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ORIGINAL ARTICLE

Assessing Cosmic Radiation Exposure Among Royal Malaysia Air Force (RMAF) Aircrews

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ABSTRACT

Introduction: Airplanes have become the most convenient way of traveling. However, what comes into concern nowadays is the cosmic radiation being exposed to the aircrews and the passengers. Research has shown that aircraft crews are at twice the risk of melanoma and other cancers due to long exposure to cosmic radiation compared to the general population. This study investigated the relationship between accumulated radiation dose and flight duration among Royal Malaysia Air Force (RMAF) Aviators. **Materials and Methods:** Thirty-two aircrews consisting of pilots, co-pilots, loadmasters, flight engineers, navigators and stewardesses were given personnel monitoring devices. The device used in this study is the Optical Stimulated Luminescence Dosimeter (OSLD) to measure the radiation dose received individually. They were also given a form containing information on flight hours to be filled out. The OSLD is collected and sent to the National Cancer Institute at the end of one month, three months and twelve months for dose reading. **Results:** The mean accumulated dose received in a year is 1.328 mSv with the average hours of flight 511 hours and in one month the reading is 0.115 mSv with 42 hours of flight. Based on the results, it can be concluded that there is significant exposure among the aircrews with the duration of the flights. **Conclusion:** The mean accumulated cosmic radiation dose in a year is within the limit of the International Commission on Radiological Protection set below 20 mSv. There is a significant relationship between cosmic radiation dose and hours of flight.
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Keywords: Aircrews, Cosmic radiation, Dose Limit, Dosimeter, Flight hours

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INTRODUCTION

Nowadays, many people prefer to travel by airplane as the most convenient and efficient option. One of the advantages of flying is reducing the time spent traveling by car, bus or train. Besides the cost of a flight ticket becoming more affordable as compared to the previous ten years, flying is also considered the safest way to travel.

However, for the past years, what has become a concern is the exposure of cosmic radiation to aircraft crews and passengers. Radiation as defined in Cambridge Dictionary is a form of energy that comes from nuclear reactions that can be very dangerous to health. The sources can be either from space, the sun, or natural sources, with the sun as the most familiar form of radiation and a source of cosmic radiation that delivers light and heat. Cosmic radiation consists of high-energy charged particles, x-rays and gamma rays produced in space. Cosmic radiation exposes the body to radiation like exposure from a medical x-ray.

Research has consistently shown that aircraft crews had an increase in the risk of melanoma and other cancers due to prolonged exposure to cosmic radiation (13). This finding is supported by a study by (8) that aviator workers are twice the risk of melanoma compared to the general population. These exposures accumulate over time and are considerably higher for aircrew than the general population, even higher than radiation workers. (14).

The main concern now is towards the increased exposure level of cosmic radiation as ionizing radiation can cause damage to the living tissue (12) mentioned that ionizing radiation is a natural phenomenon in the environment due to various sources from space, the sun, or natural sources such as the soil. However, ionizing radiations from cosmic rays have some unique characteristics as carcinogenic and mutagenic agents which can cause several impacts on human health (6).

As a result, the International Commission on Radiological Protection (ICRP) has established a recommended dose limit that aviators' workers should not be exposed to cosmic radiation of more than 20 mSv annually (7). This establishment of the dose limit indicates that other than nuclear power reactor workers and radiographers, aircrews are also recognized for their occupational exposure to cosmic radiation.

The issue has been raised on the possibility of affecting the Air Force operation if the recommendation is adopted (4). This is because Air Force flights usually are non-scheduled, so there was no exact information on how much the level of cosmic radiation exposed.

Besides, Air Force flights had additional factors to consider including acceleration forces, radar equipment and life support systems. The aircraft flew differently depending on the mission requirements concerning flight frequency, duration and altitude (14).

This study is conducted to measure and calculate how much the amount of cosmic radiation is being exposed to the aviators taking into account the duration of flight. The data required will be helpful for the aviators to monitor their yearly accumulated dose exposure and to relate it to health-related problems in the future.

MATERIALS AND METHODS

Research design

This study is a quantitative research to determine the accumulated cosmic radiation dose received by the Royal Malaysia Air Force (RMAF) for one month, three months, and twelve months by using an Optical Stimulated Luminescence Dosimeter (OSLD) and duration of flying as parameters that affected cosmic radiation.

Elaboration of the study design

This study is an experimental study that received ethical approval from the Ethics Committee for Research Involving Human Subjects Universiti Putra Malaysia (JKEUPM) with reference number JKEUPM-2020-132. In this study, thirty-two RMAF crews were chosen based on the inclusion and exclusion criteria. Each subject was given a personnel monitoring device, the Optical Stimulated Luminescence Dosimeter (OSLD) to measure the radiation dose received. The aircrew was asked to fill up a form containing information regarding on the duration of the flight. The OSLD will be collected and sent to the National Cancer Institute, Putrajaya at the end of 1st month, 3rd month and 12th month for the dose reading.

Study location

This study was conducted at Pangkalan Udara, Tentera Udara Diraja Malaysia (TUDM), Shah Alam, Selangor as it is one of the bases for TUDM. The data collection was done when the flight crews from Squadron 20 are flying.

Study population

The target population for this study is the aircrew members. This is based on ICRP no. 60, 1990, which stated that the flight crew members were to be recognized for their occupational exposure to cosmic radiation. The sampling frame for this study will focus more on the pilots and aircrews instead of the frequent flyers of commercial flights. However, more attention will be given to the pilots as they are at more risk of receiving more radiation doses as compared to the other aircrew members, for example, the stewardess. Thirty-two flight crew members of RMAF from Squadron 20 are the subjects of this study.

Sampling method and subject recruitment

The sampling method for this study is stratified sampling. Thirty-two subjects were divided into five pilots and aircrew members which consisted of six co-pilots, six flight engineers, nine loadmasters, three navigators and three stewardesses to compare accumulated cosmic radiation dose received based on their position in the airplane.

The subject was recruited based on their years of serving with TUDM with a minimum of two years. Participants had to be healthy, fit to fly and have no history of critical illness. The study included both male and female subjects, representing various position on the airplane (pilot, co-pilot, flight engineer, loadmaster and stewardess).

Research tools/instruments

The Optical Stimulated Luminescent Dosimeter (OSLD) is chosen as the ideal tool for radiation monitoring devices, proven to have high sensitivity and precision. The OSLD has been utilized worldwide, particularly in diagnostic radiology, and is also employed in space by NASA. This is because the OSLD is specifically designed to monitor X-ray, gamma-ray, beta, and neutron radiation. Additionally, the OSL dosimeter is suitable for situations where real-time information is not required, but precise accumulated dose monitoring records are needed for comparison to field measurements or for assessing the potential for long-term health effects. The dosimeter usually comes in a clip-on brooch format or identification card style, allowing it to be worn outside of clothing, typically between the waist and neck, on the front of the torso, facing the radioactive sources.

Data collection

Thirty-two healthy RMAF participants were selected based on the relevant characteristics. The study began in August 2022, with each aircrew member receiving an OSLD before every routine flight to measure the accumulated cosmic radiation dose over one, three and twelve-month periods, and ended in August 2023. At the end of the month, the OSLD was collected and sent to the National Cancer Institute, Putrajaya for dose reading. Information on the duration of flights for twelve months will be recorded in a form that were given to the aircrews.

Consent forms containing all the above-mentioned information were distributed to all Squadron 20 members. All the information will be number-coded based on their position in the airplane to keep the identity of the subject confidential.

Statistical Analysis

The data is described using descriptive analysis to determine the mean accumulated dose received by aircrews for one month, three months and a year. The data were also analysed using Simple Linear Regression to identify the association between the mean accumulated dose with hours of flight.

RESULTS

Mean cosmic radiation dose measured by month

Based on **Figure 1**, the radiation dose measured for one month, three months and a year shows an increasing pattern. Twelve months has the highest mean dose reading of 1.328 mSv, while one month has the lowest with 0.115 mSv and for three months is 0.325 mSv. It can be estimated that for one month, approximately the amount of radiation exposed to an aircrew will be around 0.1 mSv. It can be concluded that the longer the duration of radiation dose monitoring, the higher the dose reading.

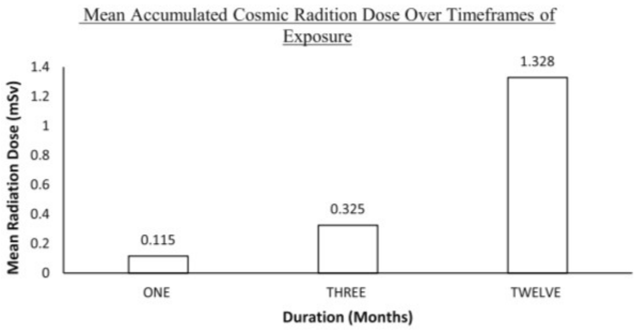

Fig. 1: Bar chart illustrating the accumulation of cosmic radiation dose received by personnel over durations of one month, three months, twelve months, showing the increasing risk of exposure associated with prolonged flight durations

The effect of duration of flying on cosmic radiation dose in one month, three months and one year for aviators

Based on **Figure 2 (A)** there is an increasing pattern between the flight hours with accumulated radiation dose in one month. The highest accumulated dose recorded is 0.116 mSv with the hours of flying being 64 hours in one month. The longest flight duration is 105 hours with the radiation dose reading measured 0.114 mSv.

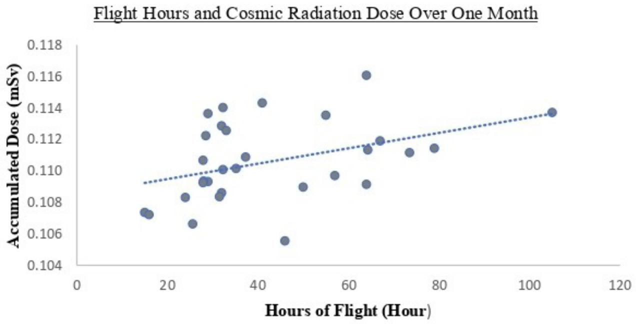

Fig. 2(A): Line graph depicting the relationship between total flight hours and the corresponding radiation dose recorded within a one-month period, representing the short-term exposure.

Figure 2 (B) shows the data is in a cluster pattern between 50 and 200 hours of flying with accumulated cosmic radiation dose. The highest accumulated dose recorded is 0.346 mSv with the longest flying hours being 525.5 hours within three months.

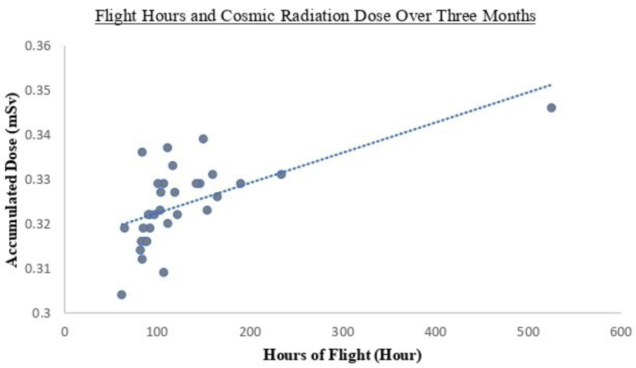

Fig. 2(B): Line graph demonstrating the accumulation pattern of cosmic radiation dose in relation to flight hours in three months, showing mid-term exposure.

As shown in **Figure 2 (C)**, an increasing pattern is seen within one year in the accumulated dose (mSv) when the hours of flight (hours) increase. The highest accumulated dose recorded is 1.392 mSv with the flying hours being 1260 hours in one year. Generally, when the time exposed to radiation is longer, the dose reading will also increase.

The statistical analysis used is Simple Linear Regression to determine the effect of the duration of flying on the accumulated radiation dose measured as shown in Table I.From the table, it can be explained that 12.8% of cosmic radiation is affected by flight hours. There is an increase of 0.109 μSv for every 0.0000478 hours in one month. Within three months it shows that 37.8% of cosmic radiation is affected by hours of flight.There is an increase of 0.316 μSv for every 0.00006776 hours with a significance value of 0.001. In one year, 11.5% of cosmic radiation is affected by flight hours. There is an increase of 1.306 μSv for every 0.0000429 hours with a significance value of less than 0.05. The significance value for all durations is less than 0.05 thus, the hypothesis, that there is a relationship between the hours of flight and measured cosmic radiation is accepted. Hence, it can be concluded that the duration of flight also contributed to the accumulated cosmic radiation dose reading.

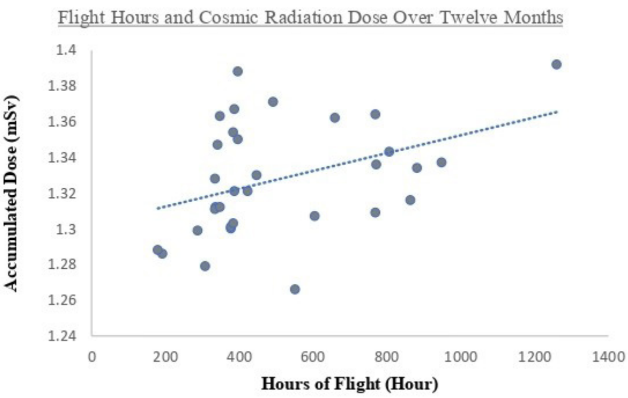

Fig. 2(C): Line graph representing the relationship between long-term flight hours and cosmic radiation dose exposure across twelve months hours of flying with the reading of cosmic radiation dose in twelve months highlighting the occupational risks among the aircrew personnel.

Table I: Summary of Cosmic Radiation Exposure by Flight Hours within One Month, Three Months and Twelve Months. This table represents the breakdown of the percentage of cosmic radiation and exposure level (μSv) corresponding to various months of flight durations. The data highlights the long-term accumulation of radiation exposure, showing a measurable rise over time.

Month	Hours of Flight (H)	Cosmic Radiation Increase with Flight Hours (%)	Radiation Increase Per Flight Hour (μSv)	Sig.
One	0.0000478	12.8	0.109	0.044
Three	0.00006776	37.8	0.316	<0.001
Twelve	0.004289	11.5	1.306	0.025

DISCUSSION

The mean accumulated cosmic radiation dose received by the aviators in a month, three months and a year using OSLD

The main objective of this study is to measure the mean accumulated cosmic radiation dose received by the aviators annually using OSLD. As suggested by the International Commission on Radiological Protection (ICRP) has set a limit of exposure of not more than 20 mSv per year. The limit applies not only to radiation workers but to flight crew members in jet aircraft who are recognized for their occupational exposure to cosmic radiation.

Based on the result obtained in this study, the mean cosmic radiation dose received by an aviator in one month is 0.115 mSv, for the duration of three months is 0.325 and in one year is 1.328 mSv. The result is within the range of the average annual effective dose for aircraft crew of 1.2 mSv to 5 mSv depending on the flight routes and can achieve a maximum of approximately 6-7 mSv in a year as stated by ICRP. The dose received by aircrews is also aligned with other recommended guidelines set by the National Council on Radiation Protection and Measurements (NCRP), which advises an effective dose limit of 20 mSv per year for individuals occupationally exposed to ionizing radiation including aircrews. In Europe, they adopted a directive standard for the protection of the health of workers by imposing that the crewmembers working schedules be arranged to keep the annual exposures below 6 mSv.

Exposure to cosmic radiation in aircrews can be affected by three factors, altitude, the geomagnetic latitude and the 11-year solar cycle. At sea level altitude, the cosmic radiation doses are 70 times less than those 20 km above the ground level (11). At higher altitudes, people are considerably exposed more to cosmic radiation than at ground level. At altitudes of jet aircraft, the cosmic radiation is 2.5-5 times more intense at the polar region than near the equator. Since the Royal Malaysia Air Force flies around states in Malaysia, the cosmic radiation penetration may be tiny compared to latitudes near the polar region because the geomagnetic field lines are parallel to the Earth's surface at the Equator. The third factor will be discussed in the next section.
Generally, this study shows that aircrews received approximately 0.1 mSv per month considering there are three factors that affect the cosmic radiation reading

The relationship between the effect of flight hours on accumulated cosmic radiation dose measured

Based on the objective of this study, the factor being tested is the cosmic radiation reading with the flying duration within one month, three months and a year. A study done (4) in 2013 shows that the duration of flying contributes to the cosmic radiation reading. For occasional flyers, the exposure to cosmic radiation can be small. However, for those who frequently fly, such as aircrew and business travelers, the annual exposure can be comparable with, or even exceed the limit of radiation workers in ground-based industries. The RMAF aviators are considered as frequent flyers, so, they spend more time at aircraft altitudes, which makes them exposed more to cosmic radiation.

The findings from this study show that, the longer the flight duration, the higher the amount of cosmic radiation received. Flight duration is calculated from the point which the aircraft departs to where it arrives in hour. Within one year, it is estimated that the mean time an aircrew spends flying is approximately 511 hours. It can be seen from the data for one month, three months and a year which shows an increasing pattern of cosmic radiation measured when the time the aircrews spent on the aircraft is longer. In 2020, research done in Indonesia (9) stated that an hour and ten minutes flight provided the lowest effective dose of 1.1 µSv while the two hours and forty minutes flight provided the highest effective dose of 3.9 µSv. The result shows that even at the same altitude, the longer the flight, the greater the exposure to cosmic radiation.

However, cosmic radiation exposure is not only because of flight duration but it can also be influenced by the activity of the solar cycles. The solar cycle is approximately 11 years and flows in the Sun's magnetic activity that manifests in the number of sunspots, solar flares and eruptions. The concept is when the solar magnetic field is stronger, less cosmic radiation reaches the Earth. Thus, solar maximum causes a radiation minimum and conversely, solar minimum is at the time of radiation maximum. At commercial aircraft operating altitude, the ratio for cosmic radiation at solar minimum to that solar maximum is about 1.2-2 and it increases as altitude increases. In this study, the cosmic radiation measurements recorded between September 2022 and November 2022 may have been influenced by variations in solar activity. Based on data presented in **Figure 2(B)**, which reflects this time frame, coincides with solar flare activity observed by NASA's Solar Dynamic Observatory. During the period of high solar activity, the Sun's magnetic field intensifies which results in reducing the cosmic rays from reaching the Earth's atmosphere. The radiation readings during this time interval may be lower due to this natural shielding effect.

This study shows a clear relationship between flight duration and cosmic radiation exposure, with aircrew accumulating higher radiation doses over longer periods. Besides that, solar activity also influences radiation exposure as seen in the events of solar flare between September and November 2022. These findings highlight the need for ongoing radiation monitoring to safeguard aircrew health, especially in long flight duration.

CONCLUSION

This study highlights that the mean accumulated cosmic radiation dose received by the Royal Malaysia Air Force (RMAF) aircrew in one year is approximately 1.2 mSv, which is within the annual exposure limit recommended by the International Commission on Radiological Protection (ICRP) of 20 mSv per year. The study also confirmed a clear and significant relationship between flight hours and cosmic radiation dose, supporting the need to monitor flight duration with other known influencing factors such as altitude, geomagnetic latitude and solar activity cycles. As flight time increases, cumulative radiation exposure increases, giving potential long-term health risks to aircrews and pilots.

Understanding the exposure patterns will help to support the development of better flight scheduling, dose monitoring systems and awareness programs to minimize radiation exposure, aiming to minimize unnecessary radiation exposure. By managing flight hours effectively and regular dosimetry assessments can help protect the health and readiness of aircrew, ensuring both short-term and long-term well-being.

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REFERENCES

1. Al-Khawlany A, Khan A, Pathan J. Review on studies in natural background radiation. Radiation Protection and Environment. 2018;41(4):215. doi:10.4103/rpe.RPE_55_18
2. Bagshaw M. Cosmic radiation in commercial aviation. Travel Medicine and Infectious Disease. 2008 May;6(3):125–7. doi:10.1016/j.tmaid.2007.10.003
3. Balasubramanian A. Atmosphere- Documentary [Internet]. 2011. Available from: https://www.researchgate.net/publication/310021347_Atmosphere-_Documentary. doi:10.13140/RG.2.2.28235.80161
4. Bennett LGI, Lewis BJ, Bennett BH, McCall MJ, Bean M, Dorй L, et al. Cosmic radiation exposure survey of an Air Force Transport Squadron. Radiation Measurements. 2013 Jan;48:35–42. doi:10.1016/j.radmeas.2012.10.012
5. Rudi Čop, Fefer D. Nature of Earth's Magnetic Field And Its Application For Commercial Flight Navigation. Springer eBooks. 2006 Jan 1;115–26. doi:10.1007/978-1-4020-5025-1_8
6. Desouky O, Ding N, Zhou G. Targeted and non-targeted effects of ionizing radiation. Journal of Radiation Research and Applied Sciences. 2015 Apr;8(2):247–54. doi:10.1016/j.jrras.2015.03.003
7. Friedberg W, Copeland K. What Aircrews Should Know About Their Occupational Exposure to Ionizing Radiation Galactic Cosmic Radiation Energetic Solar- Particle Radiation [Internet]. Available from: https://www.faa.gov/data_research/research/med_humanfacs/oamtechreports/2000s/media/0316.pdf
8. Miura K, Olsen CM, Rea S, Marsden J, Green AC. Do airline pilots and cabin crew have raised risks of melanoma and other skin cancers? Systematic review and meta-analysis. British Journal of Dermatology. 2019 Mar 18;181(1):55–64. doi:10.1111/bjd.17586
9. I Made Ardana, Aris Sanyoto, Kristyo Rumboko. An analysis of air crew exposure from cosmic radiation on Indonesian domestic flight. INIS – International Nuclear Information System [Internet]. 2020 Oct [cited 2024 August 21];57–63. Available from:

https://inis.iaea.org/records/kns44-zvz60
10. Olsen CM, Miura K, Dusingize JC, Hosegood I, Brown R, Drane M, et al. Melanoma incidence in Australian commercial pilots, 2011–2016. Occupational and Environmental Medicine. 2019 May 21;76(7):462–6. doi:10.1136/oemed-2018-105676
11. Poje M, B. Vuković, Varga M, V. Radolić, I. Miklavčić, D. Faj, et al. Relation between galactic and solar cosmic radiation at aviation altitude. Advances in Space Research. 2008 Jun 15;42(12):1913–6. doi:10.1016/j.asr.2008.06.001
12. Rьhm W, Azizova T, Bouffler S, Cullings HM, Grosche B, Little MP, et al. Typical doses and dose rates in studies pertinent to radiation risk inference at low doses and low dose rates. Journal of Radiation Research. 2018 Feb 8;59(suppl_2):ii1–10. doi:10.1093/jrr/rrx093
13. Sanlorenzo M, Wehner MR, Linos E, Kornak J, Kainz W, Posch C, et al. The Risk of Melanoma in Airline Pilots and Cabin Crew. JAMA Dermatology. 2015 Jan 1;151(1):51. doi:10.1001/jamadermatol.2014.1077
14. Shahbazi-Gahrouei D, Setayandeh S, Gholami M. A review on natural background radiation. Advanced Biomedical Research [Internet]. 2013;2(1):65. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3814895/. doi:10.4103/2277-9175.115821