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U-2 Pilot Post-Mission Fatigue Questionnaire

Molly Wade, M.S.; Jennifer Serres, Ph.D.;
Darryn Bryant, M.A.; Bruce Wright, Ph.D.;
William W. Dodson III, M.D.

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Air Force Research Laboratory
711th Human Performance Wing
U.S. Air Force School of Aerospace Medicine
Aeromedical Research Dept
2510 Fifth St.
Wright-Patterson AFB, OH 45433-7913

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14. ABSTRACT
U-2 pilots routinely conduct missions in a single-seat aircraft at altitudes above 70,000 feet, requiring the pilot to wear a full pressure suit and breathe 100% oxygen. Fatigue and cognitive performance decrements are concerns in this population due to the physical and mental stresses of the U-2 environment and the prolonged mission duration of up to 12 hours. This research investigates factors that contribute to subjective fatigue and explores fatigue countermeasure usage through a paper-based questionnaire administered to deployed U-2 pilots immediately after missions. Sixty-eight completed questionnaires were retrieved during the data collection period. The same pilot may have completed multiple questionnaires for various missions. Pilots reported awakening an average of 3.07 (± 0.75) hours prior to takeoff and an average mission duration of 9.81 (± 0.48 hours), resulting in a total time awake at landing of 12.87 (± 0.94) hours. Mean mental fatigue scores (0-10 scale with 0 being "not at all" and 10 being "extremely fatigued") for the first half of the mission, second half of the mission, and descent and landing were reported as 4.51 (± 2.58), 4.65 (± 2.26), and 3.82 (± 2.49), respectively. Additionally, unusual physical discomfort was reported in 60.3% of missions, which may contribute to subjective fatigue. Pilots used dextroamphetamine alone or in combination with caffeine in 85.29% of the missions evaluated (n=58) to increase alertness. It appears that effective countermeasure strategies are in place to prevent increases in fatigue in prolonged U-2 missions; however, changes in mission duration, mission frequency, and/or countermeasure strategies could affect fatigue in U-2 pilots.

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TABLE OF CONTENTS

Section **Page**

Distribution A: Approved for public release; distribution is unlimited. Case Number: AFMC-2014-0163, 11 Dec 2014

LIST OF FIGURES

Figure **Page**

LIST OF TABLES

Table **Page**

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1.0 SUMMARY

U-2 pilots routinely conduct missions in a single-seat aircraft at altitudes above 70,000 feet, requiring the pilot to wear a full pressure suit and breathe 100% oxygen. Fatigue and cognitive performance decrements are concerns in this population due to the physical and mental stresses of the U-2 environment and the prolonged mission duration of up to 12 hours. This research investigates factors that contribute to subjective fatigue and explores fatigue countermeasure usage through a paper-based questionnaire administered to deployed U-2 pilots immediately after missions. Sixty-eight completed questionnaires were retrieved during the data collection period. The same pilot may have completed multiple questionnaires for various missions. Pilots reported awakening an average of 3.07 (± 0.75) hours prior to takeoff and an average mission duration of 9.81 (± 0.48 hours), resulting in a total time awake at landing of 12.87 (± 0.94) hours. Mean mental fatigue scores (0-10 scale with 0 being “not at all” and 10 being “extremely fatigued”) for the first half of the mission, second half of the mission, and descent and landing were reported as 4.51 (± 2.58), 4.65 (± 2.26), and 3.82 (± 2.49), respectively. Additionally, unusual physical discomfort was reported in 60.3% of missions, which may contribute to subjective fatigue. Pilots used dextroamphetamine alone or in combination with caffeine in 85.29% of the missions evaluated (n=58) to increase alertness. It appears that effective countermeasure strategies are in place to prevent increases in fatigue in prolonged U-2 missions; however, changes in mission duration, mission frequency, and/or countermeasure strategies could affect fatigue in U-2 pilots

2.0 INTRODUCTION AND PURPOSE

U-2 pilots conduct routine missions at extreme altitudes above 70,000 feet (maximum cabin altitude is approximately 29,500 feet) for durations exceeding 9 hours. As a result of this unique mission, this population of pilots experiences a higher risk for decompression sickness (DCS). According to Hundemer et al., from January 1994 to December 2010 there were 73 documented DCS cases within the U-2 community (1). The number of DCS cases from 2006-2010 averaged 6-10 per year, more than doubling the average number of cases per year from 1994 to 2005. Additionally, an increase in the number of severe DCS cases was reported, specifically with neurological and pulmonary symptoms (1-4). When examined by high-resolution magnetic resonance imaging, increased amounts of white matter hyperintensities were found in the brains of U-2 pilots when compared with controls (4-6). This research is ongoing, and the cause of the lesions and their impact on health and performance are yet to be determined.

From 2006-2010, U-2 pilots averaged 450 annual flight hours compared to 300-350 average annual flight hours from 1994-2005. This increase in operations tempo has been hypothesized as a contributing factor in the increased incidence of DCS (1). Jersey et al. also concurred that the increase in U-2 operations tempo, along with an increase in physical activity for the pilot due to change in mission emphasis and longer mission durations, contributed to this increase in the incidence of DCS (4). As a result of the increased incidence of DCS, the U-2 Cockpit Altitude Reduction Effort modifications were initiated in 2013 to reduce the cabin altitude from 29,500 feet to 15,000 feet, minimizing the risk of DCS (7).

Since the Cockpit Altitude Reduction Effort modifications may reduce the DCS risk, lengthening mission duration and increasing mission frequency have been discussed as possible changes in U-2 operations. Fatigue has been identified as a primary risk associated with these

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potential changes. Therefore, this study investigates subjective fatigue in deployed U-2 pilots during current operations and explores the factors contributing to fatigue such as mission duration, sleep characteristics, and time between missions. This study also examines the effects of countermeasure usage on subjective alertness, as well as the effects of physical discomfort on subjective fatigue and alertness.

3.0 BACKGROUND

Numerous studies have documented cognitive performance decrements associated with fatigue, including increased reaction times (8) and decreased vigilance and alertness (9). The performance decrements caused by fatigue have been compared with performance decrements due to alcohol intoxication. Dawson and colleagues found that after 17 hours of sustained wakefulness, cognitive psychomotor performance decreased to a level equivalent to the performance impairment observed at the legal limit for alcohol intoxication (10). If fatigue levels in U-2 pilots at the end of a 12-hour mission (15-hour day) cause similar performance decrements as intoxicated individuals, their landing abilities could be impaired, causing higher mishap rates. Since the U-2 is anecdotally the most difficult plane to land in the U.S. Air Force inventory, fatigue countermeasures are in place to enhance alertness throughout missions and at landing.

U-2 pilots often use stimulants, such as caffeine and dextroamphetamine (gel-dex), as fatigue countermeasures to enhance alertness during prolonged missions. Numerous studies have documented performance improvements associated with caffeine. Doan et al. conducted an overnight 10-hour study with U.S. Air Force pilots examining the effects of caffeine compared to placebo on cognitive tasks representative of U-2 missions (11). Two doses of caffeinated tube food (200 mg each) within the 10-hour period were found to maintain cognitive performance at or near baseline and improve performance decrements associated with the placebo (no caffeine) group.

Dextroamphetamine is a commonly used stimulant to enhance alertness, vigilance, situational awareness, and feeling of well-being in sustained military operations (12). The Air Force authorized the use of amphetamines to sustain the performance of sleep-deprived pilots as early as 1961 (13). Dextroamphetamine has a half-life of 10 hours, and a 20-mg dose has been shown to improve cognitive performance to baseline levels in individuals who experience 48 hours of total sleep deprivation (14,15). Additionally, Kenagy et al. examined dextroamphetamine usage during 94 B-2 combat sorties and reported that dextroamphetamine was used in 97% of missions lasting an average of 16.9 hours (16).

Even though stimulants may enhance mental alertness and reduce subjective fatigue in U-2 pilots, the physical discomfort resulting from prolonged immobility in a single-seat aircraft may contribute to subjective pain and fatigue. Prolonged sitting in various occupations has been reported to cause low back pain (LBP) (17-19). Factors that increase the risk of developing LBP include whole body vibration, dose and exposure duration, and/or awkward postures (18-19). When combined, these factors increase the likelihood of developing LBP. Helicopter pilots, who are exposed to similar environmental stressors as U-2 pilots, showed the strongest association for LBP (18-19). Fishbain et al. reported that individuals with chronic neck and LBP have reported higher subjective fatigue levels when compared with pain-free controls (20).

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This exploratory study aims to identify the factors that contribute to subjective fatigue levels in prolonged U-2 missions. Results may be used to support fatigue countermeasure strategies and mission frequency guidelines in U-2 operations.

4.0 METHODS

4.1 Equipment

The paper-based questionnaire used in this study was developed in consultation with U-2 leadership and Department of Defense fatigue experts and was validated by five U-2 pilots (Figure 1). This study was conducted with the approval of the 711th Human Performance Wing Institutional Review Board, protocol no. FWR20130084E.

4.2 Subjects

U-2 pilots at one deployed location designated by the U-2 community were recruited to participate in the questionnaire. The intent of the questionnaire was to investigate the impact of fatigue on different missions. Therefore, it was possible for a pilot to complete the questionnaire multiple times (for different missions flown). Subjects were self-consented and the responses were anonymous.

4.3 Duration

The duration for the data collection lasted approximately 6 months. The questionnaire took the pilots no more than 5 minutes to complete.

4.4 Description of Experiment, Data Collection, and Analysis

The opportunity to participate in the paper-based questionnaire was provided to the pilot by on-site support personnel within 45 minutes after landing. This allowed adequate time to remove the full pressure suit and report to the aircrew flight equipment section. Completed questionnaires were placed in a drop-box in a designated area and mailed to investigators every 2 weeks until at least 70 questionnaires were collected.

Study responses were analyzed using Microsoft Excel (Microsoft Corp., Redmond, WA). Descriptive statistics were used to identify mission characteristics and investigate countermeasure usage, subjective mental fatigue levels for each phase of flight, self-reported alertness, and degree of reported physical discomfort.

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U-2 Pilot Questionnaire

Pre-Flight History:

How much sleep did you get last night?	<2 h	2.1-4 h	4.1-6 h	6.1-8 h	> 8 h
Rate your quality of sleep last night.	Poor	Fair	Good	Very Good	Excellent
On average, how much sleep did you get per night in the last 48 hours?	<2 h	2.1-4 h	4.1-6 h	6.1-8 h	> 8 h
Indicate any sleep aids used in the last 48 hours and amount (including OTC).	Sonota Amt:______	Ambien Amt:______	Restoril Amt:______	Other______________ Amt:______	
How long have you been deployed at this location?	0-2 wk	2-4 wk	4-6 wk	6-8 wk	>8 wk
Indicate the ground time between your last high sortie and this sortie.	<36 h	36-48 h	48-60 h	60-72 h	>72 h
Including this sortie, how many high sorties have you flown in the past 7 days?	1	2	3	4	≥5
Indicate the ground time between your last low sortie and this sortie.	<24 h	24-36 h	37-48 h	49-60 h	>60 h
How many low sorties have you flown in the past 7 days?	1	2	3	4	≥5
Have many total flight hours have you logged in the U-2?	0-250 h	250-500 h	500-750 h	>750 h	_

Flight-Specific Questions:

Indicate how long you were awake prior to takeoff in hours: __________
Indicate if takeoff occurred during the daylight or night (please circle): daylight night
Indicate if landing occurred during the daylight or night (please circle): daylight night
Please indicate the duration of your flight in hours: __________

Indicate your level of mental fatigue in the first half of the flight.	Not at all 0 1 2 3 4 5 6 7 8 9 10 Extremely			
Indicate your level of mental fatigue in the second half of the flight.	Not at all 0 1 2 3 4 5 6 7 8 9 10 Extremely			
Indicate your level of mental fatigue during descent and landing.	Not at all 0 1 2 3 4 5 6 7 8 9 10 Extremely			
Indicate the hour of flight that caffeine was consumed, the amount taken (full or half tube), and the caffeine source (i.e., pudding, apple pie, etc.).	Hour of Flight:____ Amt: _________ Source:_______	Hour of Flight:____ Amt: _________ Source:_______	Hour of Flight:____ Amt:_________ Source:_______	Hour of Flight:____ Amt:_________ Source:_______
If you ingested caffeine, please rate its effect on your alertness.	Not at all 0 1 2 3 4 5 6 7 8 9 10 Extremely			
Indicate the hour of flight that gel-dex was taken and the amount taken.	Hour of Flight:____ Amt: _________	Hour of Flight:____ Amt: _________	Hour of Flight:____ Amt:_________	Hour of Flight:____ Amt:_________
If you ingested gel-dex, please rate its effect on your alertness.	Not at all 0 1 2 3 4 5 6 7 8 9 10 Extremely			
Rate your degree of physical discomfort during your flight.	Not at all 0 1 2 3 4 5 6 7 8 9 10 Extremely			
If experienced discomfort was unusual, what was the source of the discomfort?				

Figure 1. U-2 Pilot Questionnaire

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5.0 RESULTS

During the 6-month data collection period, 72 questionnaires were retrieved. Of the 72 questionnaires, 68 were completed. Pilots reported awakening an average of 3.07 hours prior to takeoff, and average mission duration was reported as 9.81 hours, resulting in an average time awake at landing of approximately 12.87 hours as shown in Table 1.

Table 1. Descriptive Analysis of Mission Characteristics

Characteristic	Mean (h)
Time awake prior to takeoff	3.07 ± 0.75
Mission duration	9.81 ± 0.48
Time awake at landing	12.87 ± 0.94

Subjective mental fatigue scores were reported on a 0-10 scale, with 0 being “not at all” and 10 being “extremely fatigued” for three phases of flight: first half of mission, second half of mission, and descent and landing. Average self-reported mental fatigue scores during the first half, second half, and descent and landing were 4.51, 4.65, and 3.82, respectively (Table 2).

Table 2. Average Subjective Mental Fatigue for Each Phase of Flight

Phase of Flight	Mean
First half of mission	4.51 ± 2.58
Second half of mission	4.65 ± 2.26
Descent and landing	3.82 ± 2.49

Stimulants were used in approximately 92% of U-2 missions evaluated in this study. Sixty percent of missions reported the usage of gel-dex only (n=41), 7% of missions reported usage of caffeine only (n=5), 25% of missions reported usage of a combination of caffeine and gel-dex (n=17), and 7% of missions (n=5) reported no stimulant usage (Figure 2). Pilots used gel-dex alone or in combination with caffeine in 85% of missions evaluated. Pilots ingested their first dose of stimulant (caffeine or gel-dex) at an average time of 5.0 (± 2.06) hours into the mission. Second doses of stimulants occurred on average at 7.2 (± 0.94) hours.

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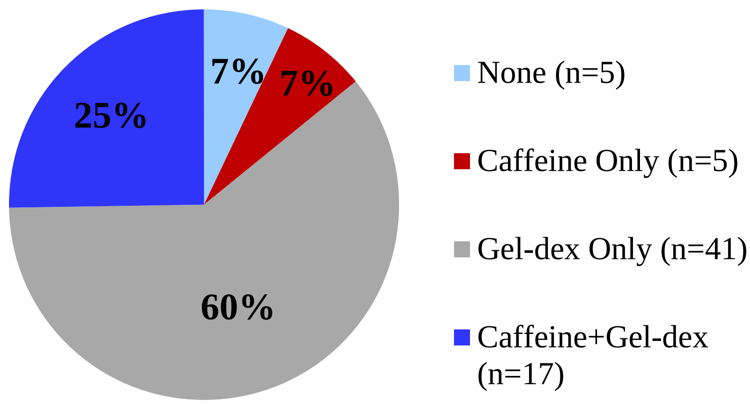

Figure 2. Countermeasure Usage in U-2 Missions

Pilots reported how each countermeasure type subjectively affected their alertness, as shown in Figure 3. Subjective effectiveness ratings were made on a 0-10 scale, with 0 being "not at all" and 10 being "extremely effective." Gel-dex was rated nearly twice as effective as caffeine in affecting alertness (8.41 vs. 4.30).

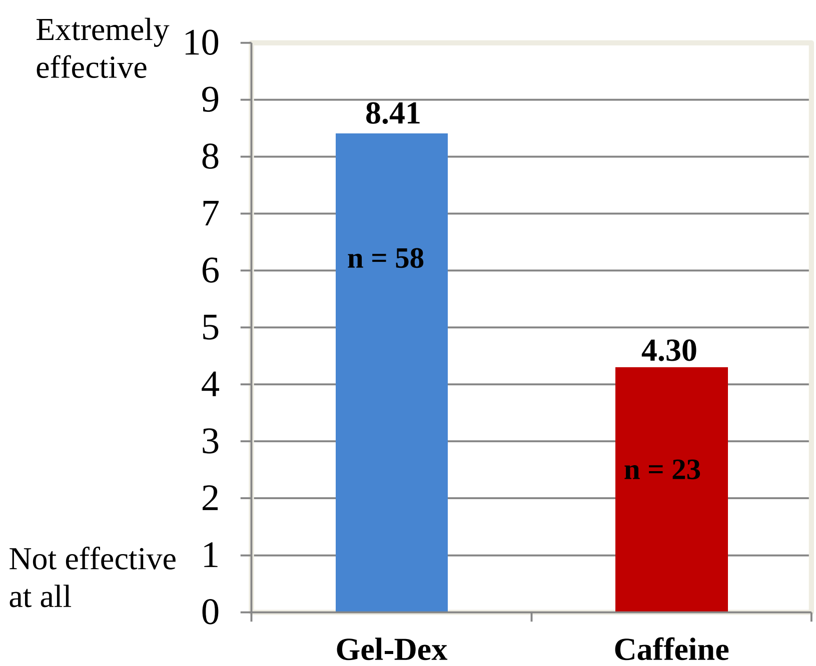

Figure 3. Average Effectiveness of Countermeasure on Alertness

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Prolonged sitting in the space-restricted U-2 cockpit causes physical discomfort in some U-2 missions. Pilots were asked to rate their degree of physical discomfort on a 0-10 scale with 0 being “not at all” and 10 being “extremely uncomfortable.” Missions in which the pilot reported unusual discomfort had a mean discomfort rating of 6.20 ± 2.17, while missions without reported unusual discomfort had a mean of 3.89 ± 1.45. Also, mean subjective mental fatigue scores were higher (6.68 ± 2.04) in missions with reported unusual discomfort than missions without (5.30 ± 1.84) as shown in Table 3.

Table 3. Subjective Physical Discomfort and Fatigue Scores

Type of Mission	Mean Discomfort Score	Mean Highest Fatigue Score
Missions with reported unusual discomfort (n=40)	6.20 ± 2.17	6.68 ± 2.04
Missions without reported unusual discomfort (n=28)	3.89 ± 1.45	5.30 ± 1.84

Following the rating of physical discomfort in the questionnaire, pilots were asked to complete the open field stating, “If experienced discomfort was unusual, what was the source of the discomfort?” Pilots reported unusual discomfort in 58.8% of missions (n=40). Figure 4 shows the body regions that were noted by the pilots as the source of physical discomfort. Multiple body regions were frequently reported as the source of physical discomfort during a single mission. Body regions affected included the back (82.5%), neck (37.5%), buttocks (25.0%), and other (12.5%).

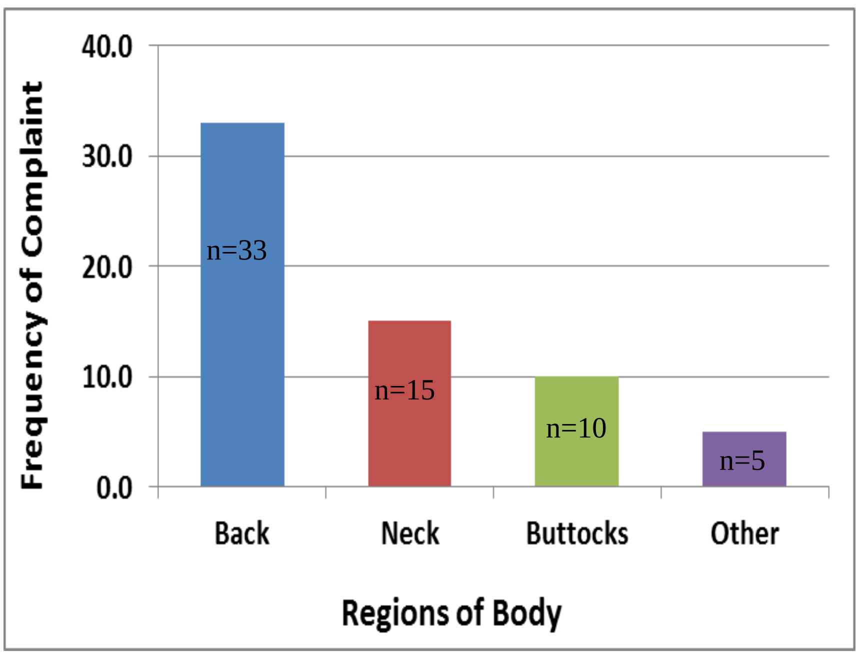

Figure 4. Body Regions Affected in Missions with Reported Unusual Discomfort

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6.0 DISCUSSION AND CONCLUSIONS

Average self-reported mental fatigue scores during the first half, second half, and descent and landing were 4.51, 4.65, and 3.82, respectively. Pilots reported less fatigue during descent and landing, likely due to their ability to intrinsically increase alertness to perform the crucial task of landing, heightened adrenaline, and/or countermeasures usage. Fatigue countermeasures were used in approximately 92% of U-2 missions evaluated in this study.

Over half of U-2 missions reported unusual physical discomfort, which may contribute to mental fatigue during prolonged missions. Additionally, the high incidence of reported back and neck pain could be a long-term health concern. Further investigation may identify methods to reduce acute and chronic effects of physical discomfort in U-2 pilots.

Because all missions captured during this data collection were of similar duration (standard deviation = 0.48 hours), comparing subjective mental fatigue levels in missions of varying duration was not possible. This was a limitation in this study. Further efforts could administer questionnaires at multiple locations with varying mission duration to evaluate the effects of mission duration on subjective fatigue. Additionally, personal identifiers were not collected in this study, so pilot-specific comparisons could not be made. Further research could involve collecting pilot identifiers so longitudinal evaluation of pilot fatigue throughout an entire deployment could be tracked. This would enable investigation into chronic fatigue levels during a deployment and comparisons between missions in the same pilot could be made.

It appears that U-2 pilots have appropriate countermeasures in place to prevent fatigue in prolonged missions. However, longer duration missions, less time between missions, and/or changes in countermeasure usage may result in higher fatigue.

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LIST OF ABBREVIATIONS AND ACRONYMS

DCS	decompression sickness
gel-dex	dextroamphetamine
LBP	low back pain
OTC	over the counter

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