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An Evaluation of Aviation Maintenance Fatigue Countermeasures Training

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16. Abstract

A major airline volunteered to help the Federal Aviation Administration Civil Aerospace Medical Institute (CAMI) test a fatigue countermeasures training adapted for maintenance employees by providing employee participants and a training facility. The three-hour classroom training was developed, delivered, and evaluated by CAMI. Written tests and self-reports were used in the evaluation of the training to measure changes in employee knowledge, attitude, and behavior regarding fatigue and how to manage the associated risk.

Questionnaires were administered up to one week before training, at the end of training, and six weeks following training. The training was effective in increasing employees' general fatigue knowledge. Training also had an immediate positive affect on employees' awareness of the importance in and commitment toward managing fatigue; however, their commitment, motivation, and self-efficacy toward fatigue management significantly declined six weeks following training.

At follow-up, there were increases in consistent use of a few good sleep routine habits and avoidance of the majority of sleep routine and health and fitness bad habits, but there was no real impact on good work-life habits. Additionally, the occurrence of good work-life habits declined. Follow-up results suggest the maintenance organization needs to better support fatigue management in the work environment to realize long-term organizational benefits of fatigue countermeasures training. A computer-based version of the fatigue countermeasures training is available online (MXfatigue.com) at no cost.

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Aviation maintenance is a 24/7 operation requiring Aviation Maintenance Technicians (AMTs) to work extended hours, nights, and rotating shifts to meet demanding flight schedules. Under the Code of Federal Regulations (Title 14 CFR §121.377), AMTs are allowed to work 24 hours per day until their next day off. Maintenance organizations have been slow to implement fatigue risk management policies despite fatigue-related catastrophic events (e.g., ValuJet Flight 592 with 110 fatalities (AAR-97-06)). To the contrary, some maintenance organizations have instituted a double standard by imposing strict "no nesting"[1] and "no napping" policies on AMTs, while permitting them to work or exceed three concecutive16-hour shifts. Such policies are counter to personal, organizational, and public safety and foster a culture where it is acceptable (and expected) to work when fatigued. This situation is partially driven by the AMT's need to earn overtime wages and the organization's need to have employees on duty for as long as necessary.

No one is immune to on-the-job fatigue risks, especially those working shiftwork[2] (Miller, 2012). For the past decade, AMTs have been working longer hours to compensate for the wage reductions since the *9/11* terrorist attacks in 2001. Long work hours, especially weekly schedules at the 60 hour or above mark, can lead to problems in certain areas of health and safety (Allen, Slavin, & Bunn, 2007). In a 2001 study examining AMT sleep and rest periods, results revealed AMTs were only getting about five hours of sleep, on average, per night (Johnson, Mason, Hall, & Watson, 2001[3]). More recently, Banks and Dinges (2007) found chronic sleep restriction below seven hours per night to be associated with significant daytime cognitive dysfunction that accumulated to levels comparable to that found after severe acute total sleep deprivation. The Banks and Dinges study resolves any question of whether or not the five hours of sleep that AMTs typically get is adequate.

Fatigue countermeasures training has been used for more than 20 years across industries (railroad, trucking, and water transport) with 24/7 operations, to mitigate on-the-job fatigue risks (Nicholson & Stone, 1987). The training can be beneficial to both the individual and the organization. Individuals who replace bad sleep and health habits with good ones benefit from improved sleep quality and quantity, while the organization benefits from improvements in performance and fewer safety-reducing turnovers, absenteeism, and morale issues (Kerin & Aguirre, 2005).

The Federal Aviation Administration (FAA) is committed to promoting aviation safety and has tasked the Civil Aerospace Medical Institute (CAMI) to research and develop the tools necessary for a practical and useful fatigue risk management system (FRMS). Developing fatigue countermeasures training tailored to aviation maintenance is an obvious starting place. The remainder of this report describes the training development process and presents the outcomes of the evaluation conducted on initial delivery of the training in a classroom setting to maintenance personnel from a major airline.

Table 1. Content covered in the training

Sleep Basics	Fatigue Basics	Fatigue Countermeasures
Sleep Process	Fatigue Hazards	Work Breaks
Circadian Rhythm	Causes of Fatigue	Napping
Sleep Disorders	How to Assess Fatigue	Sleep Routine
Sleep Debt	Fatigue Symptoms	Sleeping Environment

AVIATION MAINTENANCE FATIGUE COUNTERMEASURES TRAINING

Training Development

The development effort capitalized on existing training and used maintenance subject matter experts (SMEs) to identify specific work requirements of AMTs. Existing fatigue training programs were identified and reviewed for purposes of creating a course outline and objectives. The outline covered three main topics: sleep basics, fatigue basics, and fatigue countermeasures. Table 1 contains the

[1] Building a bed pallet at the work-site in order to sleep between shifts.

[2] Shiftwork refers to any of the following: permanent evening or night shift, rotating schedule with or without nights, split shift, extended daytime hours (start before 7:00 am or end after 5:00 pm) and extended duty hours (work period of 12+ hours).

[3] This study was completed before the airline economic crisis triggered by the *9/11* terrorist attacks in 2001.

subject matter covered under each topic. The content was reviewed by two SMEs for deficiencies, excesses, and accuracy (Hauck, Avers, Banks, & Blackwell, 2011). The final step was to develop PowerPoint® slides covering the content and relevant multimedia (i.e., audio, video, and other visual media).

Training objectives were: (a) remember symptoms of fatigue and fatigue countermeasures, (b) recognize the importance of managing fatigue risk, and (c) incorporate practical recommendations for fatigue prevention and management into one's daily routine. Training outcome measures used to determine if the objectives were met included: gains in knowledge, increased awareness of fatigue risk and the importance of managing fatigue, and an increase in self-report of fatigue-related positive behaviors and reduction of negative behaviors at home and work.

Training Delivery

A major airline agreed to participate in the initial implementation of this evaluation. The course was delivered in a classroom at their facility with 33 maintenance employees attending on a voluntary basis. A CAMI research team member with extensive experience delivering classroom instruction presented the course. The course was delivered in a 3-hour session, with 15-minute breaks between sections. The instructor used PowerPoint® slides projected on a large screen at the front of the classroom to present the training. At the conclusion of each section, the instructor led a group discussion and then reviewed the content with the class before conducting a check on understanding and knowledge with feedback.

Training Evaluation

The evaluation was conducted to validate the training in preparation for making it available for public access online, as self-paced instruction.[4] The delivered training was evaluated on four levels: learning (positive change in knowledge of and attitude toward countering fatigue), behavior modification (change in fatigue management behaviors at home and work), transfer (application of what was taught at home and work), and reaction to the training experience.

METHOD

A quasi-experimental[5] one-group pretest-posttest design with a follow-up assessment was used to evaluate the training.

Training Participants

Evaluation data were collected from 42 maintenance personnel working for a major airline. However, for various reasons, not all 42 attended training. Of the 33 who did attend training, 24 were able to participate in both of the first two data collections, which were conducted prior to and at the end of the training session. However, only 14 of them chose to participate in the follow-up data collection several weeks later. Demographic information from 24 attendees whose evaluation data were used in the analysis is reported at the beginning of the *Results* section.

Procedures

A week prior to the training, potential attendees were asked to complete either an online or paper version of the pre-measure that was available at the airline's training office. At the end of the training, a paper post-measure was administered. After handing in the post-measure, each attendee received a packet of information to take home (e.g., copy of the training slides and handouts on key topics covered in training). They were also reminded that they would be contacted in four to six weeks to complete a questionnaire, either online or paper. Six weeks following training, attendees were contacted via email or mail to complete the final measure.

Measures

All measures contained items to assess knowledge of sleep and fatigue basics and fatigue risk[6] and attitudes toward managing fatigue risk. Table 2 contains an overview of the measures (copies of instruments available upon request).

Before conducting statistical comparisons of the evaluation data, knowledge tests were scored and percent correct computed; response values (5-point scale) for the 10-item Fatigue Assessment Scale (FAS) were summed to produce a total score[7] (Michielsen, De Vries, & Van Heck, 2003), and multi-item categories were created for the Attitude Assessment and-Fatigue Management Behavioral Inventory. Categories created for the Attitude Assessment items were: *awareness of the importance* of managing fatigue, *self-efficacy* applying fatigue countermeasures, and *intent to modify behavior*. Categories created for the Behavioral Inventory items aligned with *good habits* (sleep routine, health & fitness, and work-life) and *bad habits* regarding fatigue management.

In addition, individual items from the remaining assessment instruments, as direct measures of training effectiveness, were targeted for comparison across data collections.

[4] https://hfskyway.faa.gov/hfskyway/fatiguehome.aspx.

[5] There were insufficient resources to support a control group, and it was not feasible to randomly assign AMTs in the airline's workforce.

[6] Although the three administrations contained identical knowledge test items, sufficient time elapsed between administrations to mitigate an effect of practice, with the exception of a few attendees who may have completed a paper version of the pre-measure the day of training.

[7] Two FAS items were reversed scored—higher values represent more fatigue.

Table 2. Number of assessment instruments and items across administrations			
	Pre-measure	**Post-measure**	**Follow-up measure**
Prior Fatigue Education/Training	5		
Demographics	17		
Recall Knowledge^	25	25	25
Recognition Knowledge^	15	15	15
Attitude Assessment	14	14	14
Fatigue Assessment Scale	10		10
Fatigue Management Behavioral Inventory	44		44
Physical Symptoms Self-report	19		19
Sleep Habits	6		6
Reaction to the Training Experience		9	
Behavioral Change Self-report	4		4

^Nine recall items (short answer) and five recognition items (multiple-choice) were excluded in computing the knowledge scores, due to lack of relevance to covered content.

The targeted items included: the extent to which *tiredness or fatigue* and *trouble sleeping* were experienced in the last 30 days from the Physical Symptoms Self-report (5-point scale, the items were reversed scored so high values indicated a lesser extent); adequacy of the amount of sleep on work and off days from the Sleep Habits Self-report (5-point scale with high values indicating more sleep); and changes made to manage fatigue at home and work (yes or no; if yes, how), which constituted the four Behavioral Change Self-Report items.

Analysis Plan

The purpose of the evaluation was twofold: (a) examine the potential of the course content in meeting the training objectives and (b) identify needed improvements before converting the content to online training.

Needed training improvements were extracted from a content analysis of open-ended, text-entry items on the post-measure asking which topics were most and least useful and what could be changed to improve the training.

Statistics were used to describe and test[8] for differences in average scores and ratings and response frequencies of self-report data. The following pairwise-comparisons were made to determine if training objectives were met. To assess learning, pre- and post-measures were compared, with the expectation that training has an immediate positive impact on knowledge scores and attitudes regarding the importance of and motivation and commitment to managing fatigue. To assess knowledge retention and persistence of positive attitudes toward fatigue management, follow-up measures were compared to pre- and post-measures, with the expectation that knowledge gains and positive attitude change will persist (e.g., follow-up test scores would be higher than pre-training scores), but may degrade (e.g., post-training test scores would be higher than follow-up scores). To assess training transfer, behavioral follow-up measures and pre-measures were compared, with an expected increase in the frequency of use of countermeasures at home and work, and an expected decrease in the frequency of self-reported poor sleeping, eating, and exercise habits.

RESULTS

Table 3 displays the characteristics of participants who attended the fatigue countermeasures training and completed some, if not all, of the measures being compared.

Twenty-four attendees completed items on both of the pre- and post- measures. A subset of the 24 individual also completed items on the follow-up measure. Thus, the number of participants (*n*) and average scores and self-ratings differed, as indicated for pairwise comparisons conducted across the three data collection events.

The following are the evaluation results of training impacts on learning, retention, transfer, and reaction to the training experience; changes in self-reported fatigue; and needed training improvements.

Learning

Learning was measured as the immediate impact of training on attendee knowledge and attitude. Gain in knowledge was computed as post- minus pre-training scores on short-answer and multiple-choice tests. Change in attitude was computed in the same manner for the awareness and self-efficacy items from the Attitude Assessment.

[8] Two-tailed tests were used with the conventional 0.05 p value.

Table 3. Characteristics of 24 attendees who provided data for the evaluation							
Type of Mx performed^ (%)	Avg Age (range)	Avg years of job experience (range)	Avg weekly work hrs (range)	Avg weekly OT hrs (range)	Typical work schedule^ (%)	Received prior fatigue training/ info	Prior training/ info was helpful (n=6)
17.5-Line 17.5-Component 13.0-Heavy 52.0-Other+	50.4 (41-61)	29.0 (13.0-42.8)	43.0 (10-70)	2.8 (0-16)	8.6-Rotating with afternoon and nights 91.3-Day/ extended day	25%	33.3%

Mx - maintenance; Avg - average (mean); hrs - hours; OT - overtime

^missing data from 1 attendee

+Mx management and training personnel

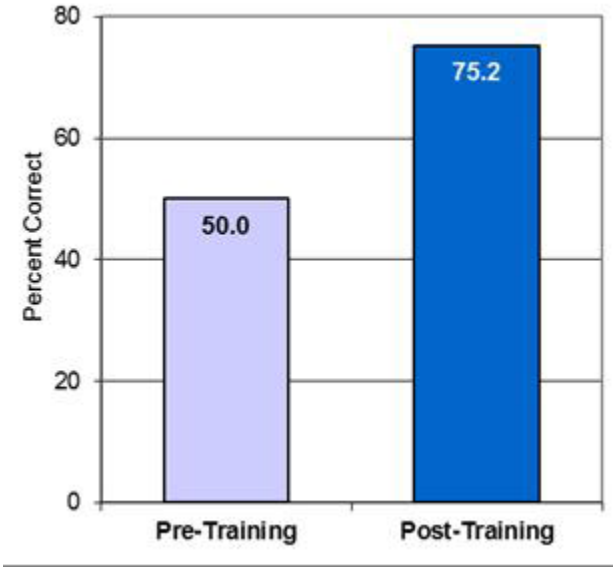

Figure 1. Immediate impact of training on knowledge test scores (mean) (n=23)

Gain in knowledge. There was an immediate impact of training on attendee fatigue-related knowledge. Average test scores increased by 50%, going from 50.0% correct before training to 75.2% correct at the end of training (see Figure 1). The gain was statistically significant (M_{diff} = 25.2, t_{22} = 8.42, pvalue ≤ .0001).

Shift in attitude. Although shifts in attendee awareness of the importance of managing fatigue and self-efficacy trended in the positive direction (see Figure 2), training only had an immediate positive impact on awareness of importance not to be fatigued at work (M_{diff}=.33, t_{23}=2.56, pvalue ≤.02) and commitment to manage fatigue (M_{diff} = .46, t_{23} =2.14, pvalue ≤.05).

Retention

Retention reflects a relatively stable gain in knowledge and change in attitude. It was measured as differences between follow-up and post-training. Comparisons were also made between follow-up and pre-training for test scores and ratings on the Attitude Assessment.

Knowledge. Attendees retained what they learned. Figure 3 shows average follow-up knowledge test scores compared to post- and pre-training scores. A slight dip in scores (M_{diff}= -6.4, NS) occurred on the 6-week follow-up test. Of importance was that the scores remained significantly higher (by 40%) on the follow-up test compared to before training (M_{diff}=19.6, t_{13}=3.86, pvalue ≤.002).

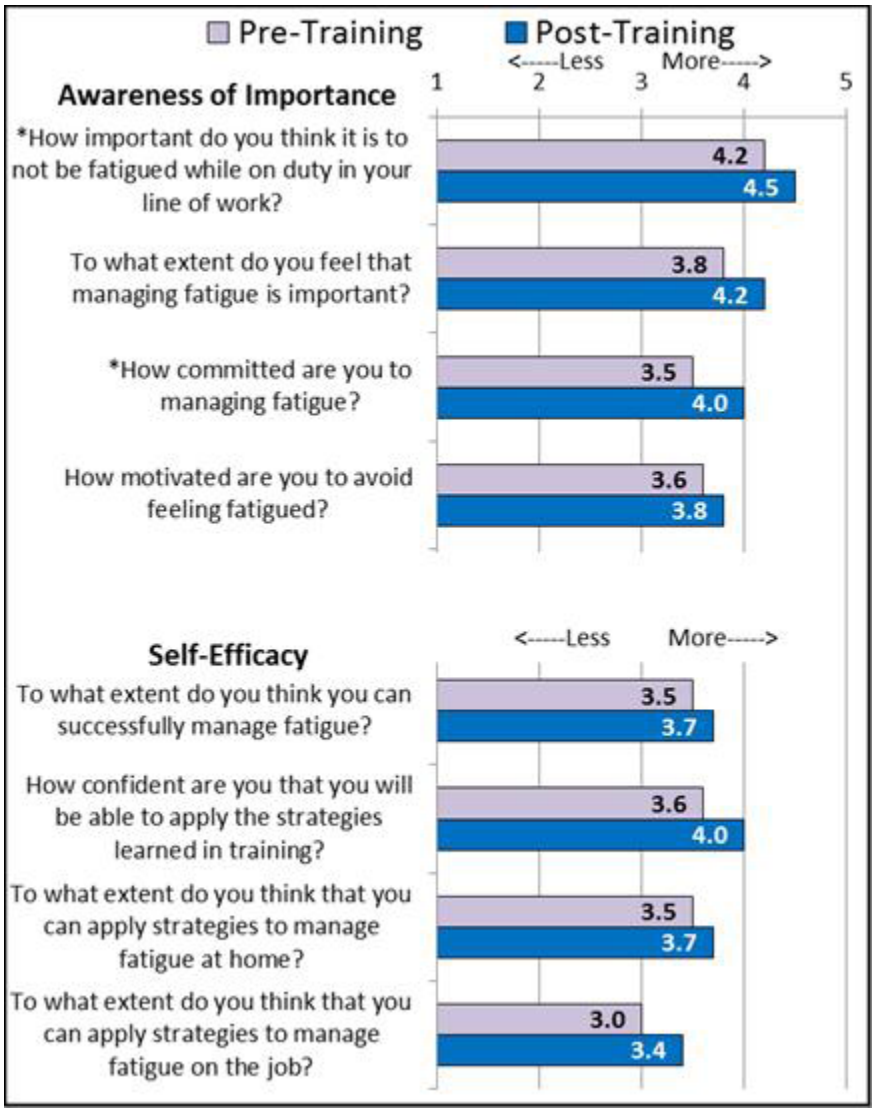

Figure 2. Immediate impact of training on attitudes (mean rating) (n=24; *signifies statistically significant shift)

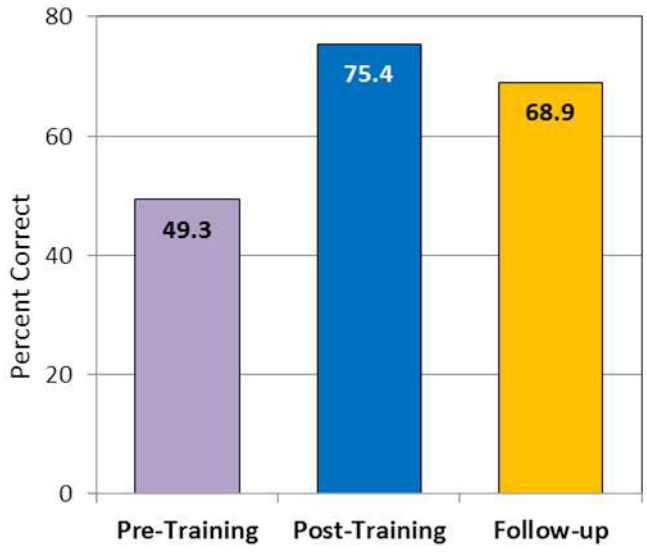

Figure 3. Knowledge test scores (mean) across administrations

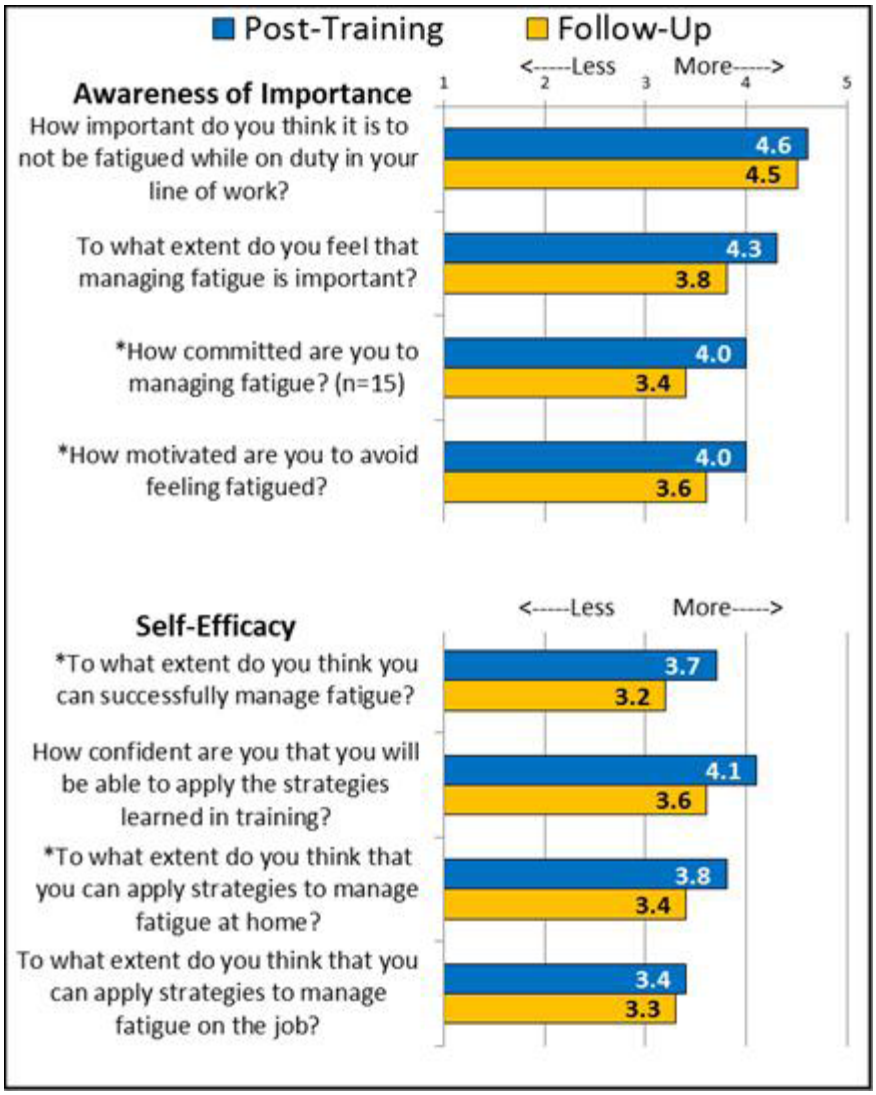

Figure 4. Retention of attitudes between training and follow-up (mean) (n=16; *signifies statistically significant shift)

Attitudes. Figure 4 shows the downward trending of awareness, self-efficacy, and intention toward fatigue management six weeks following training. The positive shift in awareness of importance and commitment to managing fatigue realized immediately after training did not persist six weeks later. In fact, the decrease in attendee commitment was statistically significant (M_{diff} = -.56, t_{15} = -2.52, pvalue ≤.02), and their motivation to avoid fatigue also dipped (M_{diff}= -.40, t_{14} = -2.45, pvalue ≤.03). As well, with time to potentially use the countermeasures presented in training, there was a statistically significant loss in the sense of being able to successfully manage fatigue in general (M_{diff}= -.50, t_{14} = -2.74, pvalue ≤.02) and, specifically at home (M_{diff}= -.44, t_{14} = -3.42, pvalue ≤.004). Overall, none of the shifts in attitude fell below the mid-points of the various scales (i.e., sometimes, somewhat, some, and moderate extent). Awareness of the importance of managing fatigue at work remained high, even though the reduced importance rating approached significance.

All Attitude Assessment items, including measures of behavioral intention, were examined between pre-training and follow-up. A notable difference between response pattern categories, awareness of importance, self-efficacy, and behavioral intention, is that all ratings for behavioral intention (Figure 5), were lower and below the mid-point of the scale, except the item asking *How much effort do you put toward avoiding fatigue?* Overall, no statistically significant differences were found; although, shifts in four of the six behavioral intention items tended in the positive direction.

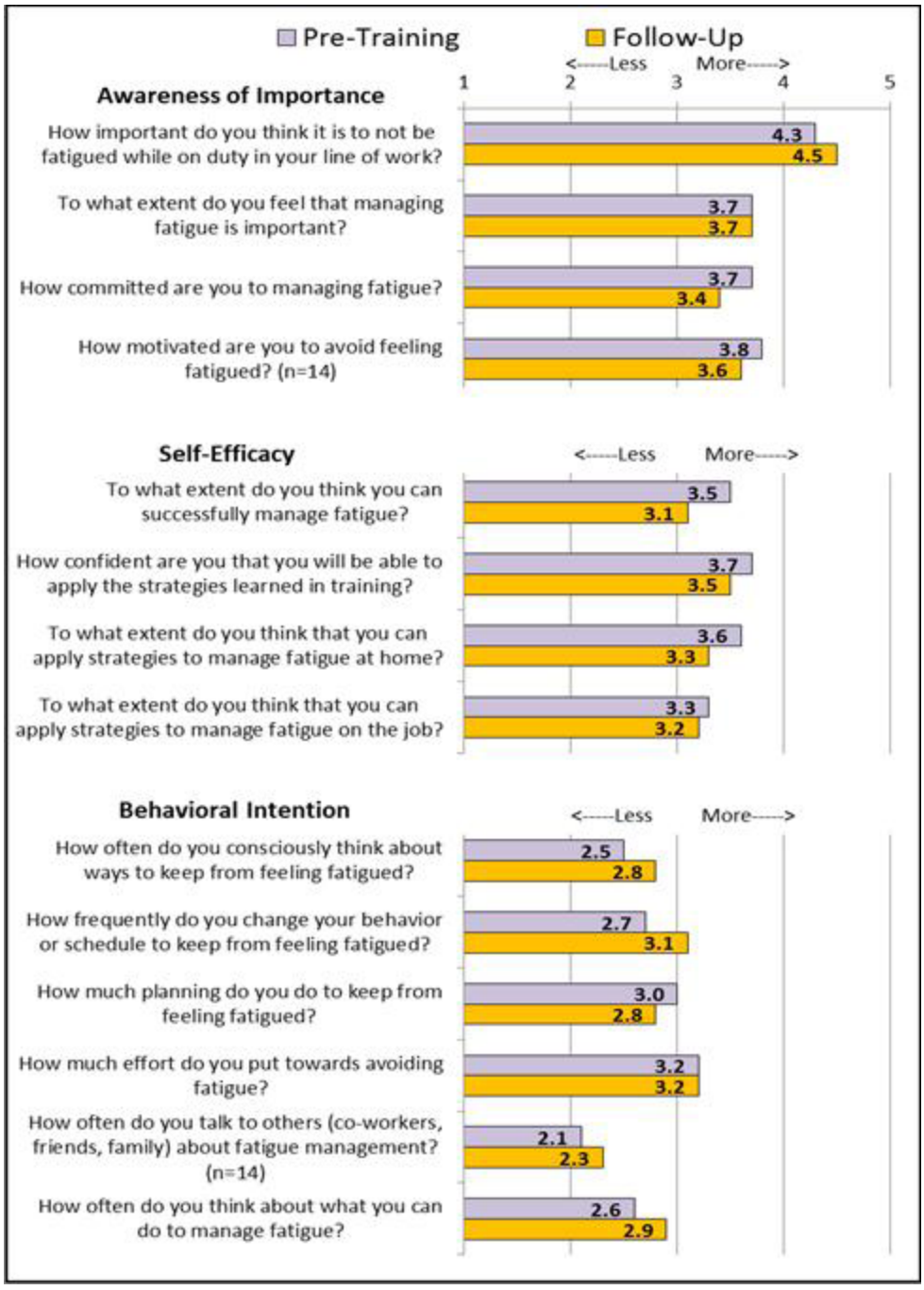

Figure 5. Difference in attitudes before training to follow-up (mean) (n=15)

Transfer

Transfer refers to the use of fatigue countermeasures covered in training in the home and work environments. Transfer assumes that the environments offer support for and opportunities to employ countermeasure recommendations. This is more likely the case at home, where there is more individual control, than at work.

The Behavioral Inventory items were used to evaluate the degree of training transfer by comparing the self-rated frequencies of engaging in good and bad habits[9] listed in the inventory. The 33 good habits were categorized as sleep routine (11), health and fitness (14), and work-life (8). There were 10 bad habits related to sleep, nutrition, and exercise.

[9] Frequency ratings were made on a 5-point scale, where "1" represented *Never*, "2" represented *Rarely*, "3" represented *Sometimes*, "4" represented *Often*, and "5" represented *Always*.

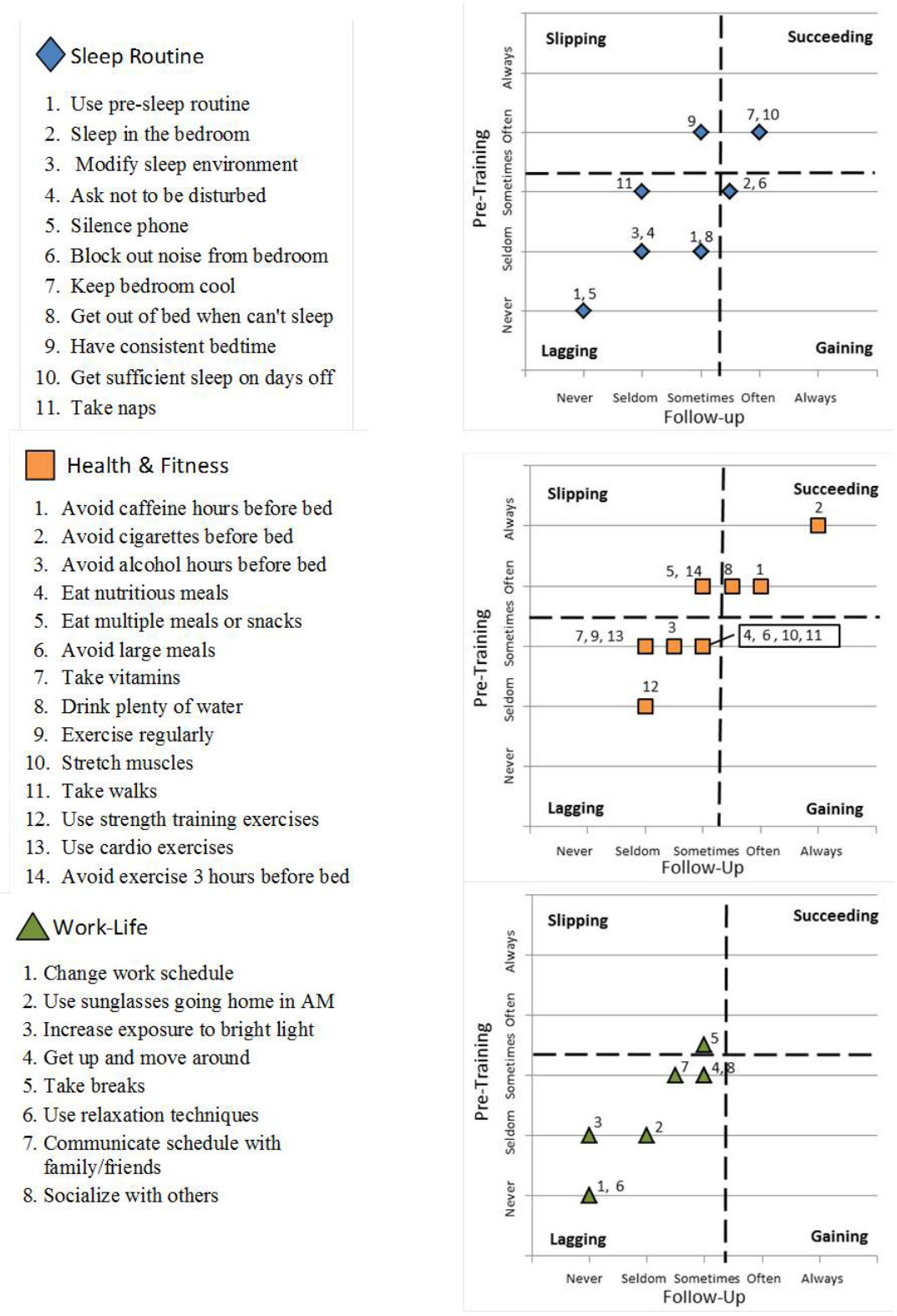

Figure 6. Occurrence of good habits before training vs follow-up (median) (n=14)

The results plotted in Figures 6 and 7 provide a relative comparison of follow-up to pre-training median[10] ratings for the good and bad habits, respectively. Each plot is separated into quadrants labeled *Succeeding*, *Gaining*, *Slipping*, and *Lagging* that indicate which behaviors have and have not transferred. The quadrants were based on the following criteria:

- *Succeeding*: the behavior consistently occurred more often than *sometimes*;

[10] Median represents the midpoint of a distribution. In this instance, the median is the value at or below where 50% rated their frequency of engaging in the specified behavior.

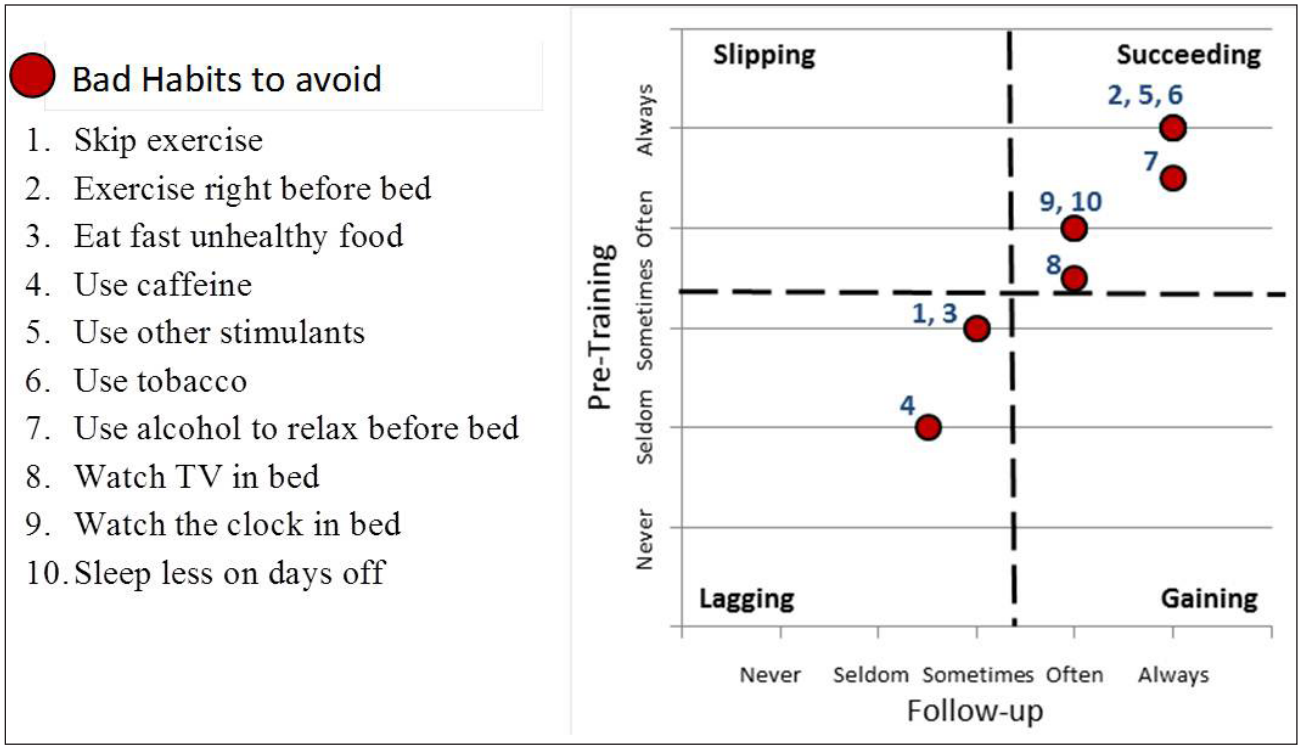

Figure7. Avoidance of bad habits before training vs. follow-up (median) (n=14)

- *Gaining*: the behavior did not occur more often than *sometimes* until after training;
- *Slipping*: before training the behavior occurred more often than *sometimes* but was not sustained at follow-up;
- *Lagging*: the behavior consistently occurred less often than *sometimes*.

Some good habits were already established. The gain in frequency of using two sleep routine countermeasures provides some evidence of a training impact on good habits. Figure 7 shows that, for the most part, attendees have succeeded in avoiding behaviors that interfere with restful sleep.

A subsequent examination was made of the average percent of attendees (n=14) reporting that they frequently (i.e., ratings of either *often* or *always*) use the countermeasures presented in training and avoid the pitfalls of bad habits. Results presented in Tables 4 thru 7 reveal more attendees were able to overcome bad habits than acquire good habits. Good habits with the positive differences (e.g., modifying sleep environment, avoiding caffeine before bed, and taking breaks) for some were easier to employ.

Additional items measuring transfer asked attendees if they had changed behaviors at home or work for purposes of managing fatigue and, if so, how. More than twice as many reported they had modified behaviors at home six weeks after training (7 of 15, 47%) compared to before training (4 of 24, 17%). This was not the case at work--fewer reported modifying behavior at follow-up (3 of 15, 20%) compared to before training (6 of 24, 25%).

Table 8 lists attendees reported behavior changes to manage fatigue at home and work. More fatigue countermeasures were used at home than at work following the training. All of the reported changes in behavior at home were countermeasures recommended during training.

Potential for Training Impact on Self-reported Fatigue

Measures of self-reported fatigue collected before training and six weeks following are summarized in Table 9. No differences were found to be statistically significant, although attendees tended to report higher rates of insufficient sleep and trouble sleeping at follow-up. Without knowing the details of their daily lives, one possible explanation for the outcome is based on the finding that the training heightened knowledge of sleep and fatigue basics, which would influence self-assessments of what it means to get an adequate amount of quality sleep.

Difference in total scores for the 10-item FAS (n=12, $M_{Pre\text{-}training}$=21.6, $M_{Follow\text{-}up}$=21.4) between the two data collection events were also not statistically significant. The range of possible total scores is 10 to 50, where higher numbers indicate more fatigue. Figure 8 shows the average self-ratings across the individual FAS items that contributed to the total score.

Table 4. Average percent (mean) of attendees reporting that they often or always used good Sleep Routine habits recommended in training			
	Pre-training	Follow-up	Difference
Modifying sleep environment	14.3	42.9	28.6
Asking not to be disturbed	28.6	50.0	21.4
Using pre-sleep routine	14.3	28.6	14.3
Silencing phone when sleep	28.6	28.6	0.0
Blocking out noise from bedroom	50.0	50.0	0.0
Taking naps	14.3	14.3	0.0
Using bedroom for sleep	50.0	46.2*	-3.8
Getting out bed when can't sleep	21.4	14.3	-7.1
Keeping bedroom cool	57.1	50.0	-7.1
Have a consistent bedtime	50.0	35.7	-14.3
Getting sufficient sleep on days off	71.4	42.9	-28.6

Table 5. Average percent (mean) of attendees reporting that they often or always used good Health & Fitness habits recommended in training			
	Pre-training	Follow-up	Difference
Avoiding caffeine before bed	50.0	64.3	14.3
Exercising regularly	21.4	23.1*	1.6
Doing cardio exercises	21.4	21.4	0.0
Eating nutritious meals	28.6	28.6	0.0
Avoiding large meals before bed	28.6	28.6	0.0
Avoiding cigarettes before bed	57.1	57.1	0.0
Stretching muscles	28.6	21.4	-7.1
Avoiding alcohol hours before bed	42.9	35.7	-7.1
Drinking water	50.0	38.5*	-11.5
Taking walks	42.9	28.6	-14.3
Eating multiple meals or snacks	28.6	14.3	-14.3
Avoiding exercise hours before bed	46.2*	30.8*	-15.4
Doing strength training	23.1	7.1*	-15.9
Taking vitamins	50.0	21.4	-28.6

*n=13

Table 6. Average percent (mean) of attendees reporting that they often or always used good Work-Life habits recommended in training			
	Pre-training	Follow-up	Difference
Taking breaks	42.9	50.0	7.1
Socializing with others	14.3	21.4	7.1
Using relaxation techniques	0.0	0.0	0.0
Communicating schedule with family/friends	21.4	21.4	0.0
Changing work schedule	7.1	0.0	-7.1
Using sunglasses when going home in the AM	35.7	28.6	-7.1
Getting up and moving around	28.6	14.3	-14.3
Increasing exposure to bright light	21.4	0.0	-21.4

Table 7. Average percent (mean) of attendees reporting that they often or always avoided Bad Habits as recommended in training			
	Pre-training	Follow-up	Difference
Not watching the clock in bed	57.1	71.4	14.3
Not using caffeine	21.4	35.7	14.3
Not exercising right before bed	78.6	92.9	14.3
Not using tobacco	64.3	76.9*	12.6
Not watching TV in bed before sleep	50.0	61.5*	11.5
Not skipping exercise	23.1	30.8*	7.7
Not eating unhealthy fast food	35.7	42.9	7.2
Not using stimulants, besides caffeine	92.9	92.9	0.0
Not using alcohol before bed	71.4	71.4	0.0
Not sleeping less on days off	64.3	57.1	-7.1

*n=13

Table 8. Behaviors used to manage fatigue (with count) at home and work before and following training			
At Home		**At Work**	
Pre-Training (n=4 of 24)	**Follow-up** (n=7 of 15)	**Pre-Training** (n=6 of 24)	**Follow-up** (n=3 of 15)
Get sufficient sleep (2)	Get sufficient sleep (2)	Think before acting (3)	Stay calm (2)
Limit activities before bedtime (2)	Don't watch TV in bed (2)	Change hours worked (1)	Better schedule (1)
Get out of bed if can't sleep (1)	Modify sleep environment (1)	Eat healthier (1)	
Eat light meal before bedtime (1)	Block out noise from bedroom (1)	Walk, instead of riding cart (1)	
Stick to consistent bedtime (1)	Stick to consistent bedtime (1)	Drink more water (1)	
Treatment for sleep disorder (1)	Communicate with family (1)	Quiet time at breaks (1)	
	Avoid eating late (1)	Light snacks at breaks (1)	

*Of the six attendees who reported previously receiving fatigue training/education, one also reported changing behaviors at home and work and two reported changing behaviors at work to manage fatigue.

Table 9. Percent of self-ratings indicating potential fatigue (n=15)		
	Pre-Training	**Follow-up**
^Inadequate amount of sleep on work days	78.6	81.3
^Inadequate amount of sleep on days off	40.0	60.0
*Bothered by trouble sleeping in last 30 days	20.0	40.0
*Bothered by tiredness or fatigue in last 30 days	43.3	33.4

^percent responding *not nearly enough, could do with a lot more*, or *could do with a little more*
*percent responding *moderately*, *very much*, or *extremely*

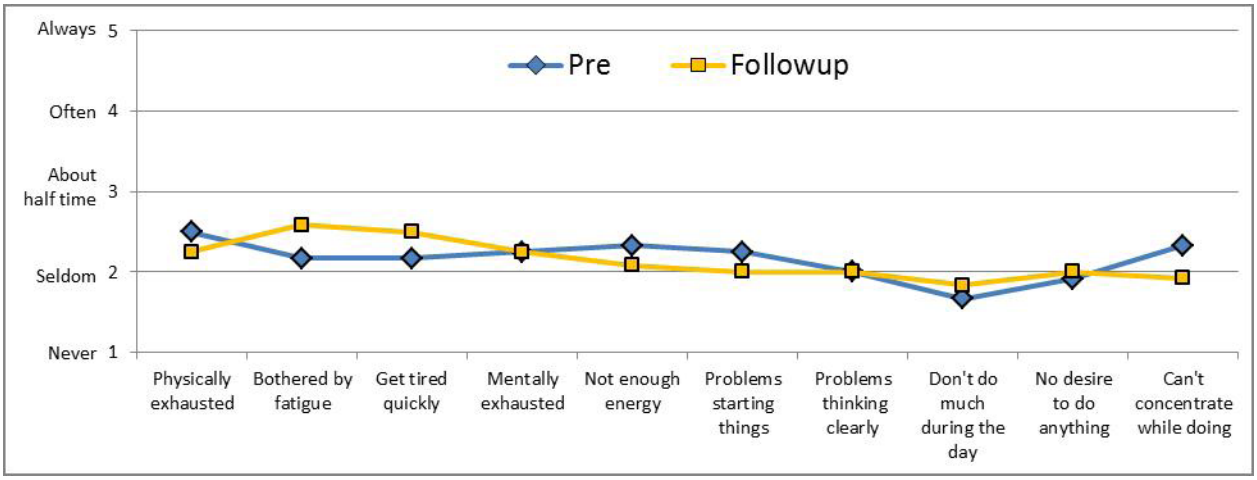

Figure 8. Fatigue Assessment Scale items (mean) (n=12)

Reaction to the Training Experience

Instructional qualities[11] of the three-hour classroom session were assessed on the post-measure. Results, based on 33 attendees who provided data on their reaction to the training experience, were overwhelmingly positive. All attendees agreed that the training was informative and useful. The vast majority agreed that training was interesting, worthwhile, and should be conducted for others (97%), and that the material was well organized (96%) and presented at the appropriate level (94%).

Training Improvements

Responses to three open-ended items asking for most and least useful topics and changes to improve the training formed the basis of feedback on needed improvements. Results from a content analysis conducted on attendee feedback are in Table 10. With the exception of a few topics that require review, the content overwhelmingly met the needs of the training audience. In fact, suggested improvements were requests for more training in terms of lengthening the course and including more training materials/media.

Other needed improvement to the training will be driven by the results indicating instability in changed attitudes, lower than expected self-efficacy regarding managing one's fatigue, and differences between rates of self-reported use of good habits and avoidance of bad habits, which indicate that it is easier to discard old behaviors than acquire new ones.

Table 10. Percent of feedback responses by evaluation item

Most Useful Topics(32 comments from 25 attendees)	**%**
Strategies for better sleep	15.6
- All information - Countermeasures - Fatigue basics - Circadian rhythm	12.5
Fatigue vs. intoxication comparison	9.4
- Fatigue management - Sleep disorders - Sleep process - Sleep requirements & evaluation	6.3
Least Useful Topics^(2 comments from 2 attendees)	**%**
- Fatigue statistics - Sleep log	50.0
Suggested Improvements(11 comments from 10 attendees)	**%**
More class time	45.5
- More training media - Customize for company	18.2
- Adjust pace - Separate classes for non-hourly and hourly employees	9.1

^14 attendees indicated all topics were useful

DISCUSSION

The evaluation of the fatigue countermeasures training content supports findings from other industries that fatigue countermeasures training can be an effective tool to increase prevention and management of fatigue at the individual level. Even though the training content was under development, it increased maintenance employees' awareness of fatigue risk management strategies and consequences of fatigue, which influenced some to change their daily activities in an effort to manage fatigue. Effectiveness of the training is partly attributable to the customization of content for AMTs and the personalization of fatigue health risks and benefits of fatigue management.

The positive shifts in the following are notable given the resistance of attitudes and behaviors to change (see Erber, Hodges, & Wilson, 1995; Wood, 2000; Ford & Ford, 2010): (a) awareness of the importance of not being fatigued at work and commitment to manage fatigue increased immediately after training, and (b) modifications of sleep routines reported at follow-up (more likely to sleep in the bedroom and block out noise from the bedroom at follow-up). However, few reported changes in work behaviors at follow-up and a rebound occurred back to pre-training levels in employees' commitment, motivation, and self-efficacy toward managing fatigue.

Modifying and sustaining new behaviors and attitudes toward fatigue can be challenging, since lifestyle changes are required. When resistance exists, a positive approach would be to treat it as valuable feedback. For instance, during class some attendees voiced resistance to changing their sleep habits. The interaction provided the instructor an opportunity to generate a better understanding of how and why they needed to modify their sleep environments. An organization can also productively engage resistance when developing or revising policies and procedures to reduce fatigue-related safety risks by: (a) involving employees, (b) focusing on the purpose of the change, (c) resolving past issues, clarifying objectives and strategies, and (d) improving the implementation plan (Ford & Ford, 2010). Productive engagement from the organization requires commitment to reduce fatigue risk on the job, otherwise employees' old

[11] Instructional qualities were assessed on a 5-point Likert scale, with the following labels: *Strongly Disagree*, *Disagree*, *Neutral*, *Agree*, and *Strongly Agree*.

patterns of behaviors will persist. Lack of productive engagement from the organization may contribute to maintenance employees feeling powerless to manage fatigue at work due to limited or no control over the work environment, the work schedule, and the accelerated pace and elevated pressure to perform.

Promoting personal and public safety by prescribing duty limitations and rest requirements that contain the right balance of safety, science, and operational efficiency for aviation maintenance, equivalent to flight crews, remains a challenge. Like pilots and flight attendants, some AMTs commute across time zones and perform consecutive extended shifts before returning home. Because there are no duty hour limitations or look-back rest requirements,[12] maintenance personnel appear to be susceptible to high levels of physical and cognitive fatigue. Implementing an effective fatigue countermeasures training program is just one step that aviation maintenance organizations should take in reducing fatigue risk to improve public safety. An online version of the fatigue countermeasure training for AMTs (MXfatigue.com) developed by the FAA is available on-demand and at no cost to individuals and organizations. To realize the safety and productivity benefits of reduced fatigue risk, organizations will need to establish fatigue management policies and procedures, such as a Fatigue Risk Management System, that apply the concepts and reinforce attitudes and behaviors taught in training.

The comprehensive evaluation approach used in this study is rare, as training evaluation efforts are often focused solely on attendee reactions to the instruction. Evaluation results were for purposes of improving training content and not intended to generalize. Future evaluations of the online content would benefit from use of a control group that does not receive training; random assignment of participants to either the training or control group; inclusion of employees representing all work schedules, especially, alternative work schedules (e.g., night shifts or extended shifts) that can render AMTs more vulnerable to human fatigue; reduce questionnaire length; and include participation from a range of aviation maintenance organizations.

[12] Before accepting a flight assignment, a flight crewmember must be able to prospectively determine that he/she will be able to look back 24 hours from the scheduled completion of each flight segment and find a legally scheduled rest within the previous 24 hours.

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