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Shift-Based Differences in Hemoglobin Levels of Female Factory Workers in Gresik

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ABSTRACT

Introduction: Work shifts, which can include morning, afternoon, or night shifts, are a system where employees are expected to carry out their responsibilities outside of regular business hours. This system may affect sleep patterns and circadian rhythms, which can result in fatigue and poor performance. Levels of haemoglobin. **Materials and Methods:** This study aims to determine the differences in haemoglobin levels between female employees working morning, evening, and night shifts at Gresik-area industries. This study uses a cross-sectional design and the observational analytical approach. Purposive sampling was used to select 35 female employees in total. After every work shift, haemoglobin levels were measured using the Point of Care Testing (POCT) method. The Two-Way ANOVA test was used to look at how the average haemoglobin levels varied between shift groups. **Results:** The results showed that the average haemoglobin concentration was 13,0 g/dL in the morning, 12,7 g/dL in the afternoon, and 12.3 g/dL in the night shift. The results of the Two-Way ANOVA test showed a significant change in haemoglobin levels across shifts, with a p-value of 0.000 ($p<0.05$). **Conclusion:** According to the study's findings, female employees haemoglobin levels significantly throughout the morning, evening, and night shifts, with the lowest levels seen during night shifts.

Keywords: Haemoglobin; Work Shifts, Female Workforce; Circadian Rhythm; Point-Of-Care Testing

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INTRODUCTION

Shift work is a scheduling system that deviates from traditional daytime hours by segmenting work into multiple shifts, including morning, afternoon, and night shifts. This system enables companies to function continuously for 24 hours to optimize productivity and efficiency [1]. Nevertheless, shift work, particularly nocturnal shifts, disrupts employees' intrinsic circadian rhythms, resulting in sleep disturbances, fatigue, and an array of health issues.

The circadian rhythm is a biological cycle that governs various physiological processes, such as sleep-wake patterns and hormone secretion. Disruption of this rhythm can diminish concentration, hinder work performance and impact physiological functions such as erythropoiesis, the production of red blood cells [2].

As a result, shift workers face a heightened risk of anemia, a condition defined by diminished hemoglobin levels that impair oxygen transport to bodily tissues [3].

Female shift workers exhibit a heightened vulnerability to sleep disorders owing to intricate hormonal fluctuations across various life stages, which subsequently impact sleep quality [4]. Sleep disturbances can disrupt erythropoiesis, leading to reduced red blood cell counts and hemoglobin levels. The discordance between work schedules and biological rhythms affects the production of melatonin and cortisol, hormones essential for regulating blood cell function and metabolism [5,6].

Moreover, physical activity during shift work may induce intravascular hemolysis, resulting in the destruction of red blood cells and a decrease in hemoglobin levels [7]. This condition is intensified by oxidative stress resulting from sleep disruption and circadian misalignment, further compromising red blood cell integrity and leading to anemia symptoms, including fatigue and diminished productivity.

Although there is increasing evidence connecting shift work to hematological health, research specifically examining hemoglobin levels in female industrial workers is scarce. This disparity is noteworthy given the distinct physiological susceptibilities of female employees and the rising prevalence of women in shift work.

This study seeks to examine the variations in hemoglobin levels among female employees working morning, afternoon, and night shifts at a factory in Gresik. The findings are anticipated to yield significant insights into the effects of shift work on the hematological health of female employees and assist in formulating workplace health policies designed to enhance worker wellbeing.

MATERIALS AND METHODS

Research participants

This observational analytical study utilized a cross-sectional design to investigate variations in hemoglobin levels among female employees across three work shifts. The research was carried out at PT GarudaFood Putra Putri Jaya in Gresik from March to April 2025. The study population consisted of female employees working in a three-shift system. Using a purposive sampling technique, 35 female workers were selected from the total population.

The inclusion criteria included: females aged 19-59 years; at least one year of employment in a rotating three-shift system (morning: 06:00-14:00, afternoon: 14:00-22:00, night: 22:00-06:00); no history of anemia; willingness to participate; and no consumption of iron supplements. The exclusion criteria encompassed pregnancy, acute illness during the study duration, termination of employment, and menstruation during the measurement intervals.

Research procedure

The study utilized a repeated-measures design with methodical data collection over three phases. Phase I (pre-analytical) encompassed participant recruitment, eligibility assessment, and the procurement of informed consent through a purposive sampling method. Phase II (analytical) involved standardized hemoglobin assessments performed 30 minutes post-shift rotation completion, with a minimum interval of 24 hours between measurements to guarantee physiological recovery. Phase III (post-analytical) encompassed result documentation, data verification, and database entry accompanied by quality control assessments.

Each participant had their hemoglobin measured after completing morning, afternoon, and night shifts in accordance with their standard work rotation schedule. Measurements were standardized across environmental conditions and temporal factors to reduce confounding variables.

Instrument

This observational analytical study utilized a cross-sectional design to investigate variations in hemoglobin levels among female employees across three work shifts. The research was carried out at PT Garuda Food Putra Putri Jaya in Gresik from March to April 2025. The study population consisted of female employees working in a three-shift system. Using a purposive sampling technique, 35 female workers were selected from the total population.

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Data analysis

Data processing employed a systematic four-stage approach: editing for completeness and consistency verification; coding with standardized participant identifiers and variable formatting; processing through double data entry into SPSS version 28,0 (IBM Corporation, Armonk, NY) with automated range and logic checks; and cleaning through outlier identification and missing value assessment.

Statistical analysis followed a hierarchical decision tree based on data distribution characteristics. Normality assessment utilized Shapiro-Wilk test ($n < 50$) supplemented by Q-Q plot visual inspection. For normally distributed data meeting sphericity assumptions (Mauchly's test), one-way repeated measures ANOVA was performed with Bonferroni correction for multiple comparisons. Non-parametric data were analyzed using Friedman's test for related samples with Wilcoxon signed-rank tests for pairwise comparisons.

Statistical significance was established at $\alpha = 0{,}05$ using two-tailed testing. Effect sizes were quantified using partial eta-squared (η^2p) for parametric tests. The null hypothesis (H_0) assumed no significant difference in mean hemoglobin concentrations across shift conditions ($\mu_1 = \mu_2 = \mu_3$), while the alternative hypothesis (H_1) predicted significant differences between at least one pair of shift conditions.

RESULTS AND DISCUSSION

Participant Characteristics

This research encompassed 35 female This research encompassed 35 female employees from PT Garuda Food Putra Putri Jaya Tbk, situated in Krikilan Village, Driyorejo District, Gresik Regency, East Java. All participants operated in rotating shifts (morning, afternoon, and night) and exhibited no history of anemia (100%). The demographic characteristics indicated diverse sleep quality patterns, with 42.86% exhibiting moderate sleep quality, 40,00% demonstrating good sleep quality, and 17,14% reflecting poor sleep quality. The consumption of iron-rich foods was primarily low, with 51,43% of individuals consuming these foods only 1-2 times per week, and 22.86% rarely consuming them. A majority of participants (71,43%) reported experiencing intermittent fatigue following work.

Hemoglobin Concentrations by Work Shift

Table 1 presents the hemoglobin level measurements across different work shifts, showing clear variations in mean values and distributions.

Table 1. Hemoglobin levels by work shift

Shift	Mean (g/dL)	SD	Min-Max (g/dL)	Normal (%)Below	Abnormal (%) Below
Morning	13,023	0,3557	12,2-13,6	100,0	0,0
Afternoon	12,754	0,4408	11,2-13,6	97,14	2,86
Night	12,329	0,3793	11,0-13,0	91,43	8,57

The morning shift demonstrated the highest mean hemoglobin level (13,023 g/dL), with all participants maintaining normal levels (⩾12,1 g/dL). A progressive decline was observed in afternoon (12,754 g/dL) and night shifts (12,329 g/dL), with increasing percentages of participants showing below-normal hemoglobin levels.
Data normality was confirmed using the Kolmogorov-Smirnov test ($p > 0{,}05$ for all groups: morning $p = 0{,}098$, afternoon $p = 0{,}080$, night $p = 0{,}200$). Homogeneity of variance was established using Levene's test ($p = 0{,}530$). Two-way ANOVA revealed significant differences between shift groups ($p = 0{,}000$).

Table 2. Post Hoc analysis results (Tukey HSD)

Comparison	p-value	Significance
Morning vs Afternoon	0,014	Significant
Morning vs Night	0,000	Significant
Afternoon vs Night	0,000	Significant

All pairwise comparisons showed statistically significant differences, indicating that hemoglobin levels vary significantly across all three work shifts.

Circadian Disruption and Hematological Changes

The results indicate a distinct trend of decreasing hemoglobin levels from morning to night shifts, corroborating the hypothesis that shift work patterns substantially affect hematological parameters. This gradual decline corresponds with the theory of circadian rhythm disruption, indicating that night shift work disrupts natural biological processes.

The optimal hemoglobin levels for the morning shift (13,023 g/dL) indicate the body's natural circadian alignment, wherein physiological processes such as erythropoiesis operate at peak efficiency. This finding aligns with the work of Morris *et al.* (2017), which demonstrated that alignment of circadian rhythms enhances erythropoietin secretion and promotes red blood cell production. The normal hemoglobin rate of 100% in morning shift workers suggests that daytime employment promotes optimal hematological function [8].

The afternoon shift demonstrated intermediate results (12,754 g/dL), which are 2,86% below normal levels. The timing of nighttime sleep opportunities may disrupt melatonin production, which generally commences around 9 PM. This hormonal disruption impacts cellular regeneration processes, such as hemoglobin synthesis [9].

The most notable effect was observed in night shift workers, with an average level of 12,329 g/dL, where 8,57% exhibited below-normal levels. This finding corroborates earlier research by Alves *et al*. (2024), which indicated that sleep disturbances and inadequate dietary patterns among night workers result in reduced hemoglobin levels [4]. The alteration of natural light-dark cycles affects melatonin production and erythropoietin regulation, both essential for red blood cell formation.

Sleep Disturbance and Erythropoiesis

The prevalence of moderate (42,86%) and poor (17,14%) sleep quality among participants is directly associated with variations in hemoglobin levels. This finding corroborates the research by Ariani *et al*. (2022), which indicated that 49 out of 96 blood donor candidates exhibiting poor sleep quality had reduced hemoglobin levels [10]. Sleep deprivation elevates free radical levels in the bloodstream, impairing liver function during essential overnight detoxification processes [11].

Insufficient sleep duration (less than 8 hours) negatively affects erythropoiesis, as critical hematological processes take place during deep sleep stages. Tirtana (2015) noted that inadequate sleep interferes with hemoglobin synthesis, resulting in suboptimal levels [12]. Circadian rhythm disruption in shift workers significantly impacts the suprachiasmatic nucleus (SCN) located in the anterior hypothalamus, which serves as the primary circadian pacemaker of the body [13].

Iron Deficiency and Occupational Factors

The consumption pattern of low iron-rich foods, with 51,43% of individuals consuming them 1-2 times weekly and 22,86% rarely, significantly contributes to the observed variations in hemoglobin levels. The deficiency in nutrition exacerbates the physiological stress associated with shift work. Rahmad (2017) established a direct correlation between reduced consumption of iron-rich foods and lower hemoglobin levels in female workers, despite adequate iron stores [14].

Poor sleep quality and inadequate iron intake synergistically contribute to hemoglobin reduction. Heme iron derived from animal sources, such as meat, liver, fish, poultry, and eggs, along with non-heme iron from plant sources like dark leafy vegetables and legumes, is crucial for effective hemoglobin synthesis. The dietary patterns observed indicate inadequate consumption of both forms of iron among the study participants [15].

Work-Related Fatigue and Physiological Stress

The documented fatigue patterns (71,43% occasional, 25,71% frequent) indicate the cumulative physiological strain associated with shift work. Prolonged muscle contraction due to production demands induces vascular compression among muscle fibers, impairing blood circulation and nutrient exchange [16]. This mechanical stress exacerbates the metabolic disturbance induced by circadian misalignment.

Sooriyaarachchi *et al*. (2023) established that circadian rhythm disruption in shift workers induces fatigue by elevating physical stress, which impacts immune system functionality and may alter hematological parameters. Chronic stress increases cortisol levels, which may inhibit red blood cell production and immune function [17].

Clinical Implications and Occupational Health

The gradual decrease in hemoglobin levels from morning to night shifts has considerable occupational health consequences. 8,57% of night shift workers with subnormal hemoglobin levels may be susceptible to occupational anemia. This discovery indicates the necessity for specialized health monitoring and intervention initiatives for shift workers, especially those on nocturnal schedules.

The Point of Care Testing (POCT) methodology employed in this study demonstrated efficacy for field-based hemoglobin evaluation, delivering instantaneous results without laboratory delays [18]. This method enables real-time health surveillance in workplace environments.

Study Limitations and Future Directions

The principal limitation of this study is the lack of a control group of non-shift workers for comparative analysis. Future research must incorporate control groups and longitudinal follow-up to evaluate enduring hematological alterations. Moreover, examining targeted dietary interventions and sleep hygiene protocols may yield effective solutions for shift workers.

The findings enhance comprehension of the impact of work schedules on hematological parameters, thereby facilitating the formulation of evidence-based occupational health policies for shift workers in manufacturing sectors. The notable disparities in all shift comparisons offer compelling evidence for the implementation of targeted health promotion strategies tailored to work schedule patterns.

CONCLUSIONS

This study seeks to ascertain the variations in hemoglobin levels among female workers according to morning, afternoon, and night shifts in factories located in the Gresik region. The analysis reveals substantial disparities in hemoglobin levels across the shift groups. Female employees on the morning shift exhibit the highest mean hemoglobin levels at 13 g/dL (range 12,2–13,6 g/dL), followed by the evening shift with an average of 12,7 g/dL (range 11,2–13,6 g/dL), while the night shift records the lowest average at 12,3 g/dL (range 11,0–13,0 g/dL). This disparity suggests that work hours influence hemoglobin levels, potentially.

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