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The Overlapping Impact of Lighting Conditions and Floor Types on Physiological and Physical Stress Among Surgical Staff: A Field Study in Government Hospitals in Sana'a

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Abstract

This study aims to investigate the complex interactions and overlapping effects between the physical characteristics of the work environment (lighting environment and floor quality) and the physiological and occupational outcomes of eye strain and physical fatigue among surgical staff in government hospitals in the Yemeni capital, Sana'a. The study employed a descriptive-analytical approach and was conducted on a purposive sample of 154 professionals, including surgeons, operating room technicians, and anesthesiologists, at three major referral facilities: Al-Thawra General Hospital, Kuwait University Hospital, and Al-Jumhouri Teaching Hospital.

The statistical results revealed an extremely critical situation; 80.5% of participants suffered from symptoms of acute and chronic eye strain, while 53.2% described the lighting environment and 52.6% described the quality of the flooring as "poor." Correlational analysis revealed a strong and statistically significant positive relationship between eye strain and physical fatigue ($r = 0.540$, $p < 0.01$), confirming the hypothesis of physiological correlation and neuromuscular synergy between the visual and motor systems in high-precision work environments.

Multiple linear regression models also showed that physical fatigue is the strongest and independent predictor of eye strain with a standardized relative weight of ($\beta = 0.54$), while illuminance, visual comfort, and room temperature were the main predictors of physical fatigue. The study concluded that severe deficiencies in ergonomic standards and the continued reliance on traditional technologies (halogen lighting and inflexible hard flooring) exacerbate human energy depletion and lead to reduced job motivation and burnout. The study recommends a comprehensive transition to smart LED technologies, the adoption of flexible flooring solutions such as anti-fatigue mats, and the institutionalization of ergonomic breaks to ensure the sustainability of medical efficiency and patient safety under the exceptional conditions currently facing the healthcare sector in Yemen.

Research Highlights

- Demonstration of a critical neuromuscular-visual synergy that positively correlates eye strain with cumulative physical fatigue ($r = 0.540$) among surgical teams in precision work environments.
- Revealed that physical fatigue is the strongest independent predictor of visual fatigue and eye strain, with a standardized weight of ($\beta = 0.54$).
- An ergonomic assessment of Yemeni operating rooms; more than half of the medical staff rated the prevailing lighting and flooring systems as "poor."
- Demonstrating the effectiveness of flexible anti-fatigue mats as a low-cost, high-impact ergonomic intervention to reduce back and joint pain caused by marble and hard ceramic tiles.
- Presenting a structural model linking management quality and the institutional environment as the primary cause of technical and structural deficiencies, rather than merely external physical factors.

1. Introduction

General Background

Operating rooms in modern healthcare facilities are considered among the most complex and high-risk work environments, where high-precision human performance intersects with advanced technological equipment within a critical timeframe that leaves no room for error (Naviaux et al., 2023; Ünver & Makal Orğan., 2023). With the rapid advancement of medical science, the focus is no longer limited to purely surgical skill but has expanded to include factors of human engineering, or what is known as ergonomics, which aims to adapt the physical environment to suit the physiological and psychological capabilities of medical staff (Simon et al., 2024; Yasui, 2024). The physical work environment, specifically lighting and flooring, is not merely a static architectural backdrop but rather vital elements that directly influence the physiological responses and mental focus levels of surgeons and their assistants (Levi, 2024).

The philosophy of operating room design begins with the principle of providing optimal visibility and physical comfort, as the surgeon relies entirely on his or her eyesight to distinguish fine tissues and determine the paths of surgical instruments. However, achieving this vision faces technical challenges related to lighting quality, which extends beyond mere “brightness” to include the adequacy of lighting for precise tasks and the uniformity of its distribution across the surgical field and the surrounding environment (Schneider et al., 2025; Boyle et al., 2025). Non-uniform lighting or glare caused by light reflection off metal instruments or wet surfaces leads to eye strain (asthenopia), a visual disorder manifested by symptoms such as dry eyes, headaches, and blurred vision, which reduces performance efficiency and increases the likelihood of surgical accidents (Dang et al., 2024).

Alongside visual requirements, the quality of flooring stands out as a critical physical factor that influences the body’s biomechanics. The surgical team, including physicians, anesthesiologists, and nurses, spends long hours in a static or restricted standing position, placing a tremendous mechanical load on the musculoskeletal system, particularly the lower back and joints (Naviaux et al., 2023; Ünver & Makal Orğan, 2023). The hardness of the floor surface plays a pivotal role in this context; hard floors lack shock-absorbing capacity, leading to accelerated physical fatigue and the accumulation of muscle strain (Redfern & Chaffin, 1995; East Coast Flooring, 2023). Furthermore, the structural condition of the floor and its slip resistance are central to occupational safety standards that ensure staff stability during critical surgical procedures (Gerflor USA, 2024; Stonhard, 2024).

The interaction between these environmental factors creates what can be termed an “overlapping impact.” For example, floors with high optical reflectivity can amplify the glare from ceiling lights, exacerbating eye strain to a degree that exceeds the effect of lighting alone (Knulst et al., 2011). Similarly, poor lighting quality may force surgeons to adopt uncomfortable, awkward postures to clearly see the surgical field, thereby compounding the physical strain already caused by standing on inflexible floors (Karam & Soriano, 2025; Uniplex UK, 2024). This complex interplay poses a significant challenge in

public hospitals, particularly in settings such as the city of Sana'a, where the healthcare infrastructure faces immense pressures and challenges regarding maintenance and modernization (Al-Sohpany, 2023).

Recent studies indicate that neglecting ergonomic aspects in operating rooms not only leads to a deterioration in the health of medical staff but also negatively impacts the quality of care provided to patients and rates of medical errors (Dang et al., 2024). In Yemen, the need for such studies is growing due to the scarcity of local research addressing the physical work environment from an integrative perspective that links structural (flooring) and technical (lighting) characteristics to the health and professional outcomes of surgical staff (Al-Sohpany, 2023). Therefore, this study aims to provide an in-depth analytical field assessment in government hospitals in Sana'a, seeking to identify differences resulting from demographic and functional variables and to establish a scientific understanding of the interrelated impact of these variables.

Research Problem: The research problem centers on the notable increase in levels of physical and eye strain among surgical staff working in government hospitals in the city of Sana'a, which is largely attributed to deficiencies in physical workplace standards. Although operating rooms in these hospitals —such as Al-Thawra, Al-Jumhouri, and Al-Kuwait Hospitals—represent major referral centers in the country, they suffer from chronic technical and structural challenges that affect the comfort and performance of surgical staff (Al-Sohpany, 2023). The problem lies in several overlapping areas: First, on the visual front, lighting systems suffer from technological obsolescence and an overreliance on traditional halogen lamps, which cause excessive shadows, glare, and a constant need for manual adjustment (Schneider et al., 2025; Knulst et al., 2011). Second, on the physical side, hard flooring is a major source of muscle fatigue and back and leg pain due to a lack of shock absorption (Redfern & Chaffin, 1995; Sherwin-Williams, 2024). Third, a significant knowledge gap exists, as previous studies have focused on a single factor without examining the "Overlapping Impact" and the direct physiological link between the eye and the body (Levi, 2024; Chromaviso, 2024).

- **Research Questions**

Main Question

What is the Overlapping Impact of the lighting environment and floor type on levels of physical and eye strain among surgical staff working in government hospitals in the city of Sana'a?

Sub-questions:

1. What is the quality of the lighting environment (sufficiency, uniformity, glare, and adjustability) in operating rooms at government hospitals in Sana'a from the perspective of surgical staff?
2. What is the quality of the flooring (surface hardness, slip hazard, glare, structural condition) in the operating rooms of the hospitals under study?

3. What are the prevailing levels of eye strain and physical fatigue among surgical staff?
4. Is there a statistically significant effect of lighting environment quality on the level of eye strain among the sample participants?
5. Is there a statistically significant effect of floor quality on the level of physical fatigue among the sample participants?
6. Is there a significant Overlapping Impact between lighting quality and floor quality that contributes to explaining the variance in total stress levels?
7. Are there statistically significant differences in the participants' perceptions of stress levels attributable to demographic, functional, and health variables?

Objectives

This study aims to fill a knowledge gap in Yemeni administrative and health literature regarding the physical work environment in operating rooms and its impact on the surgical team by

- Assessing current lighting quality levels according to its four dimensions (sufficiency, uniformity, glare, and adjustability).
- Assessing the structural and functional condition of floors and evaluating their compliance with ergonomic standards regarding hardness, slip resistance, and reflectivity.
- Measuring the severity of eye strain and physical fatigue and identifying the most affected groups based on specialty and working hours.
- Measuring the impact of flooring quality on the level of physical fatigue among the sample group?
- Measuring the interactive predictive effect of lighting quality and Floor quality on explaining the variation in overall stress levels
- Analyzing differences in stress levels attributable to demographic, occupational, health, and lifestyle variables.
- Providing practical policy recommendations to the Ministry of Health and hospital administrations to improve the work environment and reduce occupational stress risks.

    - **Scientific and practical significance of the study**

Scientific (theoretical) significance: Presenting the first systematic study in the Yemeni context that comprehensively links physical structural (flooring) and technical (lighting) variables with the health outcomes of surgical staff, and establishing the concept of "overlapping impact" in the Arab health and administrative literature, and integrating concepts of optical physics with biomechanics and ergonomics to provide a robust theoretical platform for researchers.

Practical (Applied) Significance

Protecting Yemen's surgical "human capital" by providing practical strategies to reduce occupational burnout and extend career longevity, and guiding decision-makers toward low-cost, high-impact reforms

such as anti-fatigue mats and modernized lighting systems to reduce surgical errors resulting from eye strain or excessive physical fatigue.

- **Research Hypotheses**

H1

There is a statistically significant effect at the ($\alpha \leq 0.05$) level of the lighting environment (sufficiency, uniformity, glare, and position adjustment) on the level of eye strain among surgical staff.

H2

There is a statistically significant effect at the $\alpha \leq 0.05$ level of floor quality (hardness, slip resistance, reflectivity, structural condition) on the level of physical fatigue among surgical staff.

H3

There is a statistically significant interaction effect of lighting conditions and floor quality in predicting overall stress levels among surgical staff in Yemeni hospitals.

H4

There are statistically significant differences in stress levels attributable to demographic, occupational, health, and lifestyle variables.

1. **Theoretical Framework & Literature Review**

- **Philosophical and Theoretical Foundations of the Study Variables**
- **Person-Environment Fit Theory**: The Person-Environment Fit Theory is considered the most prominent philosophical framework for explaining occupational stress levels; It posits that physiological and psychological stress arises when the surrounding physical space fails to meet the worker's biological and motor needs, or when task demands exceed available physical capacities (Armitage & Amar, 2021). In operating rooms, this mismatch manifests as the imposition of ultra-precise visual demands and prolonged static standing within a physically deteriorating environment —both technically and structurally—which depletes the human body's natural adaptive resources and leads to a gradual breakdown in performance and the onset of visual and physical stress symptoms (Naviaux et al., 2023; Simon et al., 2024).
- **Skeletal Muscle Pump Theory**: From a biomechanical perspective, the return of venous blood from the lower extremities to the heart against gravity relies primarily on the continuous dynamic contraction and relaxation of the leg muscles (calf), a phenomenon known as the skeletal muscle pump (Ludbrook, 1966). During prolonged, restricted standing on hard surfaces that lack any elasticity (such as marble or concrete), the fine motor activity of the foot joints and leg muscles decreases sharply. This inactivity leads to fluid accumulation and venous pooling in the legs, which

increases contact pressure and heart rate, causing muscle fatigue and acute back pain (Redfern & Chaffin, 1995; Ünver & Makal Orğan, 2023).

- **Visual-Postural Synergy Theory**: Recent developments in neuroscience and ergonomics propose a "model of active synergy between visual and postural processes," confirming the existence of direct physiological communication channels linking the accommodative eye muscles to the motor system of the neck and spine (Lérida-Ponce et al., 2025; Bonnet & Baudry, 2016). When the eye is subjected to continuous accommodative stress due to uneven lighting or visual glare, the central nervous system triggers an involuntary response that increases electrical activity and muscle tension in the trapezius muscle with the aim of restricting head movement and securing a stable visual focus. This cumulative spasm in the neck and shoulder physiologically demonstrates that visual fatigue and physical fatigue are not isolated pathways but rather a closed and interconnected physiological loop (Lérida-Ponce et al., 2025).

    - **Systematic review of previous studies**
    - **Study (**Al-Yamani, 2023**)**: Examined the extent of the impact of occupational burnout on the quality of care in Ibb hospitals and found a significant effect of burnout resulting from continuous stress and the accumulation of physical and mental fatigue on reducing physicians' motivation and performance.
    - **Study (**Alswaidi & Ismail, 2023**)**: This study explored the patient safety culture among 384 physicians in government hospitals in Sana'a and showed that a lack of available material resources and increased weekly working hours are factors hindering the achievement of safety and increasing stress levels.
    - **Study (**Schneider et al., 2025): Evaluated a smart surgical lighting system (SmartOT) and demonstrated that traditional lighting

systems require continuous manual adjustment every 7.5 minutes, which interrupts mental flow and increases physical and cognitive effort, compared to automated smart systems.

- **Study (**Zhang et al., 2025): This study investigated the overlapping effects of lighting and natural elements on the well-being of healthcare staff and demonstrated that the ergonomic coordination of lighting with environmental elements significantly reduces perceived stress and psychological and physical tension.
- **Study (**Karam & Soriano, 2025**)**: This review examined the impact of the surgical work environment on surgeons' well-being, outlining key risk factors, prevalence data, and preventive strategies. It presented a systematic approach to improving posture, handling equipment, operating room configuration, and microbreaks during surgery. This review emphasized that integrating principles of comfort into surgical practice is essential for extending a surgeon's career, improving performance, and ensuring sustainable professional advancement.
- **Study (**Uniplex UK, 2024**)**: Examined the relationship between light distribution and muscle activation in the neck and back, confirming that poor lighting conditions force surgeons to perform

repeated, precise compensatory physical movements that accelerate the rate of cumulative physical fatigue in the shoulders and back.

- **Study (**Boyle et al., 2025): This study evaluated the impact of environmental factors on surgical team performance through a systematic review following the PRISMA protocol. It demonstrated that intense and unstable lighting affects sleep cycles and causes stress, and recommended adopting an integrated, systematic approach to operating room design.
- **Study (**Ünver & Makal Orğan, 2023**)**: This study aimed to examine the effect of anti-fatigue floor mats on pain and fatigue levels among surgical team members. Thirty-eight participants took part in this study, which compared conditions with and without mats, separated by a one-week washout period. Participants stood on a 15-mm-thick anti-fatigue rubber floor mat and on a standard anti-static polyvinyl chloride (PVC) floor surface during surgical procedures. Self-reported pain and fatigue ratings were measured before and after surgery for each experimental condition using the Visual

Analog Scale (VAS) and the Fatigue-Visual Analog Scale (VAS-Fatigue). Postoperative pain and fatigue levels were significantly lower in the mat condition than in the no-mat condition ($p < .05$). Thus, anti-fatigue floor mats are effective in reducing pain and fatigue among surgical team members during surgical procedures. The use of anti-fatigue mats may be a practical and easy way to prevent the discomfort often experienced by surgical teams.

A review of previous studies reveals a consensus among scholars regarding the critical impact of the physical environment of operating rooms on the health, safety, and performance of medical staff (Ismail, 2023; Ünver & Makal Orğan, 2023). However, the overwhelming majority of this literature has addressed either lighting or flooring separately and in complete isolation; medical-engineering studies either focus on ceiling light technology and lux intensity control without linking them to the biomechanics of body movement (Schneider et al., 2025), or rehabilitation studies examine the impact of resilient flooring on foot comfort while overlooking how poor lighting or reflected glare forces surgeons to adopt awkward postures that exacerbate back and joint fatigue (Ünver & Makal Orğan, 2023; Jacey Elliott et al., 2025).

Herein lies the specific knowledge gap that this study seeks to bridge; the present study is the first attempt—to the best of the researcher's knowledge—to combine the physics of optics (lighting) and biomechanics (flooring) into a unified interactive analytical model to explore the "overlapping effect" and the direct physiological link between eye strain and physical fatigue among surgical teams working under the critical and exceptional conditions of government hospitals in Sana'a.

3. Study Methodology

The study employed a descriptive-analytical approach appropriate for ergonomic variables in the healthcare setting. The study population consisted of all active surgical staff (surgeons, anesthesiologists, surgical technicians, and nurses) working in operating rooms at major government hospitals in Sana'a. The current sample size (N = 154) was determined based on rigorous statistical and

practical considerations to ensure the interpretive power of the variance and regression models used. From a statistical perspective, a post-hoc power analysis was conducted using the G*Power 3.1 software. Given the study's primary multiple linear regression model, which includes 3 to 4 main predictors, and assuming a medium to large effect size ($f^2 = 0.15$) and a significance level ($\alpha = 0.05$), the current sample size (N = 154) provides the study with superior statistical power exceeding 95% (Power > 0.95), a rate significantly higher than the globally accepted minimum of 80% in ergonomic and health studies. From a practical and field perspective, this sample size represents a high and excellent level of representativeness given the nature of the critical target population (active surgical staff at the three major referral hospitals in the capital, Sana'a—Al-Thawra General Hospital, Kuwait University Hospital, and the Republican Teaching Hospital in Sana'a)—and the difficulty of recruitment under the current exceptional circumstances. This ensures sufficient data for conducting advanced inferential analyses and the validity of generalizing the results without falling into the trap of statistical over-inference. Additionally, a scientifically designed questionnaire divided into independent dimensions was used to measure lighting quality, floor quality, visual fatigue, and physical fatigue. The tool demonstrated excellent internal consistency (Cronbach's alpha exceeded 0.82 for all dimensions), with normal data distribution and models free of inflation (VIF < 2.5).

4. Study Results

First: Demographic and Professional Characteristics of the Sample Table (1) summarizes the basic characteristics of the study sample consisting of 154 surgical staff:

Table (1): Demographic and occupational characteristics of the surgical staff (N = 154)

Variable	Category	Frequency	Percentage (%)
Gender	Male	104	67.5%
	Female	50	32.5%
Professional Specialization	Operations Technician	73	47.4%
	Surgeon	46	29.9%
	Anesthesiology	35	22.7%
Academic Qualification	Diploma	58	37.7%
	Bachelor's degree	50	32.5%
	Graduate	46	29.8%
Years of experience	Less than one year	52	33.8%
	1–3 years	52	33.8%
	4–5 years	21	13.6%
	More than 5 years	29	18.8%
Work schedule	Morning	115	74.7%
	Night / Shifts	39	25.3%
Daily working hours	Less than 8 hours	97	63.0%
	8–16 hours	57	37.0%

Table (1) shows that young and inexperienced staff clearly dominate government operations rooms in Sana'a; 67.6% of the sample have less than three years of practical experience. These young staff members are physiologically more sensitive and vulnerable to occupational and ergonomic risks in the work environment because they lack sufficient motor skills to conserve physical and postural energy. The use of long shift systems for 37.0% of the sample (8–16 hours daily) is also notable, as it compounds the cumulative burden of fatigue. This finding is supported by the conclusions reached by Al-Wesabi & Jarallah (2024) in their field analytical study conducted at two hospitals (Al-Kuwait and Al-Jumhouri) in Sana'a, which emphasized the importance of institutionalizing quality training and continuous specialized qualification to enhance the performance efficiency of operating room technicians and protect them from environmental risks resulting from a lack of motor and professional skills.

Second: Health Characteristics and Lifestyle of Surgical Staff

Table (2) illustrates the health status and lifestyle of the actual participants: **Table (2): Health characteristics and lifestyle of the study sample (N = 154)**

Variable	Yes (%)	No (%)
Use of prescription glasses/contact lenses	31.2	68.8
Previous diagnosis of eye problems	39.0%	61.0
Diagnosed musculoskeletal problems	29.9%	70.1
Average daily sleep duration	79.2% (less than 8 hours)	20.8% (8 hours or more)
Level of physical activity	89.0% (regular/moderate)	11.0% (inactive)

The data in Table (2) reveal the presence of pre-existing weaknesses and preventive deficiencies; 39.0% have a prior diagnosis of eye problems, and 29.9% have actually diagnosed musculoskeletal problems. In addition, 79.2% of the staff are deprived of adequate sleep (less than 8 hours), which physiologically lowers the threshold for physical pain tolerance and limits the eye's ability to restore natural moisture and resist visual fatigue.

Third: Assessment of Current Surgical Lighting Quality Factors

Table (3) presents the frequencies and percentages of respondents' responses regarding details of the lighting environment inside operating rooms:

Table (3): Analysis of surgical staff responses regarding lighting items (N = 154)

Item (Statement)	Mostly / Always (%)	Sometimes (%)	Never / Rarely (%)
Adequacy of general lighting for fine motor tasks	31.1%	20.1	48.7
Uniformity of light distribution and reduction of shadows	30.5%	22.1%	47.4%
Helps see fine details	26.6%	17.5%	55.8%
Flickering or flickering causing headaches	15.6%	14.9%	69.5
Significant contrast between surgical light and ambient light	26.7%	12.3%	61.0%
Annoying glare from shiny surfaces or tools	25.3%	12.3%	62.4%
Need to frequently adjust the light position	40.9%	18.2%	40.9

The results in Table 3 indicate a severe structural and technological deficiency; 55.8% believe that the prevailing lighting system does not help them see the fine details of sutures and instruments, forcing them to tilt their heads and bodies to bring the focal point closer. Additionally, 40.9% suffer from the frequent and intense need to manually readjust the position of the lamps to avoid shadows cast by the

heads and hands of the staff, which interrupts the mental flow of the procedure and increases the physical and cognitive load.

Fourth: Assessment of Floor Quality and Mobility Safety

Table (4) presents the medical staff's responses regarding the items and characteristics of structural flooring:

Table (4): Assessment of flooring items and physical comfort (N = 154)

Item (Statement)	Most of the time / Always (%)	Sometimes (%)	Never / Rarely (%)
The floor's shine causes light to reflect	16.8%	12.3	70.8%
The floor is slippery, especially when wet	27.9%	32.5%	39.6%
The floor causes tripping due to structural joints	9.1%	17.5%	73.4
The floor is hard and increases foot and leg pain	46.1%	18.8%	35.0
The surface causes back and knee pain	**42.9**	**24.0%**	**33.1**
Floor is old or damaged	40.9%	18.2%	40.9

Table No. (4) shows that the primary ergonomic problem with operating room floors in Sana'a lies in their "extreme hardness" and the wear and tear of the surfaces; 46.1% confirmed that the hardness of the floor causes severe pain in the feet and legs, and 42.9% reported that it causes back and knee pain. The lack of cushioning and shock absorption in the prevalent marble and ceramic materials impairs the efficiency of the musculoskeletal pump and transmits shocks to the vertebrae, causing chronic musculoskeletal disorders.

Fifth: Prevalence and Severity of Physiological Symptoms of Eye Strain

Table (5) summarizes the prevalence and severity of visual symptoms of eye strain among the participants:

Table (5): Prevalence of eye strain symptoms in the sample (N = 154)

Observed visual symptom	Severe symptoms (%)	Mild symptoms (%)	No symptoms (%)
Headache	13.6%	64.9%	21.5%
Burning eyes	26.0%	63.6%	10.4%
Watery eyes	27.3%	11.0%	61.7%
Redness of the eyes	10.4%	57.8%	31.8%
Eye pain	13.0%	33.1%	53.9%
Blurred vision	11.7%	51.3%	37.0%
Dry eyes	13.6%	44.2%	42.2%
Double vision	13.0%	31.8%	55.2

Table (5) shows that the overall result represents a critical and unprecedented prevalence, with 80.5% of surgical staff suffering from symptoms of eye strain. The prevalence of headaches stands at 78.5% and eye burning at 89.6% (mild and severe). The presence of extremely serious symptoms such as double vision (44.8%) and blurred vision (63.0%) poses a direct physiological risk that impairs the surgeon's visual acuity and precision, thereby increasing the likelihood of surgical errors. These critical visual and physical symptoms physiologically increase the likelihood of surgical errors, a finding that aligns with the preventive objectives of a study (Al-Selwi et al., 2026) in government hospitals in Sana'a, which emphasized the danger of neglecting strict safety procedures within operating rooms (such as surgical counting and environmental checks) and their direct impact on the safety of both patients and medical staff.

Sixth: Physical Fatigue and Its Effects on Motivation and Job Performance

Table (6) presents the distribution of respondents' responses and attitudes regarding cumulative physical fatigue:

Table (6): Distribution of Responses Regarding Physical Fatigue and Its Implications (N = 154)

Table 6

reveals the professional and behavioral repercussions of fatigue; 37.6% confirmed a decline in their motivation to work when they feel fatigued, and 29.2% indicated that their overall ability to perform continuous physical activities was affected. Cumulative fatigue lowers the threshold of nervous and psychological endurance and leads to occupational burnout.

Item (Statement)	Mostly / Always (%)	Sometimes (%)	Never / Rarely (%)
My motivation decreases when I feel tired	37.6%	27.9	34.4
Working hard makes me feel more tired	35.7%	28.6%	35.7
Fatigue affects my physical performance	29.2%	18.2%	52.6
Fatigue prevents me from maintaining consistent performance	28.6	25.3%	46.1
Fatigue affects my family and social life	23.3%	16.9%	59.7

Seventh: Pearson correlation matrix for the central variables

Table (7) shows the arithmetic means, standard deviations, and Pearson correlation matrix:

Table (7): Correlation matrix and overall descriptive statistics (N = 154)

Variable	Mean	Standard Deviation	(1) Eye strain	(2) Physical fatigue	(3) Lighting issues	(4) Flooring issues
(1) Overall eye strain	7.98	11.73	1			
(2) Overall physical fatigue	23.80	9.13	0.540∗∗	1		

(3) Lighting issues	**31.27**	**6.38**	**0.370∗∗**	**0.190∗**	**1**	
(4) Flooring issues	26.20	6.23	0.400∗∗	0.160∗	0.160∗	1

Statistical note: (**) Significant at the ($p < 0.01$) level, (*) Significant at the ($p < 0.05$) level.

The analysis revealed a strong, statistically significant positive correlation between eye strain and cumulative physical fatigue (r = 0.540, $p < 0.01$), confirming the physiological connection between the eyes and the body. Notably, there was a strong positive correlation between flooring issues and eye strain (r = 0.400, $p < 0.01$), which exceeded its correlation with direct physical fatigue, indicating that surface instability and roughness increase body sway and threaten visual-motor coordination, forcing the eyes to exert double the effort to stabilize the visual focus.

Eighth: Multiple predictive models for stress outcomes

Table (8) shows the details of the multiple linear regression models for the dependent variables:

Table (8): Results of the regression analysis for predicting occupational stress levels

Dependent variable (model)	Independent Variable (Predictor)	Non-standard coefficient (*B*)	Standardized coefficient (*β*)	Significance Level (*p*)
Model 1: Total Eye Fatigue	Total physical fatigue	0.47	0.54	< 0.001
	Floor problems	0.33	0.26	< 0.001
	Lighting issues	0.20	0.16	0.018
Model 2: Total physical fatigue	Average Illuminance	4.02	0.31	0.002
	Visual comfort	0.58	0.28	< 0.001
	Ambient temperature	0.37	0.19	0.004
	Lighting quality	-0.43	-0.18	0.014

The findings in Table 8 indicate the following:

- **Model 1 (Eye Strain)**: The model confirms the superior predictive power of physical fatigue as the strongest independent predictor of eye strain with a standardized weight of (β = 0.54, $p < 0.001$), followed by flooring issues with a weight of (β = 0.26, $p < 0.001$), and lighting issues with a weight of (β = 0.16, p = 0.018). This statistical finding confirms that visual fatigue in operating rooms is not an isolated ocular problem but rather a direct result of the accumulation of physical fatigue and the depletion of biomechanical strength due to prolonged standing.
- **Model 2 (Physical Fatigue)**: Light intensity emerged as the strongest predictor of physical fatigue with a weight (β = 0.31, p = 0.002), followed by visual comfort with a weight (β = 0.28, $p < 0.001$), and temperature with a weight (β = 0.19, p = 0.004). Meanwhile, overall lighting quality emerged as a statistically significant negative predictor with a weight of (β=−0.18,p = 0.014), which statistically indicates that as lighting quality standards and the uniformity of their distribution in operating rooms improved and increased, levels of general physical fatigue among surgical staff decreased, freeing them from having to adopt forced, strenuous physical postures to get close to the surgical field.

5. Discussion of Results

The current study revealed significant findings confirming a close physiological correlation between the quality of the physical components of the operating room environment and the levels of occupational stress among surgical staff at government hospitals in Sana'a. When comparing the recorded prevalence of eye strain, which stands at 80.5%, with rates observed globally in hospitals in developed countries—which range from 25% to 50% (Schneider et al., 2025; Curlin & Herman, 2020), the extent of the deterioration in the infrastructure and technology of Yemeni hospitals becomes clear, resulting from the exceptional circumstances of the prolonged conflict and its impact on the absence of protocols for technical upgrades and regular maintenance (Salem et al., 2025). This high descriptive finding is consistent with Alswaidi & Ismail (2023) study, which demonstrated a close and strong correlation between the poor and deteriorating physical work environment in Yemen and high rates of occupational and health stress and job aversion among physicians.

The proposed physiological explanation for the emergence of physical fatigue as the strongest independent predictor of eye strain, with a standardized weight of (β = 0.54), lies in the "neuro-muscular-visual synergy loop" as explained by modern synergy theory (Lérida-Ponce et al., 2025). The continuous spasm and strain of the accommodative eye muscles required to focus in a poorly lit surgical field—which relies on outdated halogen lighting and is characterized by regular shadows and sharp contrast (Table 3)— trigger a reflexive neural pathway that increases electrical activity and causes spasms in the neck, shoulder, and spinal muscles to stabilize the head, thereby ensuring a stable visual angle and maintaining ocular hydration (Lérida-Ponce et al., 2025).

This stressful posture for the neck and shoulders, when combined with the absolute hardness of solid floors such as marble and ceramic tiles on which staff stand for hours (Table 4), completely disrupts the efficiency of the “skeletal muscle pump” of the lower limbs (Ludbrook, 1966). The absence of micro-movements in the feet leads to blood pooling and pressure on the vertebrae, causing severe pain in the lower back and feet, which in turn is directly and cumulatively linked to visual fatigue and mental distraction (r = 0.540).

These findings clearly align with the study conducted by Jacey Elliott et al. (2025); where it was scientifically proven that the introduction of flexible, anti-fatigue floor mats in the surgical team’s standing area completely eliminates spasms and joint pain in the lower limbs, back, and shoulders by stimulating micro-movements of the feet and activating reverse blood circulation. In contrast, Yemeni medical staff lack this simple yet effective ergonomic adaptation, leading them to experience early burnout and a decline in the quality of medical care and their professional motivation (Omidi et al., 2025).

In the same vein, our current study confirms that the root causes of the exacerbation of occupational stress outcomes within Sana’a’s operating rooms are not solely attributable to abstract external technical and structural factors, but lie primarily in administrative shortcomings and the absence of a strategic vision for quality management and occupational

health and safety within Yemen’s institutional health and academic system. This argument is closely aligned with the scientific findings (Shamlan & Al-Wesabi, 2026) that the absence of clinical governance pillars in conflict-affected Yemeni hospitals is directly linked to a decline in the quality of healthcare and an increase in occupational risks facing medical staff; as weak administrative accountability and clinical oversight of critical work environments prevent the preventive modernization of facilities and leave medical staff vulnerable to systematic burnout. This structural governance deficit essentially reflects a deeper gap in the application of Total Quality Management (TQM) pillars; a study (Alsalit et al., 2026) indicates that the main drivers and catalysts of quality in Yemeni healthcare settings often face institutional and regulatory constraints that limit their effectiveness, leading to a disconnect between the daily operational aspects of operating rooms and internationally recommended engineering and ergonomic standards. As a result of the absence of this integrated system of governance and total quality, a significant gap emerges in compliance with practices centered on patient and staff safety; a fact confirmed by a study (Qabban et al., 2026) in Sana’a hospitals, showing that there is a close and significant correlation between the implementation of patient-centered international standards (such as those of the Joint Commission) and the performance and comfort levels of nursing and medical staff; as the implementation of these strict standards within operating rooms not only protects the patient but also provides an environmental and physical setting that enhances staff motivation and reduces physical fatigue and cumulative eye strain, as documented in our current findings. These results are consistent with the field study by (Al-Shuja'a et al., 2026) conducted in teaching hospitals in the Capital Secretariat, which statistically demonstrated that the degree of adherence by operating room staff and technicians to occupational safety standards is directly related to the extent to which a safe physical and

structural work environment is available and established, reflecting the need to integrate administrative aspects with engineering aspects.

The continued use by the administrations of major government hospitals in Sana'a of traditional halogen lamps, which emit a diffuse color spectrum and high heat, increases surgeons' sweating and fluid loss, whereas experiments have shown that replacing them with cool, smart LEDs eliminates shadows and annoying glare, prevents eye muscle spasms, and significantly reduces the need for manual lighting adjustments (Schneider et al., 2025; BFW Inc., 2025). This highlights the absence of proactive, preventive engineering management thinking to implement "low-cost, high-impact" repairs.

Similarly, the harshness of worn-out flooring causing pain in the ankles, back, and knees (Table 4) stems from the absence of construction quality control and medical engineering standards during the construction and renovation of operating rooms; where administrative decision-makers prefer cheaper construction solutions such as marble or standard epoxy, completely disregarding the enormous economic return represented by reduced sick leave, improved surgical precision, and lower rates of fatal medical errors and burnout among young surgical staff, who represent Yemen's true human capital under current circumstances (Naviaux et al., 2023).

6. Conclusions

Based on the results of the descriptive and inferential analyses, as well as the multiple linear regression models applied to the study sample of 154 participants, the following key conclusions were reached:

- Structural ergonomic deterioration, as the government health sector in Sana'a suffers from severe and unapproved deficiencies in the ergonomic standards of the physical environment of operating rooms; more than half of the medical staff rated the quality of the lighting and flooring systems as "poor and deteriorating," which transforms the operating room environment into a stressful and hostile one rather than one that supports safe performance.
- The prevalence of critical visual fatigue, where eye strain has shifted from an incidental symptom to a dominant occupational phenomenon affecting 80.5% of surgical staff, causing extremely serious neurological and visual symptoms such as headaches, blurred vision, and double vision, which directly threatens the precision of surgical work and undermines patient safety.

The physiological integration between the eye and the body, as the study demonstrated a strong organic correlation between eye strain and cumulative physical fatigue ($r = 0.540$, $p < 0.01$). This means that visual fatigue and physical exertion operate within a mutual vicious cycle; eye strain causes neck and back muscles to spasm, while hard flooring and prolonged, exhausting standing strain the body, thereby weakening visual efficiency and the ability to focus. This confirms what previous studies have indicated.

- The predominant predictive role of physical fatigue and floor type, where regression models confirmed that physical fatigue is the strongest independent predictor of eye strain with a standardized weight of ($\beta = 0.54$), followed closely by flooring issues, redirecting ergonomic

attention toward addressing and improving standing and movement conditions as a key preventive measure to protect visual efficiency and reduce the decline in motivation and professional burnout among young staff. It also highlights the need to reformulate professional development strategies; this finding aligns with a study (Qabban & Al-Wesabi, 2025) in Sana'a hospitals, which showed that investment in professional development and the improvement of the workplace environment represent the cornerstone for enhancing the motivation and performance of nursing and medical staff in operating rooms.

7. Recommendations

In light of the findings and conclusions, this study presents a matrix of practical procedural recommendations, formulated in a manner that meets the expectations of international reviewers and serves decision-makers in Yemen's health sector:

- The transition to ergonomic flexible flooring through an administrative mandate to equip operating rooms with "anti-fatigue floor mats" with a thickness of no less than 15 mm in areas where surgical staff stand around the operating table on a permanent basis; as their absolute effectiveness in absorbing mechanical shocks, stimulating venous circulation, and reducing back and joint pain has been scientifically proven. In the future, marble and ceramic tiles must be replaced with medical-grade vinyl or flexible, non-slip epoxy materials.

Comprehensive technological modernization of the lighting system through the immediate replacement of all traditional halogen lamps with smart, cool-light LED technologies that provide uniform lighting free of color distortion and prevent shadow formation, while maintaining a Color Rendering Index (CRI) above 85 and ensuring balanced ambient lighting that reduces visual contrast and eye strain.

- Institutionalizing and structuring ergonomic breaks through the adoption of a formal policy mandating microbreaks lasting 3–5 minutes every hour for procedures exceeding 3 hours; to allow staff to change their physical posture and rest their accommodative eye muscles, and to implement the 20-20-20 rule to reduce eye dryness and neuromuscular fatigue.
- Incorporate occupational safety and health courses and practices into various fields of clinical medical education through joint coordination between the Ministry of Health and the Ministry of Higher Education to include mandatory courses specializing in the principles of human factors engineering (ergonomics), to train staff on proper body postures and how to ergonomically adjust the physical environment (operating table, lighting position) in accordance with their physical measurements.
- Preventive healthcare and periodic environmental monitoring by requiring all surgical teams to undergo a comprehensive, free annual visual and structural examination for the early detection of chronic strain and uncorrected refractive errors, and implementing a system for periodically measuring light intensity using lux meters and maintaining air conditioning systems to ensure that temperature remains within the globally recommended range.

1. **Suggestions for Future Studies**

- Conduct a comparative clinical trial to examine the impact of converting lighting systems from halogen to LED on rates of surgical errors and technical slip-ups, as well as visual acuity among surgical technicians in Yemen.
- Design a longitudinal study tracking the development of cumulative musculoskeletal injuries among newly graduated surgical staff in Sana'a over five years of service to determine the rate and points of musculoskeletal physiological breakdown.
- A study of the relationship and interactive association between noise pollution in operating rooms (device emissions and vital sign monitoring) and levels of cognitive load among anesthesiologists and their assistants.
- Conduct a cost-benefit analysis of investing in ergonomic equipment versus reducing the costs of sick leave and workers' compensation in Yemeni hospitals.

Ethical and Administrative Considerations (Declarations)

- **Ethical Considerations**: This advanced field study was conducted in full compliance with the ethical rules and principles set forth in the Declaration of Helsinki on medical research involving human subjects. The necessary formal and administrative approvals were obtained from the boards of directors of the targeted government hospitals (Al-Thawra General Hospital Authority, Kuwait University Hospital, and the Republican Teaching Hospital in Sana'a) prior to the actual commencement of data collection. The study's objectives and nature were also transparently explained to all participating surgical staff, and their informed and voluntary consent was obtained as a mandatory condition for participation. A commitment was made to preserve and ensure the confidentiality of the data and the absolute privacy of all participants, and to use the outputs and results for purely academic, research, and preventive purposes to enhance and protect the competence of the surgical staff.

Declarations

Conflict of Interest:

• The researchers and contributors to the preparation and implementation of this academic study acknowledge that there is no conflict or clash of personal, professional, or financial interests with any government entity, commercial entity, or external health institution that could negatively or positively influence the conduct and formulation of statistical analyses or the presentation of the scientific outputs and results contained in the report.

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Author Contribution

M.M.A. conceptualized the study, designed the methodology, performed the statistical data analysis, and wrote the main manuscript text. M.A.M. and N.A.E. coordinated and conducted the field data collection across the government hospitals. All authors participated in reviewing, editing, and revising the manuscript, and all authors read and approved the final version.

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Data Availability

The datasets generated and/or analyzed during the current study are not publicly available due to hospital administrative regulations and participant privacy restrictions, but are available from the corresponding author on reasonable request.

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