Association of total flight hours with lipid blood profiles among civilian pilots in Indonesia

N Chairina¹, R A Werdhani²* and D Gathmyr³

¹Aviation Medicine Specialist Program, Faculty of Medicine, Universitas Indonesia, Jakarta, 10430, Indonesia
²Department of Community Medicine, Faculty of Medicine, Universitas Indonesia, Jakarta, 10430, Indonesia
³The Command Center of Doctrine Education and Training of Indonesian National Army Air Force, Jakarta, 13560, Indonesia

*E-mail: retno.asti@ui.ac.id

Abstract. Occupational exposure to environmental factors such as cosmic radiation and hypoxia can affect the lipid metabolism and the blood lipid profile of a pilot. Accordingly, flight safety is threatened by the incidence of dyslipidemia, as a main risk factor for atherosclerosis and heart attack. This cross-sectional study aimed to identify the risk factors associated with dyslipidemia in a consecutive sample of civilian pilots who attended periodic medical check-ups at Balai Kesehatan Penerbangan, Indonesia. Blood lipid profile data were obtained through questionnaire, and variables such as the total flight hours, food intake, body mass index (BMI), smoking habit, and physical activity were included in the analysis. Among the 128 respondents who met the inclusion criteria, the prevalence of dyslipidemia was 61.7% and the low high-density lipoprotein cholesterol index was high, at 57%. Obesity and inappropriate food intake were the dominant risk factors associated with dyslipidemia in this study; namely, civilian pilots with inappropriate food intake had a 2 times risk of dyslipidemia relative to those with an appropriate food intake [odds ratio (OR) = 2.01; 95% confidence interval (CI): 0.91–4.43; p = 0.08, while obese pilots had a 4 times risk of dyslipidemia relative to those with a normal BMI (OR = 3.47; 95% CI: 1.29–10.84; p = 0.002. In conclusion, inappropriate food intake and obesity appear to contribute to increased dyslipidemia among civilian pilots in Indonesia.

1. Introduction

High blood levels of lipids have been identified as risk factors for cardiovascular disease, in the form of atherosclerosis in blood vessels which can lead to a sudden and fatal heart attack. A survey of Chinese civilian pilots conducted by Zhao et al. during 2006–2011 observed a higher prevalence of dyslipidemia compared to military aviators and the general Chinese population (59.02%–73.44%) [1]. Although hyperlipidemia does not disqualify a pilot from flight tasks, the proven association between a reduced blood lipid profile and reduced coronary heart disease risk should be seriously considered [2], especially in a Chinese study conducted by Chen (published in 2010) in which linear associations of the pilots’ body mass index (BMI) values and blood lipid profiles were observed with the number of flight hours. Specifically, increases in the blood lipid profiles were observed among civilian pilots with more than 5000 total flight hours [3]. Furthermore, Chen observed that the flight time indirectly reflected the dose of cosmic radiation, which may lead to lipid metabolism disorder. From the perspective of cardiovascular disease prevention and mitigation, further study is needed to assess the
relationship between total flight hours and other factors related to a pilot’s blood lipid profile, as these data will facilitate early management and thus mitigate the cardiovascular disease risk. The aim of this research was to identify the environmental risk factors for blood lipid abnormalities among pilots in Indonesia.

2. Methods
A cross-sectional study and consecutive sampling method was conducted in civilian pilots. The subjects were civilian pilots who attended periodic medical check-ups at Air Force Health Center, Indonesia in June 2017. The inclusion criteria were as follows: male sex; Asian ethnicity; civilian pilot; holder of professional license such as Airline Transport Pilot License, Private Pilot License, and Commercial Pilot Certificate; age of 18–65 years; and willingness to participate in the study, including the requirement for 10–12 h of fasting before a blood test. The exclusion criteria were as follows: use of a cholesterol-lowering drug, such as simvastatin, atorvastatin, Crestor, Lipitor, gemfibrozil, fenofibrate, niacin, or ezetimibe. Pilots who did not complete the study questionnaire and/or medical check-up were considered to have met the drop-out criteria.

The study protocol was approved by the Health Research Ethics Committee, Faculty of Medicine Universitas Indonesia-Cipto Mangunkusumo Hospital. The research subjects were interviewed using a structured questionnaire of demographic and environmental factors. Total cholesterol, triglycerides, high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, total flight hours, food intake pattern, body mass index (BMI), smoking habits, and physical activity were measured and analyzed. The data were processed with logistic regression analysis of SPSS version 20 and the Nutrisurvey©.

3. Results
Table 1 presents the percent distributions of common characteristics, including age, total flight hours, food intake, physical activity, BMI, smoking habit, and dyslipidemia, among the 128 subjects.

| Variables | Number (n) | %  |
|-----------|------------|----|
| Age       |            |    |
| ≤30 years | 68         | 53.1|
| >30 years | 60         | 46.9|
| Total flight hours |            |    |
| <3,300 hours | 64     | 50.0|
| ≥3,300 hours | 64   | 50.0|
| Food intake |            |    |
| Appropriate | 44   | 34.4|
| Inappropriate | 84 | 65.6|
| Physical activity |            |    |
| Appropriate | 37   | 28.9|
| Inappropriate | 91 | 71.1|
| Body mass index |            |    |
| Normal | 19 | 14.8|
| Overweight | 26   | 20.3|
| Obese | 83 | 64.8|
| Smoking habit |            |    |
| No | 70 | 54.7|
| Yes | 58 | 45.3|
Most of the subjects were 30 years of age or younger (53.1%), had inappropriate food intake (65.6%) and physical activity habits (71.1%), an obese BMI (64.8%), and without smoking habit (54.7%).

Table 2. Distribution of dyslipidemia

| Variables  | Number (n) | %  |
|------------|------------|----|
| Dyslipidemia |            |    |
| No         | 49         | 38.3|
| Yes        | 79         | 61.7|

Seventy-nine out of the 128 study subjects (61.7%) had dyslipidemia (Table 2). A further lipid profile component analysis according to NCEP-ATP III classification revealed that the majority had a desirable total cholesterol level (61.7%), followed by those with borderline high (30.5%) and high (7.8%) levels. Additionally, the majority had normal triglyceride levels (71.1%), followed by those with borderline high (14.8%), high (12.5%), and very high levels (1.6%). The majority had near/above optimal LDL cholesterol levels (43%), followed by borderline high (32%), optimal (14.8%), high (10.2%), and very high levels (0%). Finally, the majority had low HDL cholesterol levels (57%), followed by moderate (39.8%) and high levels (3.1%). Of the four lipid profiles, low HDL was the most frequently observed cardiovascular risk factor among the civilian pilots.

Table 3. The relationship between risk factors and dyslipidemia

| Variables    | Normal | Dyslipidemia | OR  | P   | 95% CI       |
|--------------|--------|--------------|-----|-----|--------------|
| Total flight hours |        |              |     |     |              |
| <3,300 hours | 24     | 40           | 62.5| 1   | Reference    |
| ≥3,300 hours | 25     | 39           | 60.9| 0.94| 0.46–1.90     |
| Food intake  |        |              |     |     |              |
| Appropriate  | 52.3   | 21           | 47.7| 1   | Reference    |
| Inappropriate| 31     | 58           | 69  | 2.44| 1.15–5.18    |
| Physical training |      |              |     |     |              |
| Appropriate  | 14     | 23           | 62.2| 1   | Reference    |
| Inappropriate| 35     | 56           | 61.5| 0.97| 0.44–2.14    |
| Body mass index (BMI) |    |              |     |     |              |
| Normal       | 12     | 7            | 36.8| 1   | Reference    |
| Overweight   | 13     | 13           | 50  | 1.71| 0.38–5.74    |
| Obese        | 24     | 59           | 71.1| 4.21| 0.007–11.99  |
| Smoking habit |        |              |     |     |              |
| No           | 25     | 45           | 64.3| 1   | Reference    |
| Yes          | 24     | 34           | 58.6| 0.79| 0.39–1.61    |

OR, odds ratio; CI, confidence interval

Table 3 demonstrates that subjects with imbalance food intake and obesity were more likely to have dyslipidemia. By contrast, the total flight hours and physical activity habit did not appear to have a significant effect on dyslipidemia.
As shown in Table 4 (final model), food intake and an obese BMI were identified as the dominant risk factors associated with dyslipidemia in civilian pilots. Specifically, the risk of dyslipidemia was 2 times higher for a pilot with inappropriate food intake compared with a pilot with appropriate food intake (OR = 2.01, 95% CI: 0.91–4.43). The risk of dyslipidemia for a pilot with an obese BMI was 3.7 times higher than that of a pilot with a normal BMI (OR = 3.74, 95% CI: 1.29–10.84).

4. Discussion
In this study, the overall prevalence of dyslipidemia among a population of Indonesian civilian pilots in 2017 was 61.7%. This value was greater than the rate of 35.9% reported by Riskedas among a population of Indonesian residents aged >15 years in 2013 [4]. Furthermore, our bivariate analysis failed to identify a significant association of the number of total flight hours with the incidence of dyslipidemia, which was inconsistent with a Chinese cross-sectional study by Huang et al. (2012) which claimed a significant association of these factors (p = 0.038; OR = 1.171; 95% CI: 1.009–1.360) [5]. This difference may be attributed to the presence of other dominant factors that could influence the incidence of dyslipidemia among civilian pilots.

According to previous studies, aircrews are exposed to an average cosmic radiation dose of approximately 5 mSv each year, compared with the 1–2 mSv exposure dose incurred by hospital workers and the general population [5-7]. Therefore, an increase in total flight hours would be expected to increase exposure to cosmic radiation. Such exposure induces a state of oxidative stress, which leads to changes in lipoprotein structure and consequent lipid metabolic disturbances. Specifically, the body releases an increased amount of lipid molecules into the bloodstream as a protective mechanism against lipid peroxidation-induced cell membrane damage, leading to dyslipidemia [5,8,9].

In addition to increased radiation exposure, an increased number of total flight hours exposes aircrews to repeated, intermittent hypoxia over time. The average cabin pressure of a commercial aircraft is 8,000 feet, with an oxygen saturation level of approximately 93% [10,11]. Intermittent exposure to such hypoxic conditions disrupts cholesterol absorption and causes an increased blood level of cholesterol [12].

This study also found that 65.6% of the subjects consumed an inappropriate or excess daily amount of food, and this factor was found to have a significant effect on the risk of dyslipidemia. Namely, inappropriate food intake increases the risk of dyslipidemia by approximately 2-fold. This result is consistent with the findings of a cross-sectional study of Yogyakarta civil servants conducted by Sudargo et al. in 2016 in which a significant correlation was identified between high carbohydrate intake and dyslipidemia (p < 0.001; OR = 4.902; 95% CI: 2.03–11.834), leading the authors to conclude that high carbohydrate intake is a risk factor for dyslipidemia [13]. In a 2016 Korean study, Song et al. also found that high carbohydrate intake was associated with elevated triglyceride and low HDL level, whereas high fat intake was positively associated with elevated total cholesterol and LDL levels. [14] Thus, the intake of fatty foods leads to increased lipogenesis and the formation of free fatty acids, which are then mobilized from adipose tissue to the liver and bind with glycogen to form triacylglycerol (TG) and increased TG synthesis in the liver leads to dyslipidemia. Furthermore, the intake of a high-carbohydrate diet increases the levels of fructose 2,6-bisphosphate, which enhances phosphofructokinase-1 activity and stimulates glycolysis. This increase in glycolysis enhances the conversion of glucose into free fatty acids, which subsequently form TG [15].
In this study, approximately 64.8% of civilian pilots in Indonesia had an obese BMI, which was found to be a dominant risk factor for dyslipidemia. This result is consistent with the findings of a Chinese cross-sectional study by Qi et al. in 2015, which claimed a significant association of obesity with an increased risk of dyslipidemia among men (p < 0.001; OR = 2.73) [16]. Obesity is defined as an excess fat tissue mass often associated with weight gain and may be complicated by hyperlipidemia. Specifically, obesity is caused by excessive fat accumulation, especially in the upper body or abdomen. Adipose tissue lipolysis is more active in the abdomen than in other areas of the body, with the consequence of an increased release of free fatty acids to the portal circulation [17-19]. Adipose tissue is the greatest depot of energy in the form of triglycerides and free cholesterol, an excess of which triggers lipogenesis. Under conditions of energy deficiency, adipose tissue releases free fatty acids and glycerol, leading to increased circulating levels of the former and resulting in dyslipidemia [20].

It was further identified that 45.3% of subjects in this study had a smoking habit. However, our analysis did not identify a significant relationship of this factor with dyslipidemia, inconsistent with an Indian case-control study by Sharma et al. in which smokers had an increased risk of dyslipidemia compared with non-smokers (p ≤ 0.05) [21]. Per cigarette, roughly 40–100 ng/ml of nicotine is absorbed quickly into the arterial blood, where it stimulates sympathetic nerve (sympathomimetic) activity and induces catecholamine release both locally from nerve fibers and systemically from the adrenal glands. Consequently, the increased circulating levels of epinephrine and norepinephrine activates adenyl cyclase in adipose tissue, which induces triglyceride lipolysis and the release of free fatty acids into the blood plasma. This mechanism leads to elevated concentrations of VLDL and LDL and reduced levels of HDL. Smoking also reduces the levels of enzymes that contribute to free cholesterol esterification, increase HDL size, and reduce the levels of ester cholesterol protein transfer [21-23].

Finally, 71.1% of the subjects in this study reported an inappropriate amount of physical activity. Our analysis did not identify a significant relationship between physical activity and dyslipidemia, consistent with the claim by Sudargo et al. that physical exercise correlates insignificantly with blood lipid levels (p > 0.05) [13]. However, these findings were inconsistent with a those of a cross-sectional study by Jing et al., which claimed that physical activity helps to reduce the risk of dyslipidemia (p < 0.01; OR = 0.78, 95% CI: 0.62–0.98) [24]. We note that regular physical activity is reported to increase cholesterol absorption and improve blood plasma lipoprotein profiles, specifically by reducing the levels of total cholesterol, triglycerides, and LDL while increasing the level of HDL [24,25].

5. Conclusion
In this study of Indonesian civilian pilots, the total flight hours did not appear to significantly affect dyslipidemia. However, both inappropriate food intake and obesity increased the risk of dyslipidemia by approximately 2 times and 4 times, respectively, relative to the reference categories. Through multivariate analysis, we concluded that an obese BMI is a dominant risk factor for dyslipidemia in this population.

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