Aircraft vibration and other factors related to high systolic blood pressure in Indonesian Air Force pilots

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Abstrak

Latar belakang: *Penerbangan dapat berdampak pada sistem kardiovaskular manusia. Penerbang terpajan antara lain pada bising dan vibrasi pesawat. Penelitian bertujuan untuk mengetahui pengaruh beberapa faktor penerbangan pada tekanan darah sistolik.*

Metode: *Penelitian nested case-control dilakukan pada penerbang Angkatan Udara Republik Indonesia yang melakukan pemeriksaan fisik tahunan di Lembaga Kesehatan Penerbangan dan Ruang Angkasa (LAKESPRA) Saryanto tahun 2003–2008. Data yang diperoleh dari rekam medik berupa umur, jumlah jam terbang, jenis pesawat, kadar glukosa puasa dan kadar kholesterol darah, lingkaran pinggang, tinggi dan berat badan, tinggi badan, serta tekanan darah.*

Hasil: *Dari 336 penerbang, terdapat 16 penerbanga dengan tekanan sistolik ³ 140 mmHg. Penerbang dengan rata-rata jam penerbangan 300-622 jam per tahun dibandingkan dengan 29-299 jam per tahun mempunyai risiko peningkatan tekanan darah sistolik tinggi sebesarf 5 kali [rasio odds suaian (ORa) = 5,05, 95% interval kepercayaan (CI) = 0,88 -23,30, P = 0,070]. Menurut jam terbang total, mereka yang memiliki 1.401-1,1125 jam dibandingkan 147-1.400 jam berisiko 3,6 kali mengalami tekanan darah sistolik tinggi (ORa = 3,58, 95% CI = 1,24-10,38). Selain itu, mereka dengan denyut nadi istirahat tinggi dibandingkan dengan denyut nadi normal istirahat memiliki 2,4 kali mengalami tekanan darah sistolik tinggi (ORa = 2,37, CI = 0,74-7,50 95, P = 0,147].*

Kesimpulan: *Vibrasi pesawat terbang tinggi, rata-rata jam terbang per tahun tinggi, dan frekuensi nadi istirahat yang tinggi meningkatkan risiko tekanan sistolik tinggi.*

Kata kunci: *tekanan darah sistolik, vibrasi pesawat terbang, frekuensi nadi istirahat, pilot*

Abstract

Background: Flight may affect the human cardiovascular system. Pilots are exposed among others to aircraft noise and vibration. This study aimed to investigate the effects of aircraft flight on systolic blood pressure.

Methods: A nested case-control study was conducted on Indonesian Air Force pilots doing annual medical check-ups at the Saryanto Institute for Medical and Health Aviation and Aerospace (LAKESPRA) from 2003 – 2008. The data extracted from medical records were age, total flight hours, type of aircraft, fasting blood glucose and cholesterol levels, waist circumference, height and weight (Body Mass Index), and blood pressure.

Results: Of 336 pilots, there were 16 with systolic pressure ≥ 140 mmHg. The pilot who had high vibration than low vibration had 2.8-fold to be high systolic blood pressure [adjusted odds ratio (ORa) = 2.83; 95% confidence interval (CI) =1.16-22.04). In term of average flight hours, those who had average flight hours of 300-622 hours per year compared to 29-299 hours per year had 5-fold increased risk to be high systolic blood pressure (ORa = 5.05; 95% CI =1.16-22.04]. Furthermore, those who had high than normal resting pulse rate had 2.4 times to be high systolic blood pressure (ORa = 2.37; 95 CI =0.81-6.97; P = 0.115).

Conclusion: High aircraft vibration, high average flight hours per year, and high resting pulse rate increase risk high systolic blood pressure in air force pilots.

Keywords: systolic blood pressure, aircraft vibration, resting pulse rate, pilots

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Epidemiological and laboratory studies suggest that transient as well as chronic noise exposure have both temporary and permanent effects on human physiology.[1,2] Through their work, pilots are chronically exposed to noise, specifically aircraft noise.[2,3] This chronic exposure to noise is known to cause noise-induced hearing loss (NIHL).[1] But nevertheless other non-auditory effects of noise need to be investigated.[2,3]

It must be remembered that the aircraft, whether fixed-wing or helicopter, is not only the source of noise of more than 100 dB, but also of vibration. This vibration is caused by the machine and propeller or rotor of the helicopter. Since sound is basically vibration, the vibrations of machines can synergized with noise and increase the deleterious effect of sound.

Therefore, short-term and long-term exposures to aircraft noise in conjunction with vibration may have auditory as well as non-auditory effects on the human body, with permanent consequences on health, such as on the cardiovascular system.[3]

A large number of epidemiologic studies in a wide variety of populations have revealed that systolic blood pressure (SBP) exerts a stronger influence than diastolic blood pressure related to the risk of cardiovascular events.[4]

It is therefore important to investigate the association between aircraft noise, vibration, and other risk factors on systolic blood pressure of pilots.

METHODS

The methods employed in this study were the same as the previous article on high diastolic blood pressure.[5] The was a nested case-control study on pilots of the Indonesian Air Force (IAF) attending annual medical examinations during indoctrination and aerophysiologic training at the Saryanto Aviation and Space Medicine Institute from January 2003 to September 2008. The medical examinations were carried out by trained doctors and nurses, specialist in their respective fields, according to strict and detailed procedures laid down by the Indonesian Air Force Medical Guidebook.[6] Data were extracted from these records.

Cases were pilots with SBP ≥140 mmHg and control with ≤119 mmHg.[7] The ratio of case to control was 1:12. Control was matched to case in terms of the month the case was diagnosed.

The major risk factor for this study was interior aircraft noise. This noise was separated into 2 categories, ≤80 dB (low) and ≥90 dB (high). Other potential aircraft risk factors were exterior aircraft noise, which was divided into 5 categories, 100 dB, 110 dB, 130 dB, 140 dB, and 160 dB; type of aircraft, transport planes, fighter planes, and helicopters; and vibration, which was divided into low or high vibration. Aircraft noises and vibration measurements were obtained from the Air Force Health Office survey.[8]

The length of employment for cases was calculated from the year becoming an IAF pilot until diagnosed with high SBP. The length of employment for controls was calculated from the year becoming an IAF pilot up to the time the case was diagnosed with high SBP. For the purpose of analysis, the length of employment was divided into 2 categories: 2 – 10 years and 11 – 25 years.

Age diagnosed with high SBP was calculated from birth until the year diagnosed with hypertension. For the purpose of analysis, age was divided into 3 categories, 23-29 years, 30-39 years, and 40-48 years. Age on starting work was calculated from the birth year until the year becoming an IAF pilot. For analysis, age was divided into 2 groups, 19 – 22 years and 23 – 26 years.

Rank was the most recent obtained by the pilots. For analysis, rank was divided into 2 groups, first officers (from second lieutenant to captain) and middle-ranked officers (major to colonel).

Total flight hours for cases were calculated from the year becoming a pilot until diagnosed with high SBP. For controls, total flight hours were calculated from the year becoming a pilot until diagnosed with high SBP. For analysis, total flight hours were divided into 2 categories, 147-1400 hours and 1401-11,125 hours. Annual average flight hours were calculated from total flight hours divided into 2 categories, 29-299 hours/year and 300-622 hours/year. Year of starting work was the year the subject became a pilot for, with 2 categories, the time periods 1980–1990 and 1991–2003.

Fasting blood glucose level was divided into 2 groups, less than or equal to 126 mg/dL and greater that 126 mg/dL. Blood cholesterol level was divided into 2 groups, less than or equal to 200 mg/dL and more than 200 mg/dL.

Body Mass Index (BMI) was calculated from body weight (kg) divided by height (m) squared or kg/m^2. BMI was divided into 3 groups, 18.00-22.99 kg/m^2, 23.00-24.99 kg/m^2, and 25.00-39.00 kg/m^2.[6]

Waist circumference was in cm and was divided into 2 groups, normal ≤90 cm and high> 90 cm.

Resting pulse rate was the number of pulses per minute taken after resting for 15 minutes, and divided into 2 groups, 50-80/minute and 81-101/minute. Selecting 80/minute as the limit was based on the ROC curve. With 75.5% sensitivity and 61.4% 1 – specificity the value obtained was 79.5/minute which was rounded out to 80/minute.

Resting pulse pressure was the difference between systolic and diastolic blood pressures. It was divided into 2 groups, 10-40 mmHg and 41-90 mmHg.

Statistical analyses were done using STATA 9.0 software.[9] A number of risk factors were examined as to whether or not they were potential confounders and/or effect modifiers. Unconditional logistic regression analysis was used in order to determine the confounding effects and to determine the risk factors for high SBP. A risk factor was considered to be a potential confounder if in the univariate test it had a *P*-value <0.25 which would be considered as a candidate for the multivariate model along with all known risk factors for high SBP.[9] Confounders were estimated by the method of maximum likelihood. Ninety-five percent confidence intervals were based on the standard error of coefficient estimates. Odds ratios (OR) were estimated by the methods of maximum likelihood.[10]

RESULTS

Table 1 showed that high SBP had already occurred in the first 2 years of work, and more were diagnosed after 11-25 years of work, the average flight hours 29-299 hours per year, total flight hours 1401-1,1125 hours, and the year of beginning work between 1991-2003.

Furthermore, Table 1 showed that subjects with high SBP and not high SBP were similarly distributed in terms of length of employment, age starting work, and rank.

When compared to reference, subject who age on diagnosis was 40-48 years and middle-ranked officers were more likely to be high SBP. On the other side, subjects starting work in 1991-2003 compare to those starting work in 1980-1990 had less likely to have high SBP.

Table 2 showed that the percentage of overweight and obese pilots, were relatively high 25% and 68.8%, respectively, in the group with high systolic blood pressure.

High and normal systolic blood pressures were similarly distributed with respect to blood cholesterol level and waist circumference. Subjects with a body mass index (BMI) and obese and high resting pulse rate, were more likely to have high systolic blood pressure when compared to references.

Table 3 showed that subjects with high and not high systolic blood pressure were not equally distributed in terms of exterior aircraft noise. When compared with reference, helicopter pilots, interior aircraft noise of 90-95 dB, more likely to increase the risk of high systolic blood pressure.

Table 4 showed that those exposed to high vibration rather than low vibration had a 2.8-fold risk of high systolic blood pressure [adjusted odds ratio (ORa) = 2.83; 95% confidence interval (CI) =1.16-22.04). In terms of average flight hours, those who with average flight hours of 300-622 hours per year compared to 29-299 hours per year had a 5-fold increased risk of high systolic blood pressure (ORa = 5.05; 95% CI =1.16-22.04]. Furthermore, those who had high compared to those with normal resting pulse rate had 2.4 times to have high systolic blood pressure (ORa = 2.37; 95 CI =0.81-6.97; P = 0.115).

DISCUSSION

This study has several limitations, one of them was the source of the data was records of medical examinations and indoctrination and aerophysiological training forms from 2003–2008. However the medical examinations followed the rigid instructions of the standardized Technical Guidelines for Medical Tests and Examinations of the IAF.[6] Another limitation was that work-related stress, exercise, and smoking were not included in this study.

Table 1. Some demographic, work characteristics and the risk of high SBP

	Systolic blood pressure				Crude Odds Ratio	95% Confidence Interval	p
	Normal (n=320)		High (n=16)				
	n	%	n	%			
Length of employment							
2-10 years	162	50.6	6	37.5	1.00	Reference	
11-25 years	158	49.4	10	62.5	1.71	0.61-4.81	0.311
Age diagnosed							
23-29 years	108	33.8	5	31.3	1.00	Reference	
30-39 years	170	53.1	6	37.4	0.76	0.23-2.56	0.661
40-48 years	42	13,1	5	31.3	2.57	0.71-9.34	0.151
Age starting work							
19-22 years	205	64.1	8	50.0	1.00	Reference	
23-26 years	115	35.9	8	50.0	1.79	0.65-4.88	0.260
Rank							
First officer	186	58.1	7	43.7	1.00	Reference	
Middle-ranked officer	134	41.9	9	56.3	1.78	0.65-4.91	0.262
Year starting work							
1980-1990	77	24.1	7	43.8	1.00	Reference	
1991-2003	243	75.9	9	56.2	0.41	0.15-1.13	0.085

Table 2. Some laboratory, physiological findings and the risk of high SBP

	Systolic blood pressure				Crude Odds Ratio	95% Confidence Interval	p
	Normal (n=320)		High (n=16)				
	n	%	n	%			
Fasting blood glucose level							
Normal	316	98.8	16	100.0	1.00	Reference	
High	4	1.2	0	0.0	na*	na	na
Blood cholesterol level							
Normal	161	50.3	7	43.7	1.00	Reference	
High	159	49.7	9	56.3	1.30	0.47-3.58	0.609
Body mass index							
Normal	62	19.4	1	6.2	1.00	Reference	
Overweight	97	30.3	4	25.0	2.56	0.28-23.41	0.406
Obese	161	50.3	11	68.8	4.24	0.54-33.50	0.171
Waists circumference							
Normal	302	94.4	15	93.8	1.00	Reference	
High	18	5.6	1	6.2	1.12	0.14-8.95	0.916
Resting pulse rate							
Normal	251	78.4	10	62.5	1.00	Reference	
High	69	21.6	6	37.5	2.18	0.77-6.21	0.144
Resting pulse pressure							
Normal	421	80.5	0	0.0	1.00	Reference	
high	102	19.5	16	100.0	na	na	na

*na = not applicable

Table 3. Some aircraft characteristics and the risk of high SBP

	Systolic blood pressure				Crude Odds Ratio	95% Confidence Interval	p
	Normal (n=320)		High (n=16)				
	n	%	n	%			
Type of aircraft							
Transport	145	45.3	5	31.3	1.00	Reference	
Fighter	104	32.5	2	12.5	0.56	0.11-2.93	0.490
Helicopter	71	22.2	9	56.2	3.68	1.19-11.37	0.024
Exterior noise							
100 dB	47	14.7	2	12.5	1.00	Reference	
110 dB	123	38.4	10	62.6	1.91	0.40-9.06	0.414
130 dB	51	15.9	2	12.5	0.92	0.12-6.81	0.936
140 dB	79	24.7	1	6.2	0.30	0.03-3.37	0.328
160 dB	20	6.3	1	6.2	1.18	0.10-13.71	0.898
Interior noise							
70-80 dB	238	74.4	7	43.8	1.00	Reference	
90-95 dB	82	25.6	9	56.2	3.73	1.35-10.34	0.011

Table 4. The relationship between interior aircraft noise, average flight hours per year, age diagnosed, resting pulse rate, and pulse pressure and the risk of high SBP

	Systolic blood pressure				Adjusted Odds Ratio*	95% Confidence Interval	p
	Normal (n=320)		High (n=16)				
	n	%	n	%			
Vibration							
Low	269	84.1	8	50.0	1.00	Reference	
High	51	15.9	8	50.0	2.83	1.16-22.04	0.000
Average flight hours per year							
29-299 hours per year	293	91.6	13	81.2	1.00	Reference	
300-622 hours per year	27	8.4	3	18.8	5.05	1.16-22.04	0.031
Resting pulse rate							
Normal	251	78.4	10	62.5	1.00	Reference	
High	69	21.6	6	37.5	2.37	0.81-6.97	0.115

*Odds ratio adjusted each others between risk factors listed on this table

The older age at which high systolic pressure was diagnosed, 40 years or older, was a risk of high systolic blood pressure (P = 0.151). This is consistent with community studies, such as the Framingham study, where systolic blood pressure was found to increase starting from adolescence to adult.[11] In the Framingham study, increased systolic blood pressure in the age group 30-49 years was mainly found due to increased resistance in the small vessels which caused increased systolic blood pressure.[11]

The average flying hours per year of 300-622 hours was a risk factor for high systolic blood pressure (P = 0.172). High average flight hours per year showed the number of sorties, or the take-off and landing, was also high. Take-offs and landings required a high level of alertness. This alertness was the product of increased sympathetic activity. High sympathetic tone stimulate the cardiovascular system, causing increased heart contractions and consequently systolic blood pressure will increase.[11,12]

Pilots beginning work in 1991 - 2003 had a 5% lower risk for high systolic blood pressure (P = 0.085). This is because the subject who began work in 1991 - 2003 was younger than the subjects who worked in from 1980 to 1990.

According to BMI, obese pilots have 4.24 times the risk for high systolic blood pressure (P = 0.171). Data from the Framingham showed an increase in blood pressure with increasing BMI.[11] In the United States, the prevalence of hypertension among people with BMI ≥ 30 kg/m2 was 42.5%, BMI 25.0 - 29.9 kg/m2 was 27.8%, and 15 , 3% in those with a BMI of 25 ≤ kg/m2.[11]

In this study, high resting pulse rate (P = 0.144) was a risk factor for high systolic pressure. High resting pulse high rate reflects high sympathetic tone. High sympathetic activity increases heart contraction (systole) which in turn increases systolic blood pressure.[11,12]

In this study, the helicopter pilots have a higher risk, 3.68 times (P = 0.024), for an increase in systolic blood pressure compared to pilots of transport aircrafts.[13] As a study in Korea, where there was an increased risk of 1.6 times for a rise in blood pressure in the population living around a helicopter base.[14]

In this study, interior aircraft noise of 90-95 dB compared to interior aircraft noise of 70-80 dB increased the risk of high systolic blood pressure by 3.73 times (P = 0.011). This meant that the effect of noise increased when the intensity was higher. This dose-dependent relationship in is similar to results of studies on the population surrounding a military air base in Okinawa.[3]

High vibration was also a factor that heightened the risk of increased systolic blood pressure by 2.30 fold (P = 0.013). This effect of local vibration on workers using hand tools, such as pneumatic drills, may be through increased sympathetic activities.[15] This will increase the strength of heart contraction (systole) and thus the systolic blood pressure.[11,12]

In the final model, factors that contribute to increased risk of high systolic pressure was high average flight hours per year (P = 0.031), high vibration (P = 0.000), and high resting pulse rate (P = 0.115). It seems that these factors may be associated with increased sympathetic tone.[12]

Furthermore, cardiovascular event rates were found to increase steeply with systolic pressure and were higher in cases of isolated systolic hypertension than diastolic hypertension.[4] Clinical trials produced similar results, again suggesting that a greater reliance should be placed on systolic pressure in evaluating the risk of cardiovascular problems.

In conclusion, high aircraft vibration, high average flight hours per year, and high resting pulse rate increase risk high systolic blood pressure in air force pilots.

Acknowledgments

The author wishes to thank all subjects who willingly participated in this study. The authors would also like to express their sincerest gratitude for the former director of Lakespra, Dr. Mariono Reksoprodjo for making this study possible, and also for Prof. Bastaman Basuki for technical assistant in data analysis.

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