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Physiological Responses to Environmental Changes and Their Impact on Human Health and Productivity: A Sustainable Development Perspective

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Index Terms

Environmental Changes; Physiological Responses; Human Health; Productivity; Sustainable Development; Occupational Health; Healthcare Professionals.

Abstract

Environmental changes have become a major challenge affecting human health, occupational performance, and sustainable development, particularly within healthcare environments where professionals are continuously exposed to multiple environmental stressors. Despite growing interest in environmental sustainability, limited empirical evidence has examined the physiological mechanisms through which environmental changes influence health and productivity in developing healthcare systems. Therefore, this study investigated the effects of environmental changes on physiological responses and their subsequent impact on health, productivity, and sustainable development among healthcare professionals at Al-Bayda Medical Center, Libya. A quantitative descriptive–analytical design was adopted, and data were collected from 70 healthcare professionals using a structured questionnaire. The collected data were analyzed using the Statistical Package for the Social Sciences (SPSS) through descriptive statistics, reliability and validity assessment, Pearson correlation, linear regression, bootstrap mediation analysis, and demographic comparison tests. The findings revealed that environmental changes significantly influenced physiological responses and exerted significant effects on health and productivity. Physiological responses partially mediated the relationships between environmental changes and both outcome variables, while productivity emerged as the strongest contributor to sustainable development. In addition, demographic characteristics explained significant differences across selected study constructs. The findings highlight the importance of improving workplace environmental conditions to protect employees' physiological health, enhance productivity, and strengthen sustainable healthcare development. The study contributes context-specific evidence from the Libyan healthcare sector and provides practical implications for integrating environmental management with occupational health strategies to support long-term institutional sustainability.

الاستجابات الفسيولوجية للتغيرات البيئية وتأثيرها على صحة الإنسان وإنتاجيته: منظور التنمية المستدامة

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الكلمات المفتاحية

التغيرات البيئية، الاستجابات الفسيولوجية، صحة الإنسان، الإنتاجية، التنمية المستدامة، الصحة المهنية، العاملون في القطاع الصحي.

الملخص

أصبحت التغيرات البيئية من أبرز التحديات المؤثرة في صحة الإنسان والأداء المهني والتنمية المستدامة، ولا سيما في بيئات العمل الصحية التي يتعرض فيها العاملون بصورة مستمرة لضغوط بيئية متعددة. وعلى الرغم من تزايد الاهتمام بالاستدامة البيئية، ما تزال الأدلة التطبيقية التي تفسر الدور الذي تؤديه الاستجابات الفسيولوجية في العلاقة بين التغيرات البيئية والصحة والإنتاجية محدودة، خاصة في الدول النامية. لذلك هدفت هذه الدراسة إلى تحليل أثر التغيرات البيئية في الاستجابات الفسيولوجية وانعكاساتها على الصحة والإنتاجية والتنمية المستدامة لدى العاملين بمركز البيضاء الطبي في ليبيا. واعتمدت الدراسة المنهج الوصفي التحليلي،

وجُمعت البيانات من 70 من العاملين في القطاع الصحي باستخدام استبانة منظمة، ثم حُللت باستخدام برنامج SPSS من خلال الإحصاءات الوصفية، واختبارات الصدق والثبات، وتحليل ارتباط بيرسون، والانحدار الخطي، وتحليل الوساطة باستخدام Bootstrap، واختبارات الفروق الديموغرافية. وأظهرت النتائج أن التغيرات البيئية تؤثر تأثيرًا معنويًا في الاستجابات الفسيولوجية، كما تؤثر بصورة مباشرة في الصحة والإنتاجية، مع وجود دور وساطة جزئي للاستجابات الفسيولوجية في تفسير هذه العلاقة. كما تبين أن الإنتاجية تمثل العامل الأكثر إسهامًا في تحقيق التنمية المستدامة، في حين فسرت بعض الخصائص الديموغرافية فروقًا معنوية في عدد من متغيرات الدراسة. وتؤكد النتائج أهمية تحسين بيئة العمل الصحية باعتبارها مدخلًا لحماية صحة العاملين، وتعزيز الإنتاجية، ودعم استدامة المؤسسات الصحية، كما تقدم الدراسة دليلًا تطبيقيًا جديدًا من البيئة الليبية يسهم في تطوير سياسات الإدارة البيئية والصحة المهنية.

1. INTRODUCTION

1.1 Research Context

Environmental changes are increasingly recognized as a major determinant of population health, workforce capacity, and the sustainability of healthcare systems worldwide. Climate change, environmental pollution, rising temperatures, and deteriorating workplace conditions have expanded the range of occupational hazards encountered by healthcare professionals, transforming environmental health from a purely ecological concern into a strategic priority for sustainable healthcare systems (Whitmee *et al*., 2015; Landrigan *et al*., 2018; Watts *et al*., 2021).

Among occupational sectors, healthcare workers are particularly vulnerable because they routinely perform physically and cognitively demanding tasks under continuously changing environmental conditions. Growing evidence indicates that exposure to environmental stressors triggers physiological responses capable of influencing workers' health, functional performance, and productivity, thereby affecting both organizational resilience and the long-term sustainability of healthcare services (Romanello *et al*., 2022; Ibar *et al*., 2021; Shetty *et al*., 2024). Understanding these interconnected relationships has therefore become essential for developing evidence-based strategies that protect healthcare workers while strengthening sustainable healthcare systems.

1.2 Research Motivation

Although substantial progress has been made in understanding the effects of environmental conditions on occupational health, current evidence remains fragmented. Most previous studies have examined environmental changes, physiological health, and work performance independently, providing limited understanding of the biological pathways through which environmental stressors influence healthcare workers' health and productivity simultaneously (Watts *et al*., 2021; Romanello *et al*., 2022). Furthermore, evidence from developing healthcare systems, particularly the Libyan healthcare sector, remains scarce despite its unique environmental and occupational challenges (WHO, 2016; Njororai *et al*., 2021). These limitations highlight the need for an integrated investigation that explains how physiological responses connect environmental changes with health, productivity, and sustainable healthcare development.

1.3 Research Aim

Building upon the identified knowledge gaps, this study develops an integrated framework to examine the relationships among environmental changes, physiological responses, health, productivity, and sustainable development within the Libyan healthcare sector. Specifically, the study investigates the role of physiological responses as the underlying mechanism linking environmental changes with employees' health and productivity, while also examining whether demographic characteristics contribute to variations in these relationships. By focusing on healthcare workers at Al-Bayda Medical Center, the study provides empirical evidence from a developing healthcare context where such integrated investigations remain limited (World Health Organization [WHO], 2016; Romanello *et al*., 2022; Njororai *et al*., 2021).

1.4 Research Contributions

The present study extends current knowledge by integrating environmental changes, physiological responses, health, productivity, and sustainable development into a single conceptual framework applicable to healthcare settings. Unlike previous studies that have largely examined these constructs independently, the proposed framework explains the biological and organizational pathways through which environmental conditions influence healthcare workforce outcomes (Watts *et al*., 2021; Romanello *et al*., 2022).

The study also contributes to the environmental health literature by providing empirical evidence from the Libyan healthcare sector, where research examining these interrelated constructs remains limited. By evaluating healthcare workers at Al-Bayda Medical Center, the findings provide context-specific evidence that may assist healthcare organizations in developing workplace strategies that promote employee wellbeing, improve productivity, and strengthen sustainable healthcare systems (World Health Organization [WHO], 2016; Aust *et al*., 2024; Njororai *et al*., 2021).

2. PLITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1 Environmental Changes and Physiological Responses

Environmental changes have become one of the most influential determinants of human health and occupational performance, particularly within healthcare settings where

employees are continuously exposed to multiple environmental stressors. Rising temperatures, poor indoor air quality, excessive noise, inadequate lighting, and increasing occupational demands create complex physiological challenges that require continuous adaptation by healthcare workers. These stressors activate a range of physiological responses involving the cardiovascular, endocrine, autonomic, and neuroendocrine systems, which are intended to maintain homeostasis but may become harmful when environmental exposure is prolonged or repeated (Watts *et al*., 2021; Romanello *et al*., 2022).

Recent evidence suggests that climate-related environmental changes have shifted from being an environmental concern to becoming a major occupational health issue. The Lancet Countdown reports consistently demonstrate that increasing exposure to extreme heat, deteriorating environmental quality, and climate-related hazards have substantially increased physiological strain among workers, particularly in health services where physical and cognitive demands remain consistently high (Watts *et al*., 2021; Romanello *et al*., 2022). Likewise, Vicedo-Cabrera *et al*. (2021) demonstrated that heat exposure substantially increases adverse physiological outcomes and contributes to excess mortality through impaired thermoregulation and cardiovascular stress, highlighting the growing importance of environmental adaptation within healthcare systems.

Within healthcare facilities, environmental conditions extend beyond outdoor climate exposure to include characteristics of the indoor workplace itself. Bayramzadeh *et al*. (2021), through a systematic literature review, demonstrated that environmental characteristics such as temperature, lighting, acoustic conditions, spatial layout, and ventilation influence physiological functioning by altering sleep quality, cardiovascular responses, stress levels, and overall physical wellbeing among healthcare staff. Similarly, Zadeh *et al*. (2018) reported that healthcare professionals consistently identified environmental characteristics as fundamental determinants of both health and work performance, while also demonstrating that perceptions of these environmental conditions differed according to occupational roles and workforce characteristics.

The physiological mechanisms underlying these relationships have been further supported by biomarker-based research. Ibar *et al*. (2021) found that occupational stress among healthcare workers was associated with elevated hair cortisol concentrations, confirming that workplace stressors are translated into measurable physiological responses. Complementing these findings, Andarini and Ramdhan (2025) concluded that physiological biomarkers, particularly cortisol-based indicators, provide robust evidence that prolonged occupational fatigue reflects sustained physiological activation capable of compromising workers' health and functional capacity. Collectively, these findings indicate that physiological responses represent the primary biological pathway through which environmental exposures influence healthcare workers' wellbeing.

Despite the growing body of evidence linking environmental conditions with physiological functioning, previous research has largely examined individual environmental stressors or isolated physiological outcomes rather than considering environmental change as a multidimensional construct influencing broader occupational outcomes. Furthermore, empirical evidence from healthcare systems in developing countries remains limited, particularly regarding how physiological responses operate as an intermediate mechanism connecting environmental changes with subsequent health and productivity outcomes. Addressing this gap is particularly important within healthcare organizations where environmental pressures, workforce demands, and sustainable service delivery intersect. Accordingly, the present study proposes that environmental changes significantly influence physiological responses among healthcare workers.

2.2 Physiological Responses, Health, and Productivity

Physiological responses constitute the principal biological mechanism through which environmental stressors influence workers' health and occupational performance. While short-term physiological adaptations help maintain homeostasis, prolonged activation of stress-response systems may impair cardiovascular function, endocrine regulation, sleep quality, cognitive performance, and emotional wellbeing, ultimately reducing employees' ability to perform efficiently. Within healthcare environments, where continuous physical and mental demands are unavoidable, these physiological changes become increasingly relevant to both individual health and organizational effectiveness (Bayramzadeh *et al*., 2021; Aust *et al*., 2024).

Evidence from healthcare settings consistently demonstrates that physiological stress is associated with measurable declines in workers' health status. Ibar *et al*. (2021) reported that elevated cortisol concentrations among healthcare workers were strongly associated with perceived occupational stress and emotional exhaustion, confirming that workplace stressors are translated into biological alterations rather than remaining purely psychological experiences. Likewise, Morales *et al*. (2019) observed that sleep deprivation and prolonged work shifts produced significant physiological dysregulation accompanied by deterioration in cognitive performance and mood, suggesting that sustained physiological strain compromises both personal wellbeing and professional functioning.

Beyond its implications for health, physiological stress also influences productivity by reducing concentration, increasing fatigue, and impairing decision-making during clinical practice. A recent systematic review by Shetty *et al*. (2024) concluded that healthcare environments supporting workers' physiological wellbeing consistently achieved higher levels of staff performance, efficiency, and workplace satisfaction. Similarly, Aust *et al*. (2024) demonstrated that organizational interventions designed to reduce physiological and psychological strain improved employees' wellbeing while enhancing overall work

performance, indicating that protecting workers' physiological health represents an essential strategy for improving healthcare productivity.

Although previous studies have independently examined physiological health outcomes or occupational performance, limited attention has been given to explaining how physiological responses simultaneously influence both health and productivity within a unified conceptual framework. This limitation is particularly evident in healthcare systems of developing countries, where empirical evidence remains scarce despite increasingly challenging environmental and occupational conditions. Accordingly, the present study proposes that physiological responses represent a critical determinant of both workers' health and productivity.

2.3 Health, Productivity, and Sustainable Development

Human health and workforce productivity are increasingly recognized as fundamental pillars of sustainable development, particularly within healthcare systems where service quality depends directly on the physical and functional capacity of healthcare professionals. Sustainable healthcare cannot be achieved solely through technological advancement or financial investment; rather, it requires maintaining a healthy workforce capable of delivering safe, efficient, and continuous healthcare services. Consequently, protecting employees' health has become a strategic priority for achieving organizational resilience and long-term sustainability (World Health Organization [WHO], 2016; Whitmee *et al*., 2015).

Recent international evidence indicates that environmental and occupational challenges threaten not only workers' health but also the sustainability of healthcare systems. The Lancet Countdown reports emphasize that climate-related health risks, occupational stressors, and environmental degradation collectively reduce workforce capacity, increase absenteeism, and weaken health system resilience, thereby limiting progress toward the Sustainable Development Goals (Watts *et al*., 2021; Romanello *et al*., 2022). Similarly, Landrigan *et al*. (2018) argued that reducing environmental health risks should be considered an essential investment in human capital because healthier workers contribute to stronger institutional performance and sustainable economic development.

At the organizational level, improving workplace conditions enhances both employee wellbeing and operational performance, creating a positive cycle that supports sustainable development. Shetty *et al*. (2024) demonstrated that healthcare environments designed to promote staff wellbeing improve performance, satisfaction, and organizational effectiveness. Likewise, Aust *et al*. (2024) concluded that interventions targeting occupational health produce measurable improvements in workforce wellbeing while strengthening institutional performance, indicating that investments in employee health generate benefits extending beyond individual outcomes to organizational sustainability.

Although previous research has acknowledged the relationships between health, productivity, and sustainability, these constructs have frequently been examined independently rather than as interconnected components of a unified framework. Evidence integrating physiological health, workforce productivity, and sustainable development remains limited, particularly in healthcare organizations operating within resource-constrained settings. This gap highlights the need to investigate how improvements in workers' health and productivity contribute simultaneously to sustainable development outcomes. Accordingly, the present study proposes that both health and productivity positively influence sustainable development.

2.4 Demographic Characteristics and Workplace Environmental Adaptation

Although environmental changes influence healthcare workers through common physiological mechanisms, growing evidence indicates that individual demographic and occupational characteristics may modify the magnitude of these effects. Factors such as age, professional experience, educational level, occupational role, and work schedule influence workers' ability to adapt to environmental stressors and may consequently affect health outcomes, work performance, and resilience within healthcare settings. Recognizing these individual differences has therefore become increasingly important for designing effective occupational health interventions and achieving sustainable workforce management (Njororai *et al*., 2021).

Recent empirical studies have shown that demographic characteristics are associated with substantial variation in employees' perceptions of workplace conditions and their subsequent occupational performance. Zadeh *et al*. (2018) demonstrated that healthcare workers assigned different levels of importance to workplace environmental characteristics according to their professional roles and demographic backgrounds, suggesting that environmental improvements may not produce identical benefits across all occupational groups. Similarly, Njororai *et al*. (2021) reported that socio-demographic characteristics, together with environmental conditions, significantly influenced the performance of community healthcare workers, emphasizing that workforce characteristics should be considered when evaluating occupational outcomes.

Despite these findings, demographic variables have frequently been treated as control variables rather than meaningful contextual factors capable of shaping the relationships between environmental conditions, physiological responses, health, and productivity. Consequently, limited evidence is available regarding whether demographic differences contribute to variations in these relationships within healthcare organizations operating in developing countries. Addressing this limitation is particularly relevant in the Libyan healthcare sector, where workforce composition, professional responsibilities, and working conditions differ across occupational groups. Therefore, the present study further

examines whether significant differences exist according to selected demographic characteristics among healthcare professionals.

2.5 Research Gap and Hypotheses Development

Despite the growing body of literature examining environmental health, occupational wellbeing, and employee performance, several important knowledge gaps remain unresolved. First, previous studies have predominantly investigated environmental changes, physiological health, and occupational productivity as separate research domains, with relatively limited attention given to the biological mechanisms through which environmental changes simultaneously influence both health and productivity. Consequently, the integrative role of physiological responses within this relationship remains insufficiently explored, particularly in healthcare settings (Watts *et al*., 2021; Romanello *et al*., 2022; Andarini & Ramdhan, 2025).

Second, although recent systematic reviews have confirmed that workplace environmental conditions substantially affect healthcare workers' physiological wellbeing and occupational performance, most available evidence has focused on individual environmental exposures such as thermal stress, workplace design, or occupational fatigue rather than examining environmental changes as a multidimensional construct encompassing diverse environmental stressors. This fragmented approach limits the understanding of how different environmental conditions collectively influence healthcare workers' physiological adaptation and subsequent organizational outcomes (Bayramzadeh *et al*., 2021; Shetty *et al*., 2024; Aust *et al*., 2024).

Third, existing empirical studies have primarily been conducted in high-income countries, whereas evidence from developing healthcare systems remains limited. In particular, little empirical research has examined these relationships within the Libyan healthcare sector despite its unique environmental, occupational, and organizational challenges. Furthermore, demographic characteristics have frequently been treated as statistical control variables rather than contextual factors that may explain variations in workers' responses to environmental conditions and occupational demands (Zadeh *et al*., 2018; Njororai *et al*., 2021).

Building upon these limitations, the present study develops an integrated conceptual framework that explains how environmental changes influence healthcare workers through physiological responses and subsequently affect health, productivity, and sustainable development. In addition, the study examines whether demographic characteristics are associated with significant differences in the proposed relationships. By integrating these constructs within a single analytical model and providing empirical evidence from the Libyan healthcare context, this study contributes to extending current knowledge while addressing an important geographical and theoretical gap in the environmental health and sustainable development literature.

3. METHODOLOGIES

This study adopted a quantitative cross-sectional survey design to investigate the relationships among environmental changes, physiological responses, health, productivity, and sustainable development among healthcare workers at Al Bayda Medical Center, Libya. Data were collected using a structured questionnaire developed from the study framework and relevant literature. The final sample comprised 70 healthcare workers from different departments. The questionnaire included demographic information and measurement items assessed on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Before hypothesis testing, the dataset was screened to verify data quality, and the reliability and validity of the measurement instrument were evaluated using Cronbach's alpha, item-total correlations, and complementary reliability indicators. Statistical assumptions, including normality, homogeneity of variance, multicollinearity, and independence of residuals, were examined before conducting inferential analyses. Where the assumptions of parametric testing were not fully satisfied, appropriate non-parametric procedures and bootstrap resampling were applied to ensure robust statistical estimation.

All statistical analyses were performed using IBM SPSS Statistics. Descriptive statistics were used to summarize the sample characteristics, while Pearson correlation and linear regression analyses were conducted to test the proposed relationships. The mediating effect of physiological responses was examined using a bootstrap regression approach, and demographic differences were assessed using independent-samples t-tests, one-way ANOVA, Mann-Whitney U, and Kruskal-Wallis tests, as appropriate. Statistical significance was established at $p < 0.05$ for all analyses.

4. RESULTS

4.1 Respondents' Demographic Characteristics

Table 1 summarizes the demographic characteristics of the 70 healthcare professionals who participated in this study. Male respondents represented the majority of the sample (61.4%), while females accounted for 38.6%. Nearly half of the respondents were younger than 30 years (48.6%), followed by those aged between 30 and 40 years (41.4%), indicating that the workforce was predominantly composed of young and early-career professionals. More than half of the participants were single (52.9%), whereas 44.3% were married.

Regarding educational attainment, most respondents held a bachelor's degree (62.9%), followed by diploma holders (35.7%), while only one participant possessed a master's degree. In terms of professional experience, the largest proportion had between five and ten years of experience (44.3%), followed by less than five years (38.6%), reflecting a workforce with moderate practical experience.

Furthermore, almost half of the respondents worked on rotational shifts (47.1%), compared with 42.9% working morning shifts and 10.0% working evening shifts.

Overall, these demographic characteristics indicate that the study sample adequately represents healthcare personnel with diverse professional backgrounds, educational levels, and work schedules, thereby providing a suitable basis for examining the relationships between environmental changes, physiological responses, health, and productivity.

Table 1. Demographic Characteristics of the Respondents (N = 70)

Percentage (%)	Frequency (n)	Category	Variable
61.4	43	Female	Gender
38.6	27	Male	
48.6	34	Less than 30 years	Age
41.4	29	30–40 years	
8.6	6	40–50 years	
1.4	1	More than 50 years	
52.9	37	Single	Marital status
44.3	31	Married	
2.9	2	Divorced	
35.7	25	Diploma	Educational level
62.9	44	Bachelor's degree	
1.4	1	Master's degree	
38.6	27	Less than 5 years	Years of experience
44.3	31	5–10 years	
5.7	4	10–15 years	
8	11.4	More than 15 years	
42.9	30	Morning shift	Work schedule
10.0	7	Evening shift	
47.1	33	Rotational shifts	

4.2 Reliability and Validity of the Measurement Instrument

The psychometric properties of the measurement instrument were assessed prior to hypothesis testing to ensure the reliability and validity of the collected data. Internal consistency was evaluated using Cronbach's alpha coefficient, while construct validity was examined using established validity indicators. As shown in Table 2, all study constructs demonstrated Cronbach's alpha values exceeding the recommended threshold of 0.70, indicating satisfactory internal consistency. Likewise, the validity indices confirmed that all constructs possessed acceptable measurement properties, supporting the suitability of the questionnaire for subsequent statistical analyses. These findings suggest that the measurement instrument was both reliable and valid for assessing the relationships among the study variables, thereby providing a sound basis for hypothesis testing and inferential analysis (Cho, 2021; Taber, 2021).

Table 2. Internal consistency reliability of the measurement instrumen

Construct	**No. of Items**	**Cronbach's α**	**Interpretation**
Environmental Changes	6	0.916	Excellent
Physiological Responses	6	0.883	Good
Health	6	0.841	Good
Productivity	5	0.857	Good

Construct	No. of Items	Cronbach's α	Interpretation
Sustainable Development (Refined)	3	0.760	Acceptable
Overall instrument	28	0.953	Excellent

Table 2 demonstrates that the measurement instrument achieved satisfactory to excellent internal consistency across all constructs. The Cronbach's alpha coefficients ranged from 0.760 to 0.916, while the overall questionnaire demonstrated excellent reliability (α = 0.953). Environmental Changes showed the highest reliability (α = 0.916), followed by Physiological Responses (α = 0.883), Productivity (α = 0.857), and Health (α = 0.841). The Sustainable Development construct initially included five items; however, two items (Q24 and Q27) were removed following the reliability analysis because they reduced internal consistency. After refinement, the construct retained three items and achieved an acceptable reliability coefficient (α = 0.760). Overall, these findings indicate that the questionnaire possesses adequate internal consistency and is suitable for subsequent correlation, regression, and hypothesis-testing analyses.

Note. Two items (Q24 and Q27) were removed during the reliability analysis to improve the internal consistency of the Sustainable Development construct. The refined construct achieved acceptable reliability (Cronbach's α = 0.760) and was used in all subsequent statistical analyses.

4.3 Descriptive Statistics and Correlation Analysis

To provide an initial overview of the relationships among the study constructs, descriptive statistics and Pearson correlation coefficients were calculated. The results indicate that all study variables recorded mean values above the neutral midpoint (3.00), suggesting generally positive perceptions among healthcare professionals regarding environmental changes, physiological responses, health, productivity, and sustainable development. Sustainable development achieved the highest mean score (M = 3.88, SD = 0.66), followed by physiological responses (M = 3.78, SD = 0.83), health (M = 3.72, SD = 0.81), productivity (M = 3.62, SD = 0.95), whereas environmental changes recorded the lowest, yet still positive, mean (M = 3.20, SD = 1.13).

Pearson correlation analysis revealed statistically significant positive associations among all study constructs ($p < 0.01$). Correlation coefficients ranged from 0.55 to 0.78, indicating moderate-to-strong relationships without evidence of excessive multicollinearity. The strongest association was observed between Health and Productivity (r = 0.78), followed by the relationship between Environmental Changes and Health (r = 0.75), and between Environmental Changes and Physiological Responses (r = 0.70). These findings provide preliminary empirical support for the proposed conceptual framework and justify proceeding with regression and mediation analyses to examine the hypothesized causal relationships.

Table 3. Descriptive statistics and Pearson correlation matrix of the study constructs (N = 70)

Variable	Mean	SD	1	2	3	4	5
1. Environmental Changes	3.20	1.13	1.00				
2. Physiological Responses	3.78	0.83	0.70**	1.00			
3. Health	3.72	0.81	0.75**	0.75**	1.00		
4. Productivity	3.62	0.95	0.67**	0.69**	0.78**	1.00	
5. Sustainable Development (Refined)	3.88	0.66	0.67**	0.55**	0.56**	0.69**	1.00

4.3.1 Correlation Analysis

Table 3 presents the descriptive statistics and Pearson correlation coefficients among the study constructs. The results indicate that all constructs were positively and significantly correlated at the 0.01 significance level, providing preliminary empirical support for the proposed conceptual framework. Environmental Changes demonstrated significant positive associations with Physiological Responses ($r = 0.700$, $p < 0.01$), Health ($r = 0.750$, $p < 0.01$), Productivity ($r = 0.670$, $p < 0.01$), and Sustainable Development ($r = 0.670$, $p < 0.01$). Similarly, Physiological Responses exhibited significant correlations with Health (r = 0.750), Productivity (r = 0.690), and Sustainable Development (r = 0.550). Health was strongly associated with Productivity (r = 0.780) and moderately correlated with Sustainable Development (r = 0.560). Furthermore, Productivity showed a significant positive relationship with Sustainable Development (r = 0.690). Overall, all correlation coefficients were positive and statistically significant while remaining below the recommended multicollinearity threshold ($r < 0.90$), indicating that the constructs were sufficiently distinct to justify subsequent multiple regression analysis. These findings provide initial empirical support for the hypothesized relationships and are consistent with the proposed theoretical framework.

Note. Correlation is significant at the 0.01 level (two-tailed).

4.3.2 Multiple Regression Analysis (H2 and H6)

Multiple regression analysis was conducted to examine the predictive relationships proposed in H2 and H6. Specifically, simple regression models were used to assess the predictive effect of environmental changes on physiological responses, health, and productivity, whereas

multiple regression analysis was performed to determine the combined contribution of health and productivity to sustainable development. Model evaluation was based on the coefficient of determination (R^2), test statistics, and significance levels.

Table 4. Multiple regression analysis for hypothesis testing (H2 and H6)

Hypothesis	Regression model	Predictor(s)	R^2	Test statistic	p-value	Decision
H2	Health ~ Environmental Changes	Environmental Changes	0.565	t=9.39	<0.001	Supported
H2	Physiological Responses ~ Environmental Changes	Environmental Changes	0.497	t=8.19	<0.001	Supported
H2	Productivity ~ Environmental Changes	Environmental Changes	0.447	t=7.41	<0.001	Supported
H6	Sustainable Development ~ Health + Productivity	Health, Productivity	0.453	F=27.74	<0.001	Partially Supported

The regression analysis demonstrated that environmental changes significantly predicted all proposed outcome variables. Environmental changes explained 56.5% of the variance in health, 49.7% of the variance in physiological responses, and 44.7% of the variance in productivity. All three regression models were statistically significant ($p < 0.001$), providing strong empirical evidence that increasing environmental stressors were associated with measurable changes in workers' physiological responses, health status, and productivity. These findings provide full support for Hypothesis H2.

Regarding sustainable development, the multiple regression model explained 45.3% of its variance. Examination of the regression coefficients indicated that productivity was the only significant predictor of sustainable development ($\beta = 0.625$, $p < 0.001$), whereas the contribution of health became statistically non-significant after controlling for productivity ($p = 0.76$). This pattern suggests that the influence of health on sustainable development is transmitted largely through productivity rather than through a direct independent effect. Consequently, Hypothesis H6 received partial support, with productivity emerging as the dominant predictor of sustainable development in the proposed model.

4.3.3 Mediation Analysis (H4 and H5)

To further examine the underlying mechanism through which environmental changes influence health and productivity outcomes, mediation analysis was conducted using the bootstrap resampling approach (5,000 bootstrap samples). This procedure was employed to determine whether physiological responses transmit the effect of environmental changes to the two outcome variables. The significance of the indirect effect was evaluated using bias-corrected 95% confidence intervals, where mediation is supported when the confidence interval does not include zero.

Table 5. Bootstrap mediation analysis results (H4 and H5)

Hypothesis	Mediation Path	Total Effect (c)	Direct Effect (c′)	Indirect Effect	95% Bootstrap CI	Mediation Type	Decision
H4	Environmental Changes → Physiological Responses → Health	0.537***	0.315***	0.222	0.110–0.365	Partial mediation	Supported
H5	Environmental Changes → Physiological Responses → Productivity	0.565***	0.300**	0.265	0.137–0.446	Partial mediation	Supported

Note. Bootstrap resampling = 5,000 samples. Mediation is considered significant when the 95% bias-corrected confidence interval does not include zero. *** $p < 0.001$; ** $p < 0.01$. Results are reported directly from the statistical analysis.

The mediation analysis demonstrated that physiological responses significantly mediated the relationships between environmental changes and both health and productivity outcomes. For the first mediation model (H4), the total effect of environmental changes on health was 0.537, while the direct effect remained statistically significant after including the mediator (0.315). The indirect effect through physiological responses reached 0.222, with a 95% bootstrap confidence interval ranging from 0.110 to 0.365, excluding zero and therefore confirming a statistically significant mediation effect.

A similar pattern was observed for productivity (H5). Environmental changes exerted a total effect of 0.565, whereas the direct effect decreased to 0.300 after accounting for physiological responses. The indirect effect was 0.265, and the corresponding 95% bootstrap confidence interval (0.137–0.446) also excluded zero, indicating a significant indirect pathway. Because the direct effects remained statistically significant in both models while the indirect effects were also significant, the

findings indicate partial mediation rather than full mediation. Consequently, both H4 and H5 were supported.

4.3.4 Summary of Hypothesis Testing

To provide an integrated overview of the empirical findings, the results of all proposed hypotheses are summarized in Table 6. The table consolidates the statistical evidence obtained from the correlation, regression, and bootstrap mediation analyses, thereby presenting the final decisions regarding each hypothesis. This summary facilitates the interpretation of the overall conceptual framework and provides a concise reference before discussing the findings in relation to previous research.

Table 6. Demographic Differences Analysis Results (H7)

Grouping variable	Affected construct(s)	Statistic	p-value	Effect size (η^2)	Decision
Job title	Health; Productivity; Sustainable Development	F = 2.82 / 4.36 / 5.03	0.046 / 0.003 / 0.007	0.113 / 0.186 / 0.165	Partially supported
Years of experience	Health; Productivity; Sustainable Development	F = 5.18 / 2.96 / 2.79	0.003 / 0.047 / 0.039	0.190 / 0.113 / 0.119	Partially supported
Work system	Health; Productivity	F = 3.27 / 3.21	0.044 / 0.047	0.089 / 0.087	supported
Educational level	Productivity	F = 9.67	0.003	0.153	supported
Age group	Health	F = 3.73	0.029	0.103	supported

The findings presented in Table 6 indicate that demographic characteristics were associated with selected study constructs rather than exerting a uniform influence across all outcomes. Significant differences were observed according to job title, years of experience, work system, educational level, and age group, although the affected constructs varied across these demographic factors. Job title and years of experience were associated with significant differences in health, productivity, and sustainable development, whereas work system significantly influenced health and productivity. In addition, educational level was significantly associated with productivity, while age differences were observed only for the health construct. These findings suggest that demographic characteristics contribute to variations in specific dimensions of environmental adaptation and occupational outcomes, but their effects are neither comprehensive nor consistent across all constructs. Accordingly, Hypothesis H7 was partially supported, indicating that demographic factors explain selected, rather than universal, differences among healthcare professionals.

5. DISCUSSION

This study provides empirical evidence that environmental changes significantly influence physiological responses, health, productivity, and sustainable development among healthcare professionals at Al-Bayda Medical Center. The findings support the proposed conceptual framework and indicate that environmental conditions affect occupational outcomes through interconnected physiological and organizational pathways. These findings reinforce the growing consensus that workplace environmental quality represents a fundamental determinant of healthcare workers' well-being and institutional sustainability (Romanello *et al*., 2022; Aust *et al*., 2024).

The significant association between environmental changes and physiological responses confirms that environmental stressors trigger measurable physiological adaptation among healthcare professionals, supporting H1. This finding agrees with recent evidence indicating that climate-related environmental exposures increase physiological strain and compromise workers' health and occupational performance (Vicedo-Cabrera *et al*., 2021; Romanello *et al*., 2022). Within the Libyan healthcare context, these results suggest that improving environmental conditions may reduce physiological stress and enhance employees' capacity to perform clinical duties efficiently.

Moreover, environmental changes significantly predicted both health and productivity, supporting H2, while physiological responses were positively associated with productivity, supporting H3. These findings suggest that unfavorable workplace environments impair employees' functional capacity and work performance through physiological adaptation mechanisms. Similar observations have been reported in recent occupational health studies, which emphasize that improving workplace environmental quality contributes to better health outcomes and higher workforce productivity (Aust *et al*., 2024; Shetty *et al*., 2024).

The mediation analysis further demonstrated that physiological responses partially mediated the relationships between environmental changes and both health and productivity, providing support for H4 and H5. These findings suggest that environmental conditions influence occupational outcomes both directly and indirectly through physiological adaptation. In other words, adverse environmental exposures increase physiological strain, which subsequently contributes to poorer health status and reduced productivity. Nevertheless, the persistence of significant direct effects indicates that additional organizational and occupational factors may also contribute to these relationships. Similar

findings have been reported in recent occupational health research, emphasizing that physiological stress represents a key mechanism linking environmental exposures with employee health and work performance rather than functioning as the sole explanatory pathway (Aust *et al*., 2024; Romanello *et al*., 2022).

Furthermore, productivity emerged as the strongest predictor of sustainable development, whereas health did not retain an independent contribution after productivity was introduced into the regression model, partially supporting H6. This finding indicates that the influence of employees' health on sustainable development is largely translated through their ability to maintain productive work performance. From an organizational perspective, healthier healthcare professionals are more capable of delivering consistent clinical services, improving institutional efficiency, and supporting long-term sustainability. This interpretation is consistent with contemporary sustainability research, which recognizes workforce productivity as a critical component linking employee well-being with sustainable organizational performance (Romanello *et al*., 2022; Leso *et al*., 2024).

Finally, the demographic analysis partially supported H7, indicating that the effects of environmental conditions were not uniformly distributed across participant characteristics. Significant differences observed according to job title, years of experience, work system, educational level, and age group suggest that individual and occupational characteristics may modify employees' responses to environmental stressors. These findings imply that environmental health interventions should be tailored to the specific needs of different professi onal groups rather than adopting a uniform approach for all healthcare workers. Similar conclusions have been highlighted in recent studies, which recommend targeted occupational health strategies to improve workforce resilience and organizational performance under changing environmental conditions (Aust *et al*., 2024; Shetty *et al*., 2024).

Overall, the present study extends current evidence by demonstrating that environmental changes influence sustainable development through interconnected physiological and organizational mechanisms within a Libyan healthcare setting. Unlike many previous studies conducted in high-income countries, this research provides empirical evidence from a resource-constrained healthcare environment, highlighting the importance of integrating environmental management, occupational health, and workforce productivity into healthcare sustainability strategies. These findings provide practical evidence for healthcare administrators and policymakers seeking to strengthen institutional resilience while protecting the health and performance of healthcare professionals.

6. CONCLUSION

The present study demonstrated that environmental changes significantly influence healthcare professionals' physiological responses, health, productivity, and sustainable development within Al-Bayda Medical Center. The findings support the proposed conceptual framework by confirming that environmental conditions affect organizational sustainability through interconnected physiological and occupational pathways. In particular, physiological responses partially mediated the effects of environmental changes on health and productivity, while productivity emerged as the principal contributor to sustainable development.

This study extends the existing literature by providing empirical evidence from the Libyan healthcare sector, where research examining the relationship between environmental conditions, physiological adaptation, and organizational sustainability remains limited. The findings emphasize that improving workplace environmental quality should be considered not only as a public health priority but also as a strategic organizational investment capable of enhancing employee well-being, productivity, and long-term institutional sustainability. Accordingly, integrating environmental management into occupational health policies may strengthen healthcare system resilience while supporting sustainable development objectives.

7. RECOMMENDATIONS

Based on the study findings, the following recommendations are proposed:

1. Healthcare institutions should implement comprehensive environmental management strategies to reduce workplace environmental stressors and improve indoor environmental quality.
2. Occupational health programs should incorporate regular physiological and environmental monitoring to identify early indicators of work-related environmental stress among healthcare professionals.
3. Hospital administrators should integrate environmental sustainability initiatives with employee health promotion programs to enhance workforce productivity and institutional performance.
4. Policymakers should strengthen environmental health regulations within healthcare facilities by prioritizing healthy workplace environments as an essential component of sustainable healthcare systems.
5. Future studies are encouraged to employ longitudinal and multicenter designs involving larger samples from different Libyan healthcare institutions to improve the generalizability of the findings and further examine the underlying mechanisms linking environmental changes with organizational sustainability.

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REFERENCES

- Andarini, D., & Ramdhan, D. H. (2025). Analysis of occupational fatigue based on saliva biomarkers in healthcare workers: A systematic review. Fatigue: Biomedicine, Health & Behavior. Advance online publication. https://doi.org/10.1080/21641846.2025.2584949

- Aust, B., Leduc, C., Cresswell-Smith, J., O'Brien, C., Rugulies, R., Leduc, M., Ni Dhalaigh, D., Dushaj, A., Fanaj, N., Guinart, D., Maxwell, M., Reich, H., Ross, V., Sadath, A., Schnitzspahn, K., Tóth, M. D., van Audenhove, C., van Weeghel, J., Wahlbeck, K., Arensman, E., & Greiner, B. A. (2024). The effects of different types of organisational workplace mental health interventions on mental health and wellbeing in healthcare workers: A systematic review. International Archives of Occupational and Environmental Health, 97(5), 485–522. https://doi.org/10.1007/s00420-024-02065-z

- Bayramzadeh, S., Ahmadpour, P., Aghaei, P., Tang, C., & others. (2021). The relationship between sensory stimuli and the physical environment in complex healthcare settings: A systematic literature review. HERD: Health Environments Research & Design Journal.

- Ibar, C., Fortuna, F., Gonzalez, D., Jamardo, J., Jacobsen, D., Pugliese, L., & Fabre, B. (2021). Evaluation of stress, burnout and hair cortisol levels in health workers at a University Hospital during COVID-19 pandemic. Psychoneuroendocrinology, 128, 105213. https://doi.org/10.1016/j.psyneuen.2021.105213

- Landrigan, P. J., Fuller, R., Acosta, N. J. R., Adeyi, O., Arnold, R., Basu, N., Baldé, A. B., Bertollini, R., Bose-O'Reilly, S., Boufford, J. I., Breysse, P. N., Chiles, T., Mahidol, C., Coll-Seck, A. M., Cropper, M. L., Fobil, J., Fuster, V., Greenstone, M., Haines, A., … Zhong, M. (2018). The Lancet Commission on pollution and health. The Lancet, 391(10119), 462–512. https://doi.org/10.1016/S0140-6736(17)32345-0

- Morales, J., Yáñez, A., Fernández-González, L., Montesinos-Magraner, L., Marco-Ahulló, A., Solana-Tramunt, M., & Calvete, E. (2019). Stress and autonomic response to sleep deprivation in medical residents: A comparative cross-sectional study. PLoS ONE, 14(4), e0214858. https://doi.org/10.1371/journal.pone.0214858

- Njororai, F., Ganu, D., Nyaranga, K. C., & Wilberforce, C. (2021). Role of socio-demographic and environmental determinants on performance of community health workers in Western Kenya. International Journal of Environmental Research and Public Health, 18(21), 11707. https://doi.org/10.3390/ijerph182111707

- Romanello, M., McGushin, A., Di Napoli, C., Drummond, P., Hughes, N., Jamart, L., … Costello, A. (2022). The 2022 report of the Lancet Countdown on health and climate change: Health at the mercy of fossil fuels. The Lancet, 400(10363), 1619–1654. https://doi.org/10.1016/S0140-6736(22)01540-9

- Shetty, R. S., Kamath, G. B., Rodrigues, L., & Bhat, S. (2024). The impact of the physical environment on staff in healthcare facilities: A systematic literature review. Buildings, 14(9), 2773. https://doi.org/10.3390/buildings14092773

- Shetty, R. S., Kamath, G. B., Rodrigues, L., & Bhat, S. (2024). The impact of the physical environment on staff in healthcare facilities: A systematic literature review. Buildings, 14(9), 2773. https://doi.org/10.3390/buildings14092773

- Vicedo-Cabrera, A. M., Sera, F., Liu, C., Armstrong, B., Milojevic, A., Guo, Y., … Gasparrini, A. (2021). The burden of heat-related mortality attributable to recent human-induced climate change. Nature Climate Change, 11(6), 492–500. https://doi.org/10.1038/s41558-021-01058-x

- Watts, N., Amann, M., Arnell, N., Ayeb-Karlsson, S., Belesova, K., Berry, H., … Costello, A. (2021). The 2021 report of the Lancet Countdown on health and climate change: Code red for a healthy future. The Lancet, 398(10311),

1619–1662. https://doi.org/10.1016/S0140-6736(21)01787-6

- Whitmee, S., Haines, A., Beyrer, C., Boltz, F., Capon, A. G., Dias, B. F. S., Ezeh, A., Frumkin, H., Gong, P., Head, P., Horton, R., Mace, G. M., Marten, R., Myers, S. S., Nishtar, S., Osofsky, S. A., Pattanayak, S. K., Pongsiri, M. J., Romanelli, C., … Yach, D. (2015). Safeguarding human health in the Anthropocene epoch: Report of The Rockefeller Foundation–Lancet Commission on planetary health. The Lancet, 386(10007), 1973–2028. https://doi.org/10.1016/S0140-6736(15)60901-1

- World Health Organization. (2016). Health workforce requirements for universal health coverage and the Sustainable Development Goals (Human Resources for Health Observer No. 17). World Health Organization.