Effect of Microgravity on Oral Cavity : Mission to Mars

***Balwant Rai, **Jasdeep Kaur**

*Editor-in-Chief, Founder of Aeronautic Dentistry, ** 162, Model Town, Kapurthala, Punjab

Abstract

To determine the influence of a simulated microgravity on oral cavity, 40 healthy male volunteers were studied before, during, just after and after 12 hr of the simulated microgravity condition of -6° head-down-tilt (HDT) bed rest. Facial function tests, mouth opening, jaw movements, tongue movements, facial sensation (Touch, pressure, temperature), taste, odour, perception of food, Salivary vitamins E and C, lactate dehygrogenase isoenzyme, MIP 1 á, Glucosyltransfer â, Malonaldehyde, 8-hydroxydeoxyguanosine, Thiocynate, salivary contents and salivary flow rate were measured. Flow rate, sodium, potassium, calcium, phosphate, protein, lactate dehygrogenase, MIP 1 alpha, Malonaldehyde, 8-hydroxydeoxyguanosine, thiocynate were found to increase significantly while Amylase activity, vitamin E & C and mouth opening were decreased in simulation environments in contradiction to normal and recovery stage. The threshold for MSG and capsaicin increased about 1.5 dilution step, while sodium chloride decreased about 2 dilution during microgravity as compared to normal conditions. Mild pain of teeth, facial oedema, mild pain mandibular angle regions, pain in sublingual and submandibular opening duct regions, abnormal facial expression, loss of sensation of pain and temperature, decreased the tongue and mandibular movement in simulation microgravity environments. These results suggest that reversible effect of microgravity is oedema of face, change in taste, abnormal expression of face, teeth pain and xerostomia . The non reversible effect of microgravity such as prevalence of periodontal disease, dental caries but different pattern than normal, stone formation in salivary duct, pre cancer or cancer, fracture of maxillary and mandibular bone and xerostomia more in astronaut as compared to normal persons. Further study will be required on large scale and long term effect of microgavity on oral cavity to prevent the adverse effect on oral cavity. Hence, aeronautic dentistry should be included in curriculum.

Key words

Mission , Mars, Microgravity, Aeronautic Dentistry.

Introduction

For many years, the prevailing concept in space human factors research has been that microgravity induced neuro-vestibular problems involving space motion sickness and disorientation during the flight [1,2], and impaired balance and neuromuscular coordination after landing [3,4]; cardiovascular and fluid-related problems of orthostatic hypotension immediately following spaceflight [5,6]; the possibility of altered cardiac susceptibility to ventricular arrhythmias [7], and reduced cardiac muscle mass and diminished cardiac function [8]; muscle-related problems of atrophy involving loss of muscle mass, strength and endurance [9,10]; decrease in the bone mineral density [11,12]; circadian rhythm-related problems involving sleep and performance [13]; and immune-related problems involving infections and immunodeficiency [14].To the best of our knowledge no study has been conducted on effect of oral cavity such as sensation on face, expression of face, jaw, movement, tongue movement , prevalence and pattern of oral disease (dental caries, periodontal disease, cancer),bone loss,effect on salivary duct, salivary flow rate and it content, Gingival cerivicular fluid contents , tooth and facial pain. The prevalence of oral diseases such as dental caries, periodontal disease and cancer is not possible in short term microgravity hence its prevalence's indirectly measured from salivary markers [15-23]. Hence this study was planned to effect of microgravity on oral cavity in simulated microgravity.

Reprint requests: Dr. Balwant Rai, BDS,MS,
Founder of Aeronautic Dentistry, Village: Bhangu, P.O. Sahuwala, Dist: Sirsa, Haryana
Email: drbalwantraissct@rediffmail.com

Materials and Methods

The subjects of this investigation were 20 male volunteers aged (18-22 years, mean weight of 72.5 +_ 3.2 kg and mean height of 174.9+_ 3.4 cm) participated in an 8-hour 6°

HDT bed-rest exposure and who had not participated in systemic endurance training for 10 day prior to study and. Each Subject was given a detailed explanation of the experimental protocol and provided written and verbal consent. Each subject completed a medical and dental history questionnaire to determine the status of systemic diseases , smoking, alcoholic and drugs history .

Protocol- All parameters and sample were taken just before stimulated microgravity were followed before HDT, throughout the time course of the HDT experiment, and during recovery. Subjects were asked to awaken at 6 A.M. on the day of the study and to remain seated or standing until arrival At research centre .Baseline control measurements were obtained during the hour before HDT. At -9 A.M. the subjects were transferred supine to

a gurney and tilted to 6' HDT, where they remained for the next 8 h. At -5 P.M. the subjects were returned to a chair and remained in a seated position for the 4-h recovery

period. Facial function tests, mouth opening , jaw movements, tongue movements, facial sensation (Touch, pressure, temperature sensation), taste, odour, perception of food, Salivary vitamins E and C, lactate dehygrogenase isoenzyme, MIP 1 alpha , Glucosyltransfer B , Malonaldehyde, 8-hydroxydeoxyguanosine,Thiocynate,salivary contents and salivary flow rate were measured as in previous studies [15-26].The data were analysed using SPSS version 11 and applied the student t test.

Results

Table -1: The unstimulated whole salivary flow rate and composition in the before simulation of microgravity, during the simulation of microgravity and just after removable of the microgravity position and after removal 12 hour of removable of microgravity in 20 healthy persons. Results are given in median (Range)

Flow rate, sodium, potassium, calcium , phosphate, protein, lactate dehygrogenase, MIP 1 alpha , Malonaldehyde, 8-hydroxydeoxyguanosine, thiocynate were significantly increased while Amylase activity, vitamins E and C and mouth opening were decreased in simulation environments as compared to normal and recovery stage (Table-1, $p<0.01$).

Table -2: The square means of the thresholds of all persons in the before simulation of microgravity, during the simulation of microgravity and just after removable of the microgravity position and after removal 12 hour of removable of microgravity in 20 healthy persons. The thresholds are reported as the dilution series values (dilution 10 is most conc., dilution 1 is least conc.

The threshold for MSG and capsaicin increased about 1.5 dilution step, while sodium chloride decreased about 2 dilution during microgravity as compared to normal (Table-2)

Table -3: The symptoms of persons in the before simulation of microgravity, during the simulation of microgravity and just after removable of the microgravity position and after removal 12 hour of removable of microgravity in 20 healthy persons. Results are given in median (Range)

Mild pain of teeth , facial oedema, mild pain mandibular angle regions, pain in sublingual and submandibular opening duct regions, abnormal facial expression, loss of sensation of pain and temperature, decreased the tongue and mandibular movement in simulation microgravity environments (table -3)

Discussion

Flow rate, sodium, potassium, calcium , phosphate, protein levels were increased in simulation environments as compared to normal while again decreasing levels after simulation environments , while support the pervious studies . It has been showed that Ramadan fasting induces a 2.7% loss of body mass and a plasma volume decrease of 7%. Orthostatic tolerance tests in the fourth week of Ramadan fasting revealed an augmented rise in the heart rate response and a decrease in pulse pressure during orthostasis compared to before and 2

Table -1

Parameters	Before simulation the microgravity	During simulation the microgravity	Just after removable simulation the microgravity	After 12 hours removable simulation the microgravity
Flow rate (ml/min)	0.02 (0.01-0.03)	0.01 (0.008-0.02)	0.017 (0.011-0.024)	0.019 (0.012-0.029)
Na (mM)	12 (8.0-15.0)	13 (9.0-18.2)	12.5 (9.3-14.3)	11.3 (9.2-14.2)
K (mM)	23.7(6.7-34.8)	25.3(7.3-36.9)	23.7(6.7-34.1)	22.4(5.8-33.1)
Total calcium (mM)	3.2(1.4-4.6)	3.6(2.4-4.8)	3.1(1.3-4.1)	3.1(1.3-4.3)
Total phosphate (mM)	7.3(1.3-11.3)	7.1(2.1-12.1)	7.2(1.5-10.8)	7.1(1.2-10.1)
Total protein (mg/ml)	4.3 (1.6-13.6)	4.6 (1.7-14.2)	4.2 (1.8-12.8)	4.1 (1.9-12.8)
Cl (Mm)	22.2 (14.9-42.1)	22.0 (14.7-43.2)	21.9 (15.6-41.2)	22.1 (14.8-44.3)
Total protein output (mg/min)	0.45 (0.23-0.96)	0.41 (0.26-0.85)	0.40 (0.21-0.83)	0.44 (0.22-0.91)
Amylase activity (micro kat/l)	324 (145-567)	267 (112-345)	312 (165-543)	323 (142-563)
vitamins E (mg/ml)	0.56 (0.32-0.76)	0.52 (0.31-0.73)	0.51 (0.31-0.75)	0.55 (0.31-0.74)
vitamins C (mg/ml)	0.34 (0.12-54)	0.33 (0.09-0.52)	0.32 (0.11-0.51)	0.31(0.10-0.47)
lactate dehygrogenase (IU/L)	2.3 (1.2-3.4)	2.4 (1.6-3.7)	2.2 (1.4-3.6)	2.1 (1.1-3.2)
MIP 1 alpha (pg/ml)	17.5 (12.6-21.5)	17.9 (13.2-22.4)	17.4 (13.1-21.6)	17.4 (12.7-21.4)
Malonaldehyde (ng/ml)	2.45 (1.45-4.34)	2.65 (1.67-4.89)	2.55 (1.44-4.64)	2.41 (1.45-4.31)
8-hydroxyde oxyguanosine (ng/ml)	0.67 (0.45-1.34)	0.69 (0.51-1.43)	0.67 (0.45-1.36)	0.63 (0.41-1.21)
Thiocynate (U/L)	34.2 (21.7-56.9)	39.2 (22.7-57)	38.4 (20.9-56)	33.6 (20.9-57.8)

Table -2

Parameters	Before simulation the microgravity	During simulation the microgravity	Just after removable simulation the microgravity	After 12 hours removable simulation the microgravity
Sucrose	3.8	3.5	3.5	3.8
Citric acid	3.1	2.9	3.1	3.1
Sodium chloride	3.4	2.8	3.3	3.4
Quinine	4.6	4.4	4.6	4.6
MSG	6.2	6.8	6.2	6.2
Capsaicin	6 .4	6 .9	6.4	6 .4
Amyl butyrate	3.2	3.1	3.2	3.2
Methone	3.1	2.8	3.1	3.1

months after Ramadan [28]. The most important effect of restricting energy intake is on calcium and bone metabolism. A moderate weight loss of 10% typically results in a 1–2% loss of bone mineral density (BMD) [29]. The MIP 1 alpha level was decreased in microgravity which is potential markers of bone loss [20]. It is very obvious that if astronauts are allowed to freely choose their food, without any predefinition of the diet or training, this may lead to a diet deficient in protein compared to the RDA [30] .For example, during the D-2 mission the average protein intake reached levels of just 56% of the RDAs for earthbound conditions. Insufficient protein consumption has an impact on whole body protein turnover and amino acid kinetics, which has to be considered in long-term space flight. However, it is the amino acids rather than the actual amount of protein that is important here [31],so in this study total protein levels were taken and it was increased in saliva which support the previous study [31]. The recommendation for fluid intake by the D-2 astronauts would be 2610 ml per day in earthbound conditions. Based on this calculation, the fluid intake of the D-2 astronauts was far below the recommended level 9 days out of 10. The average fluid intake by the D-2 astronauts reached just 75% of the recommended value. It has been observed fluid intake was far too low, if one considers that microgravity leads to muscle breakdown and calcium mobilization from bone (A. LeBlanc, personal communication) which causes additional metabolites to be excreted as in our study the flow rate of saliva were decreased and sodium , potassium and calcium levels increased .A low fluid intake leads to dehydration and finally to a reduction of plasma volume and an increase in the haematocrit. A reduction of plasma volume may result in increases in serum electrolyte levels, and therefore serum osmolality and urine osmolality increase too. The plasma volume decrease, together with increases in serum and urine osmolality and electrolyte

Table -3

Parameters	Before simulation the microgravity	During simulation the microgravity	Just after removable simulation the microgravity	After 12 hours removable simulation the microgravity
Teeth pain while articulation of teeth	No pain	Mild pain	normal	normal
Facial swelling	No swelling	Mild oedema	Mild oedema	normal
Pain while closing or opening the mouth	No pain	Mild pain in mandible angle regions	No pain	No pain
Salivary gland	Normal	Mild pain in sub-mandibular and sublingual duct opening area and swelling	Mild pain in sub-mandibular and sublingual duct opening area and swelling	Normal
Pain while moderate pressing the facial region	No pain	Mild pain in whole facial area	No pain	No pain
Facial expression	Normal	Abnormal	Abnormal	Normal
Sensation tests	Normal	Pain and	Pain and	Normal
		temperature sensation is not present	temperature sensation is not present	
Movements of tongue Jaw movements direction	Normal Normal direction	Decreased inall direction Decreased in all	Decreased in all direction Decreased in all	Normal Normal

levels, influences body fluid regulation by activating hormonal regulatory factors, i.e. vasopressin, renin and aldosterone .The levels of calium were increased in microgravity as compared to control. Insufficient calcium consumption leads to a reduction in serum calcium Levels and thereby to a secretion of parathyroid hormone (PTH) and calcitriol synthesis. Both a rise in PTH and calcitriol induce an increase in calcium retention either from the intestine or from bone. Based on that, a long-lasting insufficient calcium intake together with insufficient vitamin D are the main factors leading to a decrease in bone mineral density [33]. The decreased levels of vitamins E and C and increased in malonaldehyde levels denoted increased in free radical activity as in microgravity environments'.[18] So the free radical activity increased in microgravity as compared to normal gravity. The 8-hydroxy deoxyguanosine level were increased in saliva in microgravity environments' as compared to normal, it may be due to increased in oxidative stress [23]. Lactate dehygrogenase levels were increased in microgravity as compared to normal gravity. The threshold for MSG and capsaicin increased about 1.5 dilution step, while sodium chloride decreased about 2 dilution during microgravity as compared to normal. Mild pain of teeth , facial oedema, mild pain mandibular angle regions, pain in sublingual and submandibular opening duct regions, abnormal facial expression, loss of sensation of pain and temperature, decreased the tongue and mandibular movement in simulation microgravity environments. It may be due to physiological changes including an upward shift of body fluids toward the head, which may lead to an attenuation of the olfactory component in the flavour of foods, pressing the nerve regions or dysfunction of nerve as well as increased activity of b-AR agonists[34].

In conclusion , reversible effect of microgravity is oedema of face , change in taste, abnormal expression of face, teeth pain and xerostomia .The non reversible effect of microgravity such as prevalence of periodontal disease, dental caries but different pattern than normal, stone formation in salivary duct, pre cancer or cancer , fracture of maxillary and mandibular bone and xerostomia more in marsonaunt or astronaut as compared to normal persons. Further study will be required on large scale and long term effect of microgavity on oral cavity to prevent the adverse effect on oral cavity. Hence, aeronautic dentistry (Balwant Rai, Founder of Aeronautic dentistry) should be include in curriculum.

References

1. Davis JR, Vanderploeg JM, Santy PA, et al. Space motion sickness during 24 flights of the space shuttle. Aviat Space Environ Med, 1988; 59: 1185-1189.
2. Oman CM, Lichtenberg BK, Money KE. Space motion sickness monitoring experiment: Spacelab 1. In: Crampton GH (Ed). Motion and space sickness. Boca Raton, FL: CRC Press, 1990: 217-246.
3. Lackner J, DiZio P. Human orientation and movement control in weightless and artificial gravity environments. Exp Brain Res 2000; 130: 2-26.
4. Paloski WH, Black FO, Reschke MF, et al. Vestibular ataxia following shuttle flights: Effects of microgravity on otolith-mediated sensorimotor control of posture. Am J Otol 1993; 14: 9-17.
5. Buckey JC Jr, Lane LD, Levine BD, et al. Orthostatic intolerance after spaceflight. J Appl Physiol 1996; 81: 7-18.
6. Antonutto G, di Prampero PE. Cardiovascular deconditioning in microgravity: Some possible countermeasures. Eur J of Appl Physiol 2003; 90: 283-291.
7. Fritsch-Yelle JM, Leuenberger UA, D'Aunno DS, et al. An episode of ventricular tachycardia during long-duration spaceflight. Am J Cardiol 1998; 81: 1391-1392.
8. Herault S, Fomina G, Alferova I, et al. Cardiac arterial and venous adaptation to weightlessness during 6 month MIR spaceflights with and without thigh cuffs (bracelets). Eur J Appl Physiol 2000; 81: 384-390.
9. Baldwin KM, White TP, Arnaud SB, et al. Musculoskeletal adaptations to weightlessness and development of effective countermeasures. Med Sci Sports Exercise 1996; 28: 1247-1253.
10. Edgerton VR, Zhou MY, Ohira Y, et al. Human fiber size and enzymatic properties after 5 and 11 days of spaceflight. J Appl Physiol 1995; 78: 1733-1739.
11. Oganov VS, Grigorev AI, Voronin LI, et al. [Bone mineral density in cosmonauts after flights lasting 4.5-6 months on the orbital station MIR. Aerosp Environ Med 1992; 5: 20-24. [In Russian].
12. Vico L, Collet P, Guignandon A, et al. Effects of long-term microgravity exposure on cancellous and cortical weight-bearing bones of cosmonauts. Lancet 2000; 355: 1607-1611.

13. Gündel A, Polyakov W, Zulley J. The alteration of human sleep and circadian rhythms during spaceflight. J Sleep Res 1997; 6: 1-8.

14. Taylor GR. Overview of spaceflight immunology studies. J Leukoc Biol 1993; 54: 179-188.

15. Rai B,Kharb S,Jain R, Anand S C.Salivary peroxidation product Malonaldehyde in Various Dental Diseases.World J.Med.Sci.2006;1 (2):100-101.

16. Rai B,Kharb S, Anand S C.Thiocynate, a salivary marker of periodontitis among smokers and non-smokers:A pilot study. J Pak Denta Assoc.2007; 16: 35-7.

17. Rai B,Kharb S,Jain R,Anand S C.Biomarkers of periodontitis in oral fluids. J Oral Sci .2008; 50: 53-56.

18. Rai B, Kharb S, Jain R, Anand S.C. Salivary vitamins E and C in oral cancer, Redox. Rep. 2007; 12: 163–164.

19. Rai B, Anand S C, Jain R, Anand S C, Kharb S. Salivary lactate dehygrogenase isoenzyme in oral lichen planus.Adv.in Med.Dent Sci.2008; 2: 1-3.

20. Fine DH, Markowitz K,Furgang D,Fairlie K,Ferrandiz J,Nasri C, McKiernan M,Donnelly R,Gunsolly J.MIP 1 alpha a salivary biomarker of bone loss in a longitudinal cohort study of children at risk for aggressive periodontal disease. J Periodontol. 2008; (DOI:10.1902/jop.2008; 080296.

21. Pedersen AML,Bardow A,Nauuntofte B. Salivary changes and dental caries as potential oral markers autoimmune salivary gland dysfunction in primary sjogren syndrome. BMC Clinical Pathology. 2005; 5: 4.

22. Smith AMV,Scott-Anne KM,Whelehan MT,Berkowitz RJ,Feng C,Bowen WH.Salivary Glucosyltransfer B as a possible marker for caries activity.Caries Res 2007; 41: 445-450.

23. Rai B, Kharb S, Anand S C. Effect of scaling and root planning on salivary 8-hydroxydeoxyguanosine levels:periodontitis. J Pak Dent assoc. 2007; 16: 189-91.

24. Danielides V G, Skevas AT, Panagopoulos K , Kastanioudakis I. Value of the facial nerve latency test in the prognosis of childhood Bell's palsy.Child Nervous System. 1991; 8: 126-28.

25. Nakamura K, Morrison S F. A thermosensory pathway that controls body temperature. Nature Neuroscience. 2008; 11: 62–71.

26. Vicker Z M,Rice BL,Rose MS,Lane H W. Stimulating microgravity has little influence on taste, odor or trigeminal sensitivity. J Sensory Studies. 2001; 16: 23-32.

27. Nicogossian, AE, Huntoon CL, and Pool SL. (Editors). Space Physiology and Medicine. Philadelphia, PA: Lea & Febiger, 1994.

28. Bigard AX, Boussif M, Chalabi H, Guezennec CY .Alterations in muscular performance and orthostatic tolerance during Ramadan. Aviat Space Environ Med. 1998; 69: 341–346.

30. Bines J . Starvation and fasting. In Sadler MJ, Strain JJ, Caballero B (eds) Encyclopedia of human nutrition. Academic, San Diego, 1998; 1779–1786.

31. Deutsche Gesellschaft fuer Ernaehrung . Empfehlungen für die Naehrstoffzufuhr. Umschau Verlag, Frankfurt/Main, 1991.

32. Drummer C, Hesse C, Baisch F, Norsk P, Elmann-Larsen B, Gerzer R, Heer M (Water- and sodium-balances and their relation to body mass changes in microgravity. Eur J Clin Invest (in press)

33. Bronner F. Calcium and osteoporosis. Am J Clin Nutr 1994; 60: 831–836.

34. Smith SM, Davis-Street JE, Rice BL, Nillen JL, Gillman PL, and G Block. 2001. Nutritional status assessment in semiclosed environments: groundbased and space flight studies in humans. J Nutrition, 13: 2053-2061.