Aircraft deicing in open baskets: Study of the effects of activities on heart rate variability

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Abstract: Aircraft deicing technicians who work in open baskets endure physical strain and exposure to health and safety risks. This study aims to identify the tasks that are particularly strenuous and to measure the relationship between aircraft model and physical fatigue. To do this, the study synchronizes video recordings and the data collected by biometric vest to correlate the tasks of 12 subjects with their heart rate. Based on these data, the resting heart rate (RHR) and steady state limit (SSL) are calculated. The results of this study identify the following tasks as fatiguing: spraying de/anti-icing fluids, moving the basket and truck and deicing ground control. Also, the type of aircraft that causes the most physical fatigue is the tail-engine plane.

Keywords: De/anti-icing, aircraft, heart rate, physical fatigue

1. Introduction

Exposed to extreme weather conditions, countries in the Northern hemisphere are under safety obligations to ensure that the critical surfaces of their aircrafts are deiced prior to all take-offs, as stipulated in the Canadian Aviation Regulations (Transport Canada 2017). Aircraft deicing is performed within airports by deicing technicians from open and closed baskets. The population of deicing technicians working in open baskets has expressed that they are more tired at the end of their shift than the deicing technicians working from a closed basket (Torres Medina 2014). Apart from the main hazards related to aviation, fatigue caused by multiple factors can have consequences on the physical health of these workers (Mounet et al. 2013). The objective of this study is to identify strenuous tasks and to measure the relationship between aircraft model and physical fatigue.

2. Methodology

First, a number of observations and measurements were conducted on a sample of 12 voluntary deicing technicians working in open baskets from a population of 40. None of the subjects in this study reported suffering from heart conditions. Table 1 summarizes the averages of the subjects' individual data:

Table 1: *Average, maximum and minimum values of the subjects' individual characteristics.*

Gender	Number	Age (years)			Weight (kg)			Stature (m)		
		Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.
Men	10	33	21	54	81.1	68.0	90.7	1.83	1.64	1.95
Women	2	24			56.5	52.0	61.0	1.64	1.57	1.70

Observation of the deicing activity was achieved by video recording using two portable cameras on the open basket and one camera mounted to the deicing company's control tower. The length of these video recordings is between 60 and 90 minutes for each subject, we therefore obtained 15h52 of video recording of the 12 subjects. As we need to identify the strenuous tasks of the deicing protocol, we selected the most intense activity periods for each subject. Doing so we obtained 8h00 of data to analyze for all the subjects. From this selection, 22 different tasks were identified as taking place during the deicing activity in open baskets, sometimes occurring separately, sometimes jointly. The heart rate is a good indicator of the level of fatigue and can be used to detect work situations that are more physically demanding (Meyer 1996). Thus, the heart rate of the subjects was measured in beats per minute (bpm), using a Hexoskin MC biometric vest (Carré Technologies Inc., Montreal, Quebec, Canada). Chronological synchronization of the tasks and heart rate data collected occurred each second during the video recordings.

Next, the data was classified according to the types of aircraft that are deiced, which is based on the number of engines and their location. This is the same type of classification as the one used by the company to establish its deicing protocols. The 75 planes observed are grouped according to the following categories: "Tail-engine plane", "Propeller-powered plane" and "Twin-engine jet". Four subjects were excluded, because their heart rate was significantly higher than the steady state limit (SSL), which rendered difficult any comparison of their data with those of the other subjects. The four excluded subjects were two females and two subjects exposed to extreme weather conditions. The remaining eight subjects were divided into two groups, according to the weather conditions in which they were working, namely:

Group 1: 4 men, -5°C < temperature < 0°C, snowing

Group 2: 4 men, -5°C < temperature < -2°C, cloudy

Finally, to analyse the data, first the coefficient of determination (R^2) was calculated for each subject's heart rate on a macroscopic level, that is, for the entire length of the video recordings. Then, a closer study was made of the cardiac load by measuring the resting heart rate (RHR) when the subjects were either standing in the open basket or sitting in the truck's cab. According to the type of resting position, the following heart rate increase interval (ΔHR) was attributed: $\Delta HR_{sitting}$ = + 35 bpm or $\Delta HR_{standing}$ = + 30 bpm (Schlick et al. 2010). These last two variables made it possible to calculate each subject's SSL, by which SSL = RHR + ΔHR. Any value above this SSL threshold indicates that subjects are in a state of task-related fatigue. Exhaustion could occur if this threshold is exceeded for too long. These variables make it possible to compare the data according to the tasks being undertaken and type of aircraft being deiced.

3. Results

3.1 Macroscopic analysis of the data

The entire set of values calculated for all 12 subjects are presented in Table 2. These results show that the heart rate's coefficient of determination R^2 for the entire period being measured near toward 0.

Table 2: *Average, standard deviation and range of calculated values based on the heart rates (based on entire period measured n = 15h52min and the average length of RHR measurement for each subject = 45 min)*

Variables	Average	Standard dev.	Range
R^2	0.0366	0.0403	0.108 – 0.000750
RHR	72.8 bpm	7.83 bpm	86.0 bpm – 62.0 bpm
SSL	107 bpm	7.69 bpm	121 bpm – 97.0 bpm

3.2 Analysis of the physical load per task

This study aims to identify the deicing tasks inside of the basket that are fatiguing, taking into consideration all types of aircrafts and all 12 subjects. To do this, a comparison was made as shown in Figure 1 indicating the percentage of time during which the heart rate was greater than the SSL for each task observed. Results show that the most fatiguing tasks are the spraying of deicing fluids, the spraying of anti-icing fluids, moving the basket and the truck and deicing ground control.

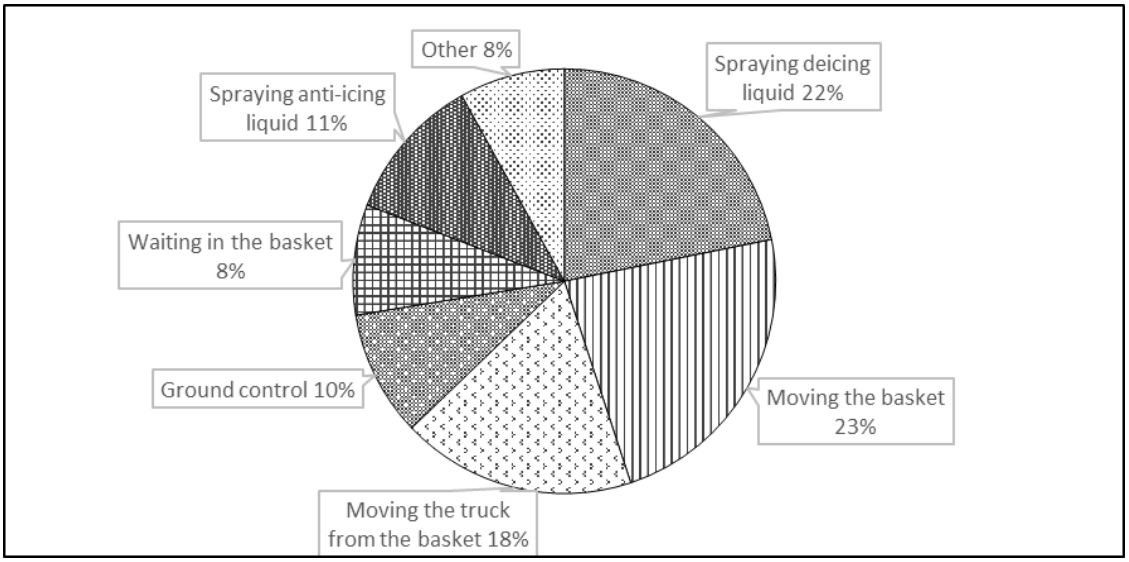

Figure 1: *Division of tasks performed when the heart rate is greater than the SSL (based on 8h00 from the analyzed data of the 12 subjects, $HR_{12\ subjects}$ > SSL during n = 2397 sec)*

3.3 Analysis of the physical load according to airplane

This study also aims to establish the effect of the type of aircraft on the workers' level of fatigue. To do this, to best isolate this factor, a distinction was made between

the percentage of time during which the heart rate was greater than the SSL for group 1 and that of group 2. We also chose to exclude the waiting periods between two planes. Then, the median of the percentages was calculated according to the type of aircraft being deiced, as illustrated in Figure 2. Some differences were noted in relation to the weather conditions between group 1 and 2. Also, the tail engine planes cause more fatigue for workers than the other airplane types.

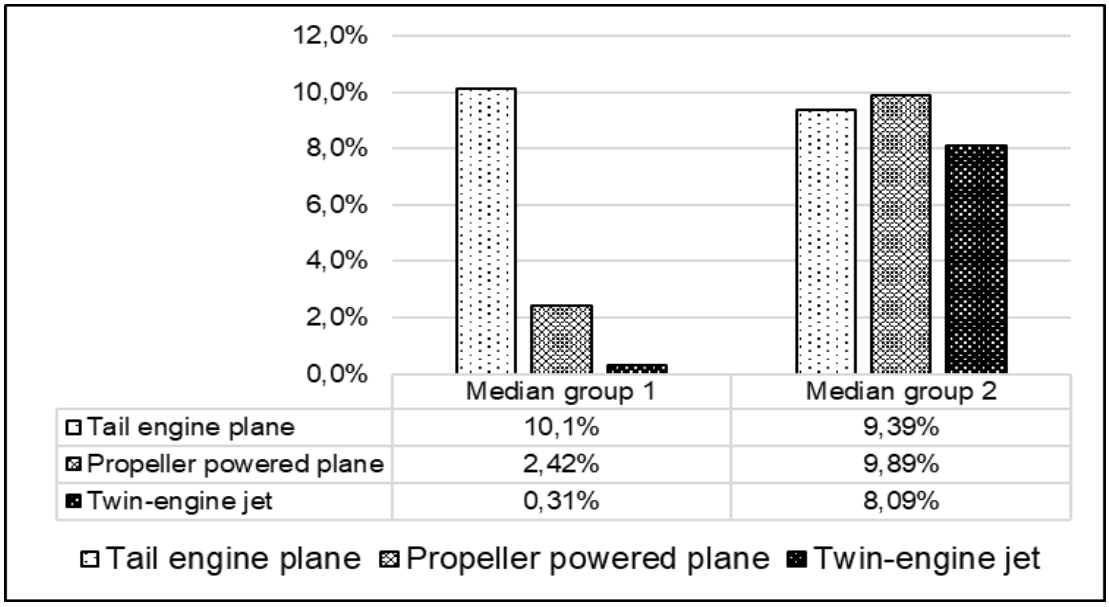

Figure 2: *Effects of airplane type being deiced when heart rate is greater than SSL for subjects in group 1 and group 2 (using 6h05 from the analysed data of the 8 subjects from group 1+2).*

4. Discussion

To begin with, as illustrated in Table 2, the fact that the coefficient of determination R^2 is near 0 for all 12 measurements demonstrates that there is no linear relationship between the heart rate and time lapse, given the heart rate's variability. Therefore, closer examination of this signal for periods of high work load is necessary to identify the causes of physical fatigue.

Additionally, based on the frequency of each task and the amount of time during which the heart rate exceeds the SSL during said task, it was possible to identify the fatiguing tasks, as shown in Figure 1. These conclusions are comparable with those in a study on the energy-expenditures of deicing in open basket, conducted using the same subjects (Landau et al. 2017). However, to support this result, it would be necessary first to measure the amplitude of the cardiac signal for each task, and second, to analyse the cumulative effect on the level of fatigue of the tasks amongst each other and also to study the recovery heart rate time.

Moreover, if the effects of weather conditions were not taken into account, it was noted that tail engine planes cause the most fatigue. In fact, in a previous study (Torres Medina 2014), the open basket deicing technicians identified this plane as being particularly problematic. The deicing procedures for these planes require systematic deicing inspection from the ground circling the entire plane while the engines are running. Yet, this situation is dangerous as it requires them to be in close proximity to the running engines. The worker's heart response during ground control might

possibly not be solely affected by physical strain, but by multiple factors and it would be interesting to delve further into these factors in a later study.

The authors of this study are not aware of there being other studies in the literature about heart rate and aircraft deicing. It is therefore impossible to compare the results herein with other reports.

5. Conclusion

This study provides preliminary conclusions in the analysis of the aircraft deicing activity in relation to the heart rate. Despite the study's limited number of subjects, it identifies the most physically fatiguing tasks for deicing technicians, namely: spraying of de/anti-icing fluids, moving the basket, moving the truck and deicing ground control. Furthermore, tail engine planes and their deicing protocol are particularly fatiguing for workers. These results could lead to future studies that further examine open basket deicing.

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