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Prevalence of operator fatigue in winter maintenance operations

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ABSTRACT

Similar to commercial motor vehicle drivers, winter maintenance operators are likely to be at an increased risk of becoming fatigued while driving due to long, inconsistent shifts, environmental stressors, and limited opportunities for sleep. Despite this risk, there is little research concerning the prevalence of winter maintenance operator fatigue during winter emergencies. The purpose of this research was to investigate the prevalence, sources, and countermeasures of fatigue in winter maintenance operations. Questionnaires from 1043 winter maintenance operators and 453 managers were received from 29 Clear Road member states. Results confirmed that fatigue was prevalent in winter maintenance operations. Over 70% of the operators and managers believed that fatigue has a moderate to significant impact on winter maintenance operations. Approximately 75% of winter maintenance operators reported to at least sometimes drive while fatigued, and 96% of managers believed their winter maintenance operators drove while fatigued at least some of the time. Furthermore, winter maintenance operators and managers identified fatigue countermeasures and sources of fatigue related to winter maintenance equipment. However, the countermeasures believed to be the most effective at reducing fatigue during winter emergencies (i.e., naps) were underutilized. For example, winter maintenance operators reported to never use naps to eliminate fatigue. These results indicated winter maintenance operations are impacted by operator fatigue. These results support the increased need for research and effective countermeasures targeting winter maintenance operator fatigue.

1. Introduction

Fatigue can best be defined as combinations of symptoms that include mental and physical elements, impaired performance, and subjective feelings of reduced alertness (Thiffault, 2011). Characteristics of fatigue include: loss of alertness, attention and vigilance; increased wandering thoughts; decreased reaction time; distorted judgement; decreased motivation; impaired memory; reduced field of vision; and increased frequency of microsleeps (Moscovitch et al., 2006). All of these factors increase the likelihood of crashes.

Fatigue can be either task-related (e.g., physical exertion, stress, and monotony) or sleep-related (e.g., sleep deprivation, poor sleep quality, and sleep disorders; May & Baldwin, 2009) and lies on a continuum. Furthermore, fatigue can be either acute (i.e., short term) or chronic (i.e., long term; Canadian Centre for Occupational Health and Safety et al., 2012). Acute fatigue is commonly experienced by most people and is related to physical activity, sleep disruptions, and circadian rhythms (Gander et al., 2011). Circadian rhythms are repeated, daily cycles of alertness levels. These repeated and predictable cycles explain why most people become tired or alert around the same times each day. Symptoms of acute fatigue can often be reduced or eliminated by rest/breaks without sleep or one night of normal sleep (Krueger, 1989). Acute fatigue may also be reduced with caffeine consumption (i.e., Camden et al., 2015). On the other hand, chronic fatigue is due to inadequate sleep across longer periods of time, which leads to a sleep debt. To recover from chronic fatigue, a few nights of long, sound sleep is needed (Gander et al., 2011).

1.1. Operator fatigue in winter maintenance operations

Although there is a significant amount of research examining the effects of fatigue in commercial motor vehicle drivers, little research has examined the prevalence and effects of driver fatigue in winter maintenance operations. Furthermore, the authors are not aware of any studies that document the prevalence of crashes involving winter maintenance vehicles.

Although winter maintenance operators are not commercial motor vehicle drivers, there are a number of similarities between these two populations regarding the susceptibility to driving while fatigued. Both groups of drivers operate a large truck, endure long work shifts (winter

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maintenance shifts sometimes exceed 18 h during winter emergencies) for many consecutive days, and have schedules that change daily. However, there are several unique characteristics of winter maintenance operations that may increase a winter maintenance operators' propensity to experience task-related and sleep-related fatigue. Unlike commercial motor vehicle drivers, winter maintenance operators are not bound by prescriptive hours-of-service regulations designed to limit fatigue. Winter maintenance operators may also experience a number of other task-related factors associated with the development of fatigue, such as sustained vibrations resulting from the snowplow equipment (e.g., tire chains and the plow hitting the pavement; Paschold & Mayton, 2011), reduced visibility due to falling snow and back-reflected light (Gimeno et al., 2006), and highly demanding, dangerous roadway conditions (Desmond and Hancock, 2001). Additionally, Spitznagel et al. (2009) found the combination of fatigue and exposure to extreme cold temperatures resulted in decreased cognitive functioning. Thus, winter maintenance operators may be prone to the same (or greater) levels of fatigue while driving during winter emergencies as commercial motor vehicle drivers.

1.2. Rationale and purpose

Due to the task-related and sleep-related factors associated with winter maintenance operations, winter maintenance operators are likely to be at an increased risk of driving while fatigued during winter emergencies. However, there is little in the way of quantitative or qualitative data to support this contention. The purpose of this study was to identify winter maintenance operators' and managers' opinions on 1) the prevalence of driver fatigue during winter maintenance operations, 2) the sources of fatigue in winter maintenance operations, and 3) the frequency of use and estimated effectiveness of fatigue countermeasures. A second phase of this project included pilot testing a naturalistic methodology to study fatigue in winter maintenance operations. The results of the second phase are published in Camden et al. (2017).

The hypotheses guiding this research were:

1 Winter maintenance operator fatigue impacts winter maintenance operations.
2 The majority of winter maintenance operators have experienced fatigue while operating a snowplow during a winter emergency.
3 Winter maintenance operators do not use the most effective fatigue countermeasures while operating a snowplow during winter emergencies.

2. Materials and methods

The methods and questionnaires discussed below were approved by the Virginia Tech Institutional Review Board (IRB# 13-429).

2.1. Participants

The research participants included winter maintenance operators and managers in states that participate in the Clear Roads winter maintenance research consortium. The Clear Roads winter maintenance consortium consisted of 29 states across the U.S. at the time of the study. The goals of the Clear Roads winter maintenance research consortium include: (1) investigate the effectiveness of winter road maintenance materials, equipment, and procedures, (2) identify best practice recommendations for winter road maintenance, (3) evaluate innovative winter maintenance technologies, and (4) support dissemination of best practices and research results.

The inclusion criteria for participating in the questionnaire were based on the individual's role/title. Participants must have been a snowplow operator or a supervisor/manager of snowplow operators. Additionally, all operators and managers involved in winter maintenance operations, regardless of their employer (e.g., state Department of Transportation [DOT], contractor, owner/operator, etc.) were allowed to complete the questionnaire. Participation in the questionnaire was voluntary, and all responses were anonymous (no personally identifiable information was collected).

2.2. Questionnaires and data collection procedures

Two questionnaires (which were part of larger project; Camden et al., 2014) were used to assess winter maintenance operators' and managers' perceptions and opinions of fatigue during winter maintenance operations. The development of the questionnaires was informed by an in-depth literature review of driver fatigue. The questionnaires included questions to assess operators' and managers' opinions of the following topics: how frequently fatigue is experienced during winter emergencies, the impact of fatigue on winter maintenance duties, the types of equipment used during winter maintenance operations, operator schedules, agency policies related to fatigue, sources of fatigue, strategies to reduce fatigue, and medical issues related to fatigue (this paper only presents results from those questions related to the prevalence of and countermeasures for fatigue). Participants were asked to identify a number of demographic characteristics that included: employer and state where employed, age, experience in winter maintenance, average length of a winter emergency shift, and maximum length of a winter emergency shift. Following these demographic questions, the operator questionnaire asked operators about their personal experiences with fatigue, whereas the manager questionnaire was designed to capture management's perceptions about winter maintenance operators' fatigue. Specifically, operators and managers were asked the following questions using Likert scales:

1 To what degree do you think fatigue impacts the operation of a snowplow during winter emergencies (1 = No Impact; 4 = Significant Impact)?
2 How often do you/winter maintenance operators feel tired (or not alert) when operating a snowplow during winter emergencies (1 = Never; 5 = Always)?
3 How often do you/winter maintenance operators feel extremely tired when driving back home after having completed the winter emergency shift (1 = Never; 5 = Always)?
4 How frequently do you/winter maintenance operators experience a lapse of concentration (e.g., forgot what you/they were doing, dozed off, etc.) during winter emergencies (1 = Never; 5 = Always)?
5 How often are you/winter maintenance operators asked to operate a vehicle for a longer duration than you/they feel comfortable/reasonable during a winter emergency (1 = Never; 5 = Always)?
6 In your opinion, how important are the following elements in regards to increasing the level of fatigue while operating a snowplow during winter emergencies (rate each element separately): vibration, type of seat, too much noise, light from headlamps, heavy traffic, too much technology inside the truck, too little technology inside the truck, and nighttime operations (1 = Not Important; 5 = Extremely Important)
7 When you/winter maintenance operators feel tired or fatigued while operating a snowplow during a winter emergency, how often do you/winter maintenance operators use each of the following strategies (rate each strategy separately): take a break from driving, move body (i.e., walk, stretch, exercise), have a conversation on cell phone or CB/radio, drink caffeine, take a quick nap, listen to the radio/music, use over the counter stimulants (e.g., NoDoze), and continue driving (1 = Never Use; 5 = Always Use)?
8 In your opinion, how effective are the following strategies to reduce fatigue while operating a snowplow during winter emergencies (rate each strategy separately): take a break from driving, move body (i.e., walk, stretch, exercise), have a conversation on cell phone or

CB/radio, drink caffeine, take a quick nap, listen to the radio/music, use over the counter stimulants (e.g., NoDoze), and continue driving (1 = Never Effective; 5 = Always Effective)?

Data collection occurred between May and July 2013. Hyperlinks to online versions of the questionnaires, as well as paper versions (if requested), were sent to representatives in each of the 29 Clear Roads states. The Clear Roads representatives distributed the questionnaires to operators and managers within their respective states via an email listserv and/or distributing paper copies. Participants' responses to the online questionnaires were automatically entered into a data set, and responses to the paper questionnaires were manually entered by a member of the research team.

2.3. Analyses

Descriptive statistics were calculated for winter maintenance operators' and managers' responses to each of the questions.

3. Results

Questionnaire responses were received from 24 of the 29 Clear Roads states, including responses from 1043 winter maintenance operators and 453 managers. Table 1 shows the number of operator and manager responses for each of the 24 states.

Table 2 presents the characteristics of the questionnaire respondents. The majority of operators and managers were between the ages of 45–65 years old, worked for their respective state's DOT, and had more than 15 years' experience in winter maintenance operations. Additionally, operators and managers reported the average winter emergency shift was 12 h long; however, the majority of respondents reported the maximum winter emergency shift may be longer than 15 h.

3.1. Prevalence and impact of fatigue during winter emergencies

Fig. 1 shows operators' and managers' opinions on the impact of fatigue in winter maintenance operations. Operators' and managers' most frequently reported that fatigue had a moderate impact on winter maintenance operations. However, 34% of operators and 21% of managers indicated fatigue had a significant impact on winter maintenance operations.

Table 3 shows the operators' responses to how often fatigue is experienced during a winter emergency shift, how often fatigue is experienced while driving home after a winter emergency shift, how often operators experience lapses in concentration while operating a snowplow, and how often winter maintenance operators are asked to work for more hours than originally planned. Operators' most frequent response to each questions is highlighted in Table 3. In general, operators indicated fatigue is sometimes experienced.

Managers answered the same questions regarding the prevalence of fatigue in winter maintenance operations. Table 4 shows managers' responses to how often fatigue is experienced during a winter emergency shift, how often fatigue is experience while driving home after a winter emergency shift, how often operators experience lapses in concentration while operating a snowplow, and how often winter maintenance operators are asked to worked more than planned. Managers' most frequent responses are highlighted. Similar to operators, managers indicated fatigue is sometimes experienced.

3.2. Sources of fatigue during winter emergencies

Table 5 shows winter maintenance operators' responses to the following question, "How important are the following elements in regards to increasing winter maintenance operators' level of fatigue during winter emergencies?" The most frequent responses are highlighted. The

Table 1
Number of operator and manager responses by state.

State	Number of Operators	Number of Managers
California	6	9
Colorado	1	1
Idaho	42	14
Illinois	22	15
Iowa	43	25
Kansas	73	31
Maine	5	4
Michigan	82	15
Minnesota	45	13
Missouri	17	11
Montana	101	40
Nebraska	72	20
New Hampshire	5	4
New York	144	14
Ohio	108	31
Pennsylvania	101	37
Rhode Island	7	14
Utah	36	26
Vermont	5	0
Virginia	49	70
Washington	29	15
West Virginia	3	2
Wisconsin	20	20
Wyoming	27	22
Total	1043	453

Table 2
Characteristics of questionnaire respondents.

	Operator % of responses	Manager % of responses
Age		
Less than 25 years old	2%	0%
25 to 35 years old	16%	6%
35 to 45 years old	26%	21%
45 to 65 years old	55%	72%
More than 65 years old	1%	1%
Experience in winter maintenance		
Less than 1 year	5%	1%
1 to 5 years	18%	4%
6 to 10 years	24%	10%
11 to 15 years	22%	17%
More than 15 years	31%	68%
Employer		
State DOT	95%	100%
Contractor	1%	0%
Owner/Operator	1%	0%
Other	3%	0%
Average length of operator winter emergency shift		
Less than 8 hours	2%	0%
8 hours	13%	7%
9 hours	1%	1%
10 hours	11%	6%
11 hours	2%	2%
12 hours	58%	66%
13 hours	2%	3%
14 hours	2%	3%
15 hours	1%	2%
More than 15 hours	5%	4%
Other	3%	6%
Maximum number of hours an operator has worked during a winter emergency		
Less than 12 hours	4%	0%
12 hours	31%	31%
13 hours	5%	2%
14 hours	8%	11%
15 hours	9%	13%
More than 15 hours	35%	43%
Other	8%	14%

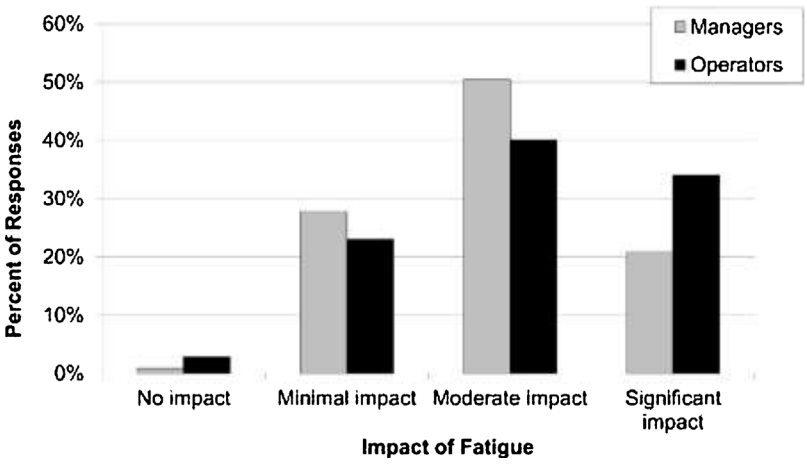

Fig. 1. Impact of fatigue in winter maintenance operations.

Table 3
Operators' responses to the prevalence of fatigue in winter maintenance.

Question	Never	Rarely	Sometimes	Most of the time	Always
Frequency of fatigue during winter emergency	3%	22%	63%	11%	1%
Frequency of fatigue while driving home after shift	4%	19%	42%	25%	9%
Frequency of lapses of concentration	18%	45%	33%	3%	0%
How often asked to work more than planned	6%	23%	40%	20%	11%

majority of winter maintenance operators reported the type of seat, light from headlamps, night time operations, and heavy traffic were "extremely important" sources of fatigue. Too much noise was a "very important" source of fatigue. Vibration, too much technology inside the truck, and too little technology inside the truck were reported to be "important" (but less important compared to the others) sources of fatigue.

Similarly, Table 6 shows winter maintenance managers' responses to the sources of fatigue during winter emergencies. The most common responses are highlighted. The majority of winter maintenance managers reported the light from headlamps, night time operations, and heavy traffic were "extremely important" sources of fatigue, and seat type was a "very important" source of fatigue. Too much noise, vibration, and too much technology inside the truck were "important" sources of fatigue, and too little technology inside the truck was reported to be a "somewhat important" sources of fatigue.

3.3. Strategies to combat fatigue during winter emergencies

Table 7 shows winter maintenance operators' responses regarding the reported use and effectiveness of several strategies to combat fatigue while driving a snowplow during a winter emergency. Winter maintenance operators reported to sometimes or more frequently use the following strategies to reduce fatigue during winter emergencies: take a break from driving, move body, drink caffeine, listen to the radio or music, and/or continue driving. Operators reported to rarely take a nap or have a conversation on a cell phone or CB radio to reduce fatigue in winter emergencies. Finally, operators reported to never use an over-the-counter stimulant (e.g., NoDoze) to reduce fatigue.

Regarding the estimated effectiveness of strategies to combat fatigue while driving a snowplow, winter maintenance operators indicated that taking a break and moving around were effective strategies to combat fatigue. Taking a nap, drinking caffeine, and listening to the radio or music were reported to be somewhat effective. Having a conversation on a cell phone or a CB radio and continuing to drive were reported as slightly effective at combating fatigue. Finally, using an over-the-counter stimulant was reported to be not effective at combating fatigue.

Table 8 shows winter maintenance managers' responses regarding the use and effectiveness of strategies to combat fatigue while driving a

Table 4
Managers' responses to the prevalence of fatigue in winter maintenance operations.

Question	Never	Rarely	Sometimes	Most of the time	Always
Frequency of fatigue during winter emergency	0%	4%	75%	19%	2%
Frequency of fatigue while driving home after shift	0%	5%	39%	43%	13%
Frequency of lapses of concentration	2%	32%	61%	4%	0%
How often asked to work more than planned	1%	18%	50%	22%	8%

Table 5
Operators' reported sources of fatigue during winter emergencies.

Source of Fatigue	Not important	Somewhat important	Important	Very important	Extremely important
Type of seat	3%	5%	13%	32%	48%
Light from headlamps	4%	7%	15%	25%	49%
Night time operations	5%	6%	15%	28%	46%
Heavy traffic	5%	8%	21%	26%	40%
Too much noise	7%	11%	26%	29%	27%
Vibration	9%	16%	29%	27%	19%
Too much technology	21%	19%	27%	18%	15%
Too little technology	24%	22%	28%	15%	11%

snowplow during a winter emergency. Winter maintenance managers indicated that operators drink caffeine and listen to the radio or music most of the time as a strategy to combat fatigue during winter emergencies. Winter maintenance managers indicated that operators sometimes take breaks, move their body, have conversations on a cell phone or CB radio, and/or continue driving to combat fatigue. Finally, winter maintenance managers reported operators rarely take a nap or use over-the-counter stimulants as a strategy to combat fatigue.

Regarding the estimated effectiveness, winter maintenance managers indicated that taking a break, moving around, and taking a nap were effective strategies to combat fatigue. Drinking caffeine and listening to the radio or music were reported to be somewhat effective. Having a conversation on a cell phone or a CB radio and using an over-the-counter stimulant were reported as slightly effective at combating fatigue. Finally, continuing to drive was reported to be not effective at combating fatigue.

4. Discussion

Results from the questionnaire showed that winter maintenance operators are impacted by fatigue. The majority of operators (75%) and managers (73%) reported that fatigue has a moderate to significant impact on winter maintenance operations. Furthermore, the majority of operators (75%) and managers (96%) reported to sometimes or always experience fatigue during winter maintenance operations. These results confirm winter maintenance operators are at risk to develop fatigue during winter emergencies.

Although operators and managers generally agreed about the frequency and impact of fatigue on winter maintenance operations, there were some differences. However, some of these differences may be the result of managers being responsible for a large team of winter maintenance operators. Approximately 15% more winter maintenance operators believed fatigue had a significant impact on winter maintenance operations compared to managers. This may be the result of poor communication between operators and managers. To address this possible miscommunication, operators should regularly discuss fatigue-related concerns with their manager. Secondly, managers (compared to winter maintenance operators) were more likely to indicate that operators became fatigued during winter operations and while driving home after a winter emergency shift. This difference may also highlight a lack of communication between operators and managers. Conversely, this difference may be due to a lack of fatigue awareness in operators. Previous research has shown that people are bad at subjectively assessing their alertness levels. Wylie et al. (1996) found there was little correlation between self-ratings of alertness and objective measures of alertness, with drivers reporting being more alert than they actually were. This illustrates the need for a study of objectively measuring fatigue in winter maintenance operations.

The prevalence of operator fatigue may be the result of task- and sleep-related fatigue (Desmond & Hancock, 2001; May & Baldwin, 2009). Operators are often called into work on short notice during a winter emergency. This may interfere with operators' normal circadian rhythm, which has been shown to significantly contribute to sleep-related fatigue (May & Baldwin, 2009). Circadian rhythms are resistant to change; thus, an operator called in to work during a time when they are normally asleep can create significant fatigue.

In addition to sleep-related fatigue, operators indicated a number of task-related sources of fatigue. Sitting on a very comfortable or uncomfortable seat over long periods of time may be conducive to the development of fatigue. Additionally, the type of seat may result in the operator experiencing unnecessary vibrations. Air-cushioned seats are one solution that may benefit winter maintenance operators who frequently experience fatigue as a result of prolonged vibration. Furthermore, operators' responses supported previous research (Desmond & Hancock, 2001) by indicating highly demanding activities and conditions were a source of fatigue. For example, reduced visibility from insufficient lighting and falling snow may cause significant eye strain.

In general, operators and managers were partially aware of the fatigue mitigation strategies known to be effective in reducing fatigue (i.e., taking a nap or break from driving). However, some of the fatigue mitigation strategies that operators and managers believed to be the most effective at reducing fatigue during winter emergencies may be underutilized. For example, a large percentage of winter maintenance

Table 6
Managers' reported sources of fatigue during winter emergencies.

Source of Fatigue	Not important	Somewhat important	Important	Very important	Extremely important
Type of seat	1%	4%	22%	42%	30%
Light from headlamps	1%	7%	18%	29%	44%
Night time operations	1%	4%	12%	33%	50%
Heavy traffic	1%	8%	19%	31%	40%
Too much noise	5%	20%	32%	31%	12%
Vibration	7%	22%	39%	23%	9%
Too much technology	9%	22%	33%	24%	12%
Too little technology	24%	34%	25%	12%	5%

Table 7
Operators' reported use and effectiveness ratings of strategies to reduce fatigue during winter emergencies.

Strategy to combat fatigue		Never/ Not Effective	Rarely/ Slightly Effective	Sometimes/ Somewhat Effective	Most of the time/ Effective	Always/ Very Effective
Break from driving	Use	2%	15%	47%	24%	11%
	Effectiveness	1%	8%	25%	42%	23%
Move body	Use	1%	7%	44%	36%	13%
	Effectiveness	1%	8%	24%	45%	22%
Conversation via phone/CB radio	Use	36%	36%	22%	5%	1%
	Effectiveness	33%	29%	24%	11%	2%
Quick nap	Use	49%	25%	22%	3%	2%
	Effectiveness	22%	13%	20%	26%	18%
Over-the-counter stimulant	Use	90%	4%	4%	1%	1%
	Effectiveness	76%	10%	9%	4%	1%
Drink caffeine	Use	7%	8%	34%	29%	22%
	Effectiveness	7%	16%	36%	28%	13%
Listen to radio/music	Use	3%	5%	23%	34%	34%
	Effectiveness	6%	13%	36%	29%	16%
Continue driving	Use	9%	17%	33%	29%	12%
	Effectiveness	48%	22%	22%	6%	2%

operators believed naps are highly effective at reducing fatigue but are rarely or never used to eliminate fatigue. This may imply that operators and managers may need a motivational intervention to increase the use of effective countermeasures during winter maintenance operations. Winter maintenance operators and managers may also need education regarding the effectiveness of fatigue countermeasures. Furthermore, some of the more prevalent fatigue mitigation strategies were reported as being less effective in reducing fatigue (e.g., listening to the radio/ music, drinking caffeine). Additionally, many operators indicated that they would continue to drive when feeling fatigue even though it was perceived to be ineffective at reducing fatigue. Thus, improved fatigue-related policies and practices may be needed to encourage operators to take more frequent breaks or quick naps. For example, state DOTs may need to create a policy that requires winter maintenance operators to take a mandatory break every four to five hours.

Additionally, new or improved technologies may be available to assistant winter maintenance operators experiencing fatigue, including fatigue monitoring and detection systems and vehicle guidance systems. Fatigue monitoring systems may be used to alert operators to the onset of fatigue. Vehicle guidance systems may provide winter maintenance operators with information about vehicle placement and obstacles difficult to see due to weather conditions. Providing operators with this information may help mitigate task-related fatigue.

5. Limitations

Although the data collected from this questionnaire were informative, there were several limiting factors. First, the questionnaire was self-report; thus, operators and managers may not have been completely truthful in their responses. However, this was unlikely as all responses were completely anonymous and all responses were sent directly to the authors. Second, the questionnaire sample was a convenience sample and not randomly selected. It is possible the individuals that chose to complete the questionnaire had stronger opinions regarding fatigue in winter maintenance operations compared to the individuals that chose not to participate. Third, objective fatigue data may indicate a different prevalence of fatigue in winter maintenance operations. Lastly, all questionnaire respondents were from states that participate in Clear Roads. Thus, the results may not be applicable to winter maintenance operations in other states or countries.

6. Conclusions

This is one of the first studies to investigate the prevalence of fatigue in winter maintenance operations. Results showed that winter maintenance operators combat fatigue during winter emergencies, and winter maintenance operations are adversely impacted by this fatigue. Winter maintenance personnel may use this information in developing schedules during winter emergencies. In particular, managers may

Table 8
Managers' reported use and effectiveness ratings of strategies to reduce fatigue during winter emergencies.

Strategy to Combat Fatigue		Never/ Not Effective	Rarely/ Slightly Effective	Sometimes/ Somewhat Effective	Most of the time/ Effective	Always/ Very Effective
Break from driving	Use	0%	6%	44%	38%	12%
	Effectiveness	0%	4%	27%	46%	22%
Move body	Use	0%	8%	45%	35%	11%
	Effectiveness	0%	6%	26%	45%	22%
Conversation via phone/CB radio	Use	14%	33%	40%	12%	1%
	Effectiveness	23%	33%	30%	12%	1%
Quick nap	Use	24%	33%	34%	7%	2%
	Effectiveness	7%	12%	28%	36%	17%
Over-the-counter stimulant	Use	44%	39%	15%	2%	0%
	Effectiveness	33%	35%	23%	8%	2%
Drink caffeine	Use	1%	2%	24%	53%	20%
	Effectiveness	2%	17%	44%	30%	7%
Listen to radio/music	Use	1%	4%	26%	46%	24%
	Effectiveness	5%	24%	40%	25%	6%
Continue driving	Use	6%	18%	37%	33%	6%
	Effectiveness	70%	18%	10%	1%	0%

encourage operators to take breaks and/or a nap during long winter emergency shifts. Managers may also encourage operators to report fatigue before, during, and after a shift. This could help improve fatigue communication between operators and managers. Finally, this research should be used to inform additional research concerning fatigue in winter maintenance operations, including: 1) objectively identify the risks of fatigue in winter maintenance operations, 2) develop objective measures of fatigue in winter maintenance operations, 3) investigate winter emergency shift length, as well as shift start and end times, to understand the effect of these factors on operator fatigue, and 4) identify effective strategies to combat fatigue in winter maintenance operations.

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