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Study of fatigue and workload among aircraft de-icing technicians

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Abstract.
BACKGROUND: Fatigue and workload experienced by aircraft de-icing personnel have been largely neglected in occupational health and safety research.
OBJECTIVE: To provide an initial assessment of fatigue and workload among de-icing ground crews.
METHODS: Company records were used to reveal possible relationships between different variables (age, seniority, truck type, and work shift). A group of 20 volunteer participants (17 men and 3 women) rated their level of fatigue before and after one shift using the Samn-Perelli fatigue scale. Workload was evaluated using the NASA-TLX method at the end of the shift.
RESULTS: The average fatigue experienced by de-icing worker was significantly greater ($P = 0.043$) for the technicians in open-basket trucks than for the ones in trucks with a cabin (4.43 vs 3.37). Furthermore, there was a significant age difference ($P = 0.048$) in the perceived level of fatigue (4.1 vs 3.1), with younger workers (< 30 years) reporting a higher level than older workers ($\geqslant$ 30 years). Overall NASA-TLX score were not significant ($P > 0.05$) for any of the factors tested: type of truck, shift and age.
CONCLUSIONS: The results suggest that particular attention should be paid to young technicians and technicians working in open-basket trucks, since the fatigue levels reported in association with these factors were higher.

Keywords: Aircraft de-icing, fatigue, workload

1. Introduction

Ice accretions on the fuselage, and more particularly on the wings of aircraft, have a major impact on aircraft aerodynamics. It can cause stalling of the aircraft and serious stability and control problems during flight and take off. According to Banke [1], despite all the progress made in improving the protection of aircraft against ice accumulation, the risk is still present. Ice can build up on aircraft surfaces in the presence of moisture, snow or freezing rain. Under such weather conditions, de-icing of aircraft on the ground becomes essential to ensure safe takeoff. Current aircraft ground de-icing practices are based primarily on the use of fluids with low freezing points and increased viscosity.

Products containing glycols (propylene glycol, ethylene glycol, diethylene glycol) are generally used. Specialized ground crews ensure the de-icing of aircraft wings often under highly constrained time frame. The manner in which this operation is conducted involves significant occupational health and safety (OHS) risks: work at heights, physical discomfort (cold, dampness, and wind), risk of slips, exposure to glycols, and major physical/mental demands. De-icing is conducted during atypical working hours (5 AM to 11 PM) spanning more than two normal shifts.

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Analysis of numerous accidents in common socio-technical systems has shown that the cause in most cases has been one or more human failings [2]. Quality problems, human error and usability problems often have the same cause. In many cases, the cause can be attributed to the design of the work system and to environmental elements such as noise, inadequate lighting, high physical loads and excessive work pace or complexity [3]. The greatest challenge to studying the conditions under which de-icing is conducted is to identify measures that can be implemented to improve system performance by decreasing the impact of the above-mentioned factors on workers.

One of the worst de-icing-related accidents on record occurred in 1995 at Montreal/Mirabel International Airport when a Boeing 747 belonging to Royal Air Maroc began to move before the de-icing operation was completed, striking both of the service vehicles. The drivers sustained minor injuries while the three occupants of the open basket trucks were fatally injured. Confusion in communications during the operation, de-icing crew non-compliance with procedures, and deficiencies in training were cited among other factors as causes of the accident [4]. The fallout from the Mirabel de-icing accident (as it is known internationally) led to sweeping changes to de-icing procedures worldwide, de-icing procedures with engines running, and radio communication protocols in particular, among others [5]. However, nearly two decades later, despite the lessons learned from Mirabel, accidents/incidents involving de-icing ground crews continue to occur [6–8]. Workload and fatigue might be playing a major role.

1.1. Fatigue and workload

Shift work and atypical work schedules have been recognized as having a significant impact on the level of fatigue experienced by workers [9,10]. Due to the potential impact of fatigue on OHS and productivity, any company whose employees work extended hours or work during hours when individuals normally sleep, should pay particular attention to workplace fatigue [11]. It is recognized that the severity of accidents is often much greater at night. Many of the major accidents in the industrial world occurred during the night: Bhopal, Three Mile Island, Chernobyl, and Exxon-Valdez, among others [12]. Working an atypical shift increases the risk of accidents and this can represent a danger to public safety, especially at night [13]. In the northern hemisphere, the absence of sunlight is significant during the de-icing season, the nights being longer than the days. Shift work has been associated with a variety of behavioral disorders. For example, shift work sleep-wake disorder can cause workers to fall asleep while working, and this is out of their control [13]. Pilots, air-traffic controllers and general maintenance technicians have been frequently the subject of studies of fatigue and workload [14–17]. This is not the case for de-icing ground crews, despite the fact that this job is critical to ensuring safe takeoff in northern regions.

Mental and physical fatigue produce very similar effects: lowered performance and quality of work, discomfort, pain and weakness, among others [11]. According to Transport Canada [18], fatigue can cause workers to: "(...) lose concentration, make mistakes in the assessment of speed and distance, react more slowly, and even fall asleep. Fatigue can also make you moody and irritable, and cause you to take risks. Each of these problems can be a danger to you and others." Fatigue and sleepiness are often used interchangeably even though they are distinct states. According to Lerman et al. [11], sleepiness is the propensity to fall asleep, while fatigue is the response of the body to lack of sleep or in some cases to extended physical or mental effort. Due to its non-specific origin and to the lack of consensus on its measurement, there is no short, universally accepted definition of fatigue [12–19]. The International Civil Aviation Organization (ICAO) defines fatigue as "A physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a crew member's alertness and ability to safely operate an aircraft or perform safety related duties."

Another factor known to influence fatigue is workload, which can be defined as "(1) the demands of your work in terms of difficulty, complexity and time pressure; and (2) the effort you have to expend in meeting those demands" [20]. Mental and physical workloads are defined differently. Given the impossibility of observing what is happening in the mind of a worker executing a task, ergonomists have found ways to conceptualize the impact of task demands on the worker and associate it with system performance [21]. Mental workload can be associated with a physiological state of stress or effort but also with subjective perception of stress, mental effort and time pressure. Objective measures of performance level or deterioration thereof can be used to define the concept of mental workload [22]. According to Hart [20], workload signifies the cost to the worker of completing a task (including the associated requirements). This author argues that "if people could accomplish everything expected of them quickly, accurately, and reliably using available resources, the concept would have little practical importance. Since they often cannot, or the human cost of maintaining performance is unacceptably high, we should take this into consideration during system design". The cost of maintaining performance appears in the form of fatigue, stress, injuries and accidents.

The objective of this paper is to report the results of a preliminary study of fatigue and workload among de-icing ground crews. Fatigue was not considered as a problem by management at the start of the study. To our knowledge, this is the first time an attempt has been made to improve understanding of the OHS implications of this somewhat unusual, but safety-critical occupation.

2. Methods

2.1. Participants

The studied population for the first phase of the study consisted of 62 employees, primarily male (85%). The first phase was entirely based on company records provided by the deicing facility itself, which were treated anonymously. For the second phase, twenty employees were recruited in person by the researcher team. The sample consisted of 17 men and three women, all of whom worked at the same airport. The number of participants corresponded to nearly one third (32%) of the de-icing technicians working at this airport. No selection criterion was used (participation was at the discretion of the employee). The whole study received approval from the university research ethics committee. Participants provided written consent prior to participation.

2.2. Procedure

At the airport chosen for this study, de-icing operations are carried out in specialized centralized de-icing facilities. The first phase was conducted using company records to reveal possible relationships between employee age and seniority (how long the employee had been working in the company) and variables such as vehicle type, work shift and employment status. For the second phase, work shifts were classified as morning (5 AM to 2 PM) and evening (2 PM to 11 PM). The 20 participants in this phase completed the Samn-Perelli rating scale of fatigue [23] at the beginning and end of their shift. They were also required to rate their workload using the NASA-TLX method [24] at the end of their shift (both ratings on the same workday). The two age ranges were below and above 30 years since around this age there is a clearly defined change in sleep pattern due to growth-linked changes in the circadian

Table 1
The variables studied

Variable	Range
Fatigue	Scale of 1 to 7
Workload	Score from 0 to 100
Shift	Day (5 am–2 pm)/evening (2 pm–11 pm)
Type of truck	Cabin/Open basket
Age	Years
Seniority	Years
Gender	Female/Male
Weather (*) conditions	Low icing conditions-Medium icing conditions-High icing conditions

*Weather conditions represent a combination of several factors recognized to increase the probability of ice accumulation on aircraft (temperature, humidity, wind speed, etc.). This classification is used by the Aviation Weather Center in the USA and Canada.

system [25]. The preferred times to go to sleep and to wake up are generally delayed in adolescents and young adults [26]. Local managers were aware of the study and able to provide simple support for the researchers where necessary, as well as allowing participant time for completing tests. Experimenters were present to deliver the tools. The workday chosen for completion of the questionnaires was not controlled, that is, no criteria were established for the selection of the workday. The weather conditions were determined from airport weather station data made available to the public by Environment Canada (http://climat.meteo.gc.ca/).

2.3. *Evaluation of fatigue*

Participants rated their level of fatigue before and after the shift using the 7-point Samn-Perelli scale [23] This was completed using the 7-point Samne-Perelli Fatigue Scale (1 = Fully alert, wide awake, 2 = Very lively, responsive, but not at peak, 3 = Okay, somewhat fresh, 4 = A little tired, less than fresh, 5 = Moderately tired, let down, 6 = Extremely tired, very difficult to concentrate, 7 = Completely exhausted, unable to function effectively). This scale is one of the most used in the subjective measurement of fatigue [27]. It has been used in the study of railway workers [28] and also for measuring fatigue among [15].

2.4. *Evaluation of workload*

Workload was assessed using the NASA-TLX. This is a subjective method of workload evaluation developed by the “Human Performance Group” at the “NASA Ames Research Center” in the USA and one of the most widely used and most validated [20,28]. In terms of ease of use, subjective measures have been found easier to administer [21]. NASA-TLX involves the use of scales that are split into twenty intervals, marked at each end as ‘Low’ and ‘High’ or ‘Good’ and ‘Poor’. There are six sub-scales: mental demand, physical demand, time constraint, performance, effort required, and frustration caused. The participants were required first to rate the influence of the six sub-scales by encircling the greater dimension in a list of pairs. These ratings were used to generate a rating that accounted for differences in the definition of workload between participants. The participants were then required to rate the degree to which each of the six dimensions (sub-scales) contributed to their workload experience [24].

Table 2
Mean (SD) age and status factors of aircraft de-icing personnel

Factor	N	Age (SD)	P(*)
Type of truck used			
Cabin	32	33.1 (13.8)	0.026
Open basket	30	26.2 (7.3)	
Employment status			
Full time	33	34.8 (16.0)	0.035
Part time	29	27.7 (7.9)	
Work shift			
Day	38	33.9 (13.7)	0.243
Evening	24	29.6 (13.6)	

*Level of alpha used to indicate significance was 0.05 and italicized p values are significant.

2.5. Analysis

The study variables are presented in Table 1. Weather conditions represent a combination of several factors recognized to increase the probability of ice accumulation on aircraft (temperature, humidity, wind speed, etc.). This classification is used by the Aviation Weather Center in the USA and Canada. Analysis of variance was used to detect significant differences. Although the scales of fatigue and workload were ordinal, parametric statistics such as ANOVA or t-tests have been used frequently for analyses of this type of variable [15,28–30]. Stiger et al. [31] have shown the validity of using parametric tests on ordinal variables, especially given that non-parametric tests remain very limited, as does understanding of the properties of these tests. This is not the first time ANOVA is used to analyze fatigue and workload rating [28].

3. Results

3.1. Analysis of different factors over the entire population of workers (First phase)

Statistical analysis was used to check for differences in employee age according to the type of truck used, employment status and work shift (Table 2). The difference in age was significant for type of truck ($P = 0.035$) and employment status ($P = 0.026$) but not for shift. Younger employees worked mostly in trucks with open baskets and more on a part-time basis. The de-icing staff of the company consisted of 40 employees (65%) younger than 30 years and 22 employees (35%) aged at least 30 years. In terms of seniority, 60% had one season of experience or less, 30% were in their first season and only 20% (13 employees) had three seasons of experience or more.

3.2. Fatigue evaluation over a sample of 20 workers (Second phase)

A comparison between the levels of fatigue experienced by workers before starting the workday and after finishing shows a significant difference ($P = 0.001$). The average rating before starting was 2.4, (SD = 1.3) while the value after the shift was 4.1 (SD = 1.0) (Fig. 1). An unusual value of 6 in the Samn-Perelli fatigue scale (Extremely tired, very difficult to concentrate) was spotted among the ratings of fatigue level before the shift. It is clearly identifiable with a star on Fig. 1 and represents a case study.

Univariate ANOVA was conducted to test the influence of the type of truck, work shift, age group and weather condition (in terms of icing creation probability) on the level of fatigue experienced after the

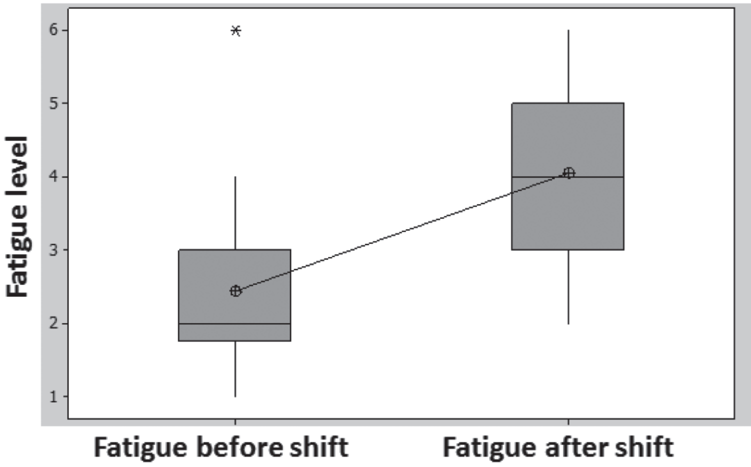

Fig. 1. Fatigue level (means) before and after the work shift. The difference was significant ($P = 0.00$). (*)Unusual value (6 = extremely tired, very difficult to concentrate) in the Samn-Perelli fatigue scale.

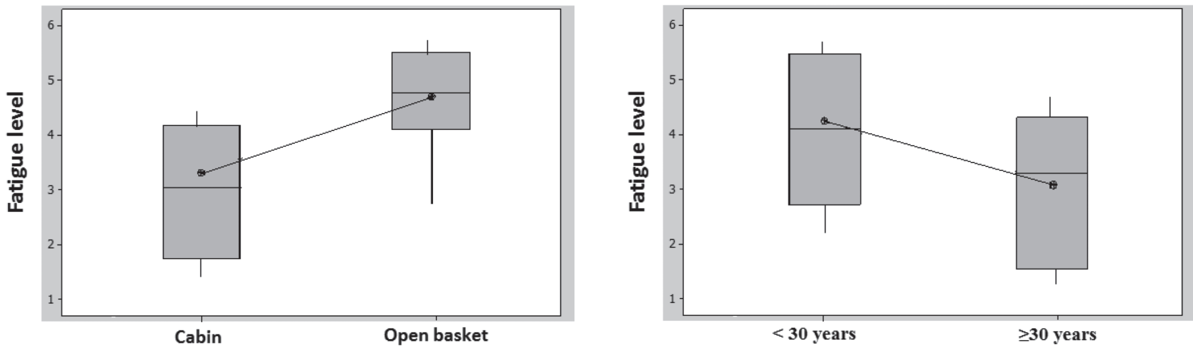

Fig. 2. Fatigue level (means) according to type of truck (A) and age group (B).

shift. The average fatigue experienced was significantly greater ($P = 0.043$) for the open-basket truck technicians (4.43, SD = 0.8) than for the ones in trucks with a cabin (3.37, SD = 0.9). Figure 2 shows these results in a boxplot. Fatigue was not significantly different ($P = 0.49$) between shifts (4.22, SD = 0.9 vs 3.85, SD = 1.0). The average level of fatigue experienced after the shift was significantly higher ($P = 0.048$) than before the shift for workers aged less than 30 years (4.1, SD = 0.9 vs 3.1, SD = 1.0), compared to workers 30 years of age or older.

Three categories of weather condition were defined: 1 = light, 2 = moderate, 3 = intense, according to icing creation probability reported by whether station. The analysis of fatigue according to the four factors (type of truck, work shift, age, and weather conditions) is shown in Table 3.

3.3. Workload evaluation for a sample of 20 workers (Third phase)

Among the six variables rated to obtain an overall score using the NASA-TLX method, mental demand had the highest mean value (59.2, SD = 18.3), see Fig. 3.

Differences in overall NASA-TLX scores were not significant for any of the factors tested (truck, work shift, age, weather). Significant differences were found when testing the six dimensions with respect to

Table 3
Analysis of the contribution of different factors to fatigue ratings among aircraft de-icing personnel

Factor	N	Fatigue	P(**)
Type of truck			
Cabin	9	3.4 (0.9)	0.043
Open basket	11	4.4 (0.8)	
Work shift			
Day	13	4.2 (0.9)	0.49
Evening	7	3.8 (1.1)	
Age			
$<$ 30 years	9	4.1 (0.9)	0.048
$\geqslant$ 30 years	11	3.1 (1.1)	
Weather Condition (*)			
Low icing conditions	4	3.0 (1.2)	0.314
Medium icing conditions	6	3.8 (0.8)	
High icing conditions	10	4.1 (1.4)	

*Weather conditions represent a combination of several factors recognized to increase the probability of ice accumulation on aircraft (temperature, humidity, wind speed, etc.). This classification is used by the Aviation Weather Center in the USA and Canada. **Level of alpha used to indicate significance was 0.05 and italicized p values are significant.

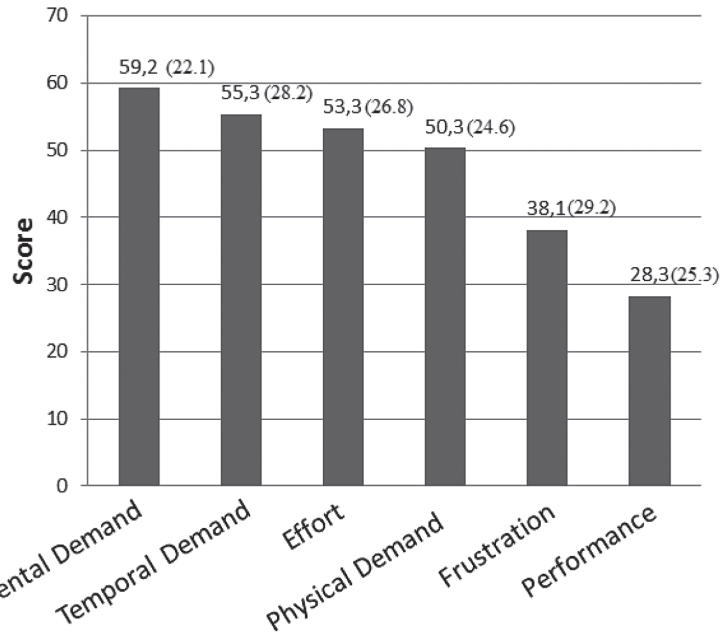

Fig. 3. Rating of the six NASA-TLX dimensions of workload (means and SD) reported by aircraft de-icing personnel.

these four factors (Table 4). Age group accounted for three out of four significant differences: mental demand ($P = 0.02$), performance ($P = 0.02$) and frustration level ($P = 0.03$). The rating of mental demand was higher among employees aged 30 years or more, compared to the younger group (69.5, SD = 22.1 vs 43.8, SD = 21.4). The younger employees on average rated their performance level higher (38.5, SD = 22.8 vs 16.0, SD = 10.5), but also their frustration level (55.0, SD = 28.4 vs 27.2, SD = 21.6). Employees working in open-basket trucks rated physical demand significantly higher ($P = 0.04$) than did employees working inside a truck cabin (68.0, SD = 20.4 vs 42.8, SD = 29.2).

Table 4
Analysis of the contribution of factors: truck, shift and age to the six dimensions forming the NASA-TLX

	N	Mental demand	P (*)	Physical demand	P	Time constraint	P	Performance	P	Effort	P	Frustration	P
Truck													
Cabin	9	68.8 (19.2)	0.09	42.8 (29.2)	0.04	60.5 (24.7)	0.32	31.11 (26.9)	0.62	51.7 (22.8)	0.77	40.0 (29.0)	0.77
Open basket	11	49.1 (25.9)		68.0 (20.4)		50.0 (18.5)		25.56 (19.7)		55.0 (25.9)		36.1 (27.3)	
Shift													
Day	13	58.7 (23.8)	0.8	54.17 (30.7)	0.71	51.5 (23.2)	0.25	29.23 (26.9)	0.79	50.7 (25.6)	0.47	38.0 (29.7)	0.99
Evening	7	55 (28.3)		(9.3 (22.9)		51.5 (23.2)		26.00 (8.22)		60.0 (18.7)		38.0 (23.6)	
Age													
$<$ 30 years	9	43.8 (22.1)	0.02	60.0 (28.3)	0.62	46.4 (15.5)	0.17	38.5 (22.8)	0.02	50.0 (25.8)	0.65	55.0 (28.4)	0.03
$\geqslant$ 30 years	11	69.5 (21.4)		53.2 (27.9)		60.9 (24.0)		16.00 (10.5)		55.4 (23.3)		27.2 (21.6)	

*Level of alpha used to indicate significance was 0.05 and italicized p values are significant.

4. Discussion

In the first phase analysis, the significant difference ($P = 0.00$) obtained for seniority with respect to the type of truck (2.78 years, SD = 0.8 cabin and 0.63 years, SD = 0.2 open basket) illustrates a selection effect. Employees who stay longer with the company tend to switch from open-basket trucks to trucks with a cabin. There is also a significant employee age difference ($P = 0.03$) between the types of truck for the same reason. Technicians working in trucks with a cabin were older than those working in open-basket trucks (33.0 years, SD = 13.7 vs. 26.2, SD = 7.3 years). There is also a significant age difference ($P = 0.04$) between part-time employees (27.7 years, SD = 7.9) and full-time employees (34.8 years, SD = 16.0). The elements mentioned above show a pattern. An employee working in an open-basket truck was generally younger, less experienced and often works part-time. This may be related to the nature of the job. De-icing is a seasonal employment available only during the winter, making it unattractive to persons seeking more stable income.

The results from the second phase analysis show a significant effect of work on the perceived level of fatigue. Fatigue level ratings at the end of the workday were higher than ratings provided before starting the workday ($P = 0.00$). The rating of 4.1 (end of workday) corresponds to "a little tired, less rested" on the Samn-Perelli scale. Powell et al. [15] obtained a similar result in a study of fatigue in a population of pilots assigned to multiple-route travel. These authors noted that no mean score for any route was above 5.0, a value often regarded as a critical threshold in civil aviation [32]. In a study of Australian railway workers reported an average fatigue rating of 4.0 with a standard deviation of 1.3 [28]. This suggests that the average rating in fatigue studies might not be very helpful for evaluating actual risk. If the critical value on the fatigue scale was set at 5.0 for the current study, it would have meant that 30% of workers surveyed rated themselves as critically fatigued. The criterion violation approach therefore seems more relevant in this type of study (By establishing a critical value, we can identify the number of times the value has been exceeded). This approach was already used by Dorrian et al. [28]. It should be noted that no employee reported the maximal value of 7 (exhausted) on the fatigue scale. A value of 6 (extremely tired) was reported once for fatigue experienced after the shift and also once before starting the shift. In our study 30% of workers reported a fatigue rating of 5 (Moderately tired, let down) in Samn-Perelli fatigue scale.

The results also showed a significant difference ($P = 0.04$) in the level of fatigue experienced after the work shift, depending on the type of truck. Employees working in open-basket trucks reported higher mean levels of fatigue compared to those working in trucks with a cabin (4.43, SD = 0.8 vs 3.37, SD = 0.9). This result may be due to a combination of factors, notably increased exposure to cold weather and glycol, and additional physical effort. Working in an open-basket is more demanding and difficult, at least physically. Although workers do not remain in the open basket all the time (they can go inside the truck) they often remain there for considerable lengths of time, notably, when the number of aircraft increases. Furthermore, there was a significant age difference ($P = 0.048$) in the perceived level of fatigue, with younger workers reporting a higher level of fatigue on average than older workers (4.10, SD = 09 vs 3.10, SD = 1.0). This is likely due to the larger number of younger employees working on the open-basket trucks.

Although the mean value of fatigue before starting the shift was 2.44 (1.29), which is acceptable, an atypical value of 6.0 was noted, which on the Samn-Perelli fatigue scale corresponds to extremely tired, very hard to concentrate. This outlier provided an interesting case study although not explored in this paper. The employee was in the younger group and worked in an open-basket truck on the morning shift. Sleep patterns are known to vary with age, due to growth-linked changes in the circadian system [25].

The preferred times to go to sleep and to wake up are generally delayed in adolescents and young adults [26]. This can cause problems, especially for activities that start early in the morning, since it is harder to get the eight hours of sleep generally considered necessary to obtain maximal recovery [26]. This can cause sleep debt in younger employees. Individual reasons such as specific time to go sleep and the amount of hours of sleeps for this worker were not determined. These elements could explain the response of the outlier.

The NASA-TLX overall score for workload was not significant for any of the factors analyzed (type of truck, work shift, age group, weather conditions). The overall score obtained using this method has its critics. Several studies show that using pairs of choices to arrive at an overall score adds very little to the results of the analysis and complicates the rating task for the workers [33]. In addition, the overall score was not designed to set a limit on the workload; it is fundamental for comparison purposes. The analysis using the six dimensions forming the partial NASA-TLX showed significant differences between age groups in terms of mental demand, performance and frustration, and for truck type in terms of the physical requirement. Employees in open-basket trucks perceived the physical requirement as significantly greater than did employees working in trucks with cabins (68.0 vs 42.8), which reinforces the finding of a significant difference between the types of truck in terms of fatigue experienced. Work in the open basket is carried out in a standing position, while using the arms significantly to operate a hand-held spraying device. In terms of energy expenditure [34], the cabin tasks can be classified as low intensity (mean metabolic rate of 100 W·m-2) while the open-basket tasks correspond to moderate intensity (165 W·m-2).

Younger employees rated their performance as higher than did older employees (38.5, SD = 22.8 vs 16.0, SD = 10.5). This might be because they had, in most cases, less experience and had not yet learned how more experienced employees define adequate performance. This result is consistent with the higher level of frustration expressed in the younger group (55.0, SD = 28.4 vs 27.2, SD = 1.6), implying that they felt less confident about completing their tasks adequately (according to NASA-TLX description off this variable). The higher rating for mental demand in the older group (69.5, SD = 21.4 vs 43.8, SD = 22.1) may be due to the higher proportion of older employees working in trucks with cabins. The tasks in the cabins are less physically demanding but require more concentration. These technicians use control panels to operate the ethylene glycol spraying system. This work involves, among other things, constant evaluation of the distance between the de-icing vehicle and the aircraft. Workers in the cabins must also manage multiple communications in parallel between the control tower and the de-icing crew (according to field observation).

Like all subjective evaluation methods, the Samn-Perelli and NASA-TLX scales can suffer from inherent bias associated with human judgment [34]. Some objective methods such as eye-tracking and biomarkers are frequently used to measure fatigue [35,36]. The complexity of these methods exceeds the scope of this preliminary study. In future research objective methods of measuring fatigue should be used.

5. Conclusions

This study of fatigue and workload experienced by aircraft de-icing personnel provides an initial assessment of an occupation largely neglected in OHS research, particularly in the context of adverse winter weather conditions. Although the sample size might be considered limited for statistical purposes, this study shows how various factors such as vehicle type and technician age could influence the performance of aircraft de-icing ground crews.

The results could suggest that particular attention should be paid to young technicians and open-basket trucks, since the fatigue levels reported in association with these factors were higher. There are also a number of other factors that could have contributed to the results of this study that were not controlled. Managerial supervision could play a role in decreasing the impact of fatigue on de-icing performance (fatigue was not considered as a problem by management at the start of the study). This could be achieved by limiting the numbers of consecutive hours and consecutive days of work. Resolving to avoid accumulation of fatigue should also lead to measures focused on work organization like work/rest strategies and shift work scheduling. Providing adequate pauses could also contribute to achieving this objective. It is necessary to educate de-icing technicians on the importance of getting eight hours of sleep.

6. Future research

A larger sample (more workers, more airports) would be helpful for using more powerful statistical tools. It would be also good to control for variables like age and experience. For example, are the young technicians feeling more fatigued because they are young or because they are inexperienced? It is almost certainly affected by the fact that they work in the open basket trucks more often than older technicians. Is the truck type more relevant than age and experience? It would be useful to conduct further research with larger numbers of workers to explore these issues further. Future studies of this subject will need to address safety performance indicators to identify clearer relationships between accidents or incidents and factors related to the conditions under which de-icing operations are carried out.

Conflict of interest

The authors have no conflict of interest to report.

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