indjaerospacemed.com

Indian Journal of Aerospace Medicine

Original Article

Effects of whole body vibration on human contrast sensitivity function

B Bhowmick[1], D Gaur[2], P Rastogi[3]

[1]Specialist in Aerospace Medicine, HoD, Department of Acceleration Physiology & Spatial Orientation, Institute of Aerospace Medicine IAF, Bengaluru, India, [2]Specialist in Aerospace Medicine & Ex-Principal Medical Officer, Headquarters Training Command IAF, Bengaluru, India, [3]Senior Advisor (Aerospace Medicine), Med Dte, Air Headquarters (RK Puram), New Delhi, India.

***Corresponding author:**
Dr B Bhowmick, MBBS, MD (Aerospace Medicine), HoD, Department of Acceleration Physiology & Spatial Orientation, Institute of Aerospace Medicine, Indian Air Force, Vimanapura, Bangalore - 560017, Karnataka, India.

biplabavmed@gmail.com

Received : 07 July 2020
Accepted : 04 September 2021
Published : 08 November 2021

DOI
10.25259/IJASM_47_2020

Quick Response Code:

ABSTRACT

Introduction: Vibration is a known aeromedical stressor in rotary-winged aircraft and is known to affect visual acuity (VA). In aerospace operational conditions, contrast sensitivity (CS) takes the upper hand over VA for optimal visual performance. Examination of the effects of low frequencies whole body vibration of short duration on CS was the desired objective of the study.

Material and Methods: Thirty healthy volunteers were exposed to low frequency whole body vibration using Multi-axial Vibration Simulator. Vibration frequency along the Z-axis varied from 4 to 20 Hz over a period of 30 min. CS was recorded in no vibration, under vibration and 30 min following exposure to vibration using CSV-1000 equipment at spatial frequencies of 3, 6, 12, and 18 cycles per degree (cpd).

Results: CS, after an initial degradation, gradually improved with the increase in frequencies of vibration for the lower spatial frequencies (3, 6 cpd). The increasing trend was also noticed for higher spatial frequencies (12, 18 cpd) till 16 Hz; thereafter, a significant dip ($P = 0.048$) was observed at 20 Hz of vibration. No significant difference was observed following 30 min of post exposure.

Conclusion: In contrast to the popular belief, an improvement in CS with increasing frequencies of vibration could be concluded from the results of the study. However, the sudden decrement in CS at higher CPD at higher frequencies of vibration could adversely affect visual performance of an aircrew.

Keywords: Visual acuity, Contrast sensitivity, Whole body vibration, Spatial frequencies

INTRODUCTION

Vibration is a known aeromedical stressor in rotary-winged aircraft. This originates mainly from the engines, gears and revolution of the rotors and gets transmitted to the aircrew through the seat. Helicopter crew is predominantly exposed to the vertical vibration in a range of 1–20 Hz.[1] Exposure to such vibrations is known to affect visual acuity (VA). Visual performance of an aircrew not only depends on the VA but also on contrast sensitivity (CS), an integrated component of vision. Military operations are often conducted at night or in conditions of limited visibility. Under such conditions, CS takes the upper hand over VA for optimal visual performance.[2]

Studies have revealed a good relationship between CS and pilot's ability to detect approaching aircraft. In contrast to VA, it has also been found to be a useful tool in assessment of pilot's ability to achieve ground target acquisition, recognition, and identification.[2] CS is also related to detection and discrimination of real-world targets, driver's ability to identify road signs, and the viewing distance for discrimination.[3,4] Hence, aviation stressors potentially affecting CS would significantly affect visual performance of the aircrew and mission effectiveness. Low frequency vibration is one such stressor in helicopter flying.

Whereas, numbers of studies have been conducted on the effects of vibration on VA, scientific literature is scant on changes in CS on exposure to vibrations of aviation significance. With this background, the study was conducted to examine the effects of low frequencies whole body vibration in isolation as well as 30 min of continuous exposure on human CS functions.

MATERIAL AND METHODS

The study was carried out in the Vibration Testing Laboratory in the Dept of Applied Physics and Biodynamics, Institute of Aerospace Medicine, IAF. Thirty healthy volunteers with mean age of 32.7 ± 5.6 years participated in the study.

Low frequency whole body vibration was simulated using Multi-axial Vibration Simulator [Figure 1]. The simulator is capable of producing linear vibration frequencies along any of X, Y, or Z axes at desired amplitudes to a seated subject.[5] Landolt C chart was used to check VA of the subjects to ensure that they have 6/6 vision (aided or unaided). The HGT CSV-1000 CS Test Equipment consisting of a translucent test chart was used to assess the CS [Figure 2]. The test chart comprises of four horizontal rows. Each row comprises of 17 circular patches, 1.5 inches in diameter. Each row starts with a single sample patch of very high contrast (100% in the sample patch of D row), having the characteristic spatial frequency of that particular row. It is followed by eight paired circular test patches that decrease in contrast from the left to right. At the testing distance of eight feet, the translucent chart presents four spatial frequencies: 3, 6, 12, and 18 cycles/degree (cpd).[6]

All participants were briefed on the test protocol and an informed written consent was obtained from all. The study was carried out in photopic condition of the laboratory (illuminance level of 500 lux), which was ensured using, digital illuminance meter which conforms to JIS 1609-1 2006 standards. CS was measured in no vibration condition, under vibration and on recovery after 30 min of vibration exposure, at spatial frequencies of 3, 6, 12, and 18 cpd. Vibration frequency along the Z-axis was made varying from 4 to 20 Hz [Table 1] with an interval of 2 Hz for 5 min for a total duration of 30 min. However, vibration frequency along the X and Y-axes was kept constant.[5] CS values were recorded in Log Units (equivalent reference value from the chart provided with CSV) instead of linear values (being very large in figures) for statistical analysis. The data were tested for normality using Shapiro–Wilk test and one-way repeated measures Analysis of variance was employed to analyze the results. Level of significance was kept at $P < 0.05$.

Figure 1: Multi-axial vibration simulator.

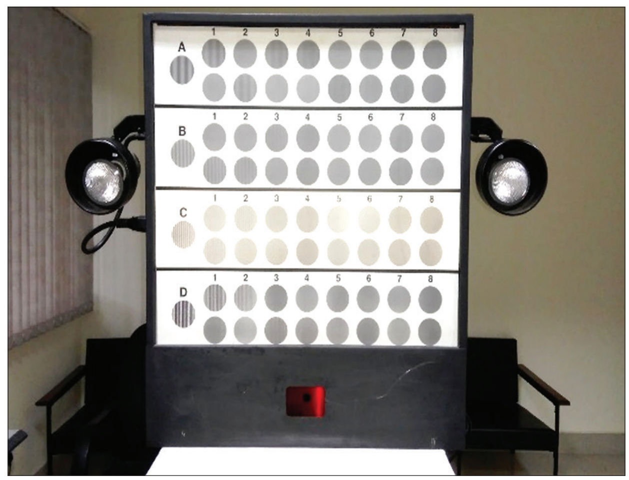

Figure 2: Vector-Vision's CSV-1000E HGT contrast sensitivity test equipment.

Table 1: Vibration profile (Z-axis) used in the present study.

Axis	Frequency (Hz)	Amplitude (m/s²)	Duration (s)
Z-axis	4	1.2	300
	6	1.2	300
	8	1.2	300
	12	1.4	300
	16	1.6	300
	20	1.8	300

RESULTS

All the subjects successfully completed the experimental profiles. The mean log CS values collected under eight different vibration conditions (Baseline, 06 vibration frequencies for 5 min duration each, and 30 min post-exposure) under four major categories based on the spatial frequencies (3, 6, 12, and 18 cpd) are depicted in Table 2. The baseline CS scores of the participants are presented in Figure 3.

Analysis of CS data revealed that after an initial degradation, CS gradually improved with the increase in frequencies of vibration for the lower spatial frequencies (3, 6 cpd). The increasing trend pattern was also noticed for higher spatial frequencies (12, 18 cpd) till 16 Hz; thereafter, a significant dip ($P = 0.048$) was observed at 20 Hz of vibration [Figure 4], but never degraded beyond baseline values.

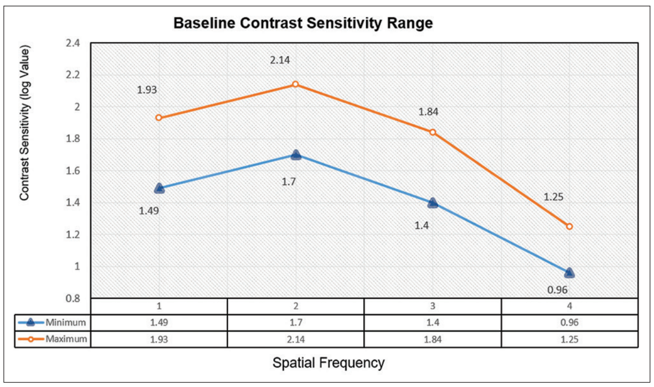

Figure 3: Graphical representation of baseline contract sensitivity scores at different spatial frequencies.

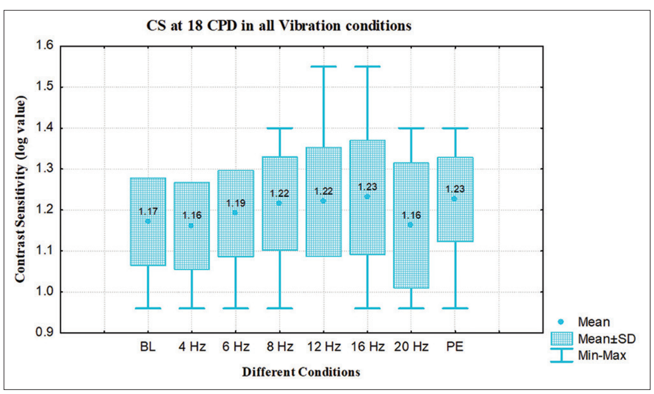

Figure 4: Whisker-Box plot of CS values of subject population at 18 cpd. CS: Contract sensitivity.

Figure 5 depicts the changes in CS 30 min post exposure as compared to baseline values. The differences in the CS were not found to be statistically significant.

DISCUSSION

Vibration, an important aeromedical stressor in helicopter flying, has the potential to affect visual performance. CS, a measure of the ability to discern between luminance of different levels in an image and is considered an important function of visual performance.[7] Hence, this study was conducted to examine the changes in CS under simulated vibration environment of aeromedical significance.

In the present study, vibration stress was simulated at frequencies range of 4–20 Hz at an interval of 2 Hz and exposure of 5 min in each frequency levels. The profile was chosen as this is operationally encountered in rotary wing aircraft[1] and such frequencies are known to affect human visual system.[8] CS was measured at spatial frequencies (3, 6, 12, and 18 cpd) using standard recommended practices.[6] It is known that these frequencies are perceived by the retinal ganglia and conveyed through a system of neural channels running parallel to each other. Each channel carries information for a limited range of frequencies only and they operate independently. The task involving the detection of a large size object based on its outline is relayed through low spatial frequencies while discerning the details of a target or viewing a small object depends on higher frequencies.[7,9,10] All the participants were having VA 6/6, aided, or unaided. The baseline values of CS [Figure 3] followed the same pattern of inverted "U" shape as documented in the CSV norms for general healthy population of that particular age group.[11]

Overall, a gradual improvement in the CS scores was observed after an initial decrement with increasing frequencies of vibration for the lower spatial frequencies. This was in contrast to our belief that CS would be adversely affected with vibration. The reasons for this improvement could not be identified clearly. However, generalized straining to attenuate the physical stress of whole body low frequency vibration could have caused some amount of straining of

Table 2: CS data in log value (Mean±SD) in different study conditions.

	Log CS values (Mean±SD) for different conditions							
Spatial frequency	**Baseline**	**4 Hz**	**6 Hz**	**8 Hz**	**12 Hz**	**16 Hz**	**20 Hz**	**Post exposure**
3 cpd	1.73±0.11	1.71±0.13	1.70±0.12	1.72±0.11	1.74±0.11	1.74±0.12	1.77±0.10	1.77±0.07
6 cpd	1.95±0.13	1.92±0.16	1.92±0.09	1.95±0.10	1.98±0.13	1.94±0.11	1.94±0.11	1.95±0.12
12 cpd	1.63±0.14	1.65±0.13	1.66±0.11	1.70±0.08	1.68±0.12	1.68±0.10	1.64±0.12	1.68±0.12
18 cpd	1.17±0.11	1.16±0.11	1.19±0.11	1.22±0.11	1.22±0.13	1.23±0.14	1.16±0.15	1.23±0.10

CS: Contrast sensitivity, cpd: Cycles per degree

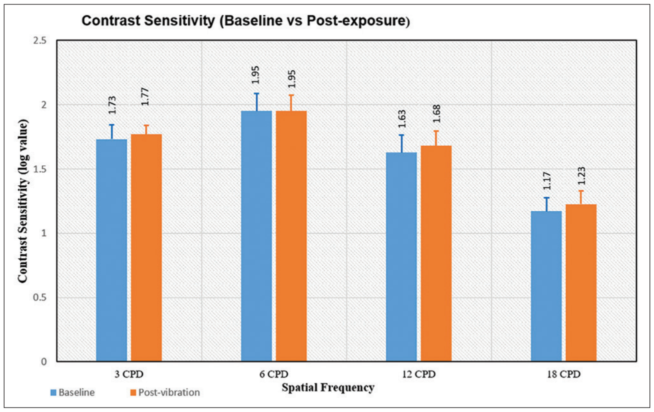

Figure 5: Histogram comparing baseline and post-exposure contrast sensitivity values (Mean±SD).

eye muscles too. Straining of eye muscles is known to cause marginal increase in VA.[12] It is possible that such straining could have contributed toward improvement in CS.

Similar pattern of change in CS was also observed for higher spatial frequencies up to 16 Hz, following which a decrement in CS was observed. The degradation was most profound with 20 Hz of vibration and in the spatial frequency of 18 cpd, and this change was statistically significant. This finding is possibly due to head level resonance which is known to occur at 20–30 Hz.[8] In operational environment, this kind of sudden decrement in CS with changing vibration may be aeromedically significant. This is because, in operational environment, many important flying activities such as detection of the edges of runway in a desert terrain, avoiding an obstacle during low ambient luminance or detecting an island in fog, all are dependent on the CS function of the pilot.[13-15]

Comparison of the 30 min post-exposure values revealed an improvement in CS in many spatial frequencies. However, such a change was not statistically significant indicating that there were no residual adverse effects of vibration on this visual performance parameter. There were certain limitations of the study; (a) the vibration profile simulated was not completely representative of the actual realistic vibration profile encountered in rotary wing aircraft and (b) the duration of exposure was for 30 min; whereas, rotary wing aircraft can fly for long duration. Hence, the effects of long duration exposure on CS could not be examined.

CONCLUSION

It can be concluded from the present study that CS, after an initial decrement, showed a consistent gradual improvement with increasing frequencies of vibration for the lower spatial frequencies. For higher spatial frequencies, similar pattern of change in CS was observed up to 16 Hz, following which a rapid decrement was observed, which was significant with 20 Hz of vibration and in the spatial frequency of 18 cpd. This finding is considered important from aeromedical operational perspective. The CS was not found to be affected 30 min post-exposure of vibration.

Acknowledgment

The authors gratefully acknowledge the permission and guidance extended by Dept of Applied Physics and Dept of Ophthalmology at Institute of Aerospace Medicine IAF. Authors also express heartfelt thanks to all participants for their voluntary participation in the study.

Declaration of patient consent

The authors certify that they have obtained all appropriate consent from the participants.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Chakraborty I. Vibration Profiles of Human Interest in Various Rotary Wing Aircrafts of IAF, Field Project Report, IAM, IAF, Bangalore; 1995.
2. Ginsburg AP, Easterly J, Evans DW. Contrast sensitivity predicts target detection field performance of pilots. In: Proceedings of the Human Society 27th Annual Meeting; 1983. p. 269-73.
3. Owsley C, Sloane ME. Contrast sensitivity, acuity and the perception of real-world targets. Br J Ophthalmol 1987;71:791-6.
4. Evans DW, Ginsburg AP. Contrast sensitivity predicts age-related differences in highway sign discriminability. Hum Factors 1985;27:637-42.
5. Numag Data Systems Pvt. Ltd. Multi-Axial Vibration Simulator. Bangalore: Numag Data Systems Pvt. Ltd.; 2011.
6. Standardized Contrast Sensitivity Tests: CSV 1000;2004. Available from: https://www.vectorvision.com/csv1000-contrast-sensitivity. [Last accesed on 22 Aug 2021].
7. Campbell FW, Maffei L. Contrast and spatial frequency. Sci Am 1974;231:106-14.
8. Moseley MJ, Griffin MJ. Effects of display vibration and whole body vibration on visual performance. Ergonomics 1986;29:977-83.
9. Abrams D, Duke-Elder S. Duke-Elder's Practice of Refraction. 9th ed. Edinburgh: Churchill Livingstone; 1985. p. 608-13.
10. Campbell FW, Robson JG. Application of Fourier analysis to the visibility of gratings. J Physiol 1968;197:551-66.
11. Pomerance G, Evans D. Test-Retest Reliability of the CSV-1000 Contrast test and its relationship to glaucoma therapy. Invest Ophthalmol Vis Sci. 1994. 35; 3357-61.
12. Miller SJ. Examination of retinal function. In: Parsons'

Diseases of the Eye. 18th ed. Oxford: Butterworth-Heinemann; 1999. p. 107.
13. Sanders MS, McCormick EJ. Text, graphics, symbols and codes. In: Human Factors in Engineering and Design. 7th ed., Ch. 4. New York: McGraw Hill International Edition; 1992. p. 5.
14. Hawkins FH. Vision and visual illusions. In: Human Factors in Flight. New Delhi: Himalayan Books; 2001. p. 114-23.
15. Hughes PK, Vingrys AJ. Reduced contrast sensitivity when viewing through an aircraft windscreen. Aviat Space Environ Med 1991;62:254-7.

How to cite this article: Bhowmick B, Gaur D, Rastogi P. Effects of whole body vibration on human contrast sensitivity function. Indian J Aerosp Med 2021;65:86-90.