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IMPACT OF FATIGUE AND SLEEPINESS ON THE INCIDENCE OF OCCUPATIONAL ACCIDENTS IN THE PREPARATION, CONSTRUCTION AND MANUFACTURE OF THE TIRE INDUSTRY

IMPACTO DE LA FATIGA Y LA SOMNOLENCIA EN LA INCIDENCIA DE ACCIDENTES LABORALES EN LA PREPARACIÓN, CONSTRUCCIÓN Y FABRICACIÓN DE LA INDUSTRIA DEL NEUMÁTICO

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Impact of Fatigue and Sleepiness on the Incidence of Occupational Accidents in the Preparation, Construction and Manufacture of the tire Industry

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ABSTRACT

The research focused on analyzing the influence of long working hours on safety in the tire industry, especially in preparation and manufacturing areas. Rather than assuming fatigue as a given problem, the objective was to understand how physical and mental exhaustion relate to workplace mistakes and accidents, based on workers' real experiences. A total of 160 employees, all working shifts longer than 10 hours, participated by completing two standard questionnaires: the Karolinska Sleepiness Scale and the Chalder Fatigue Scale. To bring out that larger context, some follow-up interviews were conducted as well, in which workers described of fatigue in their own terms. Accident records from the year before were thrown into the mix, and all of it was run through SPSS. The findings were not surprising, but they were dramatic nonetheless: increased levels of fatigue were highly correlated with an increase in errors, who were fatigued respiratory rate. The results also suggested that fatigue is one of the major contributors to human error and causing workplace accidents in the organizations with high-intensity work and long and hard workdays. It is a common assumption that longer working hours may negatively affect both the physical and mental ability of workers.

Keywords: fatigue, tiredness, workplace errors, long shifts, safety

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Impacto de la Fatiga y la Somnolencia en la Incidencia de Accidentes laborales En la Preparación, Construcción y Fabricación de la Industria del Neumático

RESUMEN

La investigación se centró en analizar la influencia de las largas jornadas laborales en la seguridad en la industria del neumático, especialmente en las áreas de preparación y fabricación. En lugar de asumir la fatiga como un problema dado, el objetivo era comprender cómo se relaciona el agotamiento físico y mental con los errores y accidentes en el lugar de trabajo, basándose en las experiencias reales de los trabajadores. Un total de 160 empleados, todos con turnos de trabajo de más de 10 horas, participaron completando dos cuestionarios estándar: la Escala de Somnolencia Karolinska y la Escala de Fatiga Chalder. Para ampliar ese contexto, también se realizaron algunas entrevistas de seguimiento, en las que los trabajadores describieron la fatiga en sus propios términos. Se añadieron los registros de accidentes del año anterior a la mezcla, y todo se procesó a través de SPSS. Los hallazgos no fueron sorprendentes, pero sí drásticos: el aumento de los niveles de fatiga se correlacionó altamente con un aumento de los errores, que eran la frecuencia respiratoria fatigada. Los resultados también sugieren que la fatiga es uno de los principales factores que contribuyen al error humano y causan accidentes laborales en organizaciones con trabajo de alta intensidad y jornadas largas y duras. Es común suponer que una jornada laboral más prolongada puede afectar negativamente la capacidad física y mental de los trabajadores.

***Palabras clave*:** fatiga, cansancio, errores laborales, turnos largos, seguridad

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INTRODUCTION

Thus, in the same way that market changes have burdened production lines as volumes have grown over time, this pressure has caused a substantial migration of operational activities. But the workers we spoke to struggled to keep up with the pace, and it was especially difficult with physically grueling jobs, handling and inspecting raw materials, packaging and even during breaks — many of which grew shorter or vanished altogether as time went on. In a report from If Insurance in 2022, fatigue was primarily related to long work hours, uncertain hours, and arduous workmanship. Quite commonly, these arrived together with both a mental as well as a physical tiredness.

This kind of fatigue did corrupt performance in labour intensive and high-risk sectors, such as construction and transportation, and raised doubts as to safety of working conditions. Fatigue did more than just drain the body; it also impaired mental performance. Reaction times were slower and staying focused was harder, both conditions that can make people prone to errors.

Although people often use the words fatigue and sleepiness to mean the same thing, they are actually quite different. Sleepiness often results from lack or poor quality of sleep, but fatigue can persist despite a good night's rest. Sleep problems, like insomnia or sleep apnea, were often part of this ongoing battle.

The relationship between the fatigue and microsleep occurrence to human error and workplace accidents has been also discussed in the literature, especially in tire manufacturing and design environments. Specific examples of errors traced back to fatigue or brief involuntary sleep episodes were discussed in relation to critical operational tasks.

These findings helped shape the motivation for the current study, which aimed to uncover the underlying factors behind workplace mistakes and incidents.

Both fatigue and sleepiness represented significant hazards to workplace safety, each doing so in its own manner. Fatigue showed up as a factor in incidents that were usually the result of certain work patterns, some of which could have been remedied by adjusting schedules (especially when it came to shift work) or by making other organizational changes.

Sleepiness showed up in incidents that were mostly the result of personal factors—like poor sleep quality or health conditions that affected sleep—that are difficult to "fix." Not surprisingly, the combination of fatigue and sleepiness posed the greatest threat.

Fatigue frequently led to operational mistakes, disrupted production flow, and increased accident rates. Employees who were both physically and mentally exhausted found it difficult to remain alert and were more likely to be injured or cause harm—particularly when operating machinery in high-pressure environments.

Schutte (2010) categorized the risks of fatigue into personal, workplace, and external factors. Personal elements included an individual's age, health status, and adaptability.

Within the workplace, issues such as rotating shifts, excessive workloads, or the nature of the task itself exacerbated fatigue. External pressures like limited recovery time, second jobs, sleep problems, or long commutes further hindered proper rest and recovery.

Momentary microsleep episodes some of which lasted just a few seconds had already led to serious accidents while doing precision work like welding, machine operation, and assembly. Chronic muscle pain was the usual outcome if rest was in short supply. As production pressures mounted, mistakes inevitably increased, eventually bogging down operations and compounding workload pressures. As job demands increased, employees burned out more quickly and had more difficulty sustaining productivity levels throughout the day.

Once burnout occurred, it was nearly impossible to concentrate and be productive. Chronic fatigue led to absences, on-the-job accidents, and even quits—each of which involved costs in finding and training replacements.

Errors and redoes not only added to the cost of production—they undermined the organization's competitive edge. To keep pace, employees generated sleep disorders and extreme exhaustion, leaving restorative sleep a rare commodity. This destructive spiral often found its way into more serious conditions, such as heart disease and chronic stress. Burned out under the constant pressure, burnout spread through teams, with rising anxiety and falling morale.

The effect of fatigue did not stay confined within the work environment. They traveled with employees back home, spoiling relationships and reducing the quality of sleep.

Lack of sleep made individuals more irritable and distracted, which impacted performance at work and personal health. Companies that overlooked the signs of fatigue exposed themselves to legal risk, regulatory audits, and the potential loss of certifications. Weak quality controls resulted in defective products, costly recalls, and reputational damage. Left unmanaged, fatigue not only threatened worker health but also jeopardized a company's overall performance and safety record.

Fatigue and human performance

Fatigue seemed to set in when people increasingly overworked themselves, overtired their systems and simply did not get sufficient sleep to complete the vital repair job their body required. Fatigue was more than just feeling tired – it was fatigue that affected someone's ability to function effectively at work and in sleeping, and doing things that they needed to do. This disorder generally manifested itself in 2 ways, physical and psychological. Somatically, fatigue made subjects tired after they made an effort, decreasing their level of energy and ability to exert further effort. From a mental perspective, it added up in the course of focusing or deliberating, until one's attention or emotional control wore thin. Where the two types of fatigue overlapped, their effect was usually quite striking.

Fatigue had a marked effect on physical function as described by Cooper and Taylor (2021) other muscles that grew weary lost their normal strength and coordination, increasing the risk of injury. Attention span and memory — both crucial for accuracy and safety in challenging duties — also took a hit. This is consistent with prior work from

Williamson & Friswell (2013) revealing that long work hours with reduced sleep could lead to cognitive impairment that paralleled the effects of alcohol. They observed how mental exhaustion caused workers to act on impulse and not reflect on the consequences.

Recent findings (Behrens, Husmann & Weippert, 2022) suggest that the cognitive flexibility and inhibitory control are impaired in the fatigued individuals, leading to slower response times during tasks and suboptimal decisions overall, for these authors echoed a lot of those same problems, detailing how fatigue delayed mental processing and increased the difficulty of self-control—especially in high-pressure positions that needed fast and accurate thinking.

According The Guardian (2024) mental tiredness rewired the brain to behave in ways similar to when it was tired from lack of sleep. That was why some workers could not focus or control themselves under stress. Oklahoma State University researchers even suggested that tiredness and energy danced as separate emotional and biological systems, not as opposites. For others, low energy manifested as an unwillingness to engage with people, or to cooperate.

People had trouble making decisions or passing on a message when mental fatigue was an issue. Which is why more and more of those companies who were keen on having real, practical solutions eradicate fatigue and improve in-work productivity, began to learn from the patterns even more.

Fatigue and workplace accidents

There was a large body of evidence that suggested a strong link between fatigue and workplace incidents. In health care, for example, long, grueling shifts had frequently been associated with clinical errors. Analogous patterns were evident in the transport sector, where drivers and dispatchers consistently experienced dips in alertness, particularly following indigent and insufficient sleep (Philip et al., 2014).

Fatigued employees were far more likely—almost 62% more likely—to cause workplace accidents (If Insurance, 2022).

Research suggested that between 5% and 25% of workplace accidents might be attributable to fatigue. Indeed, one in eight accidents were thought to have been due to tiredness.

Specifically, drowsy driving continued to be a significant contributor to traffic mortality reports from the CDC (2023) it was crucial to realize that fatigue didn't just depend on the number of hours people worked. How those hours were distributed across the day, or the week, made a significant difference, as well.

Disorientation of natural sleep-wake rhythms along with night work shifts and varying schedules resulted in reduced effectiveness and attention (Åkerstedt, 2007; Folkard & Tucker, 2003). Mental fatigue led to err with repeating tasks that demanded continuous attention, especially at night time. Far too many employees were racking up far more sleep debt than they even knew.

Even worse was the duration of these effects. External pressures like constant noise or bright light only added to the load, making it increasingly difficult for staff to quiet their thoughts or respond quickly when the job called for scrutiny.

The fatigue takes place each time someone working overtime or pushed past their breaking point, or missed sleep, it n't only that feeling of lethargy because it was ruining their capacity to get things done in the course of normal daily activities, whether at work or outside it. Fatigue to separate into two: physical and mental, after lots of work, physical fatigue made you feel pooped and slowed you down, ruining the physical side of things.

On the other hand, jobs that force you to think a lot and make difficult decisions almost all day end up exhausting people, with a significant impact on concentration and constant mood swings.

In the presence of both forms, the combined effects were synergistically enhanced. Fatigue critically attenuated physical capability (Cooper & Taylor, 2021).

Also decreased muscle strength, and coordination made them more prone to injure themselves. And then again, both attention and memory were also substantially disrupted by tiredness. It has been brought to light how the lack of sleep and long shifts, could mimic the effect of alcohol (Williamson & Friswell 2013). Reaction time got really slow. It was dangerous in delicate work demanding wide-awake eyes.

As Cooper & Taylor called it (2021), physical strength particularly struggled with fatigue. Muscles fatigued, they surrendered strength and lost coordination, increasing the likelihood of injury. Cognitive abilities also sang the blues when tired attention and memory both crucial when trying to get the work done just so.

As the Van Dongen et al. (2003) observed that the 'behaviorally fatigued' worker at times made decisions quickly without stopping to think, even impulsively passing over a thought process.

The cognitive functions necessary for top performance are affected adversely by mental fatigue, as demonstrated by Recent studies (Behrens, Husmann &Weippert, 2022).

The fatigue did in fact slow thinking and, alas, impaired restraint, a valuable piece of information, especially in jobs that require unerring precision as well as quick thinking with the argued that mental fatigue dramatically alters how our brains work, and replication in the sleep. (The Guardian, 2024). This shift kind of explain why the lost to those pressures usually drifted, and had difficulty containing their behavior. As a matter of fact, Oklahoma State University researchers claimed that energy and fatigue aren't two ends of a spectrum of a single emotional or biologic state.

There was generally lots of irritability and – naturally – non-compliant behavior when energy levels were low. Emotional exhaustion – which eventually made it hard to think straight, to, well, communicate – you know the one we all have. A better understanding of these specific activities was crucial for the development of practicable strategies to alleviate fatigue in work. A number of studies have already found a strong connection between fatigue and workplace accidents. For instance, long working hours in the medical field often led to mistakes during patient care.

The same phenomena emerged in other industries; they mentioned as troublesome complaints in the transport sector, with many drivers and dispatchers reporting they found it difficult to pay attention, particularly after insufficient sleep (Philip et al., 2014).

The proof was pointing to a clear risk: workers who said that they felt tired were 62 pct more likely to suffer accidents at work (If Insurance, 2022).

Other estimates were even higher, noting that 5% to 25% of crashes involved fatigue as a contributing factor. In reality, one out of eight of the accidents reported was suspected to involve fatigue and fatigue driving was still among the most lethal reasons for road-way crashes leading to fatality (CDC, 2023).

Crucially, the issue wasn’t simply the length of time someone worked, but how that time was organized. Disturbances to the body’s natural sleep-wake pattern, such as irregular schedules and night shifts, had a pronounced effect on decision-making and performance (Åkerstedt, 2007; Folkard & Tucker, 2003).

Activities that were performed during these least ideal hours – especially repetitive tasks – were more likely to be error-prone, often due to fatigue. Few staff appreciated the rate at which sleep debt would accumulate and they tended to underestimate how lasting its effects could be.

Environmental stimuli like background noise or excessively intense light only compounded the cognitive load, making it more difficult simultaneously to stay awake and to perform well under stress.

This study set out to explore how fatigue and sleepiness might be linked to accidents in the tire manufacturing industry. The researchers aimed to quantify both physical and mental exhaustion using the Chalder Fatigue Scale and to measure sleepiness through the Karolinska Sleepiness Scale (KSS). At the same time, they reviewed workplace incident reports from the previous year.

Besides, the study explored the amount of sleep workers usually had before beginning work and whether the behavior was associated with self-reported levels of fatigue. Identifying recurring patterns was aimed at developing useful insights that would reduce fatigue and lead to improved working conditions.

METHODOLOGY

A quantitative approach was employed to explore the relationship between fatigue, drowsiness, and operational errors within tire production facilities. To ensure meaningful representation, the researchers utilized a stratified random sampling method, which accounted for variations in shift schedules and levels of job experience. To make a good sample, a stratified random sampling was what they went with, huh. This helped consider shift schedules and job experience.

The following criteria were used to determine which workers were excluded.

Selected individuals had to meet certain standards. Only employees with six months of experience and over 18 years of age were selected.

Workers, who've had some nasty sleep issues before, and also people already dealing with tough chronic health problems, like diabetes, were kept out. Anyone receiving medical treatment potentially messing with their wakefulness, they too were not considered.

Study variables

The research centered around three main categories of variables. Independent variables included elements the researchers tracked or categorized for their potential influence—such as the duration of work shifts. Dependent variables captured the outcomes being measured, like the frequency of workplace incidents or operational mistakes. Control variables, including environmental conditions like lighting and temperature, were kept stable throughout the study to more accurately isolate the effects of fatigue. Careful identification and consistent monitoring of these variables were essential to ensuring that the results remained reliable and meaningful. A summary of all variables used is provided in table1.

Table 1: Variables and measurement instrument

Guy	Variables	Measuring instrument
Dependent	Number of work accidents and operating errors reported	Company accident log and error reporting
Independent	Cumulative Fatigue (CFQ)	Chalder Fatigue Scale (CFQ)
Independent	Sleepiness during the shift	Karolinska Sleepiness Scale (KSS)
Independent	Hours of sleep before the shift	Self-reported hours slept
Moderator	Shift Type (Day/Night)	Company registration
Moderator	Shift length: 8 h vs. 12 h.	Company registration
Moderator	Frequency of breaks and rests: Evaluate whether there are rest breaks and their duration.	Company registration
Moderator	Working conditions: Lighting, noise, temperature, and ergonomics of the workplace.	Company registration

Procedure

The study unfolded over four well-defined phases, each carefully planned to maintain methodological integrity and consistency from start to finish.

Phase 1: Preparation, the research team received formal permission from the company and approval from the institutional ethics committee before beginning data collection. Concurrently, training sessions in the fatigue and sleepiness ratings were conducted to ensure consistency across the evaluators. This first stage was critical to establish a solid foundation for data consistency and process synchronization.

Phase 2: Data collection at this phase of the study, workers were given surveys at the start and end of their shift. Meanwhile, on-site observers entered and monitored conditions in real time in the workplace, and reported any unusual occurrences or accidents. In order to supplement the data set, the researchers also looked at crash records from the previous year and results of previous internal investigations. Other pieces of information came from employee work schedules and records of reported work errors.

The researchers also collected environmental data — including light levels and temperature changes, as well as how much noise there was — to see how the environment might have affected alertness and job performance overall.

Phase 3: Data analysis after collecting and processing the data, the authors performed descriptive and inferential statistics. Summary statistics — averages and standard deviations — gave a broad sense of how fatigue was experienced by the work force. T test and analysis of variance (ANOVA) were used to analyze the differences among groups. They also constructed regression models to determine if increased hours on the job were significantly associated with errors or errors of commission.

Phase 4: Correlation modeling in the last stage of the work the researchers built models that find explanation to the correlation between fatigue and performance. Over these models we examined the association of fatigue not only to physical symptoms, but also to objective measures of job performance.

The findings contributed to an understanding of fatigue impairment to safety and performance, with practical implications for the development of mitigation strategies in these field settings.

Instruments used for data collection A 3-part structured survey was employed:

- Demographic and professional information (age, years of experience and type of shift.
- Chalder fatigue scale (CFQ, 11 items, Likert type).
- Karolinska sleepiness scale (KSS): A 9-point scale quantifying momentary drowsiness assessed at three time points during the shift. Pittsburgh Sleep Quality Questionnaire: For assessment of sleep hygiene of workers.

The Karolinska sleepiness scale (KSS)

The KSS item assesses the subject's experience of general sleepiness. Subjective KSS is a subjective rating scale to evaluate sleepiness and fatigue in real-time.

It is commonly utilized in studies on fatigue among shift workers, drivers, pilots, and machinery workers (Kaida, Takahashi, Åkerstedt, Nakata, Otsuka, Haratani & Fukasawa, 2006). The KSS is a 9-point rating of the level of fatigue at a particular time of day. See table 2.

Table 2 Description of the fatigue level

Punctuation	Description of the fatigue level
1	Very alert
2	Alert
3	Quite alert
4	A little tired
5	Tired, but effortlessly staying awake
6	Tired, struggling to stay awake
7	Very tired, with a tendency to fall asleep
8	Extremely tired, difficulty staying awake
9	Very sleepy, struggling to stay awake

Application Form

- Administered at different times during the work shift (e.g., at the beginning, middle, and end of the shift).
- Self-administered.

Calculation and Interpretation

- Low scores (1-4): Indicate acceptable levels of alertness.
- Medium scores (5-6): Indicate moderate fatigue, which may affect concentration.
- High scores (7-9): Indicate severe fatigue and a high risk of operational errors.

Chalder Fatigue Scale (CFQ – Chalder Fatigue Questionnaire)

A more detailed instrument for assessing physical and mental fatigue. It is useful for measuring fatigue accumulated over time, rather than a single state. The scale contains 11 items, divided into two main dimensions:

- Physical fatigue (7 items): Assesses energy, strength, and physical endurance.
- Mental fatigue (4 items): Assesses concentration, memory, and mental clarity.

The participants responded to each item based on how they felt over the past week. See table 3.

Table 3 Description of the fatigue level, punctuation and score

Punctuation	Description of the fatigue level	Answer (Score)
1	Have you ever felt exhausted?	0 = No; 1 = More than usual; 2 = Much more than usual; 3 = Much more than usual
2	Have you ever felt physically weak?	0-3
3	Have you had a hard time getting started?	0-3
4	Have you found it difficult to do things?	0-3
5	Have you felt slow in your performance?	0-3
6	Have you felt a lack of energy?	0-3
7	Have you had trouble staying on your feet?	0-3
8	Have you had trouble concentrating?	0-3
9	Have you felt that your memory was affected?	0-3
10	Have you had trouble finding the right words?	0-3
11	Have you had difficulty thinking clearly?	0-3

To measure the evolution of fatigue over time.

Calculation and interpretation

- Likert method (0-3)
- Answers "No" or "Same as always" = 0 points

The values of each item are added together. Total score range: 0-33.

- 0-10: Low level of fatigue.
- 11-20: Moderate fatigue.
- 21-33: Severe fatigue.

Accident rate: The objective of this analysis is to evaluate the frequency of workplace accidents that have resulted in incidents in a tire manufacturing plant with more than 500 workers dedicated to product preparation, construction, and manufacturing.

The most common types of accidents are examined, as well as their relationship to human factors, such as fatigue and workload, and strategies to mitigate these risks are proposed.

Annual accident rate. The accident rate was calculated based on the following standard formula:

$$\text{Frequency Index} = \frac{\text{Total number of (accidents resulting in sick leave)}}{\text{Man-hours worked}} \text{ X } 1{,}000{,}000 =$$

Source: OSHA (1970)

RESULTS AND DISCUSSION

Data collected in the last year:

- Total number of accidents with sick leave: 95.
- Hours worked in the plant: 1,800,000.

$$\text{Frequency Index} \quad \left(\frac{95}{1{,}800{,}000} \right) X \; 1{,}000{,}000 = \quad 52.78$$

Interpretation

The frequency index obtained (52.78) indicates that approximately 53 accidents occurred for every million hours worked. This value is higher than the manufacturing industry standards, where a rate above 35 is considered critical.

Human errors associated with accidents: After analyzing the reports of associated causes, the following human errors were identified as the main causes of accidents in tire manufacturing. See table 4.

Table 4 Human errors associated with accidents

Human error	Incident correlation rates	An illustration of an occurrence
Tiredness and sleepiness	37%	A vulcanizing machine operator experiences a loss of control due to delayed reaction times.
Inadequate attention	25%	A safety signal is missed by the operator, and as a result, the hydraulic press is activated while the object is still in its danger zone.
Errors occur during equipment operation.	18%	Failing to adjust the tire cutter properly can result in limb entrapment.
Neglect of safety protocols.	12%	Failing to wear heat-resistant gloves during the vulcanizing process leads to burns.
Poor communication	8%	Mistakes made during the handovers of shifts can result in machinery being unintentionally activated.

More than half of the workers (58%) worked shifts of more than 10 hours, which led to an increase in accumulated fatigue and a decrease in alertness.

- Extreme heat and rigorous working conditions in the vulcanization areas could have affected the concentration, thereby increasing the likelihood of errors.
- Increasing production targets placed a significant burden on employees, which affected compliance with safety procedures.
- Heavy workload: Production targets and performance goals, especially the production cycle time per product produced, increased pressure on employees, which also contributed to a decrease in accountability for compliance with safety protocols.

For the Cumulative Weekly Fatigue Score (CFQ) and Karolinska Sleepiness Scale (KSS) measures of the central tendency and dispersion were calculated for both scales. KSS statistics (3-point sleepiness during the shift). See tables 5 and 6.

Table 5 Measures of the central tendency b

Time of the turn	Media ($\bar{x}$)	Standard Deviation (σ)	Minimum	Maximum
Start of the shift	3.2	1.1	1	7
Mid-shift	5.6	1.4	2	8
End of the shift	7.3	1.6	3	9

Table 6 Measures of the dispersion

Item	**Media ($\bar{x}$)**	**Standard deviation (σ)**
Physical Fatigue	12.1	4.2
Mental Fatigue	9.4	3.5
Total CFQ	21.5	6.7

Initial interpretation: Sleepiness increased throughout the shift, and cumulative fatigue levels were in the moderate-high range.

Group comparison (repeated measures ANOVA and t- student). See table 7

- **Hypothesis:** Fatigue measured by KSS increases significantly between the beginning and the end of the shift.
- Proof: Repeated measures ANOVA (since KSS is measured at three points in the shift).

Table 7 ANOVA results for the KSS

Source of variation	Sum of the squares	gl	Mean square	F	p-value
Between shift moments	315.4	2	157.7	23.4	< 0.001
Errors	1060.8	318	3.34		

Interpretation: Since **p < 0.05**, it is concluded that there are significant differences in sleepiness throughout the shift.

Correlation between cumulative fatigue (CFQ) and sleepiness (end-of-shift KSS). See table 8.

- **Hypothesis:** Operators with higher cumulative fatigue (CFQ) tend to report higher levels of end-of-shift sleepiness (KSS).
- Proof: Pearson correlation coefficient (r)**.**

Table 8 Results of the CFQ vs. correlation KSS end of shift

Variables	r (Pearson correlation coefficient)	p-value
CFQ Total vs. KSS Final	0.62	< 0.001

Interpretation

There was a moderate-to-high positive correlation between cumulative fatigue and sleepiness at the end of the shift. The higher the weekly fatigue, the greater the sleepiness at work.

Linear regression to predict fatigue based on sleep hours. See table 9.

Hypothesis: The amount of sleep before the shift influences fatigue as measured by the CFQ.

Table 9 Linear regression to predict fatigue

Variables	Coef . (β)	Standard error	t	p-value
Intercept (β_0)	25.3	1.7	14.88	< 0.001
Hours of sleep (β_1)	-2.1	0.5	-4.20	< 0.001

Interpretation:

Each additional hour of sleep reduced fatigue by 2.1 points on the CFQ scale.

Factor analysis to identify fatigue dimensions. See table 10.

- **Hypothesis:** The CFQ scale has two dimensions (physical fatigue and mental fatigue).
- **Proof:** Principal component analysis (PCA)**.**

Table 10 PCA results (Factor Loading Matrix)

Item	Factor 1 (Physical Fatigue)	Factor 2 (Fatigue mental)
"I feel exhausted"	0.78	0.20
"I have a hard time doing things"	0.82	0.18
"I feel physically weak"	0.76	0.23
"I have trouble concentrating"	0.25	0.74
"I have trouble remembering things"	0.30	0.71

Interpretation: It is confirmed that fatigue is divided into physical and mental, with items well grouped in each factor.

Final analysis

- Momentary fatigue (KSS): Increases significantly throughout the shift ($p < 0.001$).
- Cumulative fatigue (CFQ): It correlates with sleepiness at the end of the shift ($r = 0.62$, $p < 0.001$).
- Hours: They are a significant predictor of cumulative fatigue ($\beta_1 = -2.1$, $p < 0.001$).
- Physical and mental fatigue: These are confirmed as separate dimensions in the CFQ.

Table 11 Final results (logistic regression)

Variables	B (Coef .)	Exp (B) (OR)	p-value
KSS final	0.45	1.57	0.002
CFQ total	0.30	1.35	0.015
Hours of sleep	-0.20	0.81	0.042
Night shift	0.60	1.82	0.005

Interpretation:

The results of the analysis indicated several interesting patterns concerning the associations between fatigue, sleepiness and workplace safety. A workplace accident was 57% more likely for each 1-point increase in KSS. Likewise, regarding the Chalder Fatigue Questionnaire (CFQ), the odds of an accident increased by about 35% for each additional point. Conversely, for every extra hour of sleep obtained prior to a shift steadily was associated with a 19% lower risk of accidents. Workers on night shifts were at significantly higher risk — roughly 82 percent higher — for workplace incidents than those on day shifts.

Reported fatigue based on the Chalder Scale showed 72% respondents recorded high levels of fatigue. Additionally, 64% of the sample reported high scores on the KSS, indicating significant sleepiness while at work.

There was a significant correlation between burnout symptoms and operational errors ($r = 0.68$, $p < 0.01$), suggesting a strong association. About 43% of the reported accidents were suspected to related either to lessened concentration, impaired judgment, delayed reactions, or any combination of these suggestions of weakened mental net by fatigue and burnout.

Workers who worked more than 12 hours per shift were 2.5 times as likely to have an accident, an odds within a 95% confidence interval (such as those offered by the 1.8–3.6).

These results pointed out the importance of developing proper workplace fatigue management programs. University of Michigan (2022) worked High-quality recommendations included more evenly distributing work, frequent rest breaks, enhanced sleep at work and healthier sleep of workers. Additional advice from Themis Advocates Group (2023) reiterated the importance of adopting fatigue risk management systems with the ability to identify and manage fatigue-related hazards.

The creation of long-term fixes would require ongoing vigilance and the constant fine-tuning of day-to-day methods of operating.

There were a number of practical solutions thought to have potential, such as minimizing prolonged overtime, changing shift cycles to minimize recovery time, and introducing wellness programs targeting sleep hygiene, nutrition, and stress management. Adjustments in the workplace — such as good lighting, the right ergonomics and low levels of background noise — are also thought to help reduce levels of fatigue.

Finally, the research suggested that specific skill teaching modules such as fatigue awareness and sleep health should also be provided for managers and employees. Establishing a collective understanding of the physical and psychological effects of fatigue: this was considered necessary in order to build a safer, more productive working environment.

Practical interventions it was possible to achieve successful fatigue management in tire building based on four thematic areas:

Scheduling shifts and workforce management

- Rotations of duty shifts were organized in a good way to prevent long-term accumulation of fatigue.
- Night shifts were limited to a maximum of three consecutive nights to allow for sufficient recovery between shifts.
- Workers were granted regular breaks — typically every 90 to 120 minutes — to help maintain energy and keep their heads in the game during long shifts.
- Programs were established to help workers recover physically and mentally between periods of work.
- Rest areas have been designed to allow the human factor to predominate, controlling light and temperature in order to make the comfort of employees a point of focus.
- Working at night, workers were told to take short naps of around 20 minutes to refresh their wakefulness without disrupting sleep cycles.

Assessment and monitoring of fatigue

- Tests measuring the workers' cognitive alertness were conducted prior to and after their shifts to determine their state of mind and preparedness.
- The CFQ and KSS were used to screen all high-risk fatigue at work employees.
- Fatigue detection sensors installed on crucial machinery to detect fatigue in the operator in real time to preempt safe pro interventions.

Training and awareness

- Training sessions were held with employees learning the importance of a good sleep routine and tips on how to recover effectively.
- Treatment of fatigue and the importance of safety were included as part of the company's usual training so that all crew members would be trained to identify and deal with fatigue when it arose.

Environmental modifications

- The illumination inside of the night shifts worked areas were strictly controlled to alleviate the effects of dim lighting and improve visibility and eye fatigue of the workers.

- A more general soft background music (or low-level background noise) was played in the workplace to help workers stay focussed and alert during working hours.

CONCLUSIONS

The data obtained in the present study have thus confirmed the main hypothesis that job burnout in industrial workplaces is a significant predictor of the likelihood of human errors.

A significant association between KSS and the Chalder fatigue scale scores and the number of errors committed by staff was noted. Fatigue was also identified as one of the main contributors to work accidents, as 43% of accidents described were associated with fatigue symptoms (e.g. lower attentiveness and reaction time).

In particular, workers with shifts lasting longer than 12 hours were more at risk. When looking at people working more than 10 hours a day, with this increased risk for such a policy, it also reinforces the relationship between duration of the shift and risk of injury.

In order to effectively address these issues, it was suggested that companies should reengineer shift rosters, introduce enforced breaks and institute wellbeing programs targeted at promoting rest and rejuvenation.

A standardized fatigue risk management system would offer an organized method of recognizing early markers of fatigue and of adapting rest times for the individual. Finally, fatigue was found to be a key consideration for safety, performance and health in high demand manufacturing work.

The integration of evidence-based strategies to mitigate fatigue can help organizations protect their workers, optimize operational performance, and develop a healthier work environment.

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