Case Study

Assessing Fatigue-Related Impairment with Public Safety Officers Using the Druid® Impairment App

Fatigue is a major problem for workers in safety-sensitive jobs. In early 2021, the Department of Public Safety in Highland Park, Texas (HPDPS), had its officers on a demanding 24/48 schedule, 24 hours on duty followed by 48 hours off duty. Each officer rotated every eight hours between police, fire, and EMS duties. In November 2021, HPDPS switched from this 24/48 schedule to an experimental 48/96 schedule to give the officers more time to sleep between shifts and when they were on fire or EMS duty. Using its Druid impairment app, Impairment Science, Inc. (ISI) assessed the officers' fitness for duty at both the beginning and end of their shifts under both schedules. The results indicated that the 48/96 schedule did serve to reduce fatigue-related impairment.

> Your assistance and professionalism in helping us answer this question have paid dividends for our department and I believe we will be reaping the benefit for years and years.
>
> *– Wayne Kilmer, Assistant Chief of Public Safety, Highland Park, Texas*

The fatigue experienced by police officers, firefighters, and emergency medical service (EMS) personnel has long been recognized as a threat to their safety, physical and mental health, and job performance as well as to the communities they serve.[1,2] Extensive research has shown that fatigue due to fragmented sleep and sleep deprivation impairs executive functioning, long-term memory, and sustained attention[3] and decreases performance on tasks that require short-term memory, fast reaction times, or vigilance.[4] As a result, fatigue is a major contributor to injuries in the workplace:

- An analysis of 182 investigations conducted by the National Transportation Safety Board identified operator fatigue as a probable cause, contributing factor, or finding in 20% of the cases, including 40% of highway investigations.[5]
- A review of 27 observational studies found that workers with sleep problems had a 62% greater risk of being injured compared to their coworkers.[6]
- A study of police officers found a strong association between their level of self-reported fatigue and the likelihood of their experiencing a nonfatal injury while on duty.[7]

For these reasons, the American Academy of Medicine and the Sleep Research Society declared in a joint statement that fatigue due to insufficient sleep is a serious public safety issue.[8] In fact, fatigue can be as debilitating as being high from alcohol, marijuana, or illegal substances. One study showed that on average, equivalent decrements in reaction times and response accuracy were found for a BAC (blood alcohol concentration) of 0.05% after being awake between 16.9 and 18.6 hours, and for a BAC of 0.10% after being awake between 17.7 and 19.6 hours.[9]

For police officers, job-related factors – extended work hours, overnight shifts, rotating shift assignments, and physically and mentally demanding service calls – are the principal causes of fatigue,[10] but several factors outside of work that result in sleep deficits or trigger stress are also major contributors. Whatever the source, police departments "have a clear and compelling interest in ensuring that officers are not overly fatigued on the job and that they are sufficiently alert to perform their duties properly." Departments that fail to take reasonable steps to ensure officers' fitness for duty and to manage fatigue-related impairment may "incur substantial civil liability for avoidable accidents, injuries, or misconduct" (p. 12).[2]

Police supervisors have only a handful of options for minimizing job-related fatigue. Sleep health education and sleep disorder screening are important but will have only a limited effect if the primary cause, "the combination of restricted sleep and disrupted circadian rhythms,"[11] is not addressed by optimizing their officers' shift schedule. With this understanding, the Department of Public Safety in Highland Park, Texas (HPDPS), a Dallas suburb with a population of just under 9,000 residents, asked Impairment Science, Inc. (ISI) to conduct a year-long study to investigate whether and to what degree its officers were experiencing fatigue-related impairment.

HPDPS employs 45 public safety officers. In early 2021, the officers worked 24-hour shifts, rotating every eight hours between police, fire, and EMS duties, followed by 48 hours off duty. Subsequently, HPDPS asked ISI to assess whether a newly initiated schedule – 48 hours on duty, followed by 96 hours off duty – had reduced the officers' on-the-job fatigue and otherwise improved their quality of life.

Having developed the Druid® impairment app, ISI was uniquely qualified to conduct this assessment.

The Druid Impairment App

ISI's Druid app assesses a person's level of cognitive and motor impairment due to any cause or combination of causes.[12-14] The app functions on all iOS and Android devices. Informed by published scientific research on impairment, the app requires users to perform a balance test and three game-like tasks that measure reaction time, decision-making accuracy, hand-eye coordination, and time estimation under conditions of divided attention:

- Task 1. A series of small squares and circles each flash on the screen for less than a second. One shape is designated as the target and the other as the control shape. As quickly as possible, users are asked to touch the screen where a target shape appeared and touch a small oval at the top of the screen when a control shape appeared. Halfway through the task, the target and control shapes are switched.
- Task 2. Users press a "Start" button and then a "Stop" button when they think 30 seconds have passed. At the same time, a series of small circles each flash on the screen for less than a second. As quickly as possible, users are asked to touch the screen where a circle appeared.
- Task 3. A small circle moves around the screen and occasionally jumps a short distance. Users try to keep their finger on the circle while also counting the number of small squares that each flash on the screen for less than a second.
- Task 4. Users stand on their right leg for 15 seconds while holding their smartphone or tablet as still as possible in their left hand, after which they stand on their left leg for 15 seconds while holding the device in their right hand.

All four tasks can be completed in three minutes. The app collects and integrates hundreds of measurements to produce an *impairment score* that ranges from 0 to 100. In practice, nearly all scores fall between 30 and 75.

The pattern of stimuli that Druid presents in Tasks 1-3, within specified parameters, is different each time a person uses the app. In Task 1, for example, the sequence of target and control shapes, how rapidly they are presented, and where they appear are determined at random and therefore users cannot memorize or even anticipate what they will see on the screen. Importantly, this means that once users achieve a stable baseline, their performance is highly unlikely to continue to improve when they use the app under similar conditions. Of course, their performance could change under different conditions, such as when a new shift schedule is used.

Druid Enterprise, the workplace version of the app, embeds Druid in a cloud-based software solution and provides administrative management tools for supervisors to view their employees' impairment scores either individually or collectively by age range, gender, workgroup, or other variables. Scores can be displayed over time for a specific date or over time for a range of dates (e.g., by week, month, or days of the week). Graphical displays draw attention to higher scores that may indicate impairment and thus warrant further examination.

To use Druid successfully, users take practice tests to become familiar with what the tasks require and establish a stable baseline score by means of taking three tests in a row. For a test to count, users must verify in the app that they were not distracted, tried their best, and did not feel impaired. The vast majority of users are able to establish a stable baseline after taking between three and five tests under those conditions.

Purpose of the Investigation

When the investigation began, HPDPS's public safety officers were working 24-hour shifts, followed by 48 hours off duty. Normally, the shifts were divided into three eight-hour segments (7 am to 3 pm, 3 pm to 11 pm, and 11 pm to 7 am), with one segment each for police, fire, and EMS duties.

As with any deployment schedule, assignments had to be adjusted whenever officers took unscheduled personal days, had planned vacation time, or made court appearances, which frequently resulted in other officers working extra-long shifts. Extended hours also occurred whenever HPDPS responded to mutual assistance calls from the University Park Fire Department or Dallas Fire/Rescue. Also of note, DPS requires its personnel "to be ready at any moment to transition from the law enforcement role directly into the Fire/EMS function. For this reason, every officer carries their bunker gear with them while on patrol" (https://www.hptx.org/444/Police).

There are 45 public safety officers divided into three platoons of 15 officers each. The platoons are further divided into three teams with five officers each for a total of 15 groups. In each platoon, the groups rotate through each of three ordered sequences of assigned duties as they went from one shift to the next: a) police, fire, EMS; b) Fire, EMS, Police; and c) EMS, Police, Fire. As shown in Appendix 1, over the course of 21 days, this schedule had every team follow each sequence of duties seven times, one time each for the seven days of the week.

Highland Park DPS's 24/48 schedule was feasible only because the officers were sometimes able to sleep at the station in between fire and EMS calls, especially when they were assigned those duties during the evening or overnight hours. The officers' ability to nap varied from officer to officer but also depended on the frequency of the service calls and how long it might take officers to wind down after a physically demanding or stressful incident. Off duty, the officers had just 48 hours to catch up on their sleep, spend time with family and friends, and attend to personal business before reporting for duty and starting their next 24-hour shift.

The potential consequences of this intense work schedule prompted HPDPS to ask ISI to assess whether its officers were showing signs of impairment at the end of their shifts. Later, with the support of its officers, HPDPS asked ISI to test whether a 48/96 schedule – 48 hours on duty, followed by 96 hours off duty – would reduce fatigue-related impairment. Importantly, this new schedule made it possible for HPDPS to maintain the existing patrol structure and to have teams rotate through the same ordered sequences of assigned duties during both 24-hour blocks.

There were good reasons to think the new schedule might be beneficial. Having off four days in a row might make it easier to catch up on sleep and manage their lives outside of work. This reasoning was consistent with research demonstrating that the police officers who worked four ten-hour days followed by three days off reported having more sleep than those working five eight-hour shifts with two days off.[15]

On the other hand, another study found that police officers on patrol for three 13-hour, 20-minute shifts with four days off had decreased hours of sleep, poorer quality of sleep, reduced concentration, impaired cognitive processing, and a lower quality of life compared to those working four ten-hour shifts.[16] Note, however, that HPDPS assigned officers to police duties for only eight hours per 24-hour period. Moreover, having worked the first 24 hours, the officers might be better able to nap when on fire and EMS duty during the second 24 hours.

Assessment Plan

In Phase 1, ISI assessed the 24/48 schedule over a six-week period from May 13 to June 26, 2021, with 42 officers participating. On the first day, when the officers reported for duty, ISI introduced the Druid app and then randomly assigned each person another username (e.g., Alex Olive, Terry Blue) to register through Druid Enterprise. A master list linking the officers with their usernames was kept by ISI and not shared with any HPDPS personnel. The officers learned that for the purposes of this demonstration study, they would not be questioned, disciplined, or otherwise penalized if they had elevated Druid scores. Next, the officers practiced the app three or more times, trying to get three sequential impairment scores that fell within a three-point range.

In Phase 2, ISI assessed the 48/96 schedule over another six-week period from April 4 to May 9, 2022, with 35 officers participating. This schedule was implemented in early November 2021, but the assessment initiated

at that time was suspended because of the extensive scheduling adjustments resulting from the COVID-19 pandemic and the December holidays. When resuming Phase 2, the officers once again practiced the app three or more times until they had three sequential impairment scores that fell within a three-point range.

Examining the results only for officers who participated in both Phase 1 and Phase 2, the data analysis addressed whether moving to the 48/96 schedule reduced the officers' average scores at both the start and end of their shifts. Also of interest was whether the start-of-shift scores might be less variable because the new schedule gave the officers full four days to recuperate from their previous 48-hour shift.

Findings from the Analysis

The first step in the analysis was to determine each HPDPS officer's average (mean) start-of-shift and end-of-shift Druid scores, first during Phase 1 (with the 24/48 schedule) and then during Phase 2 (with the 48/96 schedule). These data were used to calculate mean average scores across the full set of officers, which are shown in the table below.

Within-subjects *t*-tests (two-tailed) showed that the average start-of-shift scores during Phase 2 were significantly lower than the Phase 1 scores [$t_{(31)} = -8.88$, $p < .00001$] with a decrease (5.6 points). The decrease in average end-of-shift scores during Phase 2 was slightly less with a 10.6% drop (4.7 points) but still highly significant [$t_{(30)} = -6.50$, $p < .00001$].

Average Impairment Scores for Start-of-Shift and End-of-Shift Druid Tests During 24/48 and 48/96 Shift Schedules		
Start of Shift (N=32)	Phase 1 (24/48)	Phase 2 (48/96)
Officers' Average Scores		
Mean (SD)[a]	44.5 (4.1)	38.9 (3.5)
Number of Tests		
Mean (SD)	12.7 (3.0)	3.2 (1.4)
End of Shift (N=31)	Phase 1 (24/48)	Phase 2 (48/96)
Officers' Average Scores		
Mean (SD)	44.4 (4.1)	39.7 (3.9)
Number of Tests		
Mean (SD)	11.4 (4.2)	2.5 (1.3)

[a] SD = Standard deviation

Testing during Phase 2 was less frequent than during Phase 1. Therefore, the analyses were repeated, first by excluding officers who did only one test during Phase 2 and then also excluding those who did only two tests. Despite these exclusions, the results were consistent and remained statistically significant (see Appendix 2).

These findings confirm what the officers reported in two HPDPS surveys. The first survey, conducted before the 48/96 schedule began, was completed by 44 officers. The second survey, conducted 35 weeks later, was completed by 33 officers, the lower number being due to several officers leaving for training, transfers, and retirements. With the 48/96 schedule, 67% reported being "satisfied" or "very satisfied" with their sleep, compared to only 16% when the 24/48 schedule was used. The percentage who reported having a "very good" quality of life increased from 21% to 49% under the new schedule. The fact that many officers had lobbied for the 48/96 schedule may have affected their responses to some extent, but nevertheless, what they reported is borne out by their decreased Druid impairment scores.

Conclusions

Consistent with HPDPS's expectations, ISI's investigation confirmed that the new 48/96 schedule resulted in its public safety officers being significantly more fit for duty compared to when the 24/48 schedule was in place. Whether this scheduling option would work for traditional police departments is an open question. Highland Park's officers rotate between police, fire, and EMS duties and serve a small, affluent community with relatively

few fires and EMS calls for service. Thus, the officers often have many opportunities to sleep when they are not on police patrol.

HPDPS' leadership team deserves credit for implementing several best practices for addressing fatigue-related impairment.[10, 11] Especially noteworthy is HPDPS's willingness to experiment with optional scheduling policies and procedures. The leadership team welcomed input from the officers and involved them in assessing the new schedule. Going forward, HPDPS has the option of using the Druid app to monitor the officers on a regular basis to inform both day-to-day and longer-term personnel decisions. Regular testing also creates opportunities to remind officers about the importance of good sleep habits and other factors that can compromise their fitness for duty.

Authors
Chris Bensley, Impairment Science, Inc., Cambridge, MA (ISI); Michael A. Milburn, Ph.D., ISI; Wayne Kilmer, Assistant Chief, HPDPS; and William DeJong, Ph.D., ISI

References

1. Weaver, M. D., & Barger, L. K. (2019). Sleep health as an issue of public safety. In Grandner, M. A. (Ed.), *Sleep and Health* (pp. 489-499). Amsterdam, Netherlands: Elsevier Science.

2. Vila, B., Morrison, G. B., & Kenney, D. J. (2002). Improving shift schedule and work-hour policies and practices to increase police officer performance, health, and safety. *Police Quarterly*, *5*(1), 4–24.

3. Lowe, C. J., Safati, A., & Hall, P. A. (2017). The neurocognitive consequences of sleep restriction: a meta-analytic review. *Neuroscience & Biobehavioral Reviews*, *80*, 586-604.

4. Bonnet, M. H., & Arand, D. L. (2003). Clinical effects of sleep fragmentation versus sleep deprivation. *Sleep Medicine Reviews*, *7*(4), 297-310.

5. Marcus, J. H., & Rosekind, M. R. (2017). Fatigue in transportation: NTSB investigations and safety recommendations. *Injury Prevention*, *23*(4), 232-238.

6. Uehli, K., Mehta, A. J., Miedinger, D., Hug, K., Schindler, C., Holsboer-Trachsler, E., ... & Künzli, N. (2014). Sleep problems and work injuries: a systematic review and meta-analysis. *Sleep Medicine Reviews*, *18*(1), 61-73.

7. Fekedulegn, D., Burchfiel, C. M., Ma, C. C., Andrew, M. E., Hartley, T. A., Charles, L. E., ... & Violanti, J. M. (2017). Fatigue and on-duty injury among police officers: The BCOPS study. *Journal of safety research*, *60*, 43-51.

8. Luyster, F. S., Strollo, P. J., Zee, P. C., & Walsh, J. K. (2012). Sleep: a health imperative. *Sleep*, *35*(6), 727-734.

9. Williamson, A. M., & Feyer, A. M. (2000). Moderate sleep deprivation produces impairments in cognitive and motor performance equivalent to legally prescribed levels of alcohol intoxication. *Occupational and Environmental Medicine*, *57*(10), 649-655.

10. Vila, B., & Kenney, D. J. (2002). The prevalence and potential consequences of police fatigue. *NIJ Journal*, *248*, 17-21.

11. Caldwell, J. A., Caldwell, J. L., Thompson, L. A., & Lieberman, H. R. (2019). Fatigue and its management in the workplace. *Neuroscience & Biobehavioral Reviews*, *96*, 272-289.

12. Karoly, H. C., Milburn, M. A., Brooks-Russell, A., Brown, M., . . . Bidwell, L. C. (2020). Effects of high potency cannabis on psychomotor performance in frequent cannabis users. *Cannabis and Cannabinoid Research*.

13. Richman, J. E., & May, S. (2019). An investigation of the Druid® smartphone/tablet app as a rapid screening assessment for cognitive and psychomotor impairment associated with alcohol intoxication. *Vision Development Rehabilitation, 5*, 31-42.

14. Spindle, T. R., Martin, E. L., Grabenauer, M., Woodward, T., Milburn, M. A., & Vandrey, R. (2021). Assessment of cognitive and psychomotor impairment, subjective effects, and blood THC concentrations following acute administration of oral and vaporized cannabis. *Journal of Psychopharmacology*, *35*(7), 786-803.

15. Amendola, K. L., Weisburd, D., Hamilton, E., Jones, G., Slipka, M., Heitmann, A., ... & Tarkghen, E. (2011). *The shift length experiment: What we know about 8-, 10-, and 12-hour shifts in policing*. Washington, DC: Police Foundation.

16. Bell, L. B., Virden, T. B., Lewis, D. J., & Cassidy, B. A. (2015). Effects of 13-hour 20-minute work shifts on law enforcement officers' sleep, cognitive abilities, health, quality of life, and work performance: The phoenix study. *Police Quarterly*, *18*(3), 293-337.

Appendix 1: 21-Day Deployment Schedule for HPDPS Officers

There are 45 public safety officers divided into three platoons of 15 officers each (labeled A, B, and C). Each platoon is further divided into three teams with five officers each (labeled T1, T2, and T3) for a total of 15 teams. Platoon A starts with the Week 1 schedule, followed by the Week 2 and Week 3 schedules. Platoon B starts with the Week 2 schedule, followed by the Week 3 and Week 1 schedules. Platoon C starts with the Week 3 schedule, followed by the Week 1 and Week 2 schedules.

Week: Platoon	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
1: Platoon A 2: Platoon B 3: Platoon C	T1: P/F/E T2: F/E/P T3: E/P/F	Off	Off	T3: P/F/E T1: F/E/P T2: E/P/F	Off	Off	T2: P/F/E T3: F/E/P T1: E/P/F
1: Platoon C 2: Platoon A 3: Platoon B	Off	Off	T1: P/F/E T2: F/E/P T3: E/P/F	Off	Off	T3: P/F/E T1: F/E/P T2: E/P/F	Off
1: Platoon B 2: Platoon C 3: Platoon A	Off	T2: P/F/E T3: F/E/P T1: E/P/F	Off	Off	T1: P/F/E T2: F/E/P T3: E/P/F	Off	Off
Week: Platoon	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14
1: Platoon A 2: Platoon B 3: Platoon C	T3: P/F/E T1: F/E/P T2: E/P/F	Off	Off	T2: P/F/E T3: F/E/P T1: E/P/F	Off	Off	T1: P/F/E T2: F/E/P T3: E/P/F
1: Platoon C 2: Platoon A 3: Platoon B	Off	Off	T3: P/F/E T1: F/E/P T2: E/P/F	Off	Off	T2: P/F/E T3: F/E/P T1: E/P/F	Off
1: Platoon B 2: Platoon C 3: Platoon A	Off	T1: P/F/E T2: F/E/P T3: E/P/F	Off	Off	T3: P/F/E T1: F/E/P T2: E/P/F	Off	Off
Week: Platoon	**Day 15**	**Day 16**	**Day 17**	**Day 18**	**Day 19**	**Day 20**	**Day 21**
1: Platoon A 2: Platoon B 3: Platoon C	T2: P/F/E T3: F/E/P T1: E/P/F	Off	Off	T1: P/F/E T2: F/E/P T3: E/P/F	Off	Off	T3: P/F/E T1: F/E/P T2: E/P/F
1: Platoon C 2: Platoon A 3: Platoon B	Off	Off	T2: P/F/E T3: F/E/P T1: E/P/F	Off	Off	T1: P/F/E T2: F/E/P T3: E/P/F	Off
1: Platoon B 2: Platoon C 3: Platoon A	Off	T3: P/F/E T1: F/E/P T2: E/P/F	Off	Off	T2: P/F/E T3: F/E/P T1: E/P/F	Off	Off

In each platoon, the teams rotate through each of three ordered sequences of assigned duties as they go from one 24-hour shift to the next: Police, Fire, EMS (P/F/E); Fire, EMS, Police (F/E/P); and EMS, Police, Fire (E/P/F).

On Week 1/Day 1, for example, Platoon A's Team 2 starts its shift with Fire duty, then EMS, and then Police (F/E/P). On Week 1/Day 4, they start with EMS duty, then Police, and then Fire (E/P/F). On Week 1/Day 7, they start with Police duty, then Fire, and then EMS (P/F/E). The most equitable way to deploy the 15 teams is to organize the schedule into 21-day blocks, as shown in the chart.

Over the course of 21 days, every team follows each sequence of duties 7 times, distributed evenly across the days of the week, Sunday through Saturday. For example, Platoon B/Team 2 follows each sequence of duties as follows: (a) F/E/P on Days 1, 3, 5, 9, 14, 18, and 20; (b) P/F/E on Days 2, 7, 11, 13, 15, 17, and 19; and (c) E/P/F on Days 4, 6, 8, 10, 12, 16, and 21. Platoon A/Team 2 and Platoon C/Team 2 follow the same schedule.

Appendix 2

Start of Shift		End of Shift	
2-Plus Phase 2 Tests (N=29)		2-Plus Phase 2 Tests (N=21)	
Phase 1: M (SD)	44.5 (4.2)	Phase 1: M (SD)	44.5 (4.7)
Phase 2: M (SD)	39.1 (3.6)	Phase 2: M (SD)	40.1 (4.4)
$t_{(28)} = -7.94$, $p < .00001$		$t_{(20)} = -4.63$, $p = .00016$	
3-Plus Phase 2 Tests (N=20)		3-Plus Phase 2 Tests (N=14)	
Phase 1: M (SD)	44.5 (4.2)	Phase 1: M (SD)	44.5 (4.9)
Phase 2: M (SD)	38.8 (3.7)	Phase 2: M (SD)	39.1 (4.1)
$t_{(19)} = -5.93$, $p < .00001$		$t_{(13)} = -4.34$, $p = .0008$	