

# Sobriety Test and Health Examination for Fatigue Assessment Among Shift Workers in a Coal Mining Company

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## Abstract

**Purpose:** This study examines physical fatigue, sleep quality, and cardiovascular health among shift-working mine operators at PT. Manggala Alam Lestari, South Sumatra, using an integrated Sobriety Test and health examination protocol.

**Research Methodology:** A descriptive cross-sectional design was applied to 50 shift-working mine operators selected through purposive sampling. Data were collected over five days using a four-component Sobriety Test, blood pressure measurement, pulse rate monitoring, and interviews on sleep duration.

**Results:** Six participants (12%) were classified as unfit based on the Sobriety Test. Four participants (8%) had abnormal blood pressure, and four (8%) showed abnormal pulse rates. Five participants (10%) reported sleeping fewer than six hours per day, and all were identified with health abnormalities or fatigue-related issues. Conversely, all participants sleeping six or more hours per day demonstrated normal cardiovascular indicators. Health abnormalities were concentrated entirely within the sleep-deprived group.

**Conclusions:** Sleep duration of less than six hours per day was consistently associated with physical fatigue and abnormal cardiovascular indicators. The combined Sobriety Test and health examination protocol is a practical tool for pre-shift fitness-for-duty screening.

**Limitations:** The study involved a small sample from a single mining operation, limiting generalizability. Potential confounding factors such as diet, stress, and physical activity were not assessed.

**Contributions:** This study provides evidence supporting an integrated fatigue screening approach for Indonesian coal mining workers and offers a low-cost model for pre-shift fitness-for-duty assessment.

**Keywords:** *Circadian Rhythm, Coal Mining, Fatigue, Fitness for Duty, Hypertension*

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## 1. Introduction

Occupational fatigue represents one of the most pervasive and consequential health hazards in the extractive industries globally. In coal mining operations characterized by continuous twenty-four-hour

production cycles, physically demanding tasks, and mandatory shift rotation systems the co-occurrence of physical exertion, circadian disruption, and sleep deprivation creates a compounding fatigue burden that substantially elevates both occupational accident risk and long-term disease incidence ([Caldwell et al., 2019](#); [Lestari et al., 2024](#)). In Indonesia, where the coal mining sector employs hundreds of thousands of workers under demanding shift conditions, fatigue-related incidents represent a critical and underaddressed occupational safety and health (OHS) challenge.

The physiological pathways linking shift work fatigue to adverse health outcomes are well-established. Shift work particularly night shift work disrupts the endogenous circadian rhythm, which governs the timing of sleep, cardiovascular function, metabolic regulation, and immune activity ([Cheng, Liu, Hu, Cheng, Karhula, & Härmä, 2021](#)). Circadian desynchrony suppresses the physiological processes that normally accompany nocturnal rest, including blood pressure dipping, heart rate reduction, and restorative sleep architecture. Consequently, shift workers who fail to achieve adequate compensatory daytime sleep experience chronically elevated sympathetic nervous system activation, which drives sustained elevations in blood pressure and pulse rate the hallmark cardiovascular precursors of hypertension ([Madeira et al., 2021](#); [Andini & Siregar, 2024](#)).

The quantitative magnitude of this cardiovascular risk is clinically significant. [Madeira et al. \(2021\)](#) reported, in a systematic review and meta-analysis of shift work studies, that night shift workers exhibited mean increases of 2.52 mmHg in systolic blood pressure and 1.76 mmHg in diastolic blood pressure compared to day workers magnitudes that, sustained over years of shift work exposure, substantially increase the risk of hypertension, coronary artery disease, and stroke. Within the Indonesian context, [Andini and Siregar \(2024\)](#) confirmed a direct association between extended working hours and hypertension incidence, with the relationship amplified by insufficient sleep duration. These findings establish a compelling scientific rationale for systematic fatigue monitoring in shift-based mining operations.

Beyond cardiovascular risk, fatigue exerts direct effects on cognitive and motor performance that are particularly consequential in mining environments. [Frone and Tidwell \(2015\)](#) demonstrated that physical and mental fatigue components are independently associated with reduced vigilance, impaired reaction time, and elevated error rates outcomes that directly translate into elevated accident probability in high-hazard operational settings. [Hidayanti and Sumaryono \(2021\)](#) found that sleep quality mediates the workload fatigue relationship in Indonesian mining workers, establishing sleep management as an actionable intervention target for mining OHS programs.

Despite the recognized importance of fatigue assessment in mining safety management, practical and validated field-deployable fatigue screening tools remain insufficiently implemented in Indonesian coal mining operations. The Sobriety Test a standardized battery of balance, coordination, and instruction-following tasks originally developed for rapid impairment screening has been proposed as an effective field-adaptable tool for physical fatigue classification ([Ramírez-Moreno, Carrillo-Tijerina, Candela-Leal, Alanis-Espinosa, Tudón-Martínez, Roman-Flores, Ramírez-Mendoza, & Lozoya-Santos, 2021](#)). When combined with physiological health examinations (blood pressure and pulse rate measurement) and sleep duration assessment, the Sobriety Test may constitute an integrated pre-shift fitness-for-duty screening protocol capable of identifying at-risk workers before they are exposed to high-hazard mining tasks.

PT. Manggala Alam Lestari is a coal mining company operating in South Sumatra, Indonesia, whose mine operator employees work in rotating shift systems with individual shifts exceeding eight hours. The company has observed recurring employee complaints of fatigue and sleep disturbance, creating an operational context in which systematic fatigue screening carries both individual health and organizational safety significance. To date, no published study has evaluated the combined Sobriety Test and health examination protocol as an integrated fatigue assessment system within an Indonesian coal mining operation.

This study addresses this gap with three objectives: (1) to characterize the prevalence and pattern of physical fatigue, abnormal cardiovascular indicators, and sleep deprivation among shift-working mine operators at PT. Manggala Alam Lestari; (2) to assess the utility of the combined Sobriety Test and dual-phase health examination protocol as an integrated pre-shift fatigue screening system; and (3) to examine the association between sleep duration and cardiovascular health parameters in this workforce. The study contributes empirical evidence supporting the implementation of systematic, standardized fatigue monitoring as a component of OHS management in the Indonesian coal mining sector. The remainder of the paper proceeds as follows: Section 2 reviews the theoretical and empirical literature on fatigue, shift work, and occupational health screening. Section 3 describes the research methodology. Section 4 presents and discusses the findings. Section 5 provides conclusions, limitations, and directions for future research.

## 2. Literature Review and Hypotheses Development

### 2.1 Occupational Fatigue: Mechanisms and Classification

Occupational fatigue is a multidimensional construct defined as a state of reduced functional capacity resulting from sustained physical or mental effort, inadequate recovery, or circadian disruption ([Frone & Tidwell, 2015](#); [Caldwell et al., 2019](#)). Three primary fatigue dimensions are recognized in the occupational health literature: physical fatigue (depletion of musculoskeletal and cardiorespiratory capacity, manifesting as reduced strength, coordination, and endurance); mental fatigue (impaired cognitive processing, reduced vigilance, and slowed reaction time); and emotional fatigue (depleted motivational and affective resources, often associated with prolonged interpersonal demands). In mining environments, physical and mental fatigue frequently co-occur and interact, as physically exhausting work simultaneously depletes cognitive resources through sustained attentional demands and psychomotor vigilance requirements.

The physiological mechanisms underlying physical fatigue in shift workers are anchored in circadian biology. The suprachiasmatic nucleus of the hypothalamus generates a circadian rhythm that coordinates the timing of virtually all physiological processes over a roughly 24-hour cycle, including the sleep-wake cycle, cortisol secretion, body temperature variation, and cardiovascular function ([Cheng, Liu, Hu, Cheng, Karhula, & Härmä, 2021](#)). Shift work particularly night shift work requires sustained wakefulness during the biological night, when the circadian system actively promotes sleep onset and reduces cognitive and physical performance capacity. Simultaneously, shift workers attempting to sleep during daylight hours do so against the circadian system's arousal drive, resulting in shorter, fragmented, and less restorative sleep compared to equivalent time-in-bed during nocturnal sleep ([Caldwell et al., 2019](#); [Madeira et al., 2021](#)).

The cumulative effect of repeated inadequate sleep is sleep debt a quantitative deficit in sleep that compounds across successive shifts and is only partially reversed by recovery sleep. Research consistently identifies a sleep duration threshold of approximately six to seven hours per night below which physiological and cognitive performance degradation accelerates ([Maharani & Nugroho, 2022](#); [Khoirunnisa, 2023](#)). Workers chronically sleeping fewer than six hours per day exhibit elevated cortisol levels, increased sympathetic nervous system tone, reduced parasympathetic modulation, and elevated inflammatory markers a physiological profile that directly predicts elevated blood pressure and pulse rate ([Andini & Siregar, 2024](#); [El Meouchy et al., 2022](#)).

### 2.2 Shift Work, Sleep Quality, and Cardiovascular Risk in Mining

The cardiovascular consequences of shift work are among the most extensively documented occupational health outcomes in the epidemiological literature. Meta-analysis of 23 studies found that shift workers and night shift workers in particular exhibit statistically and clinically significant elevations in both systolic and diastolic blood pressure relative to day workers, with the magnitude of effect increasing with longer shift work tenure. The pathophysiological mechanism operates primarily through two pathways: (1) direct sympathoadrenal activation during forced nocturnal wakefulness, which acutely elevates heart rate and blood pressure; and (2) chronic sleep deprivation-mediated endothelial dysfunction and inflammatory activation, which structurally remodels vascular reactivity

over time, producing sustained hypertension independently of the acute shift work exposure ([Cheng et al., 2021](#); [El Meouchy et al., 2022](#)).

Within the Indonesian mining context, [Hidayanti and Sumaryono \(2021\)](#) established that sleep quality mediates the workload–fatigue relationship among mining workers, confirming that the cognitive and physical capacity deficits associated with heavy workloads are substantially amplified when sleep quality is poor. [Lestari et al. \(2024\)](#) further demonstrated that work climate, workload, and occupational stress jointly predict fatigue levels, with significant downstream effects on both health outcomes and work performance. These Indonesian-specific findings underscore the relevance of sleep and fatigue management as priority OHS concerns in the national mining sector context.

### 2.3 Physical Fatigue Assessment Methods: The Sobriety Test

Occupational fatigue can be assessed through self-report instruments (e.g., the Fatigue Severity Scale, the Karolinska Sleepiness Scale), physiological monitoring (electroencephalography, actigraphy, heart rate variability), cognitive performance testing (psychomotor vigilance task), and physical performance assessment. For field deployment in industrial settings, practical constraints including equipment cost, assessment time, and required technical expertise limit the applicability of laboratory grade instruments ([Seong et al., 2022](#); [Ramírez-Moreno et al., 2021](#)).

The Sobriety Test addresses these practical constraints by providing a rapid, portable, and equipment-light assessment of physical fatigue indicators that can be administered by trained OHS personnel in any workplace setting. Originally developed for law enforcement alcohol impairment screening, the standardized field sobriety test battery has been adapted for occupational fatigue assessment based on the observation that the motor performance deficits produced by acute fatigue including balance impairment, coordination reduction, and slowed instruction processing parallel the impairments produced by alcohol intoxication ([Ramírez-Moreno et al., 2021](#)). The test's four components straight line walking, one-leg balance, single-leg body rotation, and simple instruction response assess postural stability, proprioceptive function, vestibular-motor integration, and attention-motor coordination: all dimensions that fatigue degrades.

[Ramírez-Moreno et al. \(2021\)](#) demonstrated strong agreement between biometric fatigue test results and self report fatigue scales in a pilot study, supporting the construct validity of rapid physical testing approaches. [Seong et al. \(2022\)](#) further showed that integrated fatigue measurement systems combining physical performance and physiological monitoring achieve superior fatigue classification accuracy compared to single-method assessments, providing a scientific rationale for the combined Sobriety Test plus health examination protocol adopted in the present study.

### 2.4 Prior Empirical Studies

Table 1 summarizes the most relevant prior empirical studies on occupational fatigue, shift work, sleep quality, and fatigue assessment in mining and related industrial contexts.

Table 1. Summary of Prior Studies on Shift Work Fatigue, Sleep Quality, and Fatigue Assessment

Author(s) & Year	Setting	Method	Key Finding
Caldwell et al. (2019)	Workplace fatigue review	Systematic review	Fatigue is a multidimensional occupational hazard; circadian disruption from shift work is a primary driver of cardiovascular risk and performance impairment
Frone & Tidwell (2015)	Occupational health (multi-sector)	Scale development & validation	Three-dimensional fatigue (physical, mental, emotional) requires dedicated measurement; somatic fatigue indicators correlate with accident risk
Hidayanti & Sumaryono (2021)	Coal mining workers, Indonesia	Cross-sectional survey	Sleep quality mediates the workload–fatigue relationship in mining workers; poor sleep quality independently predicts elevated fatigue scores

Author(s) & Year	Setting	Method	Key Finding
Maharani & Nugroho (2022)	Shift workers (mixed industry)	Cross-sectional	Sleep duration < 6 hours/day significantly associated with higher fatigue levels and lower work productivity; effect is dose-dependent
Madeira et al. (2021)	Shift workers (meta-analysis)	Systematic review & meta-analysis	Night shift work associated with significant increases in systolic (+2.52 mmHg) and diastolic (+1.76 mmHg) BP; hypertension risk elevated in long-term shift workers
Cheng et al. (2021)	Hospital workers, 8-year cohort	Prospective cohort	Night shift work significantly increases metabolic syndrome risk; circadian desynchrony is the primary pathophysiological mechanism linking shift work to cardiovascular risk
Andini & Siregar (2024)	Indonesian workers	Cross-sectional	Long working hours directly associated with hypertension risk; effect amplified by inadequate sleep; findings support regulatory limits on shift duration
Ramírez-Moreno et al. (2021)	Office workers, Mexico	Pilot study, biometric signals	Fast biometric-based fatigue tests show strong agreement with self-report fatigue scales; sobriety-type physical tests are valid real-time screening tools
Seong et al. (2022)	Construction workers, South Korea	Integrated fatigue measurement system	Combined physiological monitoring and physical performance testing provides superior fatigue classification accuracy compared to single-method approaches
Lestari et al. (2024)	Industrial workers, Indonesia	Cross-sectional	Work climate, workload, and stress collectively predict fatigue; improving work environment quality reduces fatigue and improves health outcomes
Present Study (2025)	Coal mining operators, PT. Manggala Alam Lestari, South Sumatra	Descriptive cross-sectional; Sobriety Test + health examination	First study to apply combined Sobriety Test and dual-phase health examination (14:00–16:00 and 02:00–06:00) in Indonesian coal mining; 12% unfit on sobriety; 8% abnormal BP and pulse; 10% sleep-deprived, all in unfit category

As Table 1 demonstrates, the scientific evidence base for the fatigue-inducing and cardiovascular consequences of shift work is well-established. However, two specific gaps are evident: (1) no prior study has evaluated the combined Sobriety Test and dual phase health examination as an integrated fatigue screening protocol in Indonesian coal mining; and (2) the specific association between sleep duration, cardiovascular indicators, and sobriety-based fatigue classification has not been examined in this occupational context. The present study addresses both gaps directly.

### 2.5 Theoretical Framework and Research Hypotheses

The theoretical framework of this study integrates three complementary constructs. First, circadian disruption theory (Cheng et al., 2021; Caldwell et al., 2019) proposes that shift work impairs physiological homeostasis through circadian misalignment, with sleep deprivation as the primary mediating mechanism. Second, allostatic load theory (McEwen & Stellar, 1993) posits that repeated exposure to physiological stressors including sleep deprivation and forced nocturnal wakefulness generates cumulative biological wear that manifests as elevated resting blood pressure, pulse rate, and inflammatory markers. Third, human performance theory (Frone & Tidwell, 2015) links fatigue-induced performance degradation to impaired motor coordination and balance the dimensions assessed by the Sobriety Test.

Two research hypotheses are proposed:

*H<sub>1</sub>*: Shift workers sleeping fewer than six hours per day will exhibit significantly higher rates of abnormal blood pressure, abnormal pulse rate, and Sobriety Test failure compared to those sleeping six or more hours per day.

*H<sub>2</sub>*: The combined Sobriety Test and health examination protocol will identify a clinically meaningful subgroup of unfit workers among mine operators, supporting its utility as a pre-shift fitness-for-duty screening tool.

### 3. Research Methodology

#### 3.1 Research Design

This study employs a descriptive cross sectional design to characterize the distribution of physical fatigue, cardiovascular health indicators, and sleep patterns among shift-working coal mine operators (Creswell & Creswell, 2018). The cross-sectional design is appropriate for establishing the prevalence of health conditions and their co-occurrence with occupational exposure characteristics at a defined point in time, and is consistent with the descriptive-categorical analytical objectives of the study. The study is explicitly observational and non-interventional: assessment was conducted under naturally occurring operational conditions without modification of participants' work schedules, activities, or health behaviors.

#### 3.2 Research Setting and Participants

The study was conducted at PT. Manggala Alam Lestari, a coal mining company operating in South Sumatra Province, Indonesia. Mine operator employees constitute the study's occupational focus: this role involves the direct operation of coal extraction and transport equipment across rotating day and night shifts, with individual shift durations exceeding eight hours. Participants were selected using purposive sampling, with two inclusion criteria: (1) currently employed as a mine operator in a shift-based work system; and (2) willingness to participate and provide informed consent. A total of 50 participants were enrolled, representing the accessible population of mine operators available for participation during the five-day data collection period. Table 2 summarizes participant characteristics.

Table 2. Participant Characteristics (n = 50)

Characteristic	n	Percentage (%)
Total participants	50	100.0
Shift type: Day shift (primary assessment: 14:00–16:00)	25	50.0
Shift type: Night shift (primary assessment: 02:00–06:00)	25	50.0
Working hours per shift: > 8 hours	50	100.0
Sleep duration: ≥ 6 hours/day	45	90.0
Sleep duration: < 6 hours/day	5	10.0

Table 2 shows that all 50 participants were mine operators working shifts exceeding eight hours per day. The sample was evenly distributed between day-shift workers (50%) and night-shift workers (50%). Most participants reported sleeping at least six hours per day (90%), while 10% reported sleeping fewer than six hours per day, indicating the presence of a sleep-deprived subgroup potentially vulnerable to fatigue-related health and performance impairment.

#### 3.3 Instruments and Measurement Procedures

##### 3.3.1 Sobriety Test Protocol

Physical fatigue was assessed using a standardized four-component Sobriety Test administered by trained OHS personnel (Dawson, Chapman, & Thomas, 2021; Williamson, Friswell, Olivier, & Grzebieta, 2023). The test battery comprised: (1) Straight-line walking (15 meters): participants walked along a marked straight line; failure was defined as stepping off the line, losing balance, or

requiring support; (2) One-leg balance (< 10 seconds): participants stood on one leg with eyes open; failure was defined as the raised foot touching the ground before 10 seconds; (3) Single-leg body rotation: participants rotated their body through 360° while standing on one leg; failure was defined as loss of balance requiring support; (4) Simple instruction response: participants responded to standardized verbal instructions (e.g., "raise your right hand," "touch your nose"); failure was defined as incorrect or delayed response beyond 3 seconds. Classification was binary: participants who failed any component were classified as "Unfit"; those passing all components were classified as "Fit." The Sobriety Test was conducted in approximately five minutes per participant ([Sargent, Lastella, Halson, & Roach, 2020](#); [Balkin, Horrey, Graeber, Czeisler, & Dinges, 2022](#)).

### *3.3.2 Health Examination*

The health examination comprised three components. Blood pressure measurement was performed using an Omron digital sphygmomanometer (Model HEM-7120), calibrated prior to the study period. Measurements were taken twice (morning and late shift periods) with the participant seated and rested for five minutes prior to measurement; the mean of two readings was recorded. Hypertension was defined as systolic blood pressure  $\geq 140$  mmHg or diastolic blood pressure  $\geq 90$  mmHg ([WHO/ISH, 2020](#)). Pulse rate was measured using a Nonin oximeter (Model 9590), providing simultaneous SpO<sub>2</sub> and pulse rate readings; abnormal pulse was defined as < 60 bpm (bradycardia) or > 100 bpm (tachycardia). Sleep duration was assessed through structured face-to-face interview, asking participants to report their typical daily sleep duration during the current shift rotation; < 6 hours per day was adopted as the threshold for sleep deprivation, consistent with the evidence-based threshold applied by [Maharani and Nugroho \(2022\)](#) and [Khoirunnisa \(2023\)](#).

### *3.4 Data Collection Procedure*

Data were collected over five consecutive working days during January, February 2025. Ten participants were assessed each day. For day shift workers, the assessment window was 14:00–16:00 WIB, corresponding to the known peak fatigue period in the final hours of the day shift. For night shift workers, the assessment window was 02:00–06:00 WIB, corresponding to the circadian nadir the period of lowest endogenous arousal and highest fatigue vulnerability ([Boivin, Boudreau, & Kosmadopoulos, 2022](#)). The selection of these assessment windows was deliberate: capturing physiological and motor performance measures at peak fatigue phases maximizes the sensitivity of the screening protocol to detect fatigue-induced impairment that might not be evident at shift commencement ([Ferguson, Vincent, Jay, & Dorrian, 2024](#); [Doğan, & Bayram, 2024](#)). Each assessment session began with the Sobriety Test (approximately 5 minutes), followed immediately by blood pressure and pulse measurement (approximately 5 minutes), and concluded with the sleep duration interview (approximately 2 minutes). Total assessment time per participant was approximately 12 minutes ([Maisey, Cattani, Devine, Lo, & Dunican, 2021](#)).

### *3.5 Ethical Considerations*

Informed consent was obtained from all participants prior to data collection, with explicit communication that participation was voluntary, data would be anonymized, and non-participation would carry no employment consequences. Research permission was granted by PT. Manggala Alam Lestari management ([World, 2020](#); [Council, 2021](#)). Participants identified as unfit during the assessment were immediately referred to the company's occupational health nurse for clinical evaluation and appropriate rest provision before continuing work duties ([Resnik, 2023](#); [Tully, Hassan, Oswald, & Ainsworth, 2021](#)).

### *3.6 Data Analysis*

Data were analyzed descriptively using frequency counts and percentage distributions, as appropriate for the categorical classification outcomes (Fit/Unfit) generated by the Sobriety Test and health examination ([Mardiatmoko, 2020](#)). Cross-tabulation of sleep duration categories (< 6 hours vs.  $\geq 6$  hours) with cardiovascular health parameters and Sobriety Test outcomes was performed to examine the co-occurrence pattern between sleep deprivation and health abnormalities. Given the descriptive and exploratory purpose of the study and the small sample size, no inferential statistical testing was

performed; effect size estimation and statistical power considerations are addressed in the limitations section.

## 4. Results and Discussions

### 4.1 Sobriety Test Results

Table 3 presents the Sobriety Test results across all four components and the overall classification.

Table 3. Sobriety Test Results by Component (n = 50)

Sobriety Test Component	Pass (Fit)	%	Fail (Unfit)	%
Straight-line walking (15 m)	44	88.0	6	12.0
One-leg balance (< 10 seconds)	44	88.0	6	12.0
Single-leg body rotation	44	88.0	6	12.0
Simple instruction response (e.g., raise hand)	44	88.0	6	12.0
Overall Sobriety Test result	44	88.0	6	12.0

Table 3 shows that 44 participants (88%) successfully completed all four Sobriety Test components and were classified as fit, while 6 participants (12%) were classified as unfit after failing all four components simultaneously. The consistent failure pattern across all test components among the unfit workers, rather than isolated failure of individual tasks, suggests systemic rather than task-specific motor impairment, consistent with the multi-domain performance degradation associated with generalized physical fatigue.

The 12% unfit prevalence rate on the Sobriety Test is clinically significant in a mining context. [Ramírez-Moreno et al. \(2021\)](#) demonstrated that physical test-based fatigue classification tools reliably identify workers with elevated accident risk: the authors found that biometric fatigue test-identified impaired workers showed substantially longer reaction times and reduced alertness compared to fit counterparts, translating to measurably higher near-miss and incident rates. The finding that one in eight mine operators at the fatigue-peak assessment window meets criteria for physical fatigue unfit classification underscores the importance of systematic pre-shift screening in this operational context.

The assessment windows selected for this study 14:00–16:00 for day shift workers and 02:00–06:00 for night shift workers correspond to circadian-determined fatigue peaks. The 02:00–06:00 night shift window in particular captures what [Caldwell et al. \(2019\)](#) term the "circadian trough," the period of lowest endogenous arousal coinciding with the highest subjective sleepiness and greatest performance impairment. Targeting assessment at these windows maximizes screening sensitivity, consistent with the methodological recommendations of [Seong et al. \(2022\)](#).

### 4.2 Health Examination Results

Table 4 presents the health examination findings for blood pressure, pulse rate, and sleep duration.

Table 4. Health Examination Results: Blood Pressure, Pulse Rate, and Sleep Duration (n = 50)

Health Parameter	Normal (Fit)	%	Abnormal (Unfit)	%	Clinical Threshold
Blood pressure (systolic/diastolic)	46	92.0	4	8.0	≥ 140/90 mmHg = hypertensive
Pulse rate (bpm)	46	92.0	4	8.0	< 60 or > 100 bpm = abnormal
Sleep duration (hours/day)	45	90.0	5	10.0	< 6 hours = sleep-deprived
Combined unfit (any abnormal parameter)	44	88.0	6	12.0	Any single abnormality = unfit

Table 4 shows that blood pressure and pulse rate abnormalities each affected 4 participants (8%), while sleep deprivation (< 6 hours/day) was reported by 5 participants (10%). The combined unfit classification, defined as the presence of any abnormal health parameter, identified 6 participants (12%) as unfit. This prevalence is consistent with the Sobriety Test results, suggesting substantial overlap between workers classified as physically unfit and those exhibiting cardiovascular abnormalities.

The blood pressure abnormality prevalence of 8% in this 50 person shift worker sample is noteworthy in the context of prior epidemiological evidence. While individual cross-sectional snapshots cannot establish longitudinal hypertension risk, the finding of active blood pressure elevation in nearly 1 in 10 mine operators during peak fatigue hours is consistent with Madeira et al.'s (2021) meta-analytic evidence that shift workers sustain measurable blood pressure elevations relative to day workers throughout their shift work tenure. Cheng et al. (2021) further demonstrated that night shift work is independently associated with metabolic syndrome of which hypertension is a core component in an 8-year hospital cohort, suggesting that the blood pressure elevations observed here may represent an early marker of cumulative shift work cardiovascular burden.

#### 4.3 Association Between Sleep Duration and Health Indicators

Table 5 presents the cross-tabulation of sleep duration category with cardiovascular health parameters and Sobriety Test outcome.

Table 5. Cross-Tabulation: Sleep Duration vs. Health Parameters and Sobriety Test Outcome (n = 50)

Sleep Duration	Normal BP	Abnormal BP	Normal Pulse	Abnormal Pulse	Sobriety: Fit
≥ 6 hours/day (n = 45)	45 (100%)	0 (0%)	45 (100%)	0 (0%)	44 (97.8%)
< 6 hours/day (n = 5)	2 (40%)	3 (60%)	2 (40%)	3 (60%)	0 (0%)
Total (n = 50)	47 (94%)	3 (6%)	46 (92%)	4 (8%)	44 (88%)

Table 5 shows a clear concentration of health abnormalities within the sleep-deprived subgroup (< 6 hours/day, n = 5). Among these participants, three (60%) exhibited abnormal blood pressure, three (60%) showed abnormal pulse rates, and none passed the Sobriety Test (0% fit rate). In contrast, among the 45 participants sleeping six or more hours per day, blood pressure and pulse rates were uniformly normal (100%), and 44 participants (97.8%) passed the Sobriety Test. This pattern strongly supports H1, indicating that sleep duration below six hours per day is associated with cardiovascular abnormalities and increased likelihood of Sobriety Test failure in this sample.

These findings are directly consistent with the established physiological mechanisms linking sleep deprivation to cardiovascular dysregulation. Andini and Siregar (2024) documented that Indonesian workers with long working hours and insufficient sleep showed elevated hypertension odds ratios, with the effect strongest among those averaging fewer than six hours of sleep. Khoirunnisa (2023) and Barliana Anggrita Ratri et al. (2022) similarly found sleep duration to be a significant independent predictor of blood pressure abnormality in Indonesian populations. The present study's findings extend this evidence to the coal mining shift worker context, confirming that the same sleep-cardiovascular relationship documented in other populations and sectors operates in this high-risk occupational group.

The observation that four participants showed blood pressure abnormalities while five reported sleep duration < 6 hours per day with three falling in both categories suggests that not all sleep-deprived workers had yet developed measurable blood pressure elevation, consistent with the temporal progression model of sleep deprivation-induced hypertension, in which sustained cumulative sleep debt precedes overt cardiovascular manifestation (Caldwell et al., 2019; El Meouchy et al., 2022). One sleep-deprived worker showed normal blood pressure, potentially reflecting earlier-stage

exposure or individual physiological resilience, while two workers with abnormal blood pressure reported sleep duration of  $\geq 6$  hours suggesting that factors beyond sleep duration (work intensity, psychological stress, pre-existing cardiovascular vulnerability) also contribute to blood pressure elevation in this workforce.

#### **4.4 Utility of the Combined Screening Protocol**

H2 is supported: the combined Sobriety Test and health examination protocol identified a clinically meaningful subgroup of unfit workers (12% of the sample) whose physical impairment status would not have been evident through administrative records or supervisor observation alone. This finding aligns with [Seong, Park, Ahn, and Kim \(2022\)](#) demonstration that integrated fatigue measurement systems achieve superior classification accuracy compared to single-method approaches, and with [Ramírez-Moreno, Carrillo-Tijerina, Candela-Leal, Alanis-Espinosa, Tudón-Martínez, Roman-Flores, Ramírez-Mendoza, and Lozoya-Santos \(2021\)](#) validation of rapid biometric fatigue testing as a practical pre-shift screening tool.

The practical implementation model demonstrated in this study standardized four-component Sobriety Test administered by OHS personnel, followed by blood pressure and pulse rate measurement, completed in approximately 12 minutes per worker represents a feasible pre-shift screening protocol for coal mining operations. The two-phase data collection approach (peak fatigue windows for both shifts) addresses a methodological limitation of single-timepoint assessments, which may miss fatigue-induced impairment that manifests only at physiologically vulnerable circadian phases. Companies implementing this protocol as a routine pre-shift fitness-for-duty check would generate a continuous surveillance database enabling trend analysis of fatigue prevalence, shift-specific risk profiling, and early identification of workers developing cumulative fatigue burden.

For workers identified as unfit, the immediate referral protocol clinical evaluation by occupational health nurse and rest provision demonstrates the system's practical integration with existing OHS management infrastructure. Crucially, this approach reframes fatigue management from a disciplinary issue to a health management concern, creating organizational conditions more conducive to transparent self-reporting of fatigue by workers who might otherwise conceal impairment to avoid shift removal.

#### **4.5 Discussions**

The findings demonstrate that physical fatigue, sleep deprivation, and cardiovascular abnormalities are closely interconnected among shift-working mine operators at PT. Manggala Alam Lestari. The Sobriety Test identified 12% of workers as unfit, with all six affected participants failing every test component simultaneously. This uniform failure pattern suggests generalized fatigue-related impairment rather than isolated deficits in balance, coordination, or cognitive response. Such findings support previous evidence that fatigue adversely affects multiple domains of human performance, including psychomotor coordination, postural stability, reaction time, and decision-making ability, thereby increasing the likelihood of occupational accidents in high-risk industries such as mining ([Ramírez-Moreno, Carrillo-Tijerina, Candela-Leal, Alanis-Espinosa, Tudón-Martínez, Roman-Flores, Ramírez-Mendoza, & Lozoya-Santos, 2021](#)). The presence of one unfit worker in every eight operators assessed indicates that fatigue remains a significant occupational health and safety concern requiring systematic monitoring and intervention.

The timing of assessments likely contributed to the sensitivity of fatigue detection. Evaluations were conducted during physiologically vulnerable periods, namely 14:00–16:00 for day-shift workers and 02:00–06:00 for night-shift workers. These periods correspond to circadian fatigue peaks, particularly the early morning “circadian trough,” during which alertness, vigilance, and physical performance naturally decline. The results therefore reinforce recommendations that fatigue assessments should be conducted during peak-risk periods rather than only at shift commencement, as fatigue-related impairment may emerge progressively throughout a work shift.

The health examination findings further highlight the occupational health implications of shift work. Abnormal blood pressure and pulse rate were each identified in 8% of participants, while 10% reported sleeping fewer than six hours per day. Although the prevalence rates appear modest, their concentration within a relatively small workforce is noteworthy because cardiovascular abnormalities among active workers may indicate early physiological consequences of chronic sleep disruption. Previous studies have shown that long-term shift work alters circadian regulation, increases sympathetic nervous system activity, and contributes to elevated blood pressure and cardiovascular disease risk ([Jelmini, Ross, Whitehurst, & Heebner, 2023](#)). The present findings are consistent with this evidence and suggest that cardiovascular monitoring should form an integral component of fatigue management programs in mining operations.

A particularly important finding is the strong relationship between sleep duration and health outcomes. Among workers sleeping fewer than six hours per day, 60% exhibited abnormal blood pressure and pulse rates, and none passed the Sobriety Test. In contrast, workers sleeping at least six hours per day demonstrated overwhelmingly normal physiological indicators and nearly universal fitness classifications. This pattern strongly supports the proposition that insufficient sleep is a critical determinant of both physical fatigue and cardiovascular dysfunction. The findings align with previous studies reporting that inadequate sleep increases hypertension risk, impairs autonomic regulation, and reduces physical and cognitive performance ([Tomitani, Hoshida, & Kario, 2024](#)). Therefore, sleep duration appears to be a key modifiable factor influencing worker fitness and safety in shift-based mining environments.

The study also demonstrates the practical value of integrating functional fatigue testing with physiological health assessments. The combined screening protocol successfully identified a subgroup of workers whose fatigue-related impairment may not have been detectable through routine supervision or administrative records alone. Consistent with previous research, integrating multiple indicators of fatigue produces more accurate identification of at-risk workers than relying on a single assessment method. Furthermore, the protocol proved operationally feasible, requiring only approximately twelve minutes per worker and utilizing equipment commonly available within occupational health programs.

From an organizational perspective, the findings support the implementation of routine pre-shift fitness-for-duty screening in coal mining operations. Regular monitoring of fatigue, sleep quality, blood pressure, and pulse rate would enable early identification of workers experiencing cumulative fatigue burden and facilitate timely intervention before safety incidents occur. Importantly, the referral and rest protocol adopted in this study positions fatigue as an occupational health issue rather than a disciplinary matter, thereby encouraging honest reporting and fostering a stronger safety culture. Collectively, these findings indicate that integrated fatigue management strategies can contribute substantially to both worker health protection and operational safety performance in the mining sector.

## **5. Conclusions**

### **5.1 Conclusion**

This study assessed physical fatigue, cardiovascular health indicators, and sleep quality among 50 shift-working coal mine operators at PT. Manggala Alam Lestari, South Sumatra, using a combined Sobriety Test and dual-phase health examination protocol. Three principal conclusions emerge. First, 12% of the study participants ( $n = 6$ ) were classified as physically unfit on the Sobriety Test, failing all four motor performance components at the peak fatigue assessment window a prevalence rate with direct implications for pre-shift fitness-for-duty management in coal mining operations. Second, all cardiovascular health abnormalities (abnormal blood pressure: 8%; abnormal pulse rate: 8%) and all Sobriety Test failures were concentrated within the subgroup of workers sleeping fewer than six hours per day (10% of participants), confirming the six-hour sleep duration threshold as a clinically meaningful risk marker for this workforce and supporting H1. Third, the combined Sobriety Test and health examination protocol demonstrated practical utility as an integrated pre-shift fatigue screening system: it identified a clinically meaningful unfit subgroup in approximately 12 minutes per

participant using portable, low-cost instrumentation deployable in field mining conditions, supporting H2.

The practical implication is clear: coal mining companies operating shift systems should implement systematic pre-shift fitness-for-duty screening that includes physical performance assessment (Sobriety Test or equivalent) combined with cardiovascular physiological monitoring and sleep quality inquiry. Workers identified as unfit should receive immediate clinical review and rest provision rather than proceeding to high-hazard operational duties. Alongside individual-level screening, organizational-level sleep management interventions including shift schedule optimization to minimize circadian disruption, provision of adequate rest facilities for shift transition periods, and sleep hygiene education programs are indicated by the evidence linking sleep deprivation to the cardiovascular and motor performance abnormalities documented in this study.

### ***5.2 Research Limitations***

Four limitations qualify the scope and interpretation of this study. First, the small sample size ( $n = 50$ ) from a single mining operation limits statistical power and generalizability. The subgroup of sleep-deprived workers ( $n = 5$ ) is too small to support robust inferential statistical testing, and the descriptive associations reported here cannot be interpreted as causal evidence. Future studies with larger samples and matched control groups would enable formal statistical testing of the sleep duration–cardiovascular health association and estimation of effect sizes with adequate precision. Second, important confounding variables including dietary habits, physical activity levels, pre-existing hypertension diagnoses, body mass index, and occupational stress were not measured. These factors are established predictors of blood pressure and fatigue, and their omission limits the attributability of observed health abnormalities to shift work and sleep deprivation specifically. Third, sleep duration was assessed through self-report interview rather than objective measurement (actigraphy or polysomnography), introducing the potential for recall bias and social desirability effects. Fourth, the cross-sectional design precludes longitudinal inference about the development of hypertension over time or the cumulative health effects of extended shift work tenure.

### ***5.3 Suggestions and Directions for Future Research***

Future research should address the identified limitations through four principal avenues. First, longitudinal cohort studies tracking shift workers' blood pressure, sleep quality, and fatigue indicators across multiple time points ideally spanning 12–24 months would enable examination of the temporal trajectory of shift work cardiovascular burden and the identification of early biomarkers predicting hypertension onset. Randomized controlled trials of sleep management interventions (sleep hygiene education, shift schedule modification, or supervised napping provision) would provide causal evidence on whether improving sleep quality reduces fatigue prevalence and blood pressure abnormality rates in mining shift workers.

Second, expanded studies incorporating objective sleep measurement (actigraphy worn across full shift rotations), mental fatigue assessment (psychomotor vigilance task, cognitive performance battery), and psychosocial risk measurement (validated occupational stress scales) would provide a more comprehensive fatigue risk profile than the physical performance and cardiovascular indicators captured in this study. Third, multi-site comparative studies across coal mining operations in different Indonesian provinces encompassing varied shift schedules, mine types, and workforce characteristics would establish the generalizability of the Sobriety Test and health examination protocol across the diversity of the national coal mining sector. Finally, economic analysis of the cost-effectiveness of pre-shift fitness-for-duty screening comparing implementation costs against accident prevention and health care cost savings would provide the business case evidence needed to support regulatory adoption of systematic fatigue screening as an OHS management requirement in Indonesia's extractive industries.

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## Author Contributions

JF conceived and designed the study, conducted field data collection, performed data analysis, and prepared the original manuscript draft. SS contributed to the research methodology, supervised the study, validated the findings, interpreted the results, and critically reviewed and revised the manuscript. Both authors read and approved the final version of the manuscript.

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