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Flight Attendant Fatigue Recommendation II: Flight Attendant Work/Rest Patterns, Alertness, and Performance Assessment

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16. Abstract

Impaired performance induced by fatigue may compromise safety in commercial aviation. Given the direct role flight attendants play in passenger safety, the U.S. Congress ordered a comprehensive examination of fatigue in cabin crew, including a field study of actual flight operations. This report provides an overview of the field study results, focusing on objective measures of sleep patterns and neurocognitive performance (Psychomotor Vigilance Test, PVT) over a 3-4 week period in 202 U.S.-based flight attendants of all seniority levels working for network, low-cost, and regional carriers embarking on domestic and international flight operations. On average, flight attendants slept 6.3 hr on days off and 5.7 hr on work days, fell asleep 29 min after going to bed, awoke four times per sleep episode, and spent 77% of each episode actually sleeping. After controlling for reserve status, gender, and age, junior-level flight attendants had the shortest sleep latencies on their days off. Those working international operations slept significantly less (4.9 hr vs. 5.9 hr) and less efficiently (75% vs. 79%), compared with their colleagues in domestic operations. All flight attendants exhibited significant impairments during pre-work PVT tests when compared to their own optimum baseline performance. Across the workday, regional flight attendants committed fewer premature PVT responses, junior-level participants produced significantly higher post-work reaction times, and those working international flights produced better pre-work reaction times but had a greater increase in lapses. These objective data are consistent with other shift work research and echo subjective survey findings across the U.S. flight attendant community. Additional planned analyses of this dataset may identify the precise operational variables that contribute to fatigue in cabin crew.

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INTRODUCTION

Numerous factors can affect safety, performance, and quality of life in individuals working in 24-hr operational environments, and one issue receiving increased attention in commercial aviation is fatigue. Fatigue is generally defined as a state of tiredness due to prolonged wakefulness, extended work periods, and/or circadian misalignment, and is characterized by decreased alertness, diminished cognitive performance, and impaired decision-making (Åkerstedt, 1995; Dinges, 1995). Although a considerable amount of scheduling and fatigue research has been conducted with pilots in recent years, the issue of fatigue in cabin crew has received little systematic attention from the scientific community (Mallis, Banks, & Dinges, 2010). Flight attendants are popularly thought of as in-flight comfort service providers only; however, the fact remains that cabin crew serve on the front lines of passenger safety and crisis management. In addition to routine safety procedures and negotiating passenger welfare during acute emergencies due to weather, mechanical problems, or human error, the heightened threat of organized terrorist events and other disruptive passenger activities coupled with a generally increasing workload requires today's cabin crew to possess an unprecedented level of perceptiveness, interpersonal skill, and sustained vigilance.

Recognizing the prominent role played by flight attendants in protecting the traveling public and the increasing demands on this unique segment of the civilian workforce, in 2005 and 2008, the U.S. Congress directed the FAA's Civil Aerospace Medical Institute (CAMI) to conduct a multi-leveled examination of flight attendant fatigue. The comprehensive project included directives to review current policies and practices, conduct a large-scale survey of active flight attendants, and collect objective data in a field study of "real world" flight attendant operations. As expected, the regulatory reviews confirmed the potential for fatigue-promoting practices (Nesthus, Schroeder, Conners, Rentmeister-Bryant, & DeRoshia, 2007), and the survey provided detailed data on the ubiquitous perception of fatigue within the flight attendant community and the various operational factors thought to produce and exacerbate it (Avers, King, Nesthus, Thomas, & Banks, 2009).

The present report offers an overview of results from the flight attendant field study conducted from May 2009 through June 2010 by the Institutes for Behavior Resources (IBR), an independent non-profit research, services, and educational organization headquartered in Baltimore, MD, USA, in collaboration with researchers at CAMI in Oklahoma City, OK, USA. This initial report focuses primarily on objective quantitative measures of sleep and neurocognitive performance patterns in over 200 U.S.-based flight attendants of all seniority levels working for network, low-cost, and regional carriers embarking on domestic and international flight operations. The detailed assessment of sleep and performance effectiveness patterns across a broad sample of the flight attendant population complements CAMI's prior work by objectively quantifying the presence and extent of fatigue and may critically inform the development of comprehensive fatigue risk management systems or other science-based policy refinements designed to enhance cabin safety.

METHOD

All procedures described in this report were independently reviewed and approved by both the FAA CAMI and IBR Institutional Review Boards. The formal letters of approval are available upon request from the authors. All personal data have been de-identified.

Participants

Recruitment. Study requirements and recruitment materials were prepared in cooperation with CAMI officials, several airlines, and several flight attendant labor organizations. Once approved, each organization issued a customized announcement via Web site, E-mail, and/or newsletter in February 2009 and February 2010 encouraging its constituents to participate in the field study. The involvement of industry and labor representatives did not extend beyond this phase of the project. Individuals initially volunteered through an online application form documenting basic eligibility data. A total of 6,454 applications were submitted by interested volunteers. To capture the diversity inherent to the flight attendant population, only a few key exclusion criteria were applied. Specifically, applicants were excluded from further consideration if they were not actively working as a flight attendant (including on furlough), if their base of operations was outside the U.S., if a majority of their flight legs were greater than or equal to 8 hr (to avoid redundancy with ongoing long- and ultra-long-range research; this criterion was increased to 10 hr during the February 2010 recruitment campaign), if they were diagnosed with a sleep disorder, or if they did not provide adequate information in the online application form. These exclusion criteria reduced the applicant pool to approximately 5,000 individuals. These individuals were then contacted via E-mail and directed to an online survey to provide more detailed demographic and contact information, health information, and answers to several work-related questions. The same exclusion criteria were then re-applied to these data, which reduced the final applicant pool to approximately 3,000 individuals.

Selection. All eligible applicants were categorized according to three broad factors that served as the organizing framework for the study's design and the results presented herein. These factors are Carrier Type (Network, Low-Cost, or Regional), Seniority (self-identified Senior 1/3, Mid 1/3, or Junior 1/3), and majority Flight Operations (Domestic or International). This framework yielded 12 distinct flight attendant groups based on the applicable combinations of the factors: NSD (Network + Senior + Domestic), NSI (Network + Senior + International), NMD (Network + Mid + Domestic), NMI (Network + Mid + International), NJD (Network + Junior + Domestic), NJI (Network + Junior + International), LS (Low-Cost + Senior), LM (Low-Cost + Mid), LJ (Low-Cost + Junior), RS (Regional + Senior), RM (Regional + Mid), and RJ (Regional + Junior). The study was designed for a total of 210 flight attendants according to the schematic presented in Figure 1.

Within each of the 12 group types, the total target sample size plus 10 individuals was randomly selected. This sample was then statistically compared to the larger group from which it was drawn to confirm that the two did not differ significantly from each other in mean age or gender ratio. Once a representative sample was derived for each of the 12 groups, 10 individuals within each group were randomly assigned to their group's Backup Participant pool, with the remaining assigned as Primary Participants, with whom we would conduct the field study. All individuals were informed of their assignments via E-mail, which included the Informed Consent document and supplementary study reference material. The IBR project staff worked with each participant to schedule individual 3-4 week study periods and arrange for informed consent reviews, equipment delivery, and protocol training prior to study launch.

After accounting for losses due to participant withdrawal, non-compliance, removal by the research team, and equipment malfunctions, the field study ultimately yielded usable data from a total of 202 flight attendants working for 28 different airlines. Participants from Network carriers came from (in alphabetical order) Alaska, American, Continental, Delta, Northwest, United, and U.S. Airways. Participants from Low-Cost carriers came from AirTran, America West, Frontier, JetBlue, Southwest, and Spirit. Participants from Regional carriers came from Air Wisconsin, American Eagle, Atlantic Southeast, Chautauqua, Colgan, Comair, ExpressJet, Horizon, Mesa, Mesaba, Piedmont, PSA, Republic, Shuttle America, and SkyWest. All flight attendants were compensated for their participation. The final sample sizes and basic demographic data for each of the 12 flight attendants groups are presented in Table 1.

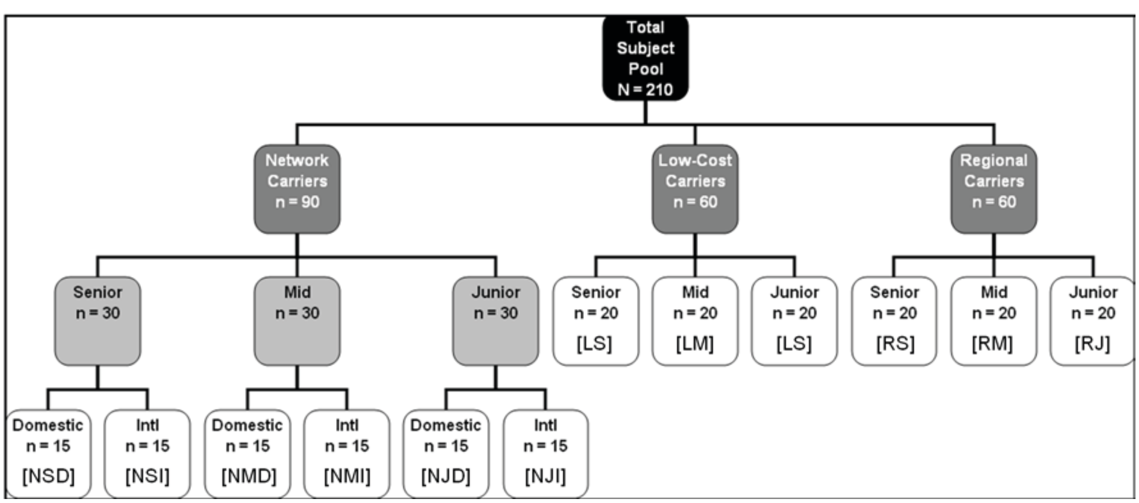

Figure 1. *Stratified field study design and target sample sizes.*

MATERIALS

As depicted in Figure 2, each participant was issued a wristwatch-shaped, waterproof actigraphy device for continuous objective recording of sleep/wake patterns (ReadiBand™, Fatigue Science, Honolulu, HI, USA), a custom-programmed touchscreen-based personal digital assistant (PDA) device for maintaining a daily activity log and collecting objective and subjective data (AT&T Tilt™), and a consumer-grade pedometer for recording steps taken while on duty as a gross objective measure of physical workload (Digi-Walker SW-200, Yamax USA, Inc., San Antonio, TX, USA). The equipment packages also contained peripheral accessories, a detailed equipment user's guide, and supplementary reference materials for use in the field.

Data Collection

Training and Scheduling. Once they received their equipment, all participants were trained on equipment use and formal data collection procedures via toll-free teleconference according to a standardized script developed by IBR scientists. All training sessions were conducted in real-time by members of a dedicated training team housed at CAMI or by IBR staff when necessary. Most training sessions were one-on-one, but no sessions were conducted with more than three flight attendants at a time. In addition to the formal training sessions, IBR scientists were available to assist by phone and E-mail 24 hr/day throughout data collection. Approximately 20 participants per month were trained and completed the study during two data collection periods: May through November 2009 and February through June 2010. Insofar as was possible, participants from all 12 flight attendant groups were included each month to evenly distribute potential seasonal and time-of-year effects.

Actigraphy. Data collection was required every day (work days and off days) throughout the duration of each participant's 3-4 week study period. The actigraphy watch was placed on the non-dominant wrist by 2000 hr the night before the first duty day of the study, where it remained for 24 hr/day and was never removed except during airport security checks, noted risky events such as during contact sports, scuba diving, or special occasions with permission from an IBR investigator (e.g., weddings).

Table 1. Final demographic information for each flight attendant group.

Carrier Type	Seniority	Flight Ops	Group ID	*n*	% Reserve	% Female	Age (yr)	
							Mean	**Range**
Network	Senior	Domestic	NSD	14	28.57	64.29	49.81	44.48 – 61.62
		International	NSI	15	20.00	73.33	55.43	43.56 – 66.67
	Mid	Domestic	NMD	15	0.00	86.67	46.81	40.48 – 53.21
		International	NMI	15	6.67	60.00	44.63	39.60 – 61.13
	Junior	Domestic	NJD	15	46.67	80.00	40.37	30.53 – 62.47
		International	NJI	14	28.57	71.43	39.32	24.48 – 59.30
Low-Cost	Senior	Domestic	LS	20	10.00	70.00	46.37	30.93 – 60.90
	Mid		LM	20	0.00	55.00	35.24	24.18 – 61.39
	Junior		LJ	16	37.50	50.00	35.60	22.13 – 63.67
Regional	Senior		RS	20	0.00	70.00	40.34	28.02 – 58.98
	Mid		RM	20	5.00	65.00	42.85	23.51 – 61.93
	Junior		RJ	18	55.56	83.33	41.82	25.50 – 57.78
All				**202**	**18.81**	**68.81**	**42.94**	**22.13 – 66.67**

Figure 2. *Actigraphy device (left), PDA device (middle), and pedometer (right) issued to each participant.*

Table 2. Operational definitions of events for the daily activity log.

Event Type	Formal Definition/Instructions	Common Practical Translations
Sleep	Log “Sleep” before going to bed for the night (intending to sleep), or any time you need to represent a sleep period of 2 or more hours.	Unnecessary
Nap	A sleep period of less than 2 hours.	Unnecessary
At Work	The period beginning at "show time" when you check-in at the airport and ending when you “check-out” for the day just before leaving the airport to return home, to a crash-pad, or to your hotel. “At Work” encompasses all work-required activities except flight time and breaks (for example, cabin prep, paperwork, cleaning, passenger assistance). Basically, if you checked in at show time and have not left the airport to go home/crash-pad/hotel, then you’re At Work.	Actively working but not getting paid primary wage; most commonly boarding and de-planing.
In Flight	Your paid work period when the aircraft you’re attending to is in the air.	Primary pay period when the doors of the plane are closed.
Work Break	Represents designated in-flight break periods, deadhead flights, flight delays, and non-overnight layovers in between legs. Basically, times when you don’t have any work-required activities to perform but have not left the airport to go home/crash-pad/hotel.	Authorized breaks during long flight legs, but most commonly sit time between flight legs.
Commute	We use this term more like a 9-to-5 office worker, so log “Commute” to represent any personal transit time from home/crash-pad/hotel to show time when you check-in at the airport for work. Commuting is also any personal transit time from the airport back to home/crash-pad/hotel after your work day has ended.	All transit time to and from the airport for work.
No Work: Home	Represents times when you do not have to work, such as the period between waking up and going to work or the period between checking out for the day and sleep. “Home” refers to your geographical location, as in your home town or home base (not necessarily the actual building you call home), "Home" also refers to the fact that you're on your own time, including trips or vacations outside your actual home town.	Most commonly time off not during a trip or reserve period.
No Work: Away	Represents the same "No Work" periods as above, but your geographical location is outside your home town because of work. Examples include extended (hotel-worthy) layovers in between legs and multi-day layovers prior to a return trip home. "Away" refers to the fact that even though you’re not working, your current geographical location away from home was determined by your work schedule.	Most commonly time off while away on a trip or at crash pad on reserve.

Pedometer. All participants were told to reset the pedometer and place it on the waist or ankle before the start of each work day. Once participants determined their preference for ankle or waist placement, they were requested to keep this position consistent throughout the entire data collection period. They manually entered the step count into the PDA device when prompted during the Post-Work test session (see below).

PDA. The majority of data was collected via the PDA device, which thus required the most participant interaction. Using a graphical interface, all participants had to maintain a daily activity log (including sleep/wake cycles), noting the location (airport code) and start time (local) of the activities described in Table 2. A pocket-sized, color-coded copy of columns 1 and 2 from the table below was provided to all participants as a quick-reference guide to assist with event entry whenever they were unsure. The logs also included a blank field for manually entering notes to provide the researchers with additional relevant information (e.g., the real location of an event if the airport code was not listed as an option on the menu), which was often useful for the research team when processing the raw data.

In addition to maintaining the activity log, participants were required to complete up to four test sessions per day: Pre-Sleep, Post-Sleep, Pre-Work, and Post-Work. Participants were instructed to complete the Pre- and Post-Sleep sessions within ~15 min of going to bed and waking up, respectively, every day throughout the study. On work days, participants were instructed to complete the Pre- and Post-Work sessions within ~1 hr of check-in and check-out (the beginning and end of the entire work day), respectively. Each session consisted of several core components, starting with a 5-min touchscreen-based Psychomotor Vigilance Test (PVT) programmed under the same parameters as the Palm-based PDA PVT previously developed at the Walter Reed Army Institute for Research (Thorne, Johnson, Redmond, Sing, Belenky, & Shapiro, 2005; Lamond, Dawson, & Roach, 2005) and effectively utilized for various field studies in 24-hr

Table 3. Individualized optimum baseline PVT performances organized by Carrier Type, Seniority, and Flight Operations.

Factor	Group	*n*	Reaction Time (msec)		Speed (1/RT)		Lapses (RTs > 500 msec)		False Starts	
			Mean	Range	Mean	Range	Mean	Range	Mean	Range
Carrier Type	Network	88	243	191 – 322	5.94	3.38 – 18.34	0.53	0.00 – 4.67	2.92	0.00 – 17.40
	Low-Cost	56	249	193 – 362	6.33	2.82 – 25.31	0.58	0.00 – 4.33	3.56	0.00 – 22.13
	Regional	57	242	204 – 334	6.01	3.09 – 20.50	0.44	0.00 – 1.88	3.38	0.00 – 28.40
Seniority	Senior	68	239	196 – 301	5.98	3.38 – 25.31	0.40	0.00 – 2.00	3.22	0.00 – 22.13
	Mid	70	248	191 – 362	6.22	2.82 – 20.50	0.60	0.00 – 4.67	3.52	0.00 – 28.40
	Junior	63	246	200 – 336	5.99	3.19 – 19.93	0.55	0.00 – 4.33	2.90	0.00 – 17.43
Flight Ops	Domestic	157	244	191 – 362	6.11	2.82 – 25.31	0.50	0.00 – 4.33	3.31	0.00 – 28.40
	International	44	244	202 – 322	5.92	3.38 – 18.34	0.58	0.00 – 4.67	2.94	0.00 – 10.80
All		**201**	**244**	**191 – 362**	**6.07**	**2.82 – 25.31**	**0.52**	**0.00 – 4.67**	**3.23**	**0.00 – 28.40**

operational environments (Lamond, Petrilli, Dawson, & Roach, 2006; Ferguson, Lamond, Kandelaars, Jay, & Dawson, 2008). Each session also included a simple 9-item visual analogue scale (VAS) subjective mood assessment and a speech analysis test requiring recitation of five randomly ordered fatigue-sensitive phrases designed for the study by Dr. Harold P. Greeley (Response Applications, LLC, Hanover, NH, USA). In addition to these core components, the Pre-Sleep session included a brief daily legal drug/pharmaceutical use questionnaire; the Post-Sleep session included a 5-item VAS-based subjective sleep quality questionnaire; and the Post-Work session included an 11-item Post-Duty Service Questionnaire and a VAS-adapted version of the NASA Task Load Index (TLX; Hart & Staveland, 1988). Test sessions generally took 8-12 min to complete. To maintain consistency across days, locations, and conditions, all participants were instructed to take their test sessions in a comfortable, normally-lit environment with as few sensory distractions as possible. All participants were informed that safety and fulfilling their professional duties supersede all research requirements and were explicitly instructed to never engage in study-related activities (data entry, testing, etc.) while actively engaged in or responsible for any work-related activities.

Data Analysis

Actigraphy. Although a variety of data were collected in the field study, the focus of this report is on the primary objective measures of sleep/wake patterns (actigraphy) and neurocognitive performance (PVT) during work days. For the actigraphy data analysis, the variables calculated for each individual were mean total sleep (min), mean sleep latency (min to fall asleep), mean number of awakenings, and mean sleep efficiency (% time spent sleeping) per sleep episode during work days or during a trip vs. off-days at home in between trips. Sleep episodes with 30 min or less of total sleep time were omitted from these calculations but will be accounted for in forthcoming fatigue modeling analyses of the field study data.

PVT. Each 5-min PVT session yields a number of output variables, including mean reaction time per trial (RT, msec), mean speed per trial (1/RT), total lapses (RTs > 500 msec), and total false starts (FS, responses prior to stimulus onset). For each individual, the top 10% mean RTs of all PVT sessions throughout the study were identified, then the means of the PVT variables from those sessions were used to define that individual's optimum baseline neurocognitive performance. PVT variables were then calculated from each Pre-Work and Post-Work session as a percent shift (RT and speed) or raw shift (lapses and FS) relative to those individualized optimal parameters, the means of which were incorporated into the project database for final analysis. Preliminary one-way Analyses of Variance (ANOVA) revealed no significant effects of Carrier Type, Seniority, or Flight Ops on all optimum baseline PVT performance measures ($Fs < 2.2$, $ps > .10$; see Table 3), which were generally consistent with PVT performances observed in laboratory settings with well-rested healthy volunteers sampled from the general population (Lim & Dinges, 2008; Loh, Lamond, Dorrian, Roach, & Dawson, 2004).

Statistics. Actigraphy data were available for 172 participants; PVT data were available for 201 participants. All actigraphy measures were analyzed by separate mixed Analyses of Covariance (ANCOVA) with respective between-groups factors of Carrier Type (Network, Low-Cost, or Regional), Seniority (Senior, Mid, Junior), and

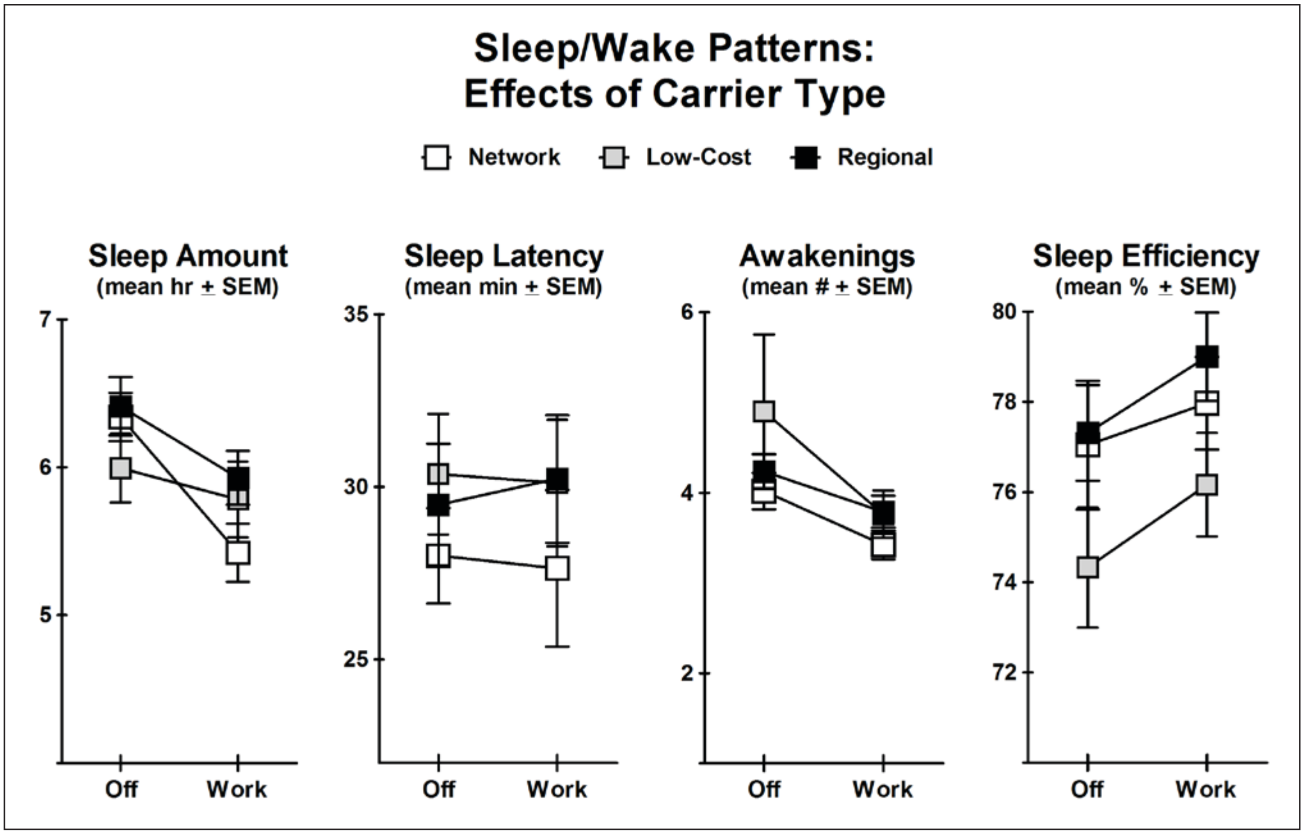

Figure 3. *Actigraphy-derived sleep/wake patterns during off days at home and while away on work trips in flight attendants from Network, Low-Cost, and Regional carriers.*

majority Flight Ops (Domestic or International) and a repeated-measures factor of Condition (Work and Off). All models included covariates of reserve status, gender, and age. All PVT measures were evaluated by separate mixed ANCOVAs with respective between groups factors of Carrier Type, Seniority, and Flight Ops and a repeated-measures factor of Time (Pre-Work and Post-Work); as with the actigraphy analyses, all models included covariates of reserve status, gender, and age. Statistical significance was set at $\alpha = .05$ for all analyses.

RESULTS

Sleep/Wake Patterns

Effects of Carrier Type. After accounting for reserve status, gender, and age, the 3 x 2 ANCOVAs revealed no significant main or interaction effects involving Carrier Type or Condition from off days to work days on sleep latency (29.1 to 29.2 min), awakenings (4.3 to 3.6), or sleep efficiency (76% to 77%; Fs < 2.3, ps > .13), although a Carrier Type x Condition trend was observed in the sleep amount variable ($F(1,166) = 2.5$, $p = .086$). This was presumably due to the Network group losing more sleep from off days to work days (from 6.4 to 5.3 hr), compared to their Low-Cost (6.0 to 5.8 hr) and Regional colleagues (6.4 to 5.9 hr; see Figure 3).

Effects of Seniority. After accounting for reserve status, gender, and age, the 3 x 2 ANCOVAs revealed no significant main or interaction effects involving Seniority or Condition from off days to work days on sleep amount (6.3 to 5.7 hr), awakenings (3.6 to 4.3), or sleep efficiency (77% to 76%; Fs < 2.1, ps > .14); however, a significant Seniority x Condition interaction emerged from the analysis of sleep latency ($F(2,166) = 4.6$, $p < .05$). Sleep latencies increased from off days to work days in the Senior (29 to 31 min) and Junior groups (25 to 30 min) but decreased in the Mid-level flight attendants (32 to 27 min), whose latencies were significantly longer than their Junior-level colleagues on off days (Fischer's LSD $p < .05$; see Figure 4).

Effects of Flight Operations. After accounting for reserve status, gender, and age, the 3 x 2 ANCOVAs revealed no significant main or interaction effects involving Flight Ops or Condition from off days to work days on sleep latency (29.1 to 29.2 min) or awakenings (3.6 to 4.3; Fs < 2.7, ps > .10); however, significant Ops x Condition interactions emerged from the analyses of sleep amount and sleep efficiency ($F(1,167)$s > 9.8, ps < .001). Although both groups slept less during work trips than on off days at home, the International flight attendants slept significantly less than their Domestic counterparts while away on work trips (4.9 vs. 5.9 hr; independent samples $t(170) = 3.4$, $p < .001$).

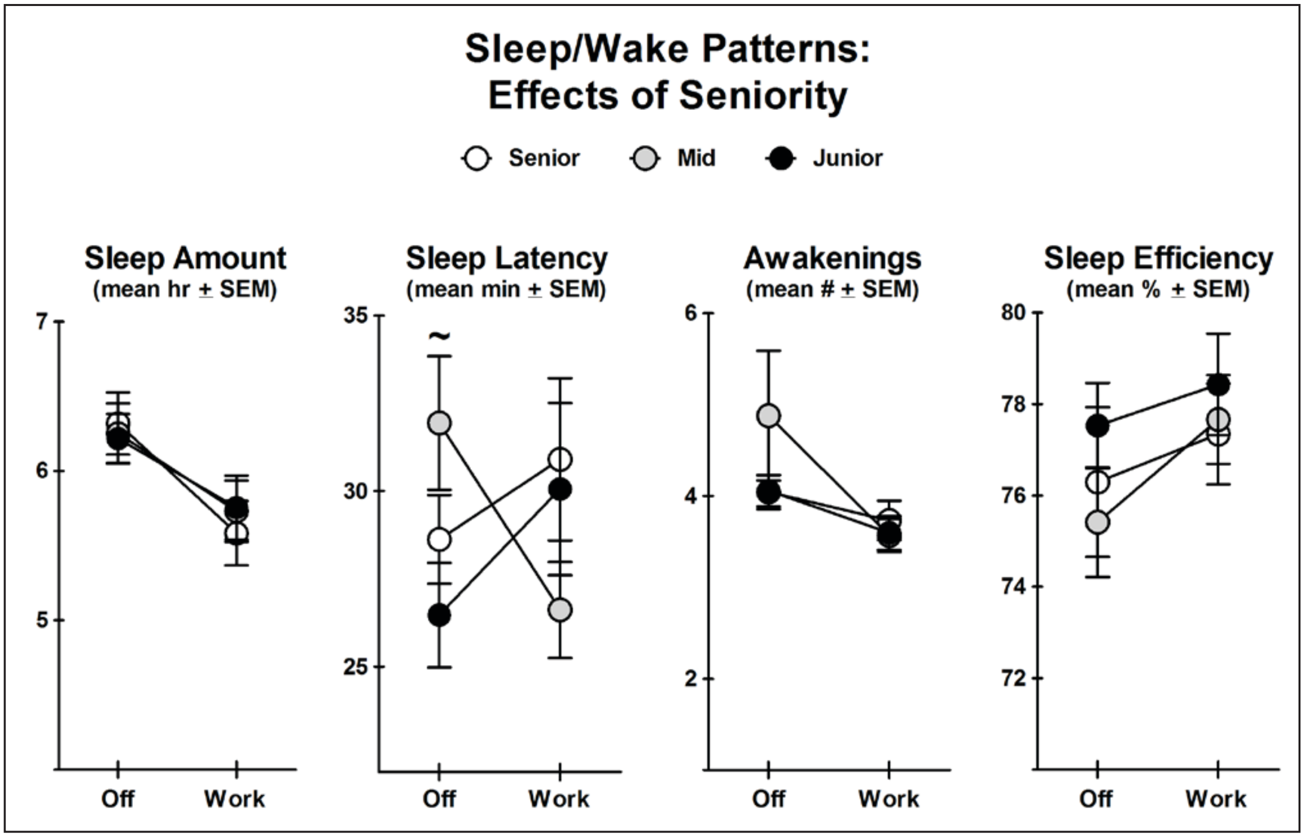

Figure 4. Actigraphy-derived sleep/wake patterns during off days at home and while away on work trips in Senior, Mid, and Junior seniority flight attendants (~ indicates Junior significantly different from Mid, p < .05).

Interestingly, sleep efficiency shifted significantly in both groups from off days to work days (paired-samples ts > 2.4, ps < .01) but increased for the Domestic group (76% to 79%), while decreasing for the International group (78% to 75%) such that sleep efficiency during work trips was significantly lower for the International flight attendants compared to their Domestic colleagues (independent samples t(170) = 2.4, p < .05; see Figure 5).

Neurocognitive Performance

Preliminary paired-samples t-tests revealed that mean PVT reaction times were significantly higher (+21.3%), response speeds were significantly slower (-14.1%), and lapses were significantly more frequent (+2.8) during Pre-Work sessions, compared to individualized optimum baseline performances (t(200)s > 7.3, ps < .001; false starts +0.1, t(200) = 0.9, p = .38). These data suggest that regardless of variations in on-duty activities, all flight attendants manifest some degree of fatigue-relevant performance impairment even before the start of the workday.

Effects of Carrier Type. After accounting for reserve status, gender, and age, the 3 x 2 ANCOVAs revealed no significant main or interaction effects involving Carrier Type or Time across the workday on PVT reaction times (+21% to +28%), speed (-14% to -17%), or lapses (+2.8 to +3.7; Fs < 2.2, ps > .14); however, a significant main effect of Carrier Type emerged from the analysis of false starts (FS) (F(2,195) = 4.4, p < .05). Whereas flight attendants from Network and Low-Cost carriers were more likely to increase mean FS on work days relative to optimum baseline (+0.33 and +0.40, respectively), simple contrasts revealed that Regional flight attendants, who committed fewer FS on work days relative to baseline (-0.53), did so significantly less than their colleagues from Network and Low-Cost carriers (ps < .05; see Figure 6).

Effects of Seniority. After accounting for reserve status, gender, and age, the 3 x 2 ANCOVAs revealed no significant main or interaction effects involving Seniority or Time across the workday on PVT speed (-14% to -17%), lapses (+2.8 to +3.7), or false starts (+0.14 to +0.07; Fs < 2.1, ps > .12); however, a significant Seniority x Time interaction emerged from the analysis of reaction times (F(2,195) = 3.0, p = .05). Paired-samples t tests revealed that mean RTs significantly increased from Pre-Work to Post-Work in flight attendants of Mid (from +19.5% to +28.3% of optimum baseline) and Junior seniority (from +22.6% to +33.1% of baseline; ts > 2.9, ps < .01), whereas their Senior colleagues were not affected (from +22.0% to +23.5% of baseline; t(67) = 0.96, p > .30). Although the groups did not differ from each other at Pre-Work (Fischer LSD, ps > .35), Post-Work RTs were significantly higher in the Junior group compared to their Senior counterparts (p < .05; see Figure 7).

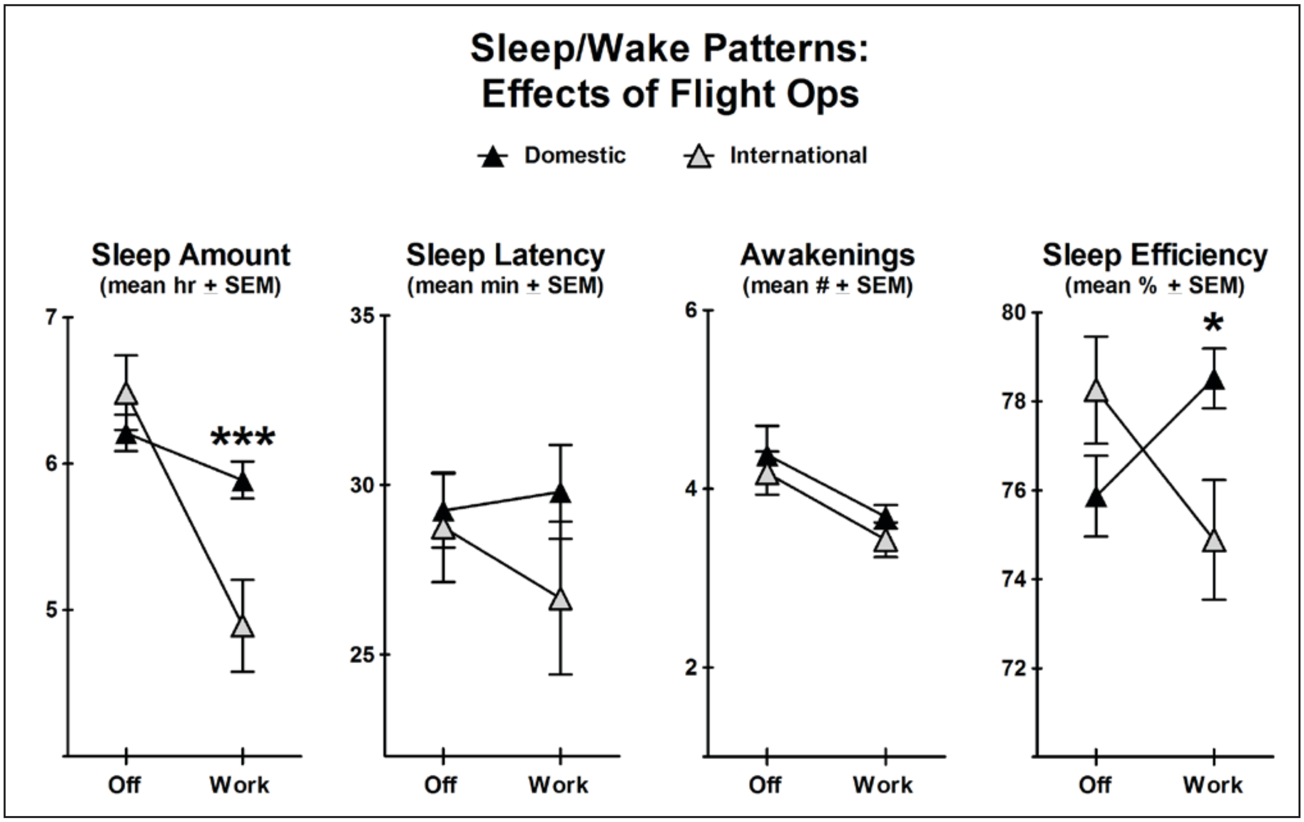

Figure 5. *Actigraphy-derived sleep/wake patterns during off days at home and while away on work trips in flight attendants that work Domestic or International flight operations (significant difference between groups indicated by *p < .05 and ***p < .01).*

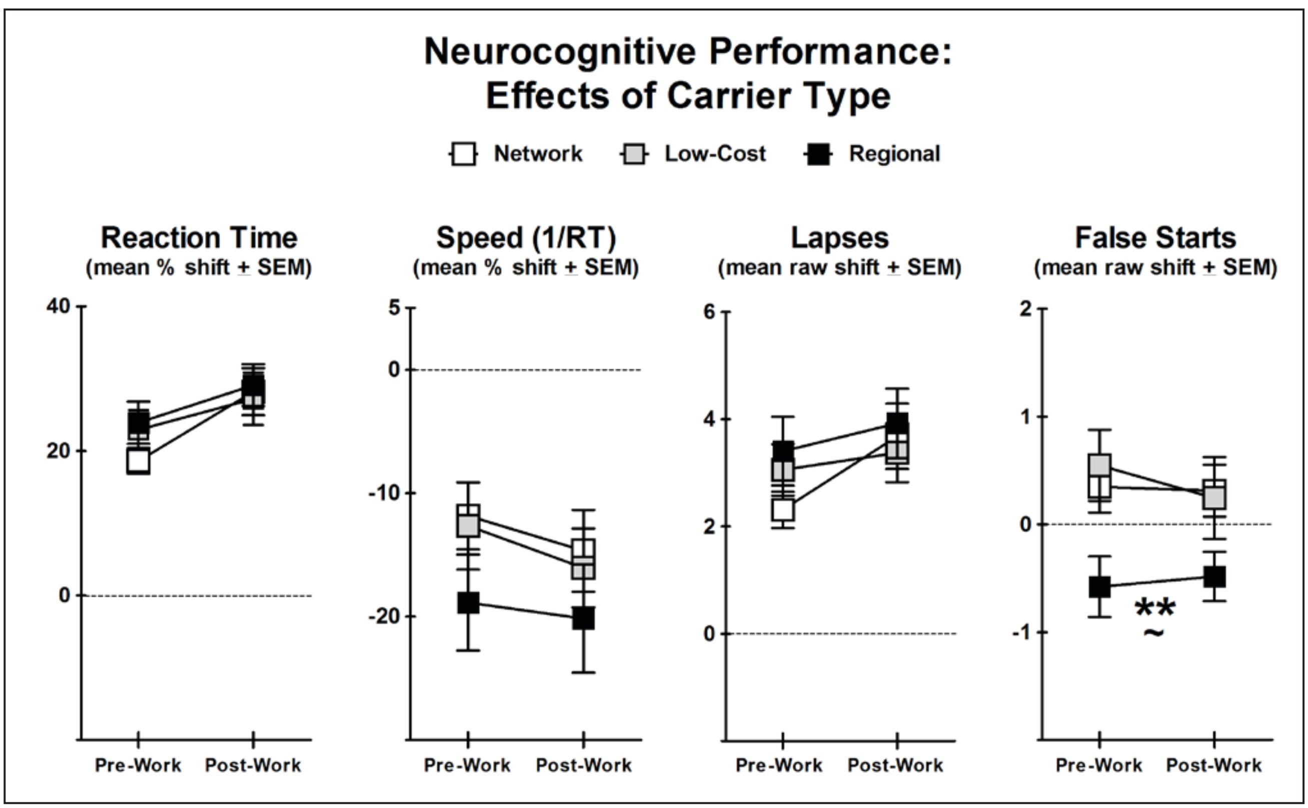

Figure 6. *Psychomotor Vigilance Test (PVT) performance during Pre-Work and Post-Work test sessions expressed as a shift from individualized optimum baseline (indicated by dashed lines at 0) in flight attendants from Network, Low-Cost, and Regional carriers (main effect: Regional vs. Low-Cost ~p < .05, Regional vs. Network **p < .01).*

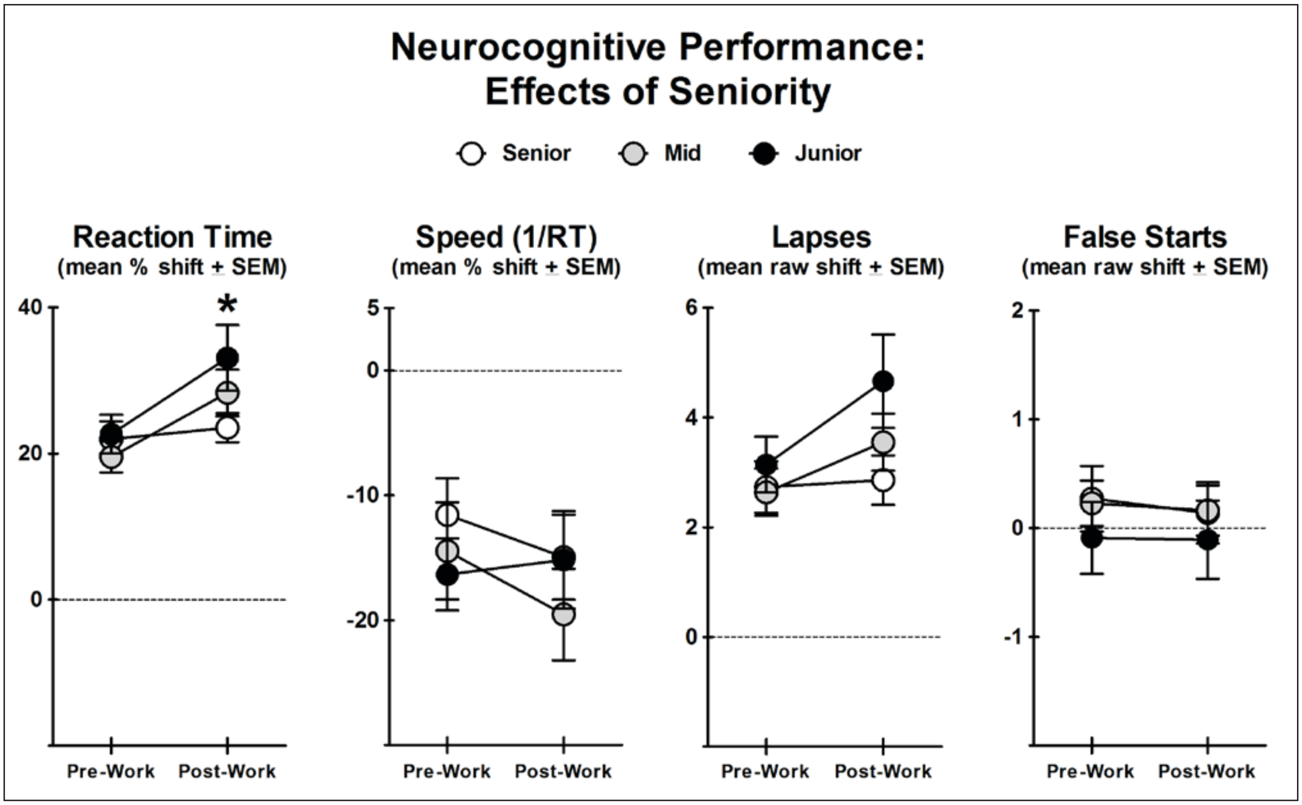

Figure 7. *Psychomotor Vigilance Test (PVT) performance during Pre-Work and Post-Work test sessions expressed as a shift from individualized optimum baseline (indicated by dashed lines at 0) in flight attendants of Senior, Mid, and Junior seniority (Junior vs. Senior *p < .05).*

Effects of Flight Operations. After accounting for reserve status, gender, and age, the 3 x 2 ANCOVAs revealed no significant main or interaction effects involving Flight Ops or Time across the workday on PVT speed (-14% to -17%) or false starts (+0.14 to +0.07; Fs < 2.9, ps > .09); but significant Flight Ops x Time interactions emerged from the analyses of reaction times and lapses (Fs(1,196) > 4.1, ps < .05). Mean RTs increased from Pre-Work to Post-Work in both the Domestic (from +23% to +28% of optimum baseline) and International groups (from +16% to +28% of baseline; paired-samples ts > 2.9, ps < .01). However, Pre-Work RTs were significantly higher in flight attendants working domestic operations compared to their international counterparts (independent samples t(98.6) = 2.5, p < .05, adjusted for unequal variance). Similarly, mean lapses increased from Pre-Work to Post-Work in both the Domestic (from +3.0 to +3.6 relative to baseline) and International groups (from +2.1 to +3.9 relative to baseline), but because the International group committed fewer lapses at Pre-Work, their increase to Post-Work was larger than their counterparts working domestic operations (independent samples t(199) = 2.2, p < .05; see Figure 8).

DISCUSSION

In their recent survey of active flight attendants, Avers and colleagues (2009) documented typical nightly sleep amounts of 7.7 hr at home and 6.5 hr while away on a work trip, with 84% of respondents reportedly experiencing subjective fatigue while on duty during their previous bid period. Our data provide evidence supporting this perception of widespread fatigue among cabin crew, but when reduced to objectively measured sleep and precisely defined performance variables, paint an even more striking picture in terms of its prevalence. Specifically, while general estimates of sleep latency and awakenings were consistent with our actigraphy data, with only 6.3 hr of sleep at home and 5.7 hr away, flight attendants' estimates of sleep amounts were approximately 1 hr (-15%) off, regardless of the setting, and more closely resemble the patterns of workers in industrial shift-work settings (e.g., Ohayon, Smolensky, & Roth, 2010; Paech, Jay, Lamond, Roach, & Feruson, 2010; Thorne, Hampton, Morgan, Skene, & Arendt, 2008).

In terms of performance, when comparing individualized optimum baseline PVT values to average Pre-Work PVT performance, false starts increased in 52% of the field study participants, speed decreased in 85%, lapses increased in 96%, and reaction times increased in 100% of the 201

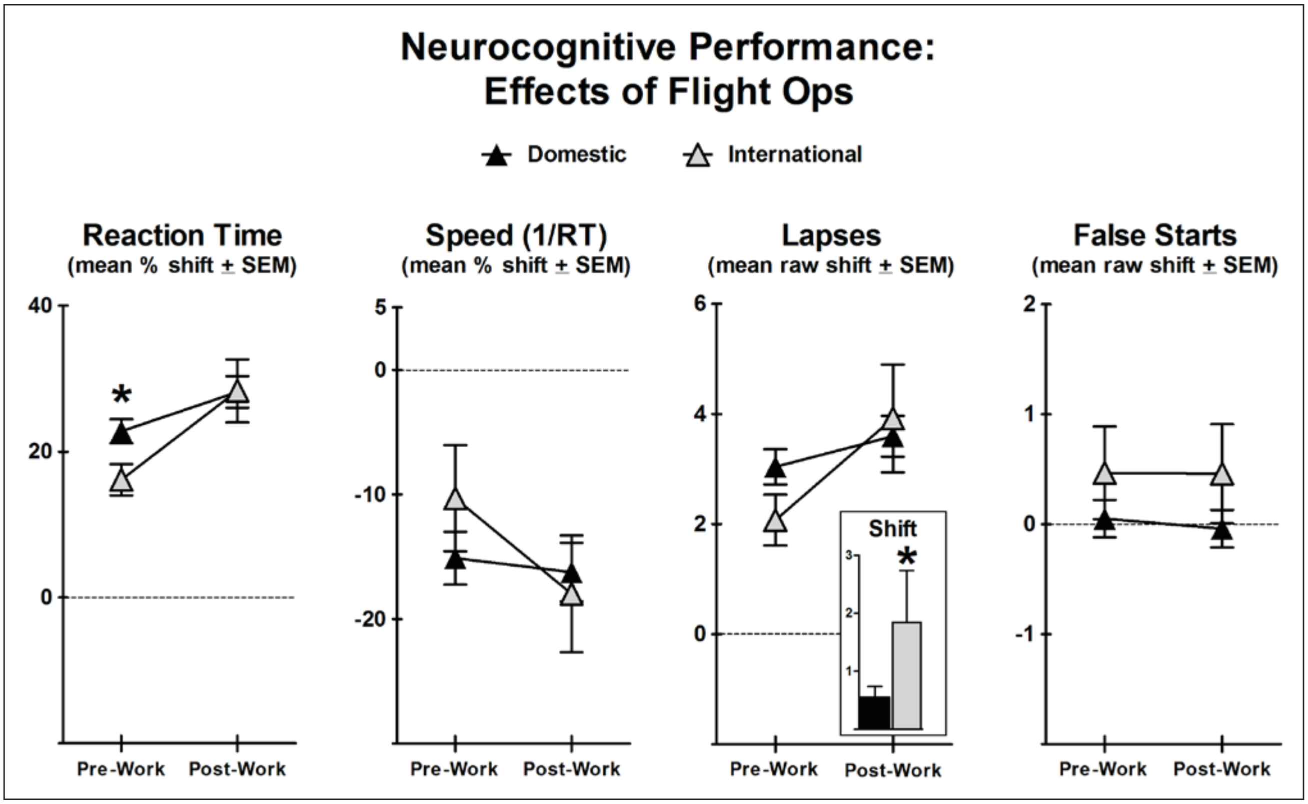

Figure 8. *Psychomotor Vigilance Test (PVT) performance during Pre-Work and Post-Work test sessions expressed as a shift from individualized optimum baseline (indicated by dashed lines at 0) in flight attendants who work Domestic or International flight operations (significant difference between groups indicated by *p < .05).*

flight attendants that provided PVT data. Similarly when compared to optimum baseline, average Post-Work false starts increased in 53%, speed decreased in 85%, lapses increased in 97%, and reaction times increased in 100%. It is worth noting that our data do not reflect performance at one specific, potentially anomalous work day or time of year, but rather each flight attendant's average pre- and post-work neurocognitive function over 3-4 weeks of continuous data collection reflecting multiple workdays and multiple trips as they naturally occurred throughout a calendar year. As such, if CAMI's survey respondents and our field study participants drawn from across the industry are representative of the flight attendant community as a whole, and our selection strategy gives us every reason to expect they were, then given the sleep/wake data and the fact that most individuals began their workday in an already compromised neurocognitive state, cabin crew may reasonably be considered chronically sleep restricted (Mollicone, Van Dongen, Rogers, Banks, & Dinges, 2010) while potentially underestimating their own fatigue.

On average, seemingly few, if any, flight attendants begin their workday at their well-rested best. Despite the importance of this finding, the significant difference between optimum baseline and Pre-Work performance variables created the potential for "floor effects;" that is, if flight attendants appear fatigued at the start of the workday, then there may be little room for performance to decline as a function of on-duty activities. However, analysis of the sleep/wake and performance data still revealed effects of the broad factors of carrier type, seniority, and flight operations. Most notably, the actigraphy data revealed significantly less sleep and reduced sleep efficiency while away on trips in flight attendants working international operations versus their domestic colleagues, which is likely a function of circadian misalignment as international crew attempt to sleep under light/dark schedules that differ radically from their own endogenous circadian rhythms.

In terms of performance, regional flight attendants committed fewer lapses than their network and low-cost colleagues, which initially suggests superior inhibitory control; however, this effect may be a consequence of the regional group having the slowest response speed, which itself could limit the likelihood of rapid premature responses. Among the more noteworthy performance effects were seniority-dependent changes in Post-Work reaction times, with significantly higher RTs in junior-level crew versus their senior-level colleagues (whose RTs did not increase significantly across the workday). Junior and senior participants did not differ from each other in total sleep amounts or Pre-Work RTs, suggesting some systematically fatiguing influence of seniority, specifically during work days. By contrast, flight attendants working international routes did not differ from their domestic counterparts at the end of their respective workdays but began their workdays with better reaction times and fewer lapses than the domestic group. Since international flight attendants obtained less sleep than domestic crew while away on work trips, the performance results suggest a superior recovery process in between trips for the international group, yet the groups did not differ from each other in average sleep amounts during off days. Although ultimately an empirical question, informal observations of our field study logs suggest that international crew have more days off in between trips than domestic crews, which is an intriguing potential mechanism given that more recovery time is required to restore performance after chronic sleep restriction versus acute sleep deprivation (see Balkin, Rupp, Picchioni, & Wesensten, 2008 for a review) which may not be accommodated by current hours of service regulations.

The consequences of flight attendant fatigue in terms of standardized performance measures are clear based on the present study; however, additional data are required to elucidate the functional consequences of these effects. That is, what does a 20% increase in reaction time or doubling of lapse rate mean in terms of routine passenger safety, crisis prevention and management, and employee health? Fortunately, accidents and other emergencies are relatively rare in aviation, but this limits the data suitable for quantifying risk, at least within a reasonable timeframe. However, validated evidence-based fatigue modeling tools are available to predict operational safety risks associated with variations in sleep/wake patterns, work schedules, and circadian factors. A forthcoming full-scale analysis of all field study sleep/wake/work patterns will employ the SAFTE (Sleep, Activity, Fatigue, and Task Effectiveness) model and related tools developed by Hursh (Hursh et al., 2004; Van Dongen, 2004) and utilized by the U.S. Department of Defense, NASA, and Department of Transportation. Such an approach yields quantitative risk metrics across individual work days and off days that are not apparent in conventional analyses of aggregate data.

In conclusion, the objective sleep/wake and PVT performance data echo and extend previous survey work suggesting that fatigue is a pervasive condition across the flight attendant community. In fact, with sleep/wake patterns similar to those of industrial shift-workers, U.S.-based flight attendants appear to share a state of chronic sleep restriction and fatigue that is considerably worse than their own perceptions. One particular strength of the present study's design that facilitated this insight was comprehensive data collection throughout each flight attendant's individual 3-4 week study period, including work days and off days, thereby allowing standardized measurements across various conditions and states of neurocognitive functioning. This approach allowed perhaps the most striking finding that regardless of workday activities, virtually all flight attendants reported for duty in an already compromised state, compared with their own individualized optimal performances. Nonetheless, sleep/wake parameters and performances across the workday were still systematically affected to some extent by the broad factors of carrier type, seniority, and flight operations. We urge caution in overgeneralizing, but in terms of fatigue-induced risk, the data suggest that (1) regional flight attendants may be more vulnerable than network or low-cost, (2) junior-ranking flight attendants may be more vulnerable than senior or mid-level, and (3) flight attendants working domestic operations may be more vulnerable than those working international trips.

Although the pattern of results within each factor suggests some intriguing possibilities, what is ultimately most important is identifying the operational variables mediating the on-duty and off-duty fatigue effects. That is, carrier type, seniority, and flight operations are by no means arbitrary categorizations, but what exactly is it about carrier type, seniority, and domestic vs. international flight operations that matters? Such categorizations may be informative for research, but when considering potential regulatory changes, the rules at the federal level cannot vary based on demographics. Informed by insights from the flight attendant survey results and the current field study findings, the stage is now set for in-depth analyses of the predictive relationships between specific operational variables and sleep/wake patterns and performance effectiveness across our entire sample of field study participants regardless of carrier type, seniority, or flight destinations. Key variables include total length of duty day, number of flight legs/segments per day, recovery time in the hotel during a trip, consecutive duty days/trip length, and number of days off in between trips. However, the data also underscore the relevance of off-duty time when flight attendants are not under direct supervision, so a number of other issues beyond regulatory control and corporate management such as distance between home and work base (initial commute) and the responsible use of off-duty time for adequate recovery sleep, are also worthy of consideration. Ultimately, fatigue risk management for an industry as large and complex as aviation can only be sustained if a comprehensive approach is adopted. Indeed, effectively managing fatigue is a cooperative enterprise between government, management, and employees at all levels. The field study presented here joins the other CAMI projects by providing carefully collected objective data on real world flight attendant operations, which may inform discussion and policy development on the issue of fatigue in cabin crew. Combined with the use of other scientifically valid methods and tools, we support the goal of reducing flight attendant fatigue to enhance passenger safety and employee health.

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