



THE IMPACT OF JET LAG ON THE EXECUTIVE FUNCTIONS OF CABIN CREW

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Introduction: Executive functions play an important role in everyday human functioning, and in the case of cabin crew they are of particular significance in the workplace due to the nature of the duties performed. Shift work, typical of flight attendants, can lead to disruptions in the circadian rhythm. Crossing time zones, in turn, can trigger jet lag, defined as rapid time zone change syndrome, which negatively affects cognitive abilities, including executive functions. The aim of the study was to determine the status of selected executive functions in cabin crew members experiencing jet lag symptoms.

Methods: The study included 20 employees of Polish Airlines LOT. The group of flight attendants consisted of 12 women and 8 men, aged 20 to 35 years ($M=26.7$, $SD=4.05$). The study was quasi-experimental in design with repeated measurement and was conducted in two stages, with a three-month interval. It employed tools for assessing various aspects of executive functions: the Tower of London Test (ToL-2), the Digit Span Test (forward and backward), the Trail Making Test (TMT), and an experimental version of the Stroop Color and Word Interference Test (SCWIT). For within-group analyses (test–retest), Student's t-test for dependent samples and its non-parametric equivalent — the Wilcoxon signed-rank test — were used. Effect size was assessed using Cohen's d and the biserial correlation coefficient r_c .

Results: The results obtained demonstrated a decline in selected aspects of executive functions occurring during the experience of jet lag symptoms. With regard to planning indicators, a greater number of moves in the ToL-2 test was observed ($p<0.001$; $d=1.3$), as well as a longer task completion time ($p=0.003$; $d=0.7$). In the SCWIT task, which enables assessment of susceptibility to interference, completion time also increased ($p=0.002$; $d=0.73$), as did the number of errors ($p<0.001$; $d=0.72$). With regard to working memory, a reduction in the number of elements in forward recall sequences ($p=0.028$; $d=0.46$) as well as backward recall sequences ($p=0.004$; $r_c=0.64$) was found. In the TMT, completion time increased for both parts (TMT-A $p=0.003$; $d=0.69$ and TMT-B $p=0.003$; $d=0.7$), and the number of errors also increased (TMT-A $p=0.046$; $r_c=0.45$ and TMT-B $p=0.003$; $r_c=0.66$).

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Conclusions: The results obtained may serve as a basis for developing strategies to minimize the negative effects of jet lag, which may translate into greater safety and effectiveness of cabin crew work. Jet lag significantly affects cognitive functions, and its course depends on both individual and environmental factors. Our observations are consistent with earlier reports and confirm the need for further research in this area.

Keywords: circadian rhythm disorders, cognitive functions, cabin crew, sleep disorders, rapid time zone change syndrome

INTRODUCTION

Executive functions (EF) is a term used to describe higher-order cognitive processes that control the programming, initiation, execution, and completion of intended actions [25]. They enable the organization, regulation, and adaptation of behavior under conditions of a changing environment. Deficits in this area manifest as disorganization of actions, cognitive rigidity, and impulsivity [8,12]. Executive functions ensure effective functioning across many areas of human activity, and their manifestations are evident in the performance of everyday tasks, in social relationships, and in professional activity. One of the processes comprising executive functions is planning, defined as a conscious process of setting goals and making decisions based on available information and deliberate assessments [17]. In psychology, planning is understood as a cognitive process involving the formulation, evaluation, and selection of actions leading to the accomplishment of intended tasks, taking into account their sequence and possible consequences [12]. Another important aspect considered within EF is working memory, also referred to as operative memory, which is responsible for the short-term storage and processing of information necessary for the performance of ongoing mental operations. It is a system that allows for the active maintenance and management of information in order to carry out cognitive tasks [1,2,22]. Equally important, from the perspective of the demands placed on cabin crew, is mental flexibility, and in particular cognitive flexibility, most commonly associated with attentional shifting or interference control, and more precisely with the ability to rapidly change one's mindset depending on the situation. It encompasses processes that allow for the modification of cognitive patterns by incorporating new stimuli from the environment and adapting to changing conditions [7,12]. The last of the executive function aspects included in the study is inhibition, understood as a cognitive control process enabling

the regulation and monitoring of mental activities [23]. It allows for the suppression of unwanted impulses, maintenance of task focus, and prevention of attention being diverted by external stimuli. In the work of cabin crew, the proper and effective functioning of executive processes plays a key role in the quality and efficiency of tasks performed. The ability to make accurate decisions, plan actions, control cognitive processes, suppress distractors and impulsive responses, and flexibly adapt to the dynamic conditions of work is of fundamental importance for safety and the effective performance of professional duties.

Deficits in the area of executive functions may occur as a result of vascular episodes or traumatic brain injuries [14]. They also arise in the course of progressive neurodegenerative and demyelinating diseases of the central nervous system, or in the context of mental disorders such as bipolar affective disorder, schizophrenia, or eating disorders [3,8,14,26]. However, a decline in executive function levels may result not only from structural changes in the brain, vascular episodes, or mental disorders. Subtle, transient, yet significant deficits may also occur as a result of sleep deprivation [19], circadian rhythm disorders, and fatigue associated with shift work [24]. Cabin crew are exposed to working hours that conflict with the natural circadian cycle. In addition, they may experience disorders associated with sudden time zone changes, referred to as jet lag. This is a circadian rhythm disorder caused by the rapid crossing of at least two time zones. It manifests as insomnia, daytime sleepiness, fatigue, reduced cognitive and physical performance, gastrointestinal complaints, and general malaise [9,34].

Jet lag is defined as rapid time zone change syndrome and results from the desynchronization of the internal biological clock with the new day-night cycle [28]. Symptoms are generally more pronounced when traveling from west to east, and are further compounded by the number of time

zones crossed, sleep deprivation, inappropriate lighting, poor diet, and insufficient physical activity. Cabin crew are particularly vulnerable to experiencing jet lag symptoms due to frequent and irregular travel, insufficient time for recovery, and the burden of numerous professional duties during flight. The symptoms may lead to a decline in cognitive and emotional performance, which carries the risk of professional errors. Jet lag is generally transient, but may lead to serious disruptions in functioning, particularly when it co-occurs with other stressors. Pathophysiologically, it is associated with dysregulation of processes governed by the circadian rhythm (e.g., sleep, body temperature, hormone levels, blood pressure) as a result of changes in light exposure, meal timing, and sleep timing [18,34].

In explaining the role of sleep in the course of cognitive processes, researchers refer to the synaptic homeostasis hypothesis concerning the function of slow-wave sleep. It posits that sleep plays a key role in restoring synaptic balance in neural networks and allows for the efficient use of brain resources, which exerts a beneficial effect on memory and learning processes [31–33]. The absence of adequate recovery as a consequence of sleep deprivation or restriction leads to a decline in the efficiency and performance of cognitive processes, emotional disturbances, and a sense of fatigue [32]. Shift work and frequent changes of time zones can significantly disrupt the circadian rhythm, which negatively affects cognitive functions. The duration and nature of work also play an important role in this regard [24]. An individual variable that may contribute to greater tolerance of irregular working hours is chronotype. Chronotype, defined as the “morningness–eveningness” dimension, is an individual characteristic determining the preferred timing of activity throughout the day [30]. According to WHO research, adaptive capacity for shift work varies between individuals and depends on health status, age, and other factors [21]. It may be assumed that individuals with an evening or extreme evening chronotype exhibit better biological adaptation to shift work. On the other hand, individuals with morning preferences are also capable of adapting to this work pattern through the application of appropriate strategies [24]. In the case of cabin crew, flight direction and individual predispositions to adaptation are of considerable importance in relation to the decline in cognitive performance and should be taken into account when scheduling work rosters.

The aim of the present study was to determine how time zone changes resulting from the specific nature of cabin crew work affect executive functions in flight attendants. The main research question was: Will flight attendants show a significant decline in executive function levels as a result of jet lag following an intercontinental flight? The hypothesis was formulated that jet lag symptoms cause a significant decline in executive function levels in flight attendants. In accordance with the available literature, the phenomenon of jet lag is one of the factors disrupting cognitive functioning [35]. The level of executive functions, as higher-order cognitive functions, may also decline as a result of jet lag. It was therefore important to verify the formulated hypothesis in a group of cabin crew employees who are exposed to disorders associated with sudden time zone changes.

The topic undertaken is significant primarily with regard to safety and work efficiency in aviation. Executive functions such as planning, working memory, inhibition, and cognitive flexibility are critical in an environment where rapid response and accurate decision-making are required. A decline in their level — for example as a result of circadian rhythm disorders — may lead to errors and poorer quality of service. The work of flight attendants involves frequent time zone crossing and a shift-based lifestyle, making them particularly susceptible to jet lag and its consequences. Despite the high level of exposure to factors conducive to the occurrence of jet lag in cabin crew, this issue remains insufficiently studied, particularly in Poland. Few studies focus on describing the consequences of rapid time zone change syndrome in cabin crew employees [4,36]. Previous research has demonstrated, among other findings, that chronic jet lag has a negative impact on cortisol levels — the stress hormone — and that this effect is independent of length of service and flying experience. It was also found that prolonged exposure to elevated cortisol concentrations in the blood, which occurs primarily following transatlantic flights but also as a result of anticipation of the negative consequences of jet lag, may lead to deterioration of cognitive functioning in cabin crew [4]. The impairment was found primarily in the areas of short-term nonverbal memory, processing speed, and attentional processes [4], as well as prospective memory [36].

The limited number of studies is likely attributable to restricted access to this professional group, the

absence of nationwide research addressing the issue of rapid time zone change syndrome, and insufficient interest in this problem, despite the fact that flight attendants work under conditions requiring consistently high cognitive efficiency and performance. The topic we have undertaken is innovative in that we focused on the decline in executive function levels observed during the occurrence of jet lag. Previous studies devoted to the symptoms and effects of jet lag have most commonly focused on sleep disorders, mood disturbances, and a general decline in cognitive performance [9,16], whereas specific and higher-order cognitive processes — such as planning, inhibitory control, cognitive flexibility, and working memory — have been analyzed less frequently. The research we have undertaken may significantly enrich knowledge regarding the negative consequences of jet lag for cognitive functioning, as it focuses on the assessment of executive functions, regarded as managerial processes that mediate between knowledge (cognition) and action. Executive functions play a key role in the regulation of behavior in situations requiring rapid decision-making and adaptation to changing conditions, and therefore their examination in the context of jet lag in cabin crew members constitutes a novel and important addition to the existing body of knowledge in this area. The results of our study may be used to develop effective preventive strategies, improve flight safety, and enhance the working conditions of cabin crew.

METHODS

Participants

Twenty individuals employed as cabin crew at Polish Airlines LOT participated in the study. The group consisted of 12 women and 8 men. The age of participants ranged from 20 to 35 years ($M=26.7$; $SD=4.05$). Participation in the study was voluntary. Only those individuals who expressed a wish to participate and provided written consent were included in the study. The inclusion criterion was a minimum length of service of at least six months. Exclusion criteria were: a diagnosed endogenous sleep disorder, color blindness, psychoactive substance dependence, pre-existing malaise due to jet lag at the time of the first measurement (assessed retrospectively), or the absence of jet lag symptoms at the time of the second assessment. Among the participants, 14 held a university degree, while 6 had completed secondary education. The average number of years of education was 15.55 ($SD=2.03$). The average age at which participants

began working as cabin crew was 23.85 years ($SD=3.57$), while the average number of years worked in this profession was 3.0 ($SD=3.21$). The study group included 10 individuals with a morning chronotype and 10 individuals with an evening chronotype. The participants were characterized by good health status, which is a mandatory requirement for working as cabin crew; 17 individuals had no diagnosed chronic condition (somatic, neurological, or psychiatric), while 3 individuals had received diagnoses (depression, asthma, PCOS). Each of these individuals was under ongoing medical supervision and was taking prescribed medications. These conditions did not constitute contraindications to the performance of the profession, and therefore these individuals were not excluded from participation in the study. None of the study participants declared regular use of psychoactive substances or reported sleep disorders; however, participants reported a deterioration in sleep quality since beginning work as flight attendants. The problems reported included difficulty falling asleep, irregular sleep hours, and more frequent awakenings.

Instruments

The study employed a set of psychological tests enabling a reliable assessment of selected aspects of executive functions. The Tower of London Test — 2nd Edition (ToL-2) is a tool used to assess planning processes and also provides insight into the entire problem-solving process involving spatial tasks of increasing difficulty [5,6]. The participant's task consists of reproducing a series of 10 different arrangements of three colored balls placed on three pegs of different lengths. The balls must be arranged in accordance with the presented pattern by moving them from peg to peg in the fewest possible moves, while adhering to two rules: moving no more than one ball at a time and not exceeding the maximum number of balls on any given peg. The ToL-2 performance indicators include: planning and execution time, number of moves, accuracy, rule violations, and frequency of exceeding limits (20 moves and 2 minutes).

Working memory was assessed using the Digit Span Forward Test and the Digit Span Backward Test, drawn from the Choynowski Memory Scale [11]. Participants were required to repeat sequences of digits of increasing length, read aloud by the examiner, either in the same order or in reverse order. The test was terminated after two errors on sequences of the same length. The performance indicator for the test is the number of correctly reproduced sequences, both forward

and backward, as well as the length of the last correctly reproduced sequence in each direction.

Inhibitory process measures were derived from the performance indicators of an experimental version of the Stroop Color and Word Interference Test [12,20]. The test consists of four parts. In the first part, participants were required to read a series of words — color names (10 rows of 5 words each) — printed in black ink on a white sheet of paper. In the second part, participants were asked to name the colors of rectangles displayed on a card. In the third part, participants were required to name the font color in which individual words (denoting color names) were printed. This part therefore required a change in response mode — ignoring the word content and focusing on the font color (e.g., the word “blue” printed in red). In the fourth part, participants were instructed to read the color name if the word was underlined, and in all other cases (no underline) to name the font color in which the word was written. The final part enables assessment of both inhibitory processes and susceptibility to interference, as well as working memory and cognitive flexibility. In each part, participants were informed that the task should be performed as quickly as possible and that they were permitted to self-correct any errors they noticed. In each task, completion time, number of errors, and number of self-corrected errors were recorded.

The final instrument used was the Trail Making Test (TMT), which enables assessment of executive control and mental flexibility — specifically the ease with which smooth attentional shifts can be performed [12,15]. The test consists of two parts (A and B). In Part A, the participant’s task is to connect circles numbered from 1 to 25 as quickly and accurately as possible, in the order determined by the numbers. In Part B, the sheet again contains 25 circles, this time including the digits 1 to 13 and the letters A through L. The participant’s task is to connect these circles by alternating between digits and letters, maintaining the sequential order of each series — numerical and alphabetical.

In each part, completion time (in seconds) and accuracy were assessed.

In addition, a questionnaire developed on the basis of the diagnostic criteria for rapid time zone change syndrome contained in the International Classification of Sleep Disorders — ICSD-3 was used to assess the severity of jet lag symptoms at the time of the second measurement following a long-haul flight. The criteria comprise: insomnia and/or excessive sleepiness accompanied by a reduction in total sleep time, impaired functioning, general

malaise or somatic symptoms (e.g., gastrointestinal disturbances), and the fact that the symptoms present cannot be accounted for by other sleep disorders, somatic, neurological, or psychiatric conditions, medications used, or psychoactive substances consumed [34]. Participants were asked whether a given symptom had occurred and were required to rate its severity on a five-point scale, where 1 indicated the absence of the symptom and 5 indicated very high severity. The overall jet lag symptom severity indicator was the total score obtained by summing the participant’s responses.

Chronotype is most commonly measured using self-report methods, in which the individual specifies their preferred daily activity pattern. In the questionnaire, participants were asked to indicate their preferred times for falling asleep and waking up. Individuals who prefer to fall asleep before 11:00 PM and wake up between 6:00 and 8:00 AM were classified as having a morning chronotype, while those preferring to fall asleep at 11:00 PM or later and waking up between 8:00 and 10:00 AM or later were classified as having an evening chronotype [27].

Procedure

The research was quasi-experimental in design, employing a repeated-measures scheme comprising two stages separated by a time interval, during which the same psychological tests were administered. The adopted research design enabled comparison of results obtained in both measurements, and thereby an assessment of the impact of jet lag severity on cognitive functioning. The research was conducted between June 2024 and March 2025 in Warsaw, in locations providing suitable conditions (silence, lighting, absence of distractors, convenient access). Participants were informed of the anonymity, confidentiality of data, voluntary nature of participation, and the possibility of withdrawing at any time, and signed written informed consent to participate in the research. The research project received approval from the Research Ethics Committee of UMCS (application No. 13/2025 dated January 23, 2025, reviewed with a positive outcome).

The procedure comprised two stages, separated by a 3-month interval to limit practice effects and solution learning. Each individual session followed a standardized procedure and was preceded by completion of a questionnaire designed to collect demographic data, information on professional experience and the number of flights completed, chronotype, and general

well-being. In the second stage, which took place 24 hours after the completion of a long-haul flight, an additional questionnaire was administered containing questions about the present jet lag symptoms and details of the most recent flight. The total score derived from the experienced symptoms constituted an index of jet lag severity. The testing component employed psychological tests recognized as valid and reliable tools for the assessment of executive functions.

The research procedure stipulated that the individual tests be administered in a fixed order: Tower of London-2 Test; Digit Span Forward Test; Color-Word Interference Test; Trail Making Test; Digit Span Backward Test. The duration of the assessment session was approximately 40 minutes, which served to limit the influence of fatigue.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics (version 29.0). Basic descriptive statistics were taken into account, including mean and standard deviation. Prior to the primary analysis, the assumptions of parametric tests were verified — normality of distribution was assessed using the Shapiro-Wilk test, while homogeneity of variance was evaluated using Levene's test. For within-group analyses (test-retest), Student's t-test for dependent samples and its non-parametric equivalent — the Wilcoxon signed-rank test — were used. Effect size was assessed using Cohen's *d* and the biserial correlation coefficient *rc*. A significance level of $\alpha = 0.05$ was adopted for all analyses.

RESULTS

To verify the main research hypothesis — that jet lag symptoms cause a significant decline in executive function levels among flight attendants

— quantitative analyses were conducted based on a comparison of task performance levels assessing selected aspects of executive functions under conditions of absence and presence of jet lag symptoms. The analyses conducted are presented with reference to the individual tools used to assess the selected aspects of executive functions discussed earlier.

The analyses presented in Table 1 indicate that significant differences were obtained for the following indices: number of tasks completed in the minimum number of moves ($p < 0.001$), total move count ($p < 0.001$), and total task execution time ($p < 0.01$). The obtained effect sizes confirm the existence of strong relationships between the aforementioned ToL-2 performance indices and the presence of jet lag. When experiencing jet lag symptoms, participants completed significantly fewer tasks in the minimum number of moves, which translated into an increase in total move count at the second measurement. These results indicate a lower level of planning ability. Total task execution time also increased significantly, while no significant differences were found with respect to the time preceding the first move. It is nonetheless evident that participants experiencing jet lag exhibited a somewhat less reflective approach, as may be indicated by the shortened initiation time at the second measurement.

The results of the analyses presented in Table 2 revealed significant differences between the two measurements with respect to execution time for task 2 ($p < 0.001$), task 3 ($p < 0.01$), and task 4 ($p < 0.01$), as well as the number of errors in task 4 ($p < 0.01$) — which involved reading the color name when the word was underlined, and in all other cases (no underline) naming the font color in which the word was written — and the total number of errors across all tasks. Significant differences were also noted for execution time for

Tab. 1. Comparison of Tower of London-2 Test performance levels across both measurements (analyses using the paired-samples Student's t-test or Wilcoxon's T-test).

	Measurement #1 M(SD)	Measurement #2 M(SD)	t/Z	p	Effect size d/rc
ZMLR-TOL	4.6 (1.67)	2.55 (1.43)	5.599	<0.001	1.252
LR-TOL	23.4 (11.19)	38.55 (13.44)	-5.814	<0.001	1.300
CI-TOL	43.75 (20.41)	38.15 (15.32)	1.154	0.131	---
CW-TOL	207.00 (64.03)	245.03 (66.28)	-3.151	0.003	0.705
PLC-TOL	0.3 (0.57)	0.5 (0.95)	-1.127	0.260	---
ZR-TOL	0.2 (0.41)	0.2 (0.52)	0.000	1.000	---

Annotation: ZMLR-TOL – Number of tasks completed in the minimum number of moves, LR-TOL – Total move count, CI-TOL – Total initiation time (in seconds), CW-TOL – Total execution time, PLC-TOL – Number of time limit violations, ZR-TOL – Number of rule violations.

--- no significance.

Bold results refer to nonparametric tests.

Tab. 2. Comparison of Color-Word Interference Test performance levels across both measurements (analyses using the paired-samples Student's t-test or Wilcoxon's T-test).

	Measurement #1 M(SD)	Measurement #2 M(SD)	t/Z	p	Effect size d/rc
C1-TNIZ	21.75 (3.06)	24.9 (2.71)	-3.323	<0.001	0.74
C2-TNIZ	29.45 (3.19)	32.5 (3.69)	-4.133	<0.001	0.924
C3-TNIZ	50.4 (10.99)	56.25 (13.43)	-3.071	0.003	0.687
C4-TNIZ	59.15 (10.71)	68.70 (17.05)	-3.252	0.002	0.727
B1-TNIZ	---	0.10 (0.45)	---	---	---
B2-TNIZ	0.15 (0.37)	0.70 (0.87)	-2.636	0.008	0.59
B3-TNIZ	0.35 (0.59)	1.5 (1.1)	-3.122	0.002	0.74
B4-TNIZ	2.15 (1.46)	3.4 (2.39)	-3.206	0.002	0.717
BSUM-TNIZ	2.65 (1.73)	5.7 (2.94)	-5.860	<0.001	1.310
BP1-TNIZ	---	---	---	---	---
BP2-TNIZ	0.15 (0.37)	0.65 (0.86)	-2.456	0.014	0.70
BP3-TNIZ	0.35 (0.59)	1.1 (1.12)	-2.207	0.027	0.49
BP4-TNIZ	0.85 (1.04)	1.05 (1.47)	-0.771	0.441	---
BNP1-TNIZ	---	0.1 (0.45)	---	---	---
BNP2-TNIZ	---	0.05 (0.22)	---	---	---
BNP3-TNIZ	---	0.4 (0.68)	---	---	---
BNP4-TNIZ	1.3(1.08)	2.35(2.54)	-2.024	0.043	0.45

Annotation: C1/2/3/4-TNIZ – Execution time for individual tasks, B1/2/3/4-TNIZ – Number of errors in individual tasks, BSUM-TNIZ – Total number of errors across all tasks, BP1/2/3/4-TNIZ – Number of corrected errors in individual tasks, BNP1/2/3/4-TNIZ – Number of uncorrected errors in individual tasks. --- – no data (no errors) / no significance.

Bold results refer to nonparametric tests.

Tab. 3. Comparison of Digit Span Forward Test and Digit Span Backward Test performance levels across both measurements (analyses using the paired-samples Student's t-test or Wilcoxon's T-test).

	Measurement #1 M(SD)	Measurement #2 M(SD)	t/Z	p	Effect size d/rc
LPC-CWp	6.50 (1.82)	5.85(1.76)	2.041	0.028	0.456
DOC-CWp	6.70 (1.08)	6.3(1.08)	-1.999	0.046	0.45
LPC-CWs	5.55 (1.96)	4.45(1.91)	-2.853	0.004	0.64
DOC-CWs	5.2 (1.15)	4.75(1.07)	-2.179	0.029	0.49

Annotation: LPC-CWp – Number of correctly reproduced digit sequences forward, DOC-CWp – Length of the last longest correctly reproduced digit sequence forward, LPC-CWs – Number of correctly reproduced digit sequences backward, DOC-CWs – Length of the last longest correctly reproduced digit sequence backward.

Bold results refer to nonparametric tests.

task 1 ($p < 0.001$), number of errors and corrected errors in tasks 2 and 3 ($p < 0.01$), and uncorrected errors in task 4 ($p < 0.05$). Participants performed significantly worse following the onset of jet lag: a greater number of errors occurred, attributable to difficulties in inhibition and impulse control, accuracy monitoring, and maintaining and adhering to the provided instructions. This was particularly evident in the more demanding tasks 3 and 4. Participants experiencing jet lag symptoms also required more time to complete the individual tasks. Effect size indices indicate a marked decline in cognitive efficiency in the domain of control and inhibition under the influence of jet lag.

The results of the analyses presented in Table 3 indicate that jet lag significantly affects working memory. In the case of digit span forward, the number of correctly reproduced sequences was significantly lower following the onset of jet lag ($p < 0.05$). Additionally, in tasks where the distribution of results did not meet the assumptions of parametric tests, a significant deterioration in performance was noted with respect to the length of the last correct forward sequence ($p < 0.05$), as well as the length and number of correct backward sequences ($p < 0.01$ and $p < 0.05$, respectively). Effect size measures indicate a moderate decline in working memory efficiency following the onset of jet lag symptoms.

Tab. 4. Comparison of Trail Making Test (variant A and B) performance levels across both measurements (analyses using the paired-samples Student's t-test or Wilcoxon's T-test).

	Measurement #1 M(SD)	Measurement #2 M(SD)	t/Z	p	Effect size d/rc
C1-TMT	26(9.37)	34.10(11.58)	-3.074	0.003	0.687
B1-TMT	0.05(0.22)	0.25(0.44)	-2.000	0.046	0.45
C2-TMT	52.75(14.84)	65.25(18.27)	-3.136	0.003	0.701
B2-TMT	0.10(0.31)	0.80(0.95)	-2.972	0.003	0.66

Annotation: C1-TMT – Execution time for version A, B1-TMT – Number of errors in version A, C2-TMT – Execution time for version B, B2-TMT – Number of errors in version B.

Bold results refer to nonparametric tests.

The results of the Trail Making Test analyses presented in Table 4 indicate that jet lag significantly affects execution time and the number of errors committed. Under conditions of jet lag symptom occurrence, execution time for both versions A and B was significantly longer ($p < 0.01$), and effect size measures indicate a strong relationship between slowing of performance and the presence of circadian rhythm disruption. Additionally, a significant increase in the number of errors was noted in both parts of the test (TMT-A – $p < 0.05$; TMT-B – $p < 0.01$), confirming a deterioration in accuracy, as well as in attentional shifting and cognitive flexibility. The effects were moderate but unambiguously demonstrate a decline in cognitive efficiency during jet lag.

DISCUSSION

The primary aim of the study was to determine changes in the level of individual aspects of executive functions under conditions of absence and presence of jet lag symptoms in cabin crew following intercontinental flights. The analyses conducted confirmed the main hypothesis. Jet lag symptoms cause a significant decline in executive function levels among flight attendants. In the Tower of London Test, participants required more time to initiate and complete tasks and executed a greater number of moves. The results indicate reduced capacities in the domain of planning — including the initiation and execution of purposeful action and its efficient progression. In the Color–Word Interference Test, participants experiencing jet lag symptoms committed more errors and required more time to complete the tasks. Additionally, reduced control was evident, manifested by a greater number of uncorrected errors. This points to impaired inhibition and increased susceptibility to interference, particularly in the more demanding tasks 3 and 4, which required simultaneous adherence to multiple rules. In part three, the task involved ignoring the semantic

content of words (which were color names) and naming the font color in which they were written. This part assessed the ability to inhibit the automatic reading process in favor of focusing on color. In part four, the task was more complex: participants were required to read the color name if the word was underlined, and in all other cases to name the font color in which it was written. This part assessed both interference resistance and cognitive flexibility and working memory, as it required rapid switching between two rules. The primary challenge was the continuous monitoring of whether a word was underlined and what the appropriate response should be, which placed additional demands on cognitive processes. In the Digit Span Forward and Backward tasks, participants' working memory deteriorated during jet lag. They reproduced on average fewer digit sequences, and memory span was also reduced, as indicated by the maximum length of the sequence correctly reproduced at the second measurement. In the Trail Making Test, the presence of jet lag symptoms was associated with a greater number of errors and longer execution time, particularly in part B, which required attentional shifting. This indicates a decline in cognitive flexibility and inhibitory control. The results across all tests unambiguously indicate that jet lag impairs cognitive functioning in cabin crew following intercontinental flights.

The data obtained confirm existing knowledge regarding jet lag symptoms, among which reduced cognitive efficiency is frequently reported [16]. Other studies also demonstrate that jet lag not only produces subjective symptoms but also objective changes in brain structure and functioning at the level of global networks and specific regions. One study examined the changes occurring during jet lag. It involved 22 individuals who had returned after a 6-day stay crossing 6 time zones. They underwent brain MRI scanning, blood sampling, and psychometric testing, all performed the day following their return. In addition to changes

in neural connectivity and hormone levels, the researchers noted a decline in cognitive processing efficiency and a reduction in concentration levels [37].

The literature also describes the effects of chronic jet lag occurring in aviation personnel [4]. The study involved 62 women aged 24 to 29 employed by international airlines. Participants were divided into two groups: ground staff and cabin crew. The study demonstrated that chronic jet lag has a negative impact on cortisol levels and cognitive abilities. Cabin crew members with four years of work experience showed significant cognitive deficits, including poorer performance on memory tests and longer reaction times compared to ground staff. No significant difference in results was found between the two groups with shorter tenure (1–3 years). Reaction time was also significantly slower among cabin crew with four years of work experience compared to ground staff. Cho et al. [4] demonstrated that chronic circadian rhythm disruption leads to cognitive deficits, primarily in working memory. The present study focused exclusively on the short-term effects of jet lag; however, the topic of chronic effects undoubtedly merits further longitudinal investigation.

In discussing the results obtained, reference may be made to the aforementioned synaptic homeostasis hypothesis, according to which sleep plays a key role in the efficient course of cognitive processes. This mechanism explains why sleep improves cognitive abilities and supports memory. During wakefulness, changes occur in action and resting potentials, disrupting natural synaptic balance. During sleep, homeostasis is restored [30]. Sleep not only consolidates what has been learned but also organizes memory traces, consolidates them, and prepares the brain for subsequent cognitive challenges. Numerous studies demonstrate that following sleep, individuals perform procedural tasks better and learn new motor sequences more rapidly [31]. Wakefulness strengthens synapses and enables learning but places a burden on the brain. Slow-wave sleep restores balance through synaptic downscaling, which protects against overload and consolidates the most important memories. The alternation of these states is crucial for memory, plasticity, and efficient brain function [33]. Jet lag may cause quantitative or qualitative sleep disturbances. As a consequence, full homeostasis may not be achieved during jet lag, resulting in impaired cognitive processing.

It is worth noting, however, that regardless of the measurement point — both during the first and the

second stage of the study — the flight attendants demonstrated good self-control (as evidenced by the low rate of rule violations), generally strong performance across all tests relative to the general population, suggesting a high level of cognitive functioning, and a fairly consistent work pace, as indicated by execution time measurements for individual tasks and the low number of time limit violations in both measurements.

The present study does not, by any means, exhaust the subject of the impact of jet lag symptoms on the cognitive efficiency of cabin crew. Future research would benefit from considering longitudinal studies on the effects of chronic jet lag in cabin crew, with particular emphasis on cognitive changes. An interesting area for investigation also appears to be the analysis of sleep quality and quantity in flight attendants across different flight configurations (route length, direction of time zone change), as well as the inclusion of individual factors (e.g., chronotype) and extra-individual factors in analyses of cognitive functioning in cabin crew experiencing jet lag symptoms. When considering the mechanisms underlying cognitive impairment, it would be of interest to verify the synaptic homeostasis hypothesis by examining the extent to which disrupted sleep during jet lag (sleep parameters) affects memory consolidation and synaptic plasticity processes.

Studies verifying the effectiveness of preventive interventions directed at cabin crew would also be of value. Establishing the degree to which modification of work schedules, extension of rest periods between flights, sleep hygiene support programs, or compensatory techniques (e.g., short naps, light exposure) can mitigate the negative consequences of jet lag for the cognitive functioning of cabin crew.

Research findings in this area may help inform the development of recommendations for cabin crew, enhancing flight safety and work efficiency — for example, through the extension of rest periods between flights and emphasis on the importance of appropriate physical preparation and recovery.

The study was subject to certain limitations. The sample size was, above all, small. For this reason, a homogeneous group was deliberately selected, comprising individuals in early adulthood with short to moderate work experience. This precludes generalization of the results to the entire population; however, the inclusion of older individuals with longer professional experience could reveal greater impairment of executive functions, as tolerance of jet lag symptoms declines with age and long-term shift

work is associated with neurobiological changes relevant to cognitive functioning. The inclusion of older participants would also constitute an additional source of variability in the results. It is well established that aging is associated with a decline in executive functions in the domains of reaction time, inhibition, attentional shifting, and susceptibility to interference [10,13]. Incorporating age as a factor in the analyses would necessitate a substantial increase in sample size. Additionally, the measurement time point (24 hours after the intercontinental flight) may have been associated with the influence of additional factors — such as fatigue, sleep deprivation, or workload — which could have co-occurred with jet lag symptoms and affected executive function levels. Age as a significant moderator was also not analyzed. It is a relevant factor influencing both executive functioning and circadian rhythm regulation. The literature indicates that aging is associated with changes in sleep architecture, circadian rhythm amplitude, and susceptibility to circadian desynchronization [29]. The present study did not conduct moderation analyses incorporating age as a potential moderating factor in the relationship between jet lag and executive function levels, due to insufficient sample size. This means it cannot be ruled out that the observed effect would differ across age groups, which limits the precision of interpretation of the results. A further limitation was the subjective assessment of jet lag symptom severity. No objective markers of circadian phase were used, such as the dim-light melatonin onset (DLMO) or hormonal assays (e.g., cortisol). The absence of such data limits the ability to unambiguously determine the degree of actual circadian desynchronization and to distinguish the effects of jet lag from those of general fatigue or sleep deprivation.

Although a number of variables were controlled for in the original design, they were not included in the in-depth analyses due to the limited statistical power of the study. Analyzing their influence would require a larger sample size, allowing for reliable modeling of relationships and avoidance of error risk. Consequently, their exclusion should be treated as an interpretive limitation of the present study. An interesting direction for future research would be a multivariate analysis incorporating, among other factors, flight duration and direction, length of stay and activities undertaken during it, as well as their influence on jet lag symptom severity and executive function levels. It should

also be noted that despite attempts to identify causal relationships, it is possible that the analyzed relationships are correlational in nature, which indicates the advisability of restricting future analyses to correlations between variables.

CONCLUSIONS

In summary, the results of the conducted study indicate that jet lag significantly affects the level of cognitive functioning. The findings are consistent with the literature and underscore the importance of accounting for the effects of jet lag, particularly in the work of aviation personnel, whose performance has direct implications for passenger safety. The data obtained indicate significant impairment of individual aspects of executive functions during jet lag:

1. In the domain of planning, slower initiation and execution of tasks were found, along with a reduced ability to initiate and carry out goal-directed actions.
2. Impaired inhibition of automatic responses and increased susceptibility to interference were demonstrated, particularly evident in tasks requiring simultaneous adherence to multiple rules.
3. In the domains of cognitive flexibility and working memory, difficulties in switching between rules were found, along with a reduced working memory span, limited capacity for rapid adaptation, and a decline in auditory working memory.
4. Problems in the domains of concentration, attentional shifting, and cognitive flexibility were revealed.

The weakening of cognitive processes occurring in the course of jet lag may have significant implications for the work of cabin crew. Difficulties in rapid decision-making and action planning in situations requiring immediate response may increase the risk of errors in the execution of safety procedures, particularly under time pressure. Limited capacity for flexible responses in non-standard situations (e.g., equipment failures, sudden passenger medical events), impaired working memory, and reduced concentration may hinder effective communication and coordination with other crew members; additionally, a decline in interference resistance may lead to difficulties in adhering to complex procedures, especially when multiple concurrent stimuli are present (e.g., noise, stress, passenger pressure).

AUTHORS' DECLARATION

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