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Circadian Rhythm and Its Effect on The Performance of Technical Services Engineers

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Abstract - This study examines the influence of circadian rhythm on the physical and mental performance of Technical Services Engineers at Lufthansa Technik Philippines. Unlike flight crews and mechanics with regulated schedules, these engineers often work irregular shifts, including afternoons and nights, potentially disrupting biological cycles. Using a cross-sectional design, data on body temperature, sleep duration, work hours, and shift schedules were collected to assess circadian rhythm. Physical performance was measured via grip strength, and mental performance through a validated aptitude test. Results indicate that individual circadian peaks, reflected by body temperature, align with optimal performance, though no significant predictive relationship was found across grouped variables. However, notable performance differences emerged between minimum and maximum temperature conditions, suggesting that synchronizing work schedules with circadian peaks may improve efficiency. Recommendations include personalized scheduling, strategic rest during circadian lows, and further research with larger samples and expanded performance metrics to enhance fatigue risk management in aviation maintenance.

Index Terms- Aviation maintenance, circadian rhythm, fatigue risk management, performance optimization, shift work, technical services engineers.

I. INTRODUCTION

The aviation industry operates continuously, 24 hours a day, 365 days a year, with minimal downtime to sustain global connectivity and economic activity. This operational demand necessitates workforce allocation across multiple shifts—morning, afternoon, and overnight—creating unconventional work patterns that often disrupt the body's circadian rhythm. Circadian rhythm, the internal biological clock regulating sleep-wake cycles and physiological processes, plays a critical role in maintaining optimal physical and cognitive performance. Disruptions to this rhythm have been linked to fatigue, reduced alertness, and increased risk of errors, posing significant challenges in safety-critical environments such as aviation maintenance.

Aircraft maintenance and repair organizations are central to ensuring airworthiness and compliance with stringent safety standards. These operations require precise coordination of resources, timely execution of tasks, and effective management of human performance. However, rotating shifts and night work—common in maintenance to minimize flight disruptions—introduce fatigue-related risks that can compromise efficiency and safety. As aviation technology advances, human labor remains the most significant cost and primary source of error, underscoring the importance of addressing human factors in maintenance operations.

Previous research highlights the adverse effects of circadian misalignment, including impaired concentration, diminished working memory, and increased susceptibility to health issues such as insomnia and metabolic disorders. In aviation, these effects are particularly concerning during night shifts, which are associated with the greatest circadian disruption. While flight crews and mechanics are subject to regulated duty time limitations, Technical Services Engineers (TSEs)—who play a vital role in maintenance planning and oversight—often work irregular schedules with less stringent controls. This gap raises questions about the potential impact of circadian rhythm on their performance and, by extension, on overall maintenance safety.

This study investigates the relationship between circadian rhythm and the physical and mental performance of TSEs at Lufthansa Technik Philippines. By analyzing physiological indicators such as body temperature alongside performance metrics, the research aims to provide evidence-based insights for optimizing work schedules. Findings may inform fatigue risk management strategies and support the development of policies on duty time, rest requirements, and personalized scheduling, ultimately enhancing safety and operational efficiency in aviation maintenance

II. BACKGROUND

Circadian rhythm plays a critical role in regulating physiological and cognitive functions. In the aviation industry, Technical Services Engineers (TSEs) often work irregular shifts, unlike flight crews and mechanics whose schedules are strictly regulated. This irregularity may disrupt biological cycles, potentially affecting performance and safety.

III. STATEMENT OF THE PROBLEM

1.What is the profile of the participants in terms of:
1.1 Age;
1.2 Sex;
1.3 Position?
2. What are the Circadian Rhythm of the participants in terms of:
2.1 Body Temperature;
2.2 Number of Hours of Sleep per day;
2.3 Number of Hours of Work per day; and
2.4 Shift Schedule?
3. What is the effect of the circadian rhythm in the physical performance of the Technical Services Engineers?
4. What significant relationship between the physical performance of the Technical Services Engineers when grouped according to their circadian rhythm?
5. What is the effect of the circadian rhythm in the mental performance of the Technical Services Engineers?
6. What is the significant relationship between the mental performance of the Technical Services Engineers when grouped according to their circadian rhythm?
7. What recommendations may be provided on the work shift based on the results of the study?

IV. RESEARCH DESIGN AND METHODOLOGY

Methods - This study employed a cross-sectional research design, collecting data from individuals working different shifts at a single point in time. This approach was chosen for its efficiency in describing population characteristics and examining potential relationships between variables.

Data collection involved diagnostic procedures that measured participants' temperature, hours of sleep, hours of work, shift schedule, and physical and mental performance. These variables were analyzed to determine each participant's circadian rhythm and its influence on their performance.

Temperature readings were recorded hourly during work hours over a four-day period to identify each participant's highest and lowest temperature points. On the fifth day, participants completed physical and mental performance tests at these identified peak and low temperature times. The resulting data were quantitatively analyzed to address the study's research questions.

Participants - The study's participants consisted exclusively of Technical Services Engineers from Lufthansa Technik Philippines. Of the 30 engineers employed in this department, all were invited to take part to strengthen the validity of the findings. A total of 24 participants agreed, comprising 15 from the morning shift, 5 from the afternoon shift, and 4 from the evening shift.

Each participant received an invitation letter explaining that involvement in the study was voluntary and that they could withdraw at any time. Basic demographic information, including age and gender, was recorded at the start of the procedure. The experimental process was explained thoroughly to all participants prior to data collection.

Instruments - The study employed several tools and instruments to collect the necessary data:

a. Information Sheet - An information sheet was used to record participant demographics, including name, age, gender, and position. It also served as the data sheet for variables related to circadian rhythm, such as body temperature, sleep duration, work duration, shift schedule, grip strength, and mental aptitude scores.

b. Thermometer - An ear thermometer was utilized to measure participants' body temperature, a key indicator of circadian rhythm. Temperatures were recorded hourly throughout each participant's work shift over a four-day period. The identified peak and lowest temperature points determined when physical and mental performance tests would be administered.

c. Hand Grip Dynamometer - A hand grip dynamometer measured grip strength, representing the participants' physical performance. Measurements were taken during each individual's highest and lowest temperature periods. Results

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were expressed in pounds (lbs) and kept confidential to prevent bias or comparison among participants.

d. Mental Aptitude Test - A validated mental aptitude test, adapted from an established online source and reviewed by a professional psychometrician, was used to assess cognitive performance. The test consisted of 15 questions with a 30-minute time limit. Both score and completion time were recorded. Participants completed the test during their highest and lowest temperature periods to compare mental performance across circadian phases.

Staistical Treatment - After completing all tests, the researchers tabulated the collected data on temperature, physical performance, and mental performance, and presented them using various statistical and graphical methods.

Frequency and Percentage - Frequency counts and percentage distributions were used to describe the number of participants in each shift group.

Graphical Presentation of Circadian Rhythm - Circadian rhythm patterns were illustrated through graphs plotting time of day (X-axis) against body temperature (Y-axis). Separate graphs were created for the morning, afternoon, and night shifts. To highlight variations among participants, additional graphs categorized individuals based on sleep duration and work duration.

Pearson-r Correlation and Linear Regression - Pearson's r was employed to examine the relationship between circadian rhythm (represented by body temperature) and physical performance (grip strength in pounds). This analysis determined the strength and direction of the relationship. Linear regression was also conducted to model the relationship between time of task (independent variable) and grip strength (dependent variable), identifying performance fluctuations throughout the circadian cycle. The regression used the equation $y = a + bx$, where y is grip strength, x is temperature, b is the slope, and a is the intercept.

One-Way ANOVA and T-Test - One-way ANOVA was applied to identify significant differences in grip strength across groups categorized by sleep duration (6, 7, or 8 hours) and by shift schedule (morning, afternoon, night), under both minimum and maximum temperature conditions. A paired, two-tailed t-test was used to compare grip strengths of participants working 7–8 hours versus those working 8–9 hours. Hypotheses were evaluated by comparing the calculated t-value with the critical t-value or by assessing significance through p-values, with $p > 0.05$ indicating acceptance of the null hypothesis.

V. RESULTS:

1. Demographic Profile of Participants - The participant group consisted mainly of young Technical Services Engineers, with 62.5% aged 24–29. Males dominated the sample at 79.17%, and 54.17% were junior engineers, indicating a relatively young and early-career workforce.

2. Circadian Rhythm of Participants

2.1 Body Temperature - Body temperature was used as the primary indicator of circadian rhythm. Morning-shift participants reached their peak temperatures (97.9–98.5°F) between 7:00–15:00. Afternoon-shift participants peaked (98.125–98.5°F) between 14:00–18:00, while night-shift participants reached their maximum temperatures (97.4–98.125°F) between 04:00–05:00. These patterns reflect shift-aligned circadian cycles.

2.2 Hours of Sleep - Participants sleeping 7–8 hours had slightly higher mean temperatures (97.8163°F) than those with 6 hours of sleep (97.7944°F), suggesting better circadian regulation with adequate sleep duration.

2.3 Hours of Work - Participants working 8–9 hours recorded slightly higher mean temperatures (97.85179°F) than those working 7–8 hours (97.82669°F). However, differences were minimal, indicating that work duration does not significantly influence circadian rhythm.

2.4 Shift Schedule - Morning and afternoon shift workers recorded higher maximum temperatures (98.5°F) than night-shift workers (98.125°F). Peak temperatures aligned with work schedules: mid-day for morning shift, early shift hours for afternoon shift, and late shift hours for night shift.

3. Effect of Circadian Rhythm on Physical Performance - Pearson correlation showed a weak and statistically insignificant relationship between circadian rhythm and grip strength (minimum temperature: $r = 0.025$, $p = 0.908$; maximum temperature: $r = 0.197$, $p = 0.356$). However, paired t-tests revealed a significant difference in grip

strength between minimum and maximum temperature conditions ($t = -11.23$, $p < 0.001$), indicating that individuals perform better physically at their personal circadian peaks, even if group-wide correlations were weak.

4. Physical Performance Across Circadian Rhythm Groups

Sleep Duration: No significant differences in grip strength across 6-, 7-, and 8-hour sleep groups under both minimum and maximum temperature conditions ($p > 0.05$). Individual variability limited group-level significance.

Work Duration: No significant difference in grip strength between 7–8 and 8–9 hour work groups at minimum temperature ($p = 0.064$). A statistically significant difference emerged at maximum temperature ($p = 0.035$), though the small sample size makes this result marginal.

Shift Schedule: Significant differences in grip strength were found across morning, afternoon, and night shifts at both minimum ($p = 0.034$) and maximum ($p = 0.0099$) temperature conditions, indicating that shift timing influences physical performance patterns.

5. Effect of Circadian Rhythm on Mental Performance - Circadian rhythm showed weak and statistically insignificant correlations with mental aptitude scores (minimum temperature: $r = 0.004$, $p = 0.642$; maximum temperature: $r = 0.101$, $p = 0.642$). However, a significant difference was found between minimum and maximum temperature conditions ($t = -2.78$, $p < 0.016$), suggesting that mental performance improves during an individual's circadian peak.

6. Mental Performance Across Circadian Rhythm Groups

Sleep Duration: No significant differences in mental aptitude scores across 6-, 7-, and 8-hour sleep groups under both temperature conditions ($p > 0.05$).

Work Duration: No significant differences between 7–8 and 8–9 hour work groups at either temperature condition ($p > 0.05$).

Shift Schedule: No significant differences across morning, afternoon, and night shifts under minimum ($p = 0.648$) or maximum ($p = 0.365$) temperature conditions.

Overall, the findings indicate that while circadian rhythm significantly affects individual physical and mental performance at their personal peak versus low points, group-level differences across sleep duration, work duration, and shift schedule are mostly insignificant, with the exception of physical performance differences across shift schedules.

VI. CONCLUSION

This study examined the circadian rhythms of Technical Services Engineers and assessed how these rhythms influence their physical and mental performance. The results generated insights into identifying individual circadian patterns and how these may be used to optimize shift scheduling.

Participant Demographics - The majority of participants were 24–29 years old, predominantly male, and largely junior engineers, indicating a young and early-career workforce.

Circadian Rhythm Patterns - Body temperature served as the primary indicator of circadian rhythm, revealing natural peaks and dips associated with fluctuating performance levels.

Sleep Duration: Participants with 7–8 hours of sleep demonstrated better performance compared to those with only 6 hours.

Work Duration: Those working 8–9 hours exhibited slightly better performance than those working 7–8 hours.

Shift Schedule: Morning and night-shift workers showed relatively better performance compared to afternoon-shift workers.

Effect on Physical Performance - Circadian rhythm showed a positive effect on physical performance, as individuals performed better during their temperature peaks.

Group Comparison – Physical Performance, when participants were grouped according to circadian-related factors (sleep duration, work duration, and shift), no significant differences were found in physical performance across groups.

Effect on Mental Performance - Circadian rhythm also positively influenced mental performance, with participants performing better during their personal circadian peak times.

Group Comparison – Mental Performance, similar to physical performance, the mental performance of participants showed no significant differences when grouped by circadian-related factors.

Overall, the study highlights that circadian rhythm significantly affects individual performance but does not produce strong group-level differences across sleep duration, work hours, or shift schedules.

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