ROS

COMMENTARY ARTICLES

The Safety Issues of Onboard Wi-Fi: Possible Interactions of Oxidative Stress from High Altitude, Cosmic Radiation, and Wi-Fi Radiation

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ABSTRACT | At flight altitudes, cabin crew are occupationally exposed to higher levels of cosmic radiation compared to "on Earth" levels. This difference comes from decreased protective role of the Earth's atmosphere (thinner atmosphere) and the Earth's magnetic field at flight altitudes. Oxidative stress in aviation pilots was more pronounced in intercontinental routes pilots which can be caused by exposure to higher levels of cosmic radiation. Furthermore, exposure to high altitude also leads to oxidative stress. Recently, airlines provide in-flight Wi-Fi to make their passengers able to remain connected in the sky. While this high-tech service which needs special engineering and maintenance considerations, is gaining popularity, at the same time it raises concerns about its potential adverse health effects. Radiofrequency radiation generated by Wi-Fi hotspots or mobile phones also causes oxidative stress. It's worth noting that as radiofrequency is a non-ionizing radiation which cannot remove an electron from an atom or molecule, formation of free radicals has been proposed as a possible mechanism for its carcinogenesis. The effect of Wi-Fi radiofrequency radiation on circadian rhythm is another major concern. The adverse effects of exposure to radiofrequency radiation on antioxidant function, in terms of both the daily antioxidative levels and the circadian rhythmicity are well studied. This paper addresses the safety issues of onboard Wi-Fi from the point of view of possible interactions of oxidative stress caused by high altitude, cosmic radiation, and Wi-Fi radiation.

KEYWORDS | Cosmic radiation; Oxidative stress; Wi-Fi radiation

Scientists believe that humans are not physiologically equipped for high altitudes. The health status of flight crew has been widely studied. Aviation personnel are most likely to encounter disorders such as hypoxia (low oxygen concentration in the air and reduced diffusion of oxygen from the lungs to the blood due to decreased atmospheric pressures at high altitudes). Despite significant lower levels of smoking, flight attendants have been reported to show a 3-fold increase in the age-adjusted prevalence of chronic bronchitis. Furthermore, despite significant lower prevalence of hypertension and obesity, the prevalence of cardiac disease in female flight attendants has been reported to be 3.5 times higher than the general population [1]. The prevalence of sleep disorders, depression, and fatigue was also 2 to 5.7

times higher than the general population. The reproductive cancer rate was also 34% higher in female flight attendants. It was also shown that flight attendant with longer job tenure had higher rates of chronic bronchitis, heart disease in females, skin cancer, hearing loss, depression and anxiety[1]. In this light, it has been reported that statutory medical certification for flight attendants will not benefit either flight safety or occupational health [2].

Desynchronization between the body's internal clock and the new light/dark cycle at the destination and the circadian rhythm problems seem to play a key role in flight-linked disorders such as sleep disturbance, attention and concentration problem, and fatigue. It was previously believed that the exposures from common sources such as Wi-Fi routers and mobile phones are low level radiations which lie within national and international standards. However, new studies have provided substantial evidence indicating adverse effects even at levels well below current standards. Wireless fidelity (Wi-Fi) refers to a wireless network for computers which utilizes radiofrequency (RF) radiation for communication (something like two-way radio communication). Wi-Fi systems operate at high frequency (2.4 GHz or 5 GHz) and emit low levels of RF (0.1 W compared to 1–2 W for mobile phones).

Over the past several years, Mortazavi et al. have expanded their focus on studying the health effects of exposure to some common and/or occupational sources of non-ionizing electromagnetic fields (EMFs) such as cellular phones, mobile base stations, mobile phone jammers, laptop computers, radars, dentistry cavitrons, MRI, Wi-Fi routers as well as different coils. As human exposure to Wi-Fi radiation has increased rapidly over the past years, other researchers and Mortazavi et al. have studied the health effects of these exposures [3–9]. Although due to its low power, Wi-Fi radiation is usually considered safe, its effects on children, hypersensitive people and pregnant women can be a great concern. Furthermore, onboard environment and its significant difference from that on the ground (air pressure and fluctuation, temperature, humidity, vibration, and remaining seated for long periods of time) may affect the potential health effects of exposure to Wi-Fi radiation. For example, the oxygen saturation of blood decreases with altitude. This can affect the risk of DNA damages caused by free radicals generated by radiofrequency radiation.

In radiation biology (biological effects of ionizing radiations such as x and gamma rays) it is generally believed that when x or gamma rays interact with matter, they produce high energy electrons which in turn interact with water molecules to create highly reactive free radicals (such as hydroxyl). Free radicals in turn react with DNA and make base damages. Although DNA base damages can chemically be repaired, in the presence of molecular oxygen they produce peroxyl radicals which are much more damaging (difficult or impossible for the cell to repair these damages). In this light, hypoxia can restore the damages produced by free-radicals while presence of molecular oxygen makes these damages permanent and irreparable (damage fixation). Interestingly, the story for exposure to non-ionizing onboard Wi-Fi is entirely different. Exposure to high altitude and decreased oxygen pressure increases the formation of reactive oxygen species (ROS) and nitrogen species (RNS) which in turn increases the oxidative damage to lipids, proteins and DNA (**Figure 1**).

Cabin crew are occupationally exposed to higher levels of cosmic radiation compared to our exposures on Earth [10]. This higher exposure rate comes from decreased protective role of the Earth's atmosphere (the thinner atmosphere while atmosphere acts a shield against cosmic radiation) and the Earth's magnetic field at flight altitudes [11]. It has been reported that the oxidative stress in aviation pilots is more pronounced in pilots who are involved in intercontinental routes (that leads to exposure to higher levels of cosmic radiation) [12]. Moreover, exposure to high altitude also causes oxidative stress [13]. Recently, some airlines provide in-flight Wi-Fi to make their passengers able to remain connected in the sky. However, it is only a small proportion of domestic and international flights. While this high-tech service which needs special engineering and maintenance considerations is gaining popularity, at the same time, it raises concerns about its potential adverse health effects. Radiofrequency radiation generated by Wi-Fi hotspots or mobile phones also causes oxidative stress [14–16]. It has been reported that among 100 currently available peer-reviewed papers published on the oxidative effects of low intensity radiofrequency radiation, 93 confirmed that radiofrequency induces oxidative effects in biological systems [14]. It's worth noting that as radiofrequency is a non-ionizing radiation which cannot remove an electron from an atom or molecule, formation of free radicals

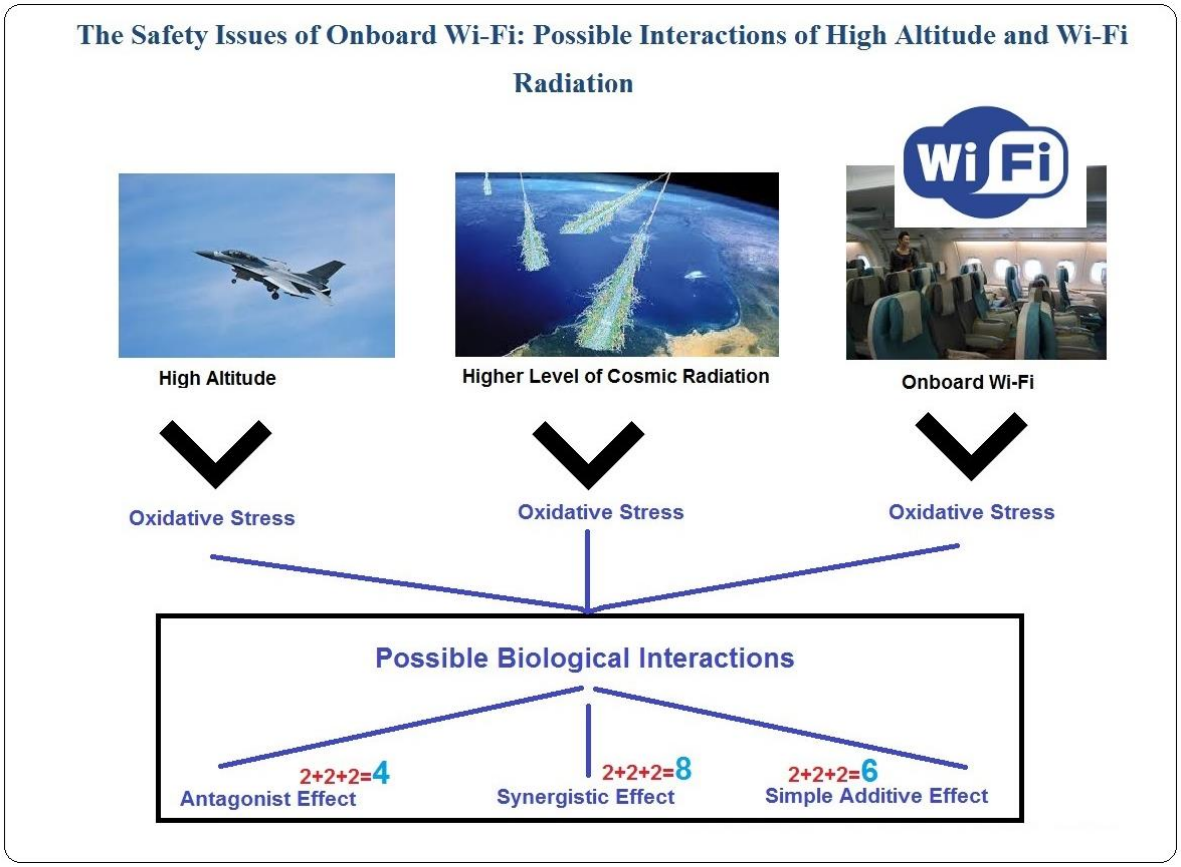

FIGURE 1. High altitude, higher levels of cosmic radiation as well as Wi-Fi radiofrequency radiation produce oxidative stress. The interaction of these factors in flight crew has not been studied so far.

has been proposed as a possible mechanism for its carcinogenesis [15].

The effect of Wi-Fi radiofrequency radiation on circadian rhythm is another major concern. The adverse effects of exposure to radiofrequency radiation on antioxidant function, in terms of both the daily antioxidative levels and the circadian rhythmicity are well studied [16]. In this light, further studies are needed to investigate the biological effects of onboard Wi-Fi.

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REFERENCES

1. McNeely E, Gale S, Tager I, Kincl L, Bradley J, Coull B, et al. The self-reported health of U.S. flight attendants compared to the general population. *Environ Health* 2014; 13(1):13. doi: 10.1186/1476-069x-13-13.
2. Griffiths RF, Powell DM. The occupational health and safety of flight attendants. *Aviat Space Environ Med* 2012; 83(5):514–21.
3. Taheri M, Mortazavi SM, Moradi M, Mansouri S, Hatam GR, Nouri F. Evaluation of the effect of radiofrequency radiation emitted from Wi-Fi router and mobile phone simulator on the antibacterial susceptibility of pathogenic bacteria listeria monocytogenes and *Escherichia coli*. *Dose Response* 2017; 15(1):1559325816688527.

doi: 10.1177/1559325816688527.
4. Shekoohi-Shooli F, Mortazavi SM, Shojaei-Fard MB, Nematollahi S, Tayebi M. Evaluation of the protective role of vitamin c on the metabolic and enzymatic activities of the liver in the male rats after exposure to 2.45 GHz of Wi-Fi routers. *J Biomed Phys Eng* 2016; 6(3):157–64.
5. Paknahad M, Mortazavi SM, Shahidi S, Mortazavi G, Haghani M. Effect of radiofrequency radiation from Wi-Fi devices on mercury release from amalgam restorations. *J Environ Health Sci Eng* 2016; 14:12. doi: 10.1186/s40201-016-0253-z.
6. Mortazavi SA, Taeb S, Mortazavi SM, Zarei S, Haghani M, Habibzadeh P, et al. The fundamental reasons why laptop computers should not be used on your lap. *J Biomed Phys Eng* 2016; 6(4):279–84.
7. Zarei S, Mortazavi SM, Mehdizadeh AR, Jalalipour M, Borzou S, Taeb S, et al. A challenging issue in the etiology of speech problems: the effect of maternal exposure to electromagnetic fields on speech problems in the offspring. *J Biomed Phys Eng* 2015; 5(3):151–4.
8. Taheri M, Mortazavi SM, Moradi M, Mansouri S, Nouri F, Mortazavi SA, et al. *Klebsiella pneumonia*, a microorganism that approves the non-linear responses to antibiotics and window theory after exposure to Wi-Fi 2.4 GHz electromagnetic radiofrequency radiation. *J Biomed Phys Eng* 2015; 5(3):115–20.
9. Mortazavi G, Mortazavi SM. Increased mercury release from dental amalgam restorations after exposure to electromagnetic fields as a potential hazard for hypersensitive people and pregnant women. *Rev Environ Health* 2015; 30(4):287–92. doi: 10.1515/reveh-2015-0017.
10. Alves MC, Galeano DC, Santos WS, Lee C, Bolch WE, Hunt JG, et al. Comparison of the effective dose rate to aircrew members using hybrid computational phantoms in standing and sitting postures. *J Radiol Prot* 2016; 36(4):885–901. doi: 10.1088/0952-4746/36/4/885.
11. Bagshaw M. Cosmic radiation in commercial aviation. *Travel Med Infect Dis* 2008; 6(3):125–7. doi: 10.1016/j.tmaid.2007.10.003.
12. De Luca C, Deeva I, Mariani S, Maiani G, Stancato A, Korkina L. Monitoring antioxidant defenses and free radical production in space-flight, aviation and railway engine operators, for the prevention and treatment of oxidative stress, immunological impairment, and pre-mature cell aging. *Toxicol Ind Health* 2009; 25(4–5):259–67. doi: 10.1177/0748233709103032.
13. Bakonyi T, Radak Z. High altitude and free radicals. *J Sports Sci Med* 2004; 3(2):64–9.
14. Yakymenko I, Tsybulin O, Sidorik E, Henshel D, Kyrylenko O, Kyrylenko S. Oxidative mechanisms of biological activity of low-intensity radiofrequency radiation. *Electromagn Biol Med* 2016; 35(2):186–202. doi: 10.3109/15368378.2015.1043557.
15. Havas M. Can non-ionizing radiation cause cancer? *Archives of Physics Research* 2017; 8(1):1–2.
16. Cao H, Qin F, Liu X, Wang J, Cao Y, Tong J, et al. Circadian rhythmicity of antioxidant markers in rats exposed to 1.8 GHz radiofrequency fields. *Int J Environ Res Public Health* 2015; 12(2):2071–87. doi: 10.3390/ijerph120202071.