



Original Article

Effect of 21 days of yogic exercises (*Suryanamaskar*) on orthostatic and neurovestibular responses following 4 hours of head-down tilt

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ABSTRACT

Objectives: The practice of yoga is known to modulate autonomic and postural physiology. Exposure to microgravity leads to adaptive changes in all physiological systems, notably in cardiovascular (CVS) and neurovestibular. Head-down tilt (HDT) is an effective earth-based analog for simulating the effects of microgravity on the cardiovascular system. It also simulates the effects of cephalad fluid shift on the neurovestibular system. *Suryanamaskar* includes a sequence of static and dynamic exercises which are known to affect the autonomic and vestibular systems. This study aimed to evaluate the effects of yogic exercises (*Suryanamaskar*) on HDT-induced changes in CVS and neurovestibular physiology.

Material and Methods: Ten age-matched, healthy male participants took part in the study. Initial baseline data of their CVS responses to head-up tilt and coriolis time interval (CTI) estimation following eight orthogonal head movements in Barany's Chair mode of the AirFox® DISO Simulator were recorded before and after 4 hours of HDT. The participants practiced 12 sets of *Suryanamaskar* under supervision for 21 days. Thereafter, the same physiological parameters were recorded after exposure to 4 hours of HDT. The findings were then compared using repeated measures analysis of variance.

Results: Mean age of the participants was 34.2 ± 3.9 years. The findings suggested that there was a significant reduction in heart rate (-5.8 beats/min) and systolic blood pressure (-3.1 mmHg) on exposure to HDT after yogic intervention. The comparisons of diastolic blood pressure and CTI pre and post-*Suryanamaskar* practice, however, did not yield statistically significant results.

Conclusion: The effect of HDT on CVS physiology can be potentially altered by the practice of *Suryanamaskar*, primarily by improved orthostatic tolerance due to autonomic stabilization. However, influence of *Suryanamaskar* on the neurovestibular effects of short exposure to HDT, especially the effects on the semi-circular canals, needs further research. This has operational significance in the current world scenario, as we see private astronauts being sent on sub-orbital and orbital flights for a very short experience of microgravity

Keywords: Coriolis time interval, Head down tilt, Head-up tilt, Microgravity, Orthostatic intolerance, *Suryanamaskar*, Yoga

INTRODUCTION

The practice of Yoga is known to modulate several physiological parameters in homeostasis.^[1] Extant literature suggests the benefits of yoga in varied professions, be it sedentary or an active lifestyle of an athlete.^[2] *Suryanamaskar* or “Sun Salutation” is one of the routines offered by yoga which influences the human physiology in various domains. It consists of 12 sets of sequential

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exercises, one complementing the previous posture that applies stretch and pressure alternately in major muscle groups of the body. The flexion postures are practiced with expiration to residual volume and the extension postures are performed with inhalation to total lung capacity.^[3] There are both static and dynamic components in the postures, which produce an autonomic response by activating the “muscle metaboreflex.”^[3] This increases the sympathetic activity in blood vessels and, hence arterial pressure. Increase in the heart rate is, however, achieved due to the withdrawal of parasympathetic activity at the sinus node.^[4] Kinematic analysis of *Suryanamaskar* reveals that it challenges balance and posture by inducing varying base of support.^[5] It also increases mobility and muscular endurance.^[5,6]

Exposure to microgravity generates compensatory responses in all physiological systems. The cardiovascular (CVS) and neurovestibular systems specifically undergo major adaptive changes during initial phases of microgravity exposure. These manifest in the astronauts as Space Adaptation Syndrome.^[7] The main CVS effect seen in acute microgravity exposure is the cephalad fluid shift, leading to body fluid redistribution and activation of compensatory responses within the autonomic system as well as in the organs responsible for control of intravascular volume.^[8] Due to mismatch in sensory reception, the gravireceptors in otoliths, first de-adapt and then adapts to microgravity. This usually manifests in the initial week of spaceflight as space motion sickness.^[9] However, on return to Earth and re-exposure to 1 g conditions, the decompensated neurovestibular system again shows signs of sensory-motor conflict in the form of entry motion sickness.^[10] Interestingly, these neurovestibular symptoms are seen even in very short duration spaceflights where the otoliths do not get enough time to de-adapt and harvest mal-inputs of gravireception. Thus, the role of fluid shift inside the semicircular canals, potentially leading to the manifestation of Space and Entry Motion Sickness in these spaceflights, needs to be investigated.

Head-down tilt (HDT) is one of the widely accepted Earth-based space analogs utilized for rapid induction of physiological effects of microgravity.^[11] The initial period of HDT is only meant to simulate cephalad fluid shift and body fluid redistribution. While the apparent cardiorenal response-induced diuresis is a known phenomenon in HDT, it is not so evident in actual initial space dwelling.^[12] However, in space, the intracellular volume is increased significantly.^[13] Plasma volume depletion is usually seen in longer-duration space missions, clinically manifested as weight loss and post-flight orthostatic intolerance.^[14] Short-duration HDT of even 2 hours has previously been found to induce rapid CVS effects commensurate with neutralization of the hydrostatic pressure gradient and the vascular fluid shift from lower limbs.^[15] Furthermore, 4 hours of HDT has been done

previously to demonstrate segmental fluid redistribution using bioimpedance as a measure of tissue resistance.^[16] Hence, 4 hours of HDT exposure was considered adequate in this study with the hypothesis that it will produce altered CVS and neurovestibular responses due to cephalad fluid shift. Operationally also, the time duration is relevant in the current world scenario, especially as we see private astronauts being sent on sub-orbital and orbital flights for a very short experience of microgravity. The selection criteria for these private astronauts are not so stringent, which further validates the reason why the CVS and neurovestibular responses after short-duration microgravity exposure need to be assessed. The CVS challenge was administered using 70° head-up tilt; while the neurovestibular challenge was provided in terms of voluntary head movements during angular motion. This paper, thus, aims to study the physiological effects of simulated microgravity exposure and find out if yoga is able to alleviate the challenges.

MATERIAL AND METHODS

Ten healthy male volunteers between age 20 and 40 who were not on any kind of medication and did not suffer from any musculoskeletal, cardiorespiratory, or neurovestibular disorders were selected. Any intervening infection of the volunteers during the conduct of the study rendered them unfit for further participation. After obtaining informed consent, the individuals were subjected to vestibular challenge by angular motion at 5 rotations per minute inside the AirFox® DISO simulator in Barany's Chair mode. Coriolis time interval (CTI) was measured at each head movement in orthogonal planes during the run. CTI is the time interval between onset of head movement (manifesting as tumbling sensation in the participants) and the time when they confirmed that the sensation died down. A reduction in CTI would mean better physiological response to these sudden motion stimuli, indicating neurovestibular adaptation. On another day, the participants were subjected to orthostatic stress by 70° Head-up tilt (HUT) for 20 min. Heart rate (HR), systolic blood pressure (SBP), and diastolic blood pressure (DBP) were measured.

On subsequent days, the DISO® run and HUT responses were measured after exposure to 4 hours of 6° HDT. The participants were then subjected to a 21-day daily yogic routine where they performed the 12 postures of *Suryanamaskar* for 30 minutes in the morning. Due importance was given to ensure regular supervision during practice of yoga in the participants through direct observation, monitoring by yoga experts, and debriefs. After 21 days of practice of *Suryanamaskar*, the participants were again subjected to DISO® run and HUT after 4-h HDT. The experimental protocol has been diagrammatically represented in Figure 1. The responses were compared using

repeated measures analysis of variance. Confidence level was kept at 95% (Z score 1.96) for sample size estimation and subsequent statistical analysis.

RESULTS

Normal distribution of data was ascertained using direct observation of the results. The mean age group of ten participants was 34.2 ± 3.9 years with physical parameters as tabulated below [Table 1]. Comparison between mean weight and mean body mass index pre and post-practice of *Suryanamaskar* (using paired t-tests) did not yield any statistical significance.

Post-yoga, there was a significant reduction in mean supine HR as compared to pre-yoga measurements ($P < 0.01$, F-value 1631.2). There was also a significant difference in average HR during HDT pre and post-yoga ($P < 0.05$). Analysis of change in HR (Δ HR) from HDT to 0 min of HUT revealed significant increase in Δ HR post-yoga ($P < 0.05$) [Table 2].

There was a significant reduction in mean supine SBP after yogic intervention (F-value 4.023 and $P < 0.05$ after Bonferroni correction), whereas the effect of HDT and Yoga on the reduction did not reveal any significance statistically [Table 3].

There was a significant reduction in mean supine DBP post-yoga post-HDT ($P < 0.05$). However, *post hoc* analysis failed to establish any statistical significance. Mean DBP during HDT was also significantly less after yoga ($P < 0.05$) [Table 4].

The mean CTIs of the participants during the three occasions of measurements are represented in Figure 2. There was no significant change in CTI in any of three readings.

Table 1: Mean height, weight, and BMI (Mean±SD).

	Pre-yoga	Post-yoga	Level of significance
Height (cm)	172.5±4.2		-
Weight (kg)	73.7±5.5	73.3±6.9	0.631
BMI (kg/m ²)	24.7±1.2	24.4±1.6	0.062

BMI: Body mass index, SD: Standard deviation

DISCUSSION

HDT is a suitable analog to simulate the fluid shift effects of microgravity. The CVS responses obtained in the study with 4 hours of HDT are consistent with the findings of intravascular volume redistribution, thus substantiating the duration of exposure chosen.

Suryanamaskar is known to modulate autonomic and postural responses. It is understood that *Suryanamaskar* cannot be performed in the absence of gravity, and hence, it is not applicable during actual spaceflights. The *asana* was selected with the principle that it can be scheduled during the pre-flight phase of space missions.

Comparison of physical parameters pre and post-yoga showed no significant change. While even short-term practice of yoga is known to help in the reduction of weight in obese individuals, such is not so with non-obese people.^[17] Hence, a change in the weight of participants was neither expected nor observed in this study [Table 1].

It is known that the high cardiac filling pressure and thoracic blood volume that occurs due to cephalad fluid shift induced by HDT influence the low and high pressure baroreceptors, resulting in a reflex decrease in HR and peripheral vascular resistance.^[18] The responses observed in this study are in consonance with the extant literature [Table 2]. The modulation of autonomic nervous system by *Suryanamaskar* in favor of parasympathetic system was seen by reduction in HR in the study by Bhutkar *et al.*^[19] Reduction in HR during HDT was found to be similar to the study done by Levine *et al.* which stated that the initial response to HDT was a decrease in HR followed by stabilization over a period of 14 days.^[20] In this study, it is evident that 21 days of *Suryanamaskar* had a positive effect on parasympathetic system. The Δ HR from HDT to 0 min of HUT was found to be higher after 21 days of yoga. It, however, did not negatively affect the individuals' response to HUT as the mean HR at 0 min of tilt was similar pre and post-yoga.

SBP responses during HDT and HUT before and after yoga [Table 3] indicate that change of position from HDT to HUT

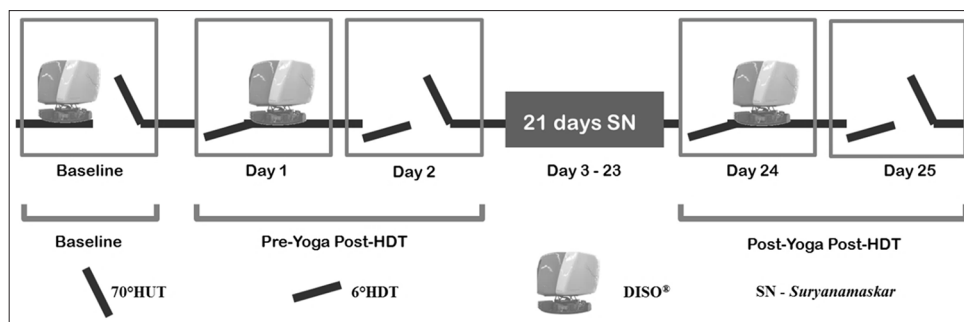


Figure 1: Diagrammatic representation of the experimental protocol. HDT: Head-down tilt, HUT: Head-up tilt

Table 2: HR response (in bpm) to HUT following HDT before and after yoga.

Time interval (min)	Baseline	HDT	HDT+Yoga
Supine			
0	72.8	73.3	70.3
2	74.4	73.8	70.3
4	75.8	73.9	68.7
6	74	72.5	69.6
8	74.6	73.6	70.4
10	74.8	75.8	69.5
Mean supine HR	74.4	73.8	69.8**
HDT			
0		73.5	69.2
30		69.9	67.9
60		68.6	65.2
90		70	65.6
120		70.6	64.8
150		68.3	64.5
180		69.2	64.8
210		68.6	64.3
240		68.7	64.2
Mean HDT HR		69.7	65.6*[†]
HUT			
0	97.7	91.4	93.1
2	92.3	87.9	89
4	86.3	84.4	86.4
6	86.9	89.5	80
8	80.3	85	81.4
10	84	79.4	83.9
12	83.2	83.5	85.1
14	80.1	78.6	81.1
16	84.2	82.1	78.3
18	79.9	80.8	79.1
20	80.2	79.2	79.1
Δ HR [®]		21.7	27.5*[†]

*Significant at $P \leq 0.05$. **Significant at $P \leq 0.01$. [†]Pre-Yoga Post-HDT group vs. Post-Yoga Post-HDT group. [®]From Mean HDT HR to 0 min HUT HR. HDT: Head-down tilt, HUT: Head-up tilt. Δ : Denotes delta change from Mean HDT value to 0 min value of HUT. Bold values denote significance

resulted in fall of SBP, which is considered normal response to orthostatic challenge induced by baroreceptor reflex. The effect of *Suryanamaskar* on the reduction of SBP was also evident, which was also seen by Udupa *et al.* and Bhutkar *et al.*^[19,21] However, the Δ SBP post-yoga was lesser compared to pre-yoga, although statistically not significant. It is felt that this response may be an important finding in the sense that practice

Table 3: SBP responses (in mm Hg) to HUT following HDT before and after yoga.

Time interval	Baseline	HDT	HDT+Yoga
Supine			
0	128.4	125.4	121.3
2	128.3	123.4	121.2
4	123.9	124	123.1
6	122.8	122.7	120.9
8	123.3	124.7	122
10	123.1	124.6	122.1
Mean supine SBP	124.9	124.1	121.8*[†]
HDT			
0		123.2	121.8
30		119.5	119.9
60		117.1	118.2
90		116.4	116.7
120		116.1	116.6
150		115.3	115.6
180		115.9	116.4
210		115	114.5
240		122.6	115.7
Mean HDT SBP		117.9	117.3
HUT			
0	116.1	112.4	114.3
2	120.1	119.2	113.3
4	116.9	123	119.4
6	119.9	120.2	119.4
8	120	124.7	119.6
10	119.3	119	122.2
12	122.3	120.7	121.2
14	121.8	119	120.6
16	121.8	121.1	121
18	119.8	120.1	121.7
20	121.7	120.8	120.6
Δ SBP [®]		5.5	3.0

*Significant at $P \leq 0.05$. [†]Pre-Yoga Post-HDT group vs. Post-Yoga Post-HDT group. [®]From Mean HDT SBP to 0 min HUT SBP. HDT: Head-down tilt, HUT: Head-up tilt, SBP: Systolic blood pressure. Δ : Denotes delta change from Mean HDT value to 0 min value of HUT. Bold values denote significance

of *Suryanamaskar* for 21 days yielded relatively less fluctuation of SBP in response to orthostasis after 4 hours of microgravity. Such a finding may need to be substantiated by studies with a larger number of participants and possibly longer duration of practice of yoga, before surmising that *Suryanamaskar* may have beneficial effects in maintaining cerebral perfusion and preventing post-flight orthostatic intolerance.

Table 4: DBP responses (in mmHg) to HUT following HDT before and after yoga.

Time interval (min)	Baseline	HDT	HDT+Yoga
Supine			
0	81.1	80.2	76.8
2	81	78.4	77.1
4	79.6	78.2	78
6	80.2	80.3	77.5
8	79.6	78.8	74.5
10	80.9	77.8	75.9
Mean supine DBP	80.4	78.9[§]	76.6^{*,#,†}
HDT			
0		79.9	77.2
30		79.7	76.3
60		79.4	76.3
90		79.0	76
120		78.6	75.4
150		77.9	77.5
180		79.6	76
210		77.6	76.9
240		77.6	76.5
Mean HDT DBP		78.8	76.5*
HUT			
0	80	82.9	79.7
2	81.2	79.6	76.8
4	80.3	82.1	74.6
6	81.3	79	75.5
8	80.4	79.8	75.4
10	79.7	78.8	74.9
12	81.4	78.4	75.7
14	81.7	77.2	75.3
16	81.1	77.6	77.1
18	80.6	77.6	75.5
20	79.3	77	77.1
ΔDBP [®]		4.1	3.2

[§]Baseline group vs. Pre-Yoga Post-HDT group *Significant at P≤0.05.
[#]Baseline group vs. Post-Yoga Post-HDT group. [†]Pre-Yoga Post-HDT group vs. Post-Yoga Post-HDT group. [®]From Mean HDT DBP to 0 min HUT DBP. HDT: Head-down tilt, HUT: Head-up tilt, DBP: Diastolic blood pressure. Δ: Denotes delta change from Mean HDT value to 0 min value of HUT. Bold values denote significance

Yogic intervention reduced the supine DBP further compared to pre-yoga assessment, possibly due to reduced sympathetic activity. There was, however, no change in DBP at the end of 4-hours HDT [Table 4]. Interestingly, these findings are consistent with the findings in the astronauts of Apollo and Skylab crew in 1972.^[22] Overall, the decrease in fluctuation of BP at the onset of tilt suggests that *Suryanamaskar* helped

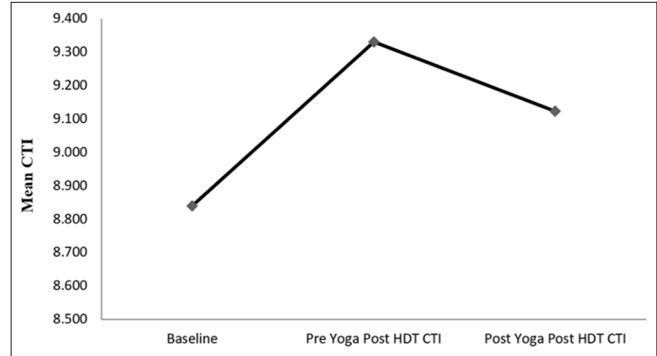


Figure 2: Mean coriolis time interval response. CTI: Coriolis time interval, HDT: Head-down tilt

in the maintenance of cerebral circulation even with sudden orthostatic challenge.

The minimal changes observed in the ΔSBP and ΔDBP in response to HUT meant that the recovery and stabilization were rapid, even after neutralization of the hydrostatic pressure gradient and the vascular fluid shift induced by HDT. The findings are consistent with the physiological changes in microgravity as reported by Banerjee and Banerjee.^[15]

Neurovestibular decompensation in microgravity is an important adaptive entity that primarily involves mismatched utricular gravireception. The adaptation manifests during the initial stages of spaceflight as Space Motion Sickness and again on return to Earth as Entry Motion Sickness. However, as substantiated by Stepanek *et al.* even in commercial space tourism consisting of very short duration spaceflight, there are incidences of motion sickness on return to Earth.^[23] This manifestation cannot be explained by otolith effects, as there is just not enough time in microgravity for otoliths to deadapt/re-adapt. Hence, the study aimed to identify whether HDT (primarily the vestibular congestion due to cephalad fluid shift) influenced the responses of semi-circular canals and if *Suryanamaskar*, due to its known influence on balance and posture, can alter the responses.^[5] That is why, the exposure to angular velocity was planned after HDT, and not during HDT, to simulate an experience of return from a very short duration commercial spaceflight. However, the CTI responses did not yield statistically significant differences with either HDT or *Suryanamaskar*. This suggests that the effect of short-duration microgravity may not be of concern to the semi-circular canals. However, it is pertinent to bring out that in this study, the vestibular challenge was introduced only in the superior semi-circular canals during the orthogonal head movements. The influence of posterior canals was not assessed, which may be a limitation of the study. Furthermore, *Suryanamaskar* may not be the exercise of choice modulating the vestibular

system for achieving desired adaptive responses. There are other *yogic asanas* which have demonstrated reduction in the symptoms of motion sickness during similar vestibular challenges.^[24]

To summarize, while the study was able to show *Suryanamaskar's* effect on HR and SBP, it did not produce statistically significant influences in DBP and CTI. One possibility is the small sample size. Furthermore, it probably warranted more aggressive intervention in terms of duration of yogic exercise to induce further changes in the physiological parameters. It is also possible that the duration of yoga may have been adequate, but, the changes that were induced by 4 hours of HDT were themselves so small that even smaller changes due to yoga were barely detectable. Due importance was given to ensure regular practice of yoga in the participants. However, their diet and other lifestyle habits could have had an influence in the outcome of the study.

CONCLUSION

From this study, it can be concluded that the effect of HDT on CVS physiology can be potentially altered by the practice of *Suryanamaskar*, primarily by improved HR and SBP responses. However, influence of *Suryanamaskar* on CTI after short exposure to HDT needs further research.

Ethical approval: The research/study was approved by the Institutional Review Board at Institute of Aerospace Medicine, Indian Air Force, number IAM/Dissertation/2016-19/MD, dated 21st February, 2018.

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