. Changes in fixation duration with 16 set size were not found significant ($P > 0.05$) when values on day 3, 7, 14, and 21 at high altitude and in case of return from high altitude compared with the value of baseline neither for Indian nor for Kyrgyz soldiers. HA_D3: Day 3 at high altitude, HA_D7: Day 7 at high altitude, HA_D14: Day 14 at high altitude, HA_D21: Day 21 at high altitude.

Table 4: Effects of various independent variables on fixation duration and saccade latency.

	Average fixation duration			Saccade latency		
	F value	df	P value	F value	df	P value
DE	6.183*	2.63, 44.75	0.002	5.14*	4.19, 71.23	0.001
Set size	4.37NS	1,17	0.052	0.67NS	1,17	0.42
DE X Set size	1.165*	5, 85	0.030	0.45NS	5,85	0.80
Group	1.45NS	1,17	0.244	11.00*	1,17	0.004
DE X Group	2.76*	5,85	0.023	2.55*	5,85	0.033
Set size X Group	0.54NS	1,17	0.47	2.09NS	1,17	0.166
DE X Set size X Group	1.16NS	5,85	0.33	0.67NS	5,85	0.64

Note: DE= Days of Experiments. Results of two-way mixed design ANOVA (within/repeated-between measure) presented by F, df, and P values to show the significant effects of various individual independent variables as well as interactions among them, where Group is the between measure factor and DE, and Set size are within measure factors. * indicates the effects are significant (p<0.05), NS indicates the effects are not significant (p>0.05)

Table 5: Post hoc analysis for changes in average fixation duration:

Individual pair of Days of Experiment	Level of Significance
BL versus Day_03	0.729
BL versus Day_07	1.000
BL versus Day_14	0.174
BL versus Day_21	**0.013**
BL versus RFH	0.102
Day_03 versus Day_07	0.488
Day_03 versus Day_14	1.000
Day_03 versus Day_21	0.072
Day_03 versus RFH	1.000
Day_07 versus Day_14	1.000
Day_07 versus Day_21	**0.009**
Day_07 versus RFH	**0.000**
Day_14 versus Day_21	0.335
Day_14 versus RFH	1.000
Day_21 versus RFH	0.972

Bold pairs show a significant change in the dependent variables. Baseline (BL) and Return from high altitude (RFH).

Table 6: Post hoc analysis for changes in saccade latency:

Individual pair of days of experiment	Level of significance
BL versus Day_03	1.000
BL versus Day_07	1.000
BL versus Day_14	1.000
BL versus Day_21	**0.022**
BL versus RFH	1.000
Day_03 versus Day_07	0.138
Day_03 versus Day_14	1.000
Day_03 versus Day_21	**0.009**
Day_03 versus RFH	1.000
Day_07 versus Day_14	0.491
Day_07 versus Day_21	**0.003**
Day_07 versus RFH	0.058
Day_14 versus Day_21	0.340
Day_14 versus RFH	1.000
Day_21 versus RFH	0.815

Bold pairs show a significant change in the dependent variables. Baseline (BL) and Return from high altitude (RFH).

as electroencephalogram and functional magnetic resonance imaging-based imaging will be of immense guidance to demarcate the task-specific activation of the cortical regions. Hence, future studies may be directed at exploring the effects of other variants of visual search such as conjunction search, more set sizes, and an earlier onset of experiments at HA involving a larger sample. Furthermore, a detailed socioeconomic and ethnogenetic profiling of both groups will also be considered critically for future investigations.

CONCLUSION

A prominent impact of the ethnicity factor was observed when the task performance of Indian soldiers got acclimatised from day 3 onward at HA and Kyrgyz soldiers were found to struggle to acclimatise throughout the residency period at HA. This was further confirmed by increased values of RTP, RTA, an intercept of reaction time X set size function, fixation duration, and saccade latency. Besides, the effect of acute exposure, there may be a contribution of demographics and geographic factors in this process. However, this generalization of the result is strictly attributed to this cohort of the studied groups.

Authors' contributions

DB: Concept generation, preparation of study protocol, data collection, analysis, and draft writing; KR: Concept generation and data collection; KK, PV, MS, and AA: Day-wise data collection; AM and AS: Finalisation of the draft.

Ethical approval

The study protocol was approved by the Institutional Ethics Committee on the use of humans as experimental subjects. Ethical approval number is IEC/DIPAS/D-9/2.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

Financial support and sponsorship

The study was funded by the Defence Research and Development Organisation (DRDO), India.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

REFERENCES

1. Ophir-Arbelle R, Oron-Gilad T, Borowsky A, Parmet Y. Is more information better? How dismounted soldiers use video feed from unmanned vehicles: Attention allocation and information extraction considerations. J Cogn Eng Decis Making 2013;7:26-48.
2. Phillips EK, Jentsch FG. Supporting situation awareness through robot-to-human information exchanges under conditions of visuospatial perspective taking. J Hum robot interact 2017;6:92.
3. Zani A, Tumminelli C, Proverbio AM. Electroencephalogram (EEG) alpha power as a marker of visuospatial attention orienting and suppression in normoxia and hypoxia. An exploratory study. Brain Sci 2020;10:140.
4. Obana T, Kozhevnikov M. State Effects of Action Video-game Playing on Visuospatial Processing Efficiency and Attention among Experienced Action Video-game Players. Proceedings of the Annual Conference of the Cognitive Science Society; 2012. p. 34.
5. Masel MC, Peek MK. Ethnic differences in cognitive function over time. Ann Epidemiol 2009;19:778-83.
6. Boivin MJ. The effect of culture on a visual-spatial memory task. J Gen Psychol 1991;118:327-34.
7. Heller PL, Briones DF, Schiffer RB, Guerrero M Jr., Royall DR, Wilcox JA, *et al*. Mexican-American ethnicity and cognitive function: Findings from an elderly southwestern sample. J Neuropsychiatry Clin Neurosci 2006;18:350-5.
8. Hill CM, Dimitriou D, Baya A, Webster R, Gavlak-Dingle J, Lesperance V, *et al*. Cognitive performance in high-altitude Andean residents compared with low-altitude populations: From childhood to older age. Neuropsychology. 2014;28:752-60.
9. Yu L, Feng J, Zhou C, Zhu X, Lou X, Yang J, *et al*. Cognitive function mainly shaped by socioeconomic status rather than chronic hypoxia in adolescents at high altitude. High Alt Med Biol. 2022;23:223-31.
10. Wolfe JM. Visual search. Curr Biol 2010;20:R346-9.
11. Wolfe JM. What can 1 million trials tell us about visual search? Psychol Sci 1988;9:3-9.
12. Kristjánsson A. Reconsidering visual search. i-perception 2015;6:2041669515614670.
13. Brigham FJ, Zaimi E, Matkins JJ, Shields J, McDonnouugh J, Jakubecy JJ. The eyes may have it: Reconsidering eye-movement research in human cognition. In: Technological applications. Emerald (MCB UP); 2001. p39-59.
14. Drew T, Boettcher SE, Wolfe JM. One visual search, many memory searches: An eye-tracking investigation of hybrid search. J Vis 2017;17:5.
15. Gomes KM, Riggs SL. Analyzing visual search techniques using eye tracking for a computerized provider order entry (CPOE) task. Proc Hum Factors Ergon Soc Annu Meet 2017;61:691-5.
16. Wolfe JM. Visual search. In: Fawcett JM, Risko EF, Kingstone A, editors. The handbook of attention. MIT Press; 2015. p. 27-56.
17. Wolfe JM, Horowitz TS. Five factors that guide attention in visual search. Nat Hum Behav 2017;1:0058.
18. Wolfe J, Horowitz T. Visual search. Scholarpedia 2008;3:3325.
19. Yoshimura N, Yonemitsu F, Marmolejo-Ramos F, Ariga A, Yamada Y. Task difficulty modulates the disrupting effects of oral respiration on visual search performance. J Cogn 2019;2:21.
20. Henderson JM, Choi W, Luke SG, Desai RH. Neural correlates of fixation duration in natural reading: Evidence from fixation-related fMRI. Neuroimage 2015;119:390-7.
21. Antoniades C, Ettinger U, Gaymard B, Gilchrist I, Kristjánsson A, Kennard C, *et al*. An internationally standardised antisaccade protocol. Vision Res 2013;84:1-5.
22. Sanborn MR, Edsell ME, Kim MN, Mesquita R, Putt ME, Imray C, *et al*. Cerebral hemodynamics at altitude: Effects of hyperventilation and acclimatization on cerebral blood flow and oxygenation. Wilderness Environ Med 2015;26:133-41.
23. Ernsting J, Sharp GR, Harding RM. Hypoxia and hyperventilation. In: Ernsting J, King P, editors. Aviation Medicine. London: Butterworths; 1988. p. 45-59.
24. Smith T. Aviation hypoxia, cognition, and human performance. Proceedings of the ASMA 2013. Available from: https://asmameeting.org/asma2013_mp/pdfs/asma2013_present_500.pdf
25. Ray K, Kishore K, Vats P, Bhattacharyya D, Akunov A, Maripov A, *et al*. A temporal study on learning and memory at high altitude in two ethnic groups. High Altitude Med Biol 2019;20:236-44.
26. Saini S, Vats P, Sharma AK, Ray K, Sarybaev A, Singh SB. Effect of altitude and duration of stay on pulmonary function in healthy Indian Males. Def Life Sci J 2018;3:307.
27. Gaur P, Saini S, Ray K, Akunov A, Maripov A, Sharma SK, *et al*. Influence of altitude on pulmonary function: A comparative study on Indian and Kyrgyz healthy males. Def Life Sci J 2020;5:3-9.
28. Gaur P, Sartmyrzaeva M, Maripov A, Muratali Uulu K, Saini S, Ray K, *et al*. Cardiac acclimatization at high altitude in two different ethnicity groups. High Altitude Med Biol 2021;22: 58-69.
29. Vats P, Ray K, Majumadar D, Amitabh DA, Joseph DA, Bayen S, *et al*. Changes in cardiovascular functions, lipid profile, and body composition at high altitude in two different ethnic groups. High Alt Med Biol 2013;14:45-52.
30. Saini S, Vats P, Bayen S, Gaur P, Ray K, Kishore K, *et al*. Global expression profiling and pathway analysis in two different population groups in relation to high altitude. Funct Integr Genomics 2019;19:205-15.

How to cite this article: Bhattacharyya D, Ray K, Kishore K, Vats P, Sartmyrzaeva M, Akunov A, *et al*. Visuospatial attention at high altitude in two ethnically distinct groups of soldiers. Indian J Physiol Pharmacol. 2024;68:265-74. doi: 10.25259/IJPP_421_2023