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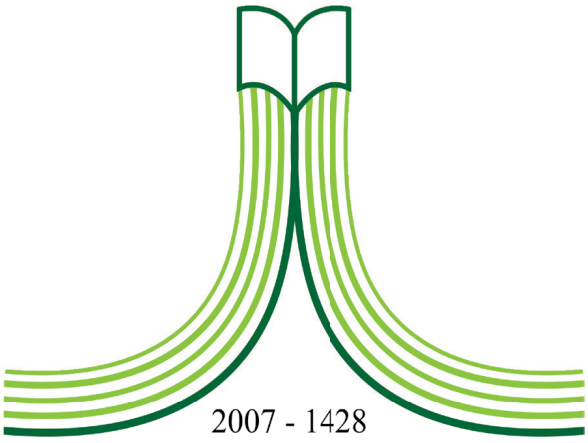

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Optimizing Autism Spectrum Disorder Screening with Machine Learning: Identifying Key Behavioral Predictors and Model Performance

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Abstract
Autism Spectrum Disorders (ASD) are becoming increasingly common worldwide, highlighting the need for accurate and reliable early detection methods. Utilizing machine learning for early detection is crucial for enhancing screening processes. This study investigates how behavioral traits can help identify ASD through machine learning algorithms. The performance of several techniques, including Gradient Boosting, Support Vector Machines, and Naïve Bayes, is compared. The analysis reveals that A9, A6, A7, and A5 are the most significant predictors of ASD, while A10, A8, A4, A3, A2, and A1 exhibit some predictive value but are less substantial. The results demonstrate excellent performance across various machine learning classifiers for ASD detection. Gradient Boosting achieved perfect classification (Accuracy = 0.98%, F1-Score = 0.98%), indicating powerful predictive ability. Support Vector Machine (SVM) produced nearly perfect results (Accuracy = 0.97%, F1-Score = 0.97), while Naïve Bayes also performed well (Accuracy = 0.96%, F1-Score = 0.96), despite its simpler design. These findings highlight the effectiveness of ensemble methods (Gradient Boosting) and kernel-based models (SVM) in ASD screening, with potential for clinical application in early diagnosis. Policymakers are encouraged to adopt machine learning-based screening tools to support early and accurate ASD diagnosis, which can lead to better patient outcomes.

Keywords: Autism Spectrum Disorder (ASD), Disease Screening, Machine learning, Gradient boosting, Support Vector Machine (SVM), Naïve Bayes

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1. Introduction

1. Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition that affects communication, social interaction, and behavior. Early and accurate diagnosis is crucial, as timely interventions can significantly enhance developmental outcomes and overall quality of life. Traditional diagnostic approaches rely on behavioral assessments conducted by specialists, which can be time-consuming, subjective, and resource-intensive. As a result, there is a growing need for objective, data-driven, and accessible tools that can assist in early ASD screening.

2. Machine learning (ML) has emerged as a transformative technology in healthcare analytics, enabling the discovery of hidden patterns in complex behavioral data. Recent studies have demonstrated its effectiveness in detecting ASD traits using datasets such as Q-Chat-10 and similar screening instruments [1]–[9]. Techniques such as Decision Trees, Support Vector Machines (SVM), and Naïve Bayes have shown encouraging results in identifying behavioral and developmental markers of ASD. Furthermore, feature selection methods—such as Principal Component Analysis (PCA) and chi-square tests—have improved diagnostic accuracy and model interpretability [2], [7]. The integration of machine learning into autism research, as highlighted by Thabtah [6], represents a significant advancement in technology-assisted diagnosis, leading to the development of tools such as the ASDTests mobile app [3], [4], which enable large-scale, early behavioral screening.

3. However, many prior studies have emphasized deep learning or image-based modalities that require high computational resources and extensive datasets. While powerful, such models often lack interpretability and are not always practical for clinical or low-resource settings. Moreover, studies that leverage behavioral questionnaires have usually limited their analyses to basic classification without comprehensive feature ranking or interpretability assessment.

4. This study introduces an interpretable, resource-efficient, and high-performing ASD screening framework that objectively identifies the most influential behavioral predictors using classical machine learning models. By combining ensemble (Gradient Boosting) and kernel-based (SVM) classifiers with rigorous feature-ranking techniques (Information Gain, Gain Ratio, Chi-Square, and Gradient Boosting Feature Importance), this research provides a balanced trade-off between predictive accuracy and model transparency. Unlike prior studies that relied on image-based datasets [22], IoT-based emotion recognition [23], or explainable deep learning models [24], our work focuses on behavioral screening using the Q-Chat-10 questionnaire.

5. The main objectives and contributions of this study are as follows:

- Novel integration of classical ML algorithms with multi-criteria feature selection, enhancing interpretability and robustness in behavior-based ASD detection.
- Comprehensive feature importance analysis, objectively identifying key behavioral traits (A9, A7, A5, and A6) that significantly influence ASD prediction.
- Comparative evaluation of three complementary classifiers—Gradient Boosting, SVM, and Naïve Bayes—demonstrating that lightweight ensemble and kernel-based methods can achieve accuracy comparable to deep learning while maintaining interpretability.
- Clinical and practical relevance, offering a transparent and computationally efficient screening framework that can be adapted to assist clinicians and policymakers in early ASD detection, especially in resource-limited environments.
- By addressing gaps in interpretability, accessibility, and behavioral focus, this research contributes a methodologically sound and practically viable solution for enhancing ASD screening and early diagnosis.

2. METHOD

2.1 Dataset

1. The dataset used in this paper results from an autism screening of toddlers, which includes influential features for further analysis, particularly in determining autistic traits and improving the classification of ASD cases. This dataset contains 1,054 instances and 18 attributes, including the target variable. The dataset comprises 1,054 instances, with a balanced distribution between ASD and non-ASD cases (approximately 50.3% and 49.7%, respectively). Data preprocessing included binary encoding, handling of missing values, and stratified 10-fold cross-validation to mitigate imbalance.

Table 1. Feature descriptions.

Feature	Type	Description
A1	Binary (0, 1)	Does your child respond by looking at you when you call their name?
A2	Binary (0, 1)	How easily can you establish eye contact with your child?
A3	Binary (0, 1)	Does your child use pointing gestures to express a desire for something? (e.g., a toy that is out of reach)
A4	Binary (0, 1)	Does your child want to share something they find interesting with you?
A5	Binary (0, 1)	Does your child engage in pretend play? (e.g., care for dolls, talk on a toy phone)
A6	Binary (0, 1)	Have you noticed if your child pays attention to what you're looking at?
A7	Binary (0, 1)	If someone in your family feels down, does your child try to comfort them? (e.g., stroking hair, hugging them)
A8	Binary (0, 1)	Would you describe your child's first words as:
A9	Binary (0, 1)	Does your child make use of basic gestures? (e.g., wave goodbye)
A10	Binary (0, 1)	Does your child gaze into space without any apparent purpose?
Target variable	Binary (Yes, No)	Yes (ASD traits) or No (no ASD traits)

2. Attributes A1- A10: These items are part of the Q-Chat-10, where possible answers to questions are "Always," "Usually," "Sometimes," "Rarely," and "Never." These responses are mapped to binary values ("1" or "0") in the dataset. For questions 1-9 (A1- A9), if the response is "Sometimes," "Rarely," or "Never," a value of "1" is assigned. For question 10 (A10), a response of "Always," "Usually," or "Sometimes" results in a "1" being assigned. A cumulative score of more than 3 across all 10 questions indicates potential ASD traits; otherwise, no ASD characteristics are observed.

3. The remaining Features are collected from the ASDTests application [12]. The target variable is assigned automatically based on the score obtained by the user during the screening process using the ASDTests application.

2.2 Feature Importance Analysis

1. This section details the methodology employed to identify the most influential behavioral features in predicting ASD traits within the Q-Chat-10 dataset. Feature selection is crucial for building parsimonious and interpretable models while mitigating the risk of overfitting.

2. Several feature ranking methods were utilized to evaluate the importance of each feature:

- Information Gain: This metric quantifies the reduction in uncertainty about the target variable (ASD traits) achieved by knowing the value of a particular feature. Features with higher Information Gain are deemed more informative [14].
- Gain Ratio: A normalized version of Information Gain that addresses the bias toward features with many values [14].
- Gini Index: Measures the impurity of a node in a decision tree, with higher values indicating greater impurity. Features that effectively reduce Gini impurity are considered more critical [15].
- Chi-Square Test (χ^2): Evaluates the statistical dependence between a feature and the target variable. Higher χ^2 values suggest stronger associations.
- Gradient Boosting Feature Importance: Derived from the Gradient Boosting algorithm, this metric reflects the contribution of each feature to the model's predictive performance [16].

Table 3. Features Ranks

Features	Information gain	Gain ratio	Gini Index	χ^2	Gradient Boosting
A9	0.278	0.278	0.142	179.324	14.666
A7	0.229	0.245	0.136	117.035	11.546
A5	0.252	0.252	0.136	158.969	11.228
A2	0.174	0.175	0.092	124.8	10.858
A6	0.246	0.25	0.139	144.613	10.5
A1	0.191	0.193	0.108	116.759	9.714
A8	0.144	0.144	0.078	104.003	9.467
A4	0.199	0.199	0.109	131.189	9.284
A10	0.023	0.024	0.014	14.1	6.437
A3	0.137	0.141	0.072	105.916	5.699

Table 3 and Figure 2 provide a summary of the feature ranking results. While A9, A6, A7, and A5 emerged as the most prominent predictors, the remaining features (A10, A8, A4, A3, A2, and A1) also exhibited varying predictive power. Although lower than the top four, their rankings suggest potential contributions to ASD prediction. Features such as Jaundice, Sex, family_mem_with_ASD, and Ethnicity demonstrated minimal predictive power. The observed rankings provide valuable insights into the relative importance of different behavioral features in predicting ASD traits.

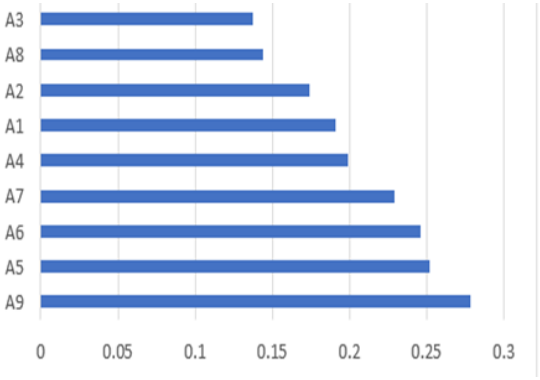

Figure 2. Information Gain Feature Importance Ranking

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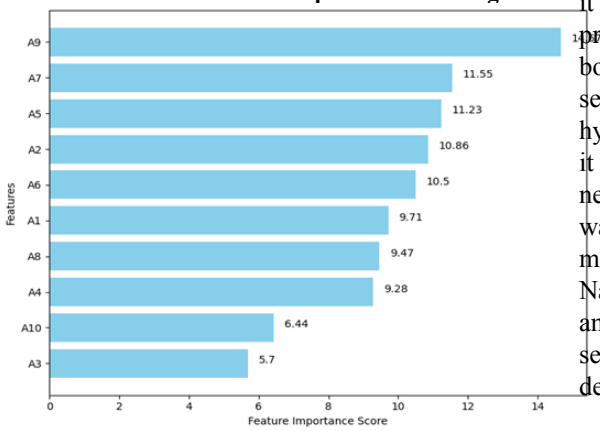

Figure 3: Gradient Boosting Feature Importance Ranking

The feature importance analysis summarized in Table 2, Figure 2, and Figure 3 highlights key predictors of ASD traits within the Q-Chat-10 dataset. Features A9, A7, A5, and A6 consistently emerged as the most influential predictors across multiple ranking methods, indicating their strong relevance to ASD prediction. Features A2, A1, A8, and A4 showed moderate predictive power, while A10 and A3 ranked lowest, contributing minimal influence. Figure 2 emphasizes the dominance of A9, A7, and A5 in the Information Gain ranking, while Figure 3 further confirms their significance through Gradient Boosting Feature Importance scores. These findings highlight the importance of communication gestures and social responses in accurately predicting ASD traits.

2.3 ML-based Toddler ASD predictive models

Machine learning (ML) techniques have shown promising results in the early detection of several diseases and disorders, including autism spectrum disorder (ASD) in young children. In this research, we applied many machine learning methods, including:

• **Gradient Boosting** is a machine learning technique used for regression and classification tasks. It creates a strong predictive model by combining multiple weak learners, usually decision trees, into an ensemble. The algorithm works iteratively, adding one tree at a time and adjusting subsequent trees to correct the errors of earlier ones [18]. Key features of this classifier include:

Maximum Number of Trees: This hyperparameter is used to determine the number of trees; the more trees there are, the better the performance of the classifier. Learning Rate: This hyperparameter minimizes the contribution of each tree.Replicable Training: Fix the random seed to enable the replicability of the results.

• **Support Vector Machines (SVM):** Support Vector Machine (SVM) is a supervised learning method employed for classification and regression tasks, though it is primarily utilized in classification scenarios. The primary objective of SVM is to determine the optimal boundary, known as the hyperplane, that effectively separates the classes within the feature space. This hyperplane is positioned to maximize the gap between it and the nearest data points from each category. These nearest points are referred to as support vectors. SVM was chosen due to its strong performance on small-to-medium datasets with high-dimensional features, while Naïve Bayes provides a probabilistic baseline. LSTM and attention-based models, though powerful, were not selected as the dataset is relatively small and sequential dependencies are limited in Q-Chat-10 responses.

In two-dimensional space, a hyperplane functions as a line that divides data into two categories, while in three dimensions, it appears as a plane. As the dimensionality increases, it assumes a more abstract form. The goal is to identify the hyperplane that most effectively separates the classes, maximizing the distance between this boundary and the closest data points, referred to as support vectors, which play a crucial role in defining the decision boundary. The margin, defined as the distance between the hyperplane and these support vectors, is also maximized to enhance classification accuracy. When the data is not linearly separable, the kernel trick can be utilized to shift the original feature space into a higher dimension. This transformation permits linear separation using kernel functions such as linear, polynomial, radial basis function, and sigmoid, each offering distinct data mappings [18].

• **Naive Bayes:** The Naïve Bayes algorithm is a well-established probabilistic classifier that leverages the concept of probability to solve classification problems straightforwardly and efficiently. By applying the principles of Bayes' theorem, this method learns the likelihood of individual items, their attributes, and the categories to which those attributes correspond. It operates within a supervised learning framework, categorizing new instances by assigning them to the class with the highest probability of membership. The classification process involves two key stages: A) Training phase: During this stage, the algorithm calculates the probability distribution based on the training data. B) Prediction phase: For a test instance, it assesses the posterior probability for that unknown sample, determining its most likely class based on the highest posterior probability, known as Maximum A Posterior (MAP) [19].

2.4 Hyperparameter Tuning

A hyperparameter-tuning process optimized the performance of each machine learning model. Due to computational limitations, manual tuning was conducted. The key hyperparameters and their tuning strategies are described below:

Gradient Boosting: Maximum Number of Trees: This hyperparameter was manually adjusted to determine the number of trees in the ensemble. Higher values generally improve performance but can also lead to overfitting. Values ranging from 100 to 200 were tested, with a focus on identifying a balance between performance and computational efficiency.

Support Vector Machines (SVM): Kernel: Given the nature of the data, the radial basis function (RBF) was evaluated. gamma constant in kernel function(g): was auto tuned. The recommended value is 1/k, where k is the number of attributes. SVM was chosen due to its strong performance on small-to-medium datasets with high-dimensional features, while Naïve Bayes provides a probabilistic baseline. LSTM and attention-based models, though powerful, were not selected as the dataset is relatively small and sequential dependencies are limited in Q-Chat-10 responses.

Naive Bayes: The provided text doesn't mention any specific hyperparameter tuning for Naive Bayes.

To ensure robust and generalizable results, we evaluated the performance of each machine learning model using a 10-fold cross-validation approach. This technique helps mitigate overfitting and provides a more reliable estimate of model performance on unseen data. In 10-fold cross-validation, the dataset is divided into 10 folds. The model is trained on 9 folds and tested on the remaining fold, repeating this process 10 times, each serving as the test set once. The reported performance metrics (AUC, Accuracy, F1 Score, Precision, Recall, and MCC) represent the average performance across these 10 folds. This approach provides a more comprehensive assessment of the models' ability to generalize to new data compared to a single train-test split.

3. RESULTS AND DISCUSSION

3.1 Predictive Performance Analysis

The predictive performance of the three machine learning models—Gradient Boosting, Support Vector Machine (SVM), and Naïve Bayes—was rigorously evaluated using stratified 10-fold cross-validation to ensure robustness and generalization. Evaluation metrics included the Area Under the Curve (AUC), Accuracy, F1-Score, Precision, Recall, and the Matthews Correlation Coefficient (MCC). Table 4 summarizes the results.

Table 4: Model's performance Metrics

Classifier	AUC	Accuracy	F1-Score	Precision	Recall	MCC
Gradient Boosting	0.999	0.980	0.980	0.980	0.980	0.953
SVM	0.998	0.976	0.976	0.976	0.976	0.944
Naïve Bayes	0.997	0.961	0.962	0.964	0.961	0.914

The results indicate that all three classifiers achieved robust predictive performance, with Gradient Boosting exhibiting the highest accuracy (98.0%) and AUC (0.999). The SVM model followed closely (accuracy = 97.6%, AUC = 0.998), while Naïve Bayes also demonstrated competitive results (accuracy = 96.1%, AUC = 0.997) despite its relatively simple probabilistic framework. These findings highlight the effectiveness of ensemble and kernel-based learning approaches in modeling behavioral data for ASD prediction.

When compared with previously published studies using similar datasets, the proposed approach demonstrates advancements in predictive accuracy. For instance, Rashed et al. [1] reported accuracies ranging from 96 to 98% using Random Forest and Logistic Regression. In contrast, Alzakari et al. [2] achieved 97.3% accuracy with explainable AI models based on optimized decision trees. In contrast, the proposed Gradient Boosting model achieved 98.0% accuracy with an AUC of 0.999, reflecting improvement in generalization performance while preserving model interpretability. This enhanced outcome is primarily attributed to the model's optimized hyperparameter configuration and ensemble learning architecture. The near-comparable performance of the SVM further reinforces its robustness in capturing complex, high-dimensional behavioral interactions characteristic of ASD screening datasets [19].

Table 5 presents a comparative summary of the proposed models' performance relative to prior machine learning approaches from the literature.

Table 5. Comparative summary of the proposed models

Study / Model	Dataset	Technique	Accuracy (%)	Remarks
Tabtah (2017) [3]	Q-Chat-10	Decision Tree	92.0	Early behavioral model; limited feature selection
Thabtah et al. (2018) [7]	Q-Chat-10	Random Forest	96.8	Strong baseline; moderate interpretability
Heinsfeld et al. (2018) [5]	ABIDE	Deep Neural Network	97.0	High accuracy; requires neuroimaging data
Alzakari et al. (2024) [2]	Hybrid dataset	Explainable AI (XAI)	97.3	Interpretable; higher computational cost
Proposed (2025)	Q-Chat-10	Gradient Boosting + Feature Ranking	98	Highest accuracy; interpretable and lightweight

The comparative findings indicate that the proposed Gradient Boosting model, when integrated with feature-ranking techniques, demonstrates strong and consistent predictive performance, maintaining a high level of interpretability compared to existing ASD screening approaches. Unlike previous studies that depend on large or multimodal datasets (e.g., ABIDE MRI data), the present framework relies solely on behavioral indicators derived from the Q-Chat-10, making it more feasible and scalable for use in both clinical and community-based screening environments. The promising performance of the proposed framework can be attributed to the following factors. First, a rigorous feature selection process combining Information Gain, Gain Ratio, Chi-Square, and Gradient Boosting importance was employed to retain only the most informative behavioral indicators. Second, the use of a balanced dataset (50.3% ASD vs. 49.7% non-ASD) and 10-fold stratified cross-validation enhanced generalizability and minimized class imbalance bias. Third, the ensemble learning structure of Gradient Boosting effectively modeled complex, non-linear relationships among key behavioral traits—particularly A9 (gestures), A7 (empathy behaviors), and A5 (pretend play)—which are established markers of ASD-related social interaction [7], [9]. Finally, the model's interpretability aligns with prior behavioral psychology findings [3], [9], reinforcing its empirical soundness and clinical relevance.

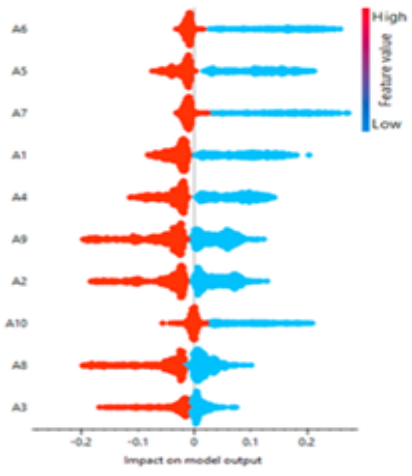

Figure 3. Gradient Boosting Model Explain for Target Class=0

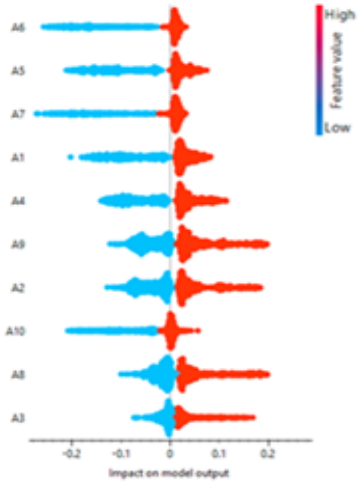

Figure 4. Gradient Boosting Model Explain for Target Class=1

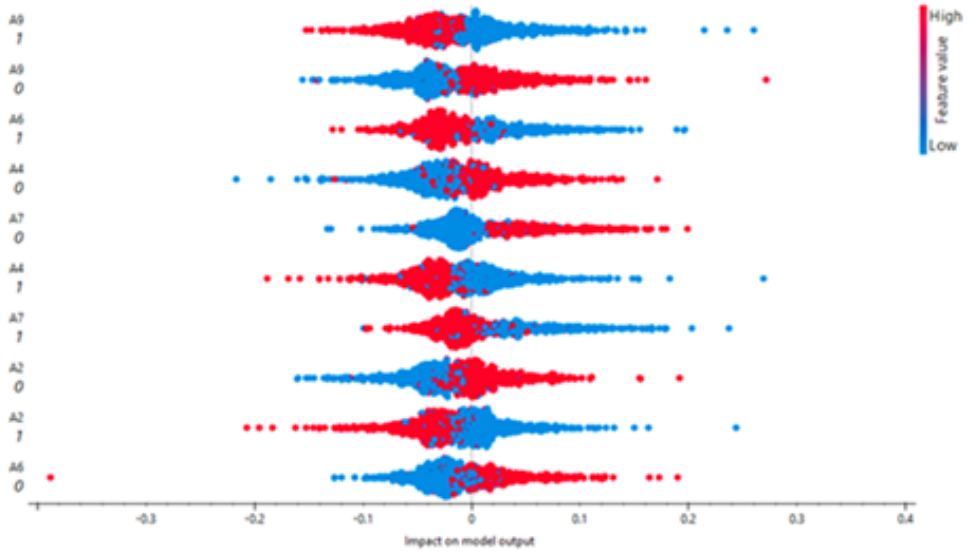

Figure 7. Naïve Bayes Model Explain for Target Class=0

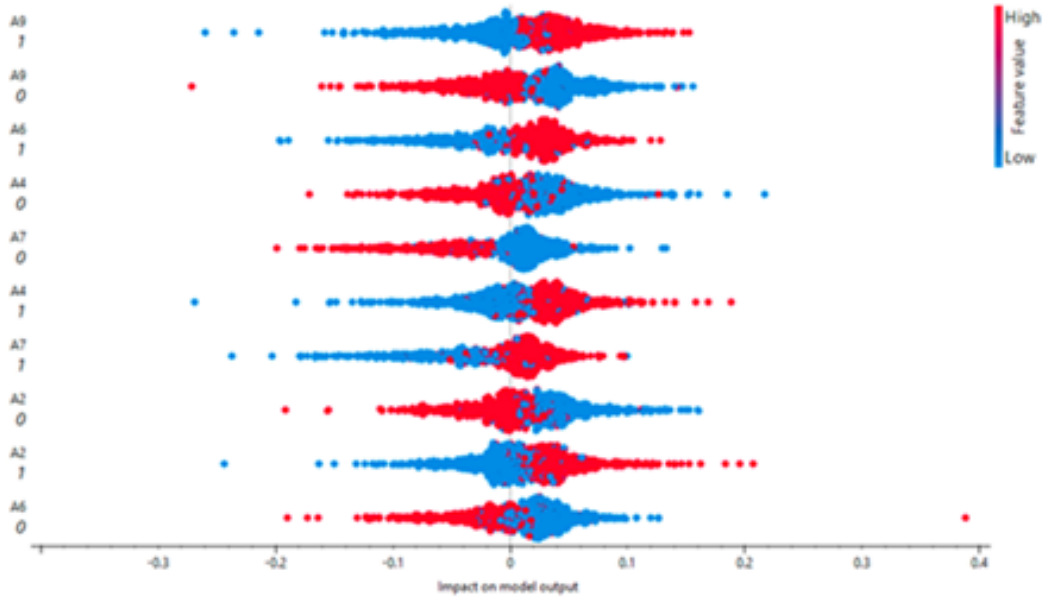

Figure 8. Naïve Bayes Model Explain for Target Class=1

Figures 3–8. Visualization of feature importance and class separation across Gradient Boosting, SVM, and Naïve Bayes models.

3.2 Discussion of Potential Biases and Limitations

Although the proposed framework demonstrated high predictive accuracy (96%, 97% and 98%) and strong generalization, several limitations warrant acknowledgment. The dataset, obtained from a single online source (ASDTests), may introduce cultural and demographic bias, as behavioral interpretations such as "pretend play" or "comforting behavior" can vary across populations. Moreover, the binary encoding of Q-Chat-10 responses, while computationally efficient, may reduce behavioral nuance.

To mitigate potential overfitting, the study employed stratified 10-fold cross-validation and multi-criteria feature selection (Information Gain, Gain Ratio, Chi-Square, and Gradient Boosting importance), which enhanced model stability and interpretability. Nevertheless, validation using independent and more diverse datasets is necessary to confirm the robustness of these findings.

Although Gradient Boosting and SVM achieved high accuracy, their decision-making processes remain partially opaque, highlighting the need for future integration of explainable AI (XAI) frameworks to enhance clinical interpretability and trust. Additionally, the absence of direct collaboration with clinicians in this phase limits immediate clinical applicability; such a partnership will be prioritized in future work to ensure practical validation and usability.

4. CONCLUSION

This study demonstrates the effectiveness of machine learning techniques, particularly Gradient Boosting, Support Vector Machines, and Naïve Bayes, in accurately predicting Autism Spectrum Disorder (ASD) using behavioral data from the Q-Chat-10 dataset. Through comprehensive feature selection and ranking, the analysis identified key behavioral predictors A9 (gestures), A7 (empathy), and A5 (pretend play) that consistently influenced ASD classification, highlighting their diagnostic relevance.

The proposed models achieved high accuracy and interpretability, offering a computationally efficient and clinically practical framework for early ASD screening. While results are promising, the study acknowledges limitations related to dataset representativeness and binary encoding, which may affect generalizability. These challenges were mitigated through cross-validation and rigorous feature selection, ensuring robust performance.

Future work should extend model validation across diverse and longitudinal datasets, incorporate multimodal behavioral and physiological data, and integrate explainable AI (XAI) techniques to enhance transparency and clinical adoption. Overall, the findings emphasize the potential of interpretable ML models to support early, data-driven, and accessible ASD diagnosis in both research and healthcare settings.

5. REFERENCES

1. *A. E. E. Rashed, W. M. Bahgat, A. Ahmed, T. A. Farrag, and A. E. M. Atwa, "Efficient machine learning models across multiple datasets for autism spectrum disorder diagnoses," Biomedical Signal Processing and Control, 2024, p. 106949. DOI: https://doi.org/10.1016/j.bspc.2024.106949*
2. *S. A. Alzakari, L. Zhao, H. Abbas, and M. Bakillah, "Early detection of autism spectrum disorder using explainable AI and optimized teaching strategies," Journal of Neuroscience Methods, 2024, p. 110315. DOI: https://doi.org/10.1016/j.jneumeth.2024.110315*
3. *F. Tabtah, "Autism Spectrum Disorder Screening: Machine Learning Adaptation and DSM-5 Fulfillment," in Proc. 1st Int. Conf. Med. Health Informatics, Taichung City, Taiwan, 2017, pp. 1–6. DOI: https://doi.org/10.1145/3107514.3107515*
4. *F. Thabtah, "ASDTests: A mobile app for ASD screening." [Online]. Available: www.asdtests.com (accessed Dec. 20, 2017).*
5. *A. S. Heinsfeld, A. R. Franco, R. C. Craddock, A. Buchweitz, and F. Meneguzzi, "Identification of autism spectrum disorder using deep learning and the ABIDE dataset," NeuroImage: Clinical, vol. 17, pp. 16–23, 2018. DOI: https://doi.org/10.1016/j.nicl.2017.08.017*
6. *F. Thabtah, "Machine Learning in Autistic Spectrum Disorder Behavioural Research: A Review," Informatics for Health and Social Care, 2019.*
7. *F. Thabtah, F. Kamalov, and K. Rajab, "A new computational intelligence approach to detect autistic features for autism screening," International Journal of Medical Informatics, vol. 117, pp. 112–124, 2018. DOI: https://doi.org/10.1016/j.ijmedinf.2018.06.009*

8. *"The classification of autism spectrum disorder by machine learning methods on multiple datasets for four age groups," Measurement: Sensors, 2023, p. 100774. DOI: https://doi.org/10.1016/j.measen.2023.100774*
9. *X. Zhu et al., "Machine Learning Approaches for ASD Detection," Bioengineering, vol. 10, no. 10, p. 1131, 2023. DOI: https://doi.org/10.3390/bioengineering10101131*
10. *"Machine Learning Models in ASD Diagnosis," BMC Psychiatry, vol. 24, p. 6116, 2024. DOI: https://doi.org/10.1186/s12888-024-06116-0*
11. *"Role of ML in Autism Spectrum Disorder," SN Computer Science, vol. 2, p. 776, 2021. DOI: https://doi.org/10.1007/s42979-021-00776-5*
12. *"ASDTests." [Online]. Available: https://www.asdtests.com/ (accessed Oct. 10, 2024).*
13. *S. J. Wisniewski and G. D. Brannan, "Correlation (Coefficient, Partial, and Spearman Rank) and Regression Analysis," National Library of Medicine, 2024.*
14. *J. R. Quinlan, "Induction of decision trees," Machine Learning, vol. 1, pp. 81–106, 1986.*
15. *J. R. Quinlan, C4.5: Programs for Machine Learning. Morgan Kaufmann Publishers, San Mateo, CA, 1993.*
16. *L. Breiman, J. Friedman, R. A. Olshen, and C. J. Stone, Classification and Regression Trees, 1st ed., Chapman & Hall/CRC, 1984. DOI: https://doi.org/10.1201/9781315139470*
17. *J. H. Friedman, "Greedy function approximation: A gradient boosting machine," Annals of Statistics, vol. 29, pp. 1189–1232, 2001.*
18. *S. Xia, F. Zhang, and C. Zhang, "A Gradient Boosting-Based Classification Technique for Assisted Prediction Algorithm Research," in Proc. 2023 IEEE Int. Conf. Image Process. Computer Applications (ICIPCA), Changchun, China, 2023, pp. 371–375. DOI: https://doi.org/10.1109/ICIPCA59209.2023.10257866*
19. *J. Cervantes, F. Garcia-Lamont, L. Rodríguez-Mazahua, and A. Lopez, "A comprehensive survey on support vector machine classification: Applications, challenges and trends," Neurocomputing, 2019. DOI: https://doi.org/10.1016/j.neucom.2019.10.118*
20. *I. H. Witten, E. Frank, and M. A. Hall, Data Mining: Practical Machine Learning Tools and Techniques, 3rd ed. Morgan Kaufmann, Burlington, MA, USA, 2011.*
21. *J. Qin and Y. Lou, "L1-2 Regularized Logistic Regression," in Proc. 53rd Asilomar Conf. Signals, Systems, and Computers, Pacific Grove, CA, USA, 2019, pp. 779–783. DOI: https://doi.org/10.1109/IEEECONF44664.2019.9048830*
22. *Atlam, E.S., Aljuhani, K.O., Gad, I., Abdelrahim, E.M., Atwa, A.E.M., and Ahmed, A., 2025. Automated identification of autism spectrum disorder from facial images using explainable deep learning models. Scientific Reports, 15(1), p.26682.*
23. *Almars, A.M., Gad, I., and Atlam, E.S., 2025. Unlocking autistic emotions: developing an interpretable IoT-based EfficientNet model for emotion recognition in children with autism. Neural Computing and Applications, pp.1-20.*
24. *Atlam, E.S., Masud, M., Rokaya, M., Meshref, H., Gad, I., and Almars, A.M., 2024. EASDM: Explainable autism spectrum disorder model based on deep learning. Journal of Disability Research, 3(1), p.20240003.*

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Health Indicators and Health Satisfaction among University Employees: Insights and Implications for Occupational Health Practice.

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Abstract
Introduction: Employees' health plays a crucial role in promoting an organization's productivity and achieving its goals. In universities, the impact of employees' health extends beyond personal outcomes, influencing the lives of students, and potentially compromising their quality of education.
Aim: To describe the health indicators and health satisfaction of Jazan University employees.
Methods: A cross-sectional survey was conducted among 393 employees from September to December 2023. Data were collected through an online survey and analyzed using IBM SPSS Statistics (V25.0).
Results: More than half of the participants (53.4%) reported having at least one chronic condition, and 72.5% were overweight, obese, or extremely obese, and 48.1% reported never engaging in exercise behaviors. On average, participants were moderately satisfied with their health (M = 3.64). Non-academicians were more likely to be satisfied with their health (M=3.73, range 1-5) (p=.009), more likely to be smokers (80%) (p<.001), and less likely to engage in routine physical exercise (0%) (p= .049) compared to academicians.
Conclusion: In alignment with Saudi Vision 2030, it is imperative that concerted efforts be made to promote and enhance the quality of employees' health. Universities must implement comprehensive wellness programs that effectively address the biopsychosocial health of their workforce.

Keywords: Health promotion; Risk management; Risk factors; workers well-being; Health determinants

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1. Introduction

According to the World Health Organization (WHO), health is more than just the absence of illness; it is a state of complete physical, mental, and social well-being (World Health Organization (WHO), 2021). Because the health of human capital is fundamental to the growth and sustainability of organizations, economies, and societies, it is increasingly being recognized as a strategic priority—not just a medical concern. A healthy workforce drives productivity, innovation, and resilience, making employee well-being a cornerstone of national development. In alignment with this understanding, Saudi Arabia's Vision 2030—the Kingdom's comprehensive roadmap for economic diversification and societal advancement—places significant emphasis on improving population health as a key pillar of national progress (Suleiman & Ming, 2025).

As part of Vision 2030, the Saudi government has launched a variety of transformative health sector reforms designed to enhance both preventive and therapeutic healthcare services. These initiatives include the expansion of primary healthcare centers, increased investment in digital health technologies, the promotion of health awareness campaigns, and efforts to shift the national healthcare model from treatment-based care to preventive, proactive care. The goal is not only to improve the quality of life for individuals but also to reduce the burden of chronic diseases, improve life expectancy, and enhance workforce productivity across all sectors. By prioritizing health in Vision 2030, Saudi Arabia acknowledges that human capital—comprising the knowledge, skills, and well-being of its people—is a vital driver of long-term development. This vision aligns with global trends that emphasize well-being economics, where the success of a country is increasingly measured not only by Gross Domestic Product, but also by the physical and mental health of its citizens. In this context, improving employee health—especially in critical sectors like higher education—is essential to ensuring that institutions are equipped to deliver high-quality education, conduct impactful research, and contribute effectively to national goals. Despite these efforts, there remains a pressing need to extend these health initiatives more directly to workplaces, including universities, where stress-related illnesses and occupational health risks are often overlooked. Integrating health promotion into institutional policies, fostering a culture of wellness, and supporting mental health services within academia will be crucial steps toward aligning the goals of Vision 2030 with the real needs of the country's workforce.

Health indicators such as smoking, physical activity, and the prevalence of chronic conditions are among the key priorities identified in Saudi Arabia's Vision 2030. These factors are recognized as critical determinants of individual and population health, with far-reaching implications for workforce productivity, healthcare costs, and the Kingdom's broader social and economic development(Chowdhury et al., 2021) . As Vision 2030 seeks to transform Saudi Arabia into a thriving, knowledge-based economy, promoting healthier lifestyles and addressing preventable health risks have become essential components of national strategy. Improving these health indicators through targeted public health interventions, workplace wellness programs, and supportive policy frameworks is not only vital for enhancing the well-being of the population but also for ensuring that the workforce—including those in higher education—is equipped to support the Kingdom's ambitious goals. In this context, universities play a pivotal role, both as institutions of learning and as large employers. Their contributions to Vision 2030 go beyond education and research; they must also serve as models for healthy, productive work environments.

Employee health and well-being in the university sector directly influence organizational performance, academic excellence, and the ability to attract and retain talent(Riza et al., 2025). Addressing health-related challenges among university staff—through preventive health measures, mental health support, and wellness promotion—has been identified as a key strategy for boosting both individual performance and institutional outcomes (Taweel, 2020; Biman et al., 2021; Rahman & Al-Borie, 2020). When universities prioritize staff well-being, they create conditions that support higher levels of engagement, creativity, and job satisfaction, all of which are crucial to fulfilling their educational missions.

Furthermore, a growing body of research supports the strong link between employee health and productivity. Studies have consistently shown that healthy employees are more likely to be productive, resilient, and actively contribute to both organizational goals and broader societal development (Centers for Disease Control and Prevention [CDC], 2022; HBR Analytic Services, 2013; Institute for Health and Productivity Studies, 2015). In contrast, poor health among employees—particularly in cognitively and emotionally demanding sectors like academia—can lead to reduced job performance, absenteeism, and long-term burnout(Lee, 2019). In today's rapidly evolving academic landscape, university employees face increasing demands, including continuous professional development, innovative teaching practices, interdisciplinary research, community outreach, and administrative responsibilities. These expectations, while essential for institutional advancement, can exert significant negative impact on employees' physical, psychological, and social well-being (Sanchez et al., 2019). Without adequate institutional support, these pressures may undermine the very goals that Vision 2030 seeks to achieve. Universities

that invest in employee health are not only contributing to national development objectives but are also building a more sustainable, high-performing, and human-centered academic environment(McDonald et al., 2021)

Literature Review

The available literature consistently highlights the profound impact of high work pressure on both academic and non-academic staff within tertiary institutions. Mounting workloads, administrative demands, performance expectations, and insufficient support systems contribute to a work environment that often places employees at significant risk for deteriorating health. Empirical studies show a strong statistical association ($p < .001$) between high occupational stress and a range of adverse physical health outcomes, including persistent headaches, obesity, hypertension, and even more serious conditions such as cardiovascular diseases (Isamail et al., 2013; Khalilzadeh et al., 2020; Liu et al., 2015). These physical health challenges can lead to increased absenteeism, reduced work efficiency, and a decline in overall institutional productivity.

In addition to physical health concerns, psychological consequences of prolonged work-related stress are equally alarming. Faculty and administrative staff exposed to sustained pressure are more prone to mental health disorders such as anxiety, chronic stress, depression, and burnout ($p < .001$). These conditions not only impair personal well-being but also erode professional effectiveness, interpersonal relationships at work, and the ability to mentor or support students effectively. Psychological distress in academic environments can create a ripple effect that hampers collaboration, reduces innovation, and diminishes the overall quality of academic output.

On a global scale, the economic and societal implications of these mental health issues are staggering. According to the World Health Organization (WHO, 2024), anxiety and depression lead to the loss of approximately 12 billion working days each year, amounting to a financial loss of around US$1 trillion in global productivity. This data emphasizes the urgent need for institutions—particularly in the education sector—to prioritize mental health and implement preventive measures. Fostering a healthier work environment not only benefits individual employees but also strengthens institutional resilience and academic excellence.

The impact of the health status of university employees extends well beyond individual consequences, influencing broader institutional and societal outcomes. In academic environments, university employees—particularly faculty members and administrative staff—are integral to delivering quality education, maintaining operational efficiency, and fostering a positive learning atmosphere. When their physical or mental health deteriorates, these essential functions are inevitably affected. For instance, poor health among university employees has been shown to negatively influence student performance, academic engagement, and the overall university environment. A study by Abdul Manaf et al. (2021) found that the compromised health of Malaysian university employees significantly disrupted their ability to fulfill academic responsibilities, which in turn adversely impacted students and their academic experiences. This cascade effect underscores how staff well-being directly correlates with the quality of education delivered and the success of educational institutions.

Despite the critical role universities play in shaping the intellectual, social, and economic landscape of a country, there is a notable lack of research focused on the health and well-being of university employees in Saudi Arabia. While Saudi universities are rapidly evolving in response to national development goals—such as those outlined in Vision 2030—employee well-being remains an underexplored area. The scarcity of studies in this domain poses a challenge for evidence-based policy-making and the implementation of health-supportive workplace practices. Without a comprehensive understanding of the health challenges faced by university staff in the Saudi context, it becomes difficult to design interventions that ensure their well-being, which ultimately affects the sustainability and quality of higher education in the region.

Considering that employees at academic institutions are the cornerstone of these organizations, exploring their health and well-being becomes imperative. In light of the paucity of literature in the context of an academic setting, the current study seeks to describe the health indicators and health satisfaction of Jazan University employees. It aims to: (1) describe the prevalence of health indicators and health satisfaction among employees of Jazan University and compare the results between academicians and non-academicians, (2) investigate the association between health indicators, health satisfaction, and sociodemographic factors among employees of Jazan University, and (3) investigate the impact of health indicators and sociodemographic factors on health satisfaction among employees of Jazan University.

2. Methods

This study employed a cross-sectional descriptive-analytical methodology. A cross-sectional approach seizes information from a heterogeneous sample at one point, thereby allowing for the assessment of associations between health indicators and health satisfaction among

employees of Jazan University. This kind of design helps detect patterns and relations without the connotation of causation. It is particularly appropriate for public health research targeting the identification of risk factors and disparities. The study was carried out between September and December 2023, utilizing the convenience sampling method among employees of Jazan University.

2.1 Sample

The sample size for this study was determined based on the total population of university employees, using a standard formula for calculating sample size from a finite population. The calculation was performed at a 95% confidence level, with a margin of error (α) set at 0.05, and assuming a population proportion (p) of 50%, a commonly used estimate when prior data on variability is unavailable. This conservative assumption maximizes the required sample size and ensures that the sample is sufficiently representative of the target population. The formula applied was:

Finite population correction formula: n'= (z^2 x p̂(1-p̂)/ε²)/(1+ (z^2 x p̂(1-p̂))/ε²N)

Where (z) is the z score (1.96), ε is the margin of error (5%), (p̂) is the population proportion (50%), and (N) is the population size (3846).

Based on this formula, the final calculated sample size required for the study was 393 participants, comprising both academic and non-academic university employees. The survey was distributed to all university employees, including academic faculty and administrative/support staff. Participation invitations were sent via official university email addresses, and further promoted through institution-affiliated social networking platforms, such as university-managed WhatsApp groups. This multi-channel dissemination strategy enhanced the survey's visibility and reach, while helping to maintain inclusiveness of the sampling process.

The voluntary and anonymous nature of the survey was clearly communicated to participants to encourage honest and accurate responses, thereby improving data reliability. Recruitment was concluded once the targeted sample size of 393 was achieved.

2.2 Ethical considerations

Approval was obtained from Jazan University's Ethical Committee (Approved no. REC-45/02/738). The goal and purpose of the study were outlined in the survey's cover letter. Participants were informed that their participation in the study was optional and anonymous, and their privacy was protected throughout the research.

2.3 Inclusion and exclusion criteria

Academic and non-academic employees 18 years old or older were invited to participate in the study. Employees on scholarship, maternity leave, sabbatical leave, or exceptional leave of more than two months were excluded.

2.4 Study materials

A self-administered anonymous survey comprising two sections was prepared and administered to the participants. Before the main study, a pilot test was conducted on a small subset of participants to obtain feedback regarding the questions' logical flow and clarity. After refining the questions, the survey was made available through official university email addresses and social networking to reach a maximum number of participants, and the response rates were tracked. After data collection was complete, the researchers cleaned the data and analyzed the responses. This systematic approach ensured that the survey was effective and reliable in gathering the appropriate information.

The first section of the survey contained the sociodemographic information of the participants, including sex, age, marital status, occupation type, and service duration. Occupation type was classified as either academic or non-academic. Academic employees are defined as individuals engaged primarily in teaching, research, or academic administrative roles, such as professors, lecturers, and demonstrators. Non-academic employees include those in supportive, clinical, technical, or administrative roles, such as clinicians (e.g., medical doctors working in university health services), lab technicians, IT staff, and administrative personnel. The job titles and functions were classified based on institutional employment categories provided by the university, while recognizing that there may be diverse educational backgrounds (e.g., IT or engineering degrees) within both groups.

The second section of the survey comprised variables pertaining to health indicators and health satisfaction. Health indicators included body mass index (BMI), smoking status, presence of chronic conditions, and physical activity. BMI was calculated by dividing each participant's body weight by the square of his or her height (kg/m2). BMI was then categorized based on the WHO BMI guideline (2000) (<1 8.5 kg/m2 is underweight, 18.5–24.9 kg/m2 is normal weight, 25.0 to 29.9 kg/m2 is overweight, 30.0 to 34.9 kg/m2 is obese, and ≥ 35 kg/m2 is extremely obese) (Ismail et al., 2013). Smoking status was measured using a single item indicating current smoking behavior. Current smoking was defined as Smoking at least 100 cigarettes or equivalent at the current time (WHO, 2013). This variable was measured using a dichotomous response (yes/no). Assessment of chronic conditions—such as diabetes, hypertension, or

hypercholesterolemia—was assessed based on a single, self-report item. Participants were asked "Have you received a medical diagnosis of diabetes, hypertension, or hypercholesterolemia, or are you currently taking medication for any of these conditions?" Responses were recorded as yes or no.

To evaluate the physical activity levels, the physical activity subscale of the Health Promoting Lifestyle Profile II (HPLP-II) was used (Walker et al., 1987) . This subscale consists of eight positively stated items, and the total score is calculated by considering the mean of these eight items. Total scores range from 1–4 (1 = never, 2 = sometimes, 3 = often, and 4 = routinely exercise), with higher scores indicating greater participation in physical activity. The validity and reliability of the physical activity subscale have been established in prior research for both English and Arabic versions (Al-Khawaldeh, 2014; Walker et al., 1987).

Health satisfaction was defined as the degree to which individuals feel satisfied with the state of their health (Ashgar, 2022). This variable was assessed based on a single question: "How satisfied are you with your health?" Participants were required to indicate their level of satisfaction on a 5□point scale ranging from 1 (completely dissatisfied) to 5 (completely satisfied).

Statistical analysis

Data were analyzed using IBM SPSS Statistics (V25.0). An independent sample t-test was used to compare mean differences between academicians and non-academicians for interval variables, and a chi-square test was used to examine associations between categorical variables. A two-tailed Pearson's correlation test was used at an α of .05 to assess the magnitude and direction of the associations between interval variables. Multiple regression analysis was conducted to measure the impact of health indicators and sociodemographic factors on health satisfaction among the employees of Jazan University. Statistical significance was set at $p < 0.05$.

3. Results

3.1 Sample characteristics

The mean age of the participants in this study was 42.42 years (SD = 6.19). Most were women (64.1%), married (81.7%), and academicians (61.1%). Table 1 presents the detailed demographic characteristics.

3.2 Health indicators and health satisfaction

More than half of the participants (53.4%) reported having at least one chronic condition, with hypertension (20.6%), high cholesterol (13.7%), and diabetes (13.0%) being the most commonly reported conditions. Most of the participants were non-smokers (96.2%), however, a significant proportion were overweight, obese, or extremely obese (72.5%), and nearly half had never engaged in exercise behaviors (48.1%). The mean (SD) for BMI of the participants was 29.14 (12.42), the mean (SD) for exercise participation was 2.05 (0.80), the mean (SD) for health satisfaction was 3.64 (0.93). Table 2 provides further details on health indicators and exercise behaviors.

3.3 Comparison of health indicators and health satisfaction between academicians and non-academicians

Health indicators and health satisfaction were compared between academicians and non-academicians. Non-academicians were more likely to be satisfied with their health (M=3.73, range 1-5) (p=.009), more likely to be smokers (80%) (p<.001), and less likely to engage in routine physical exercise (0%) (p= .049) compared to academicians. However, no significant differences were observed in chronic conditions (p = .436), BMI (p = .514), and exercise behaviors (p = .711).

3.4 Correlation between health indicators and health satisfaction

Pearson's r correlation coefficient was used to examine the relationships among intervale variables, and chi-square test was used for nominal variables. BMI was found to be significantly associated with age (r = .23, p < .001), sex (Eta= .02, p < .001), social status (Eta= .08, p < .001), job type (Eta= .03, p < .001), years of experience (r = .17, p < .001), presence of chronic conditions (Eta = .16, p < .001), and smoking status (Eta = .30, p <.001). Having chronic conditions was significantly associated with age (Eta= .06, p < .001), sex (phi = -.20, p < .001), years of experience (Eta= .03, p < .001), and BMI (Eta = .16, p < .001). Exercise behavior was found to be significantly associated with sex (Eta= .11, p < .001), social status (Eta= .25, p < .001), job type (Eta= .02, p < .001), and having chronic conditions (Eta= .09, p < .001).

Smoking status was significantly associated with age, (Eta= .05, p= .002) sex (phi = .27, p < .001), social status (phi= .16, p= .037), job type (phi =.17, p < .001), years of experience (Eta= .017, p < .001), BMI (Eta= .30, p < .001), having chronic conditions (phi =.19, p < .001), and physical exercise (Eta= .03, p < .001). Health satisfaction was significantly associated with sex (Eta= .23, p < .001), social status (Eta= .13, p= .009), job type (Eta= .19, p= .006), and having chronic conditions (Eta= .21, p= .003) (Table 3).

3.5 Effect of health indicators on health satisfaction

Multiple regression analyses was conducted to evaluate the effect of health indicators and demographic factors (age, sex, social status, job type, years of

experience, BMI, having chronic conditions, exercise behaviors, and smoking status) on health satisfaction. However, the model revealed a non-significant effect on health satisfaction ($F = 1.00$, $p = .438$). In addition, years of experience was the only variable that revealed a significant partial effect on health satisfaction ($t = -2.05$, $p = .041$).

4. Discussion

This study investigated key health indicators and overall health satisfaction among university employees, revealing a concerning pattern of poor health outcomes within the sample. Notably, 53.4% of respondents reported having at least one chronic disease, while 72.5% were classified as overweight or obese, and 48.1% engaged in insufficient physical activity. Despite these alarming statistics, overall health satisfaction was reported at a moderate level ($M = 3.65$ on a 5-point scale), indicating a possible disconnect between individuals' perceptions of their health and actual health status. These findings align with prior research conducted in a Malaysian public university, where similar patterns of physical inactivity and high prevalence of overweight and obesity were observed among academic and non-academic staff (Abdul Manaf et al., 2021). This consistency suggests that university employees, regardless of national context, may be particularly vulnerable to health risks due to sedentary job demands, high work-related stress, and limited opportunities for physical activity during the workday.

Furthermore, the current study found that chronic health conditions were significantly associated with sex, a trend consistent with national-level data. According to the Household Health Survey conducted by the General Authority for Statistics (2018), women in Saudi Arabia are 1.4% more likely than men to develop chronic conditions, pointing to possible gender-based disparities in lifestyle, healthcare access, or biological risk factors.

The health issues identified in this study reflect broader national and global public health challenges. Chronic non-communicable diseases (NCDs)—such as cardiovascular disease, diabetes, chronic respiratory conditions, and cancer—are the leading causes of mortality and healthcare expenditure worldwide. In Saudi Arabia, the burden of these diseases is particularly significant. According to the World Health Organization (WHO, 2021), chronic conditions accounted for 41 billion SAR, or 35.0% of total government health expenditure, in 2019. The mortality statistics are equally concerning: in 2020, nearly 20,000 deaths in the Kingdom were attributed to the four main chronic conditions—cardiovascular diseases (47.0%), diabetes (41.0%), chronic respiratory diseases (8.0%), and cancer (4.0%) (WHO, The Kingdom of Saudi Arabia, 2021).

These findings underscore the urgent need for targeted health interventions and workplace wellness strategies within the university setting. As universities are both knowledge hubs and major employers, they have a critical role to play in promoting healthier lifestyles, supporting disease prevention, and reducing the overall burden of chronic illnesses among their employees. Addressing these issues is not only a matter of individual health but also a strategic imperative for enhancing workforce productivity and achieving broader national development goals, such as those outlined in Saudi Vision 2030.

In the current sample, the prevalence of overweight and obesity was alarmingly high, reaching 72.5%. This is significantly higher than the national weighted prevalence of obesity (BMI $\geq$ 30) in Saudi Arabia, which stood at 24.7% in 2020, according to Althumiri et al. (2021). Within the study sample, 34.3% of participants met the criteria for obesity, indicating a substantially elevated health risk compared to the general population. This discrepancy may be attributed to the specific characteristics of university employees, who often engage in sedentary work, experience high levels of stress, and may lack time or access to regular physical activity, all of which are known contributors to weight gain.

Further analysis revealed that certain subgroups within the sample were at greater risk for elevated body mass index (BMI). Specifically, older adults, male, academicians, individuals with longer years of work experience, those diagnosed with one or more chronic diseases, and smokers were more likely to have higher BMIs compared to their counterparts. These findings align with existing literature, which identifies age, smoking, chronic illness, and occupational factors as significant predictors of overweight and obesity (Bonde & Viikari-Juntura, 2013). The accumulation of risk over time—whether through age-related metabolic changes, chronic disease comorbidity, or prolonged exposure to occupational stress—may partly explain these associations.

Previous studies have consistently shown that being overweight or obese, particularly when combined with other risk factors such as chronic disease, smoking, and physical inactivity, can significantly contribute to the decline of both physical and psychological health (Jia & Liu, 2021; Lavallee et al., 2021). The consequences include a higher risk for cardiovascular disease, type 2 diabetes, musculoskeletal problems, depression, and reduced quality of life. Moreover, these health conditions can lead to decreased work productivity, increased absenteeism, and greater healthcare costs, all of which have implications for both individual well-being and institutional efficiency (Alsalem & Alhaiz, 2021).

These findings underscore the urgent need for targeted health promotion programs within university settings, particularly those aimed at weight management, smoking cessation, chronic disease prevention, and lifestyle modification. By addressing these interconnected risk factors, institutions can play a proactive role in safeguarding employee health and supporting national efforts—such as those outlined in Saudi Vision 2030—to reduce the prevalence of lifestyle-related diseases and promote a healthier, more productive workforce.

On average, participants in the current study reported moderate satisfaction with their health, with a mean score of M = 3.64 (SD = 0.93) on a five-point scale. This level of self-reported health satisfaction suggests that, despite the presence of concerning health indicators such as overweight, chronic diseases, and physical inactivity, many individuals still perceive their overall health in a relatively positive light. This finding is consistent with data from the General Authority for Statistics (2018), which reported that 95.0% of Saudi adults rated their health as good, highlighting a widespread trend of favorable self-perceived health among the population, even when objective health indicators may suggest otherwise.

Prior research has demonstrated a strong correlation between self-rated health and various domains of well-being, including physical health status, mental health conditions, and cognitive functioning (Caramenti & Castiglioni, 2022). Self-perceived health is often used as a proxy for broader quality-of-life measures and is known to predict health outcomes such as morbidity and mortality. However, it remains a subjective measure, heavily influenced by individual expectations, personal experiences, cultural norms, and social comparisons.

Interestingly, the current study found that objective health indicators—such as BMI, presence of chronic disease, physical inactivity, and smoking status—did not significantly predict health satisfaction among participants. This suggests that health satisfaction is not always directly aligned with clinical or behavioral health measures, supporting the notion that it is a highly subjective and multidimensional construct. This disconnect may be due to psychological adaptation, differing personal thresholds for what constitutes "good health," or social influences that shape how individuals assess their own health relative to others.

While academicians are traditionally associated with core academic functions such as teaching, research, and publishing, recent evidence highlights a growing expansion in their professional responsibilities. As noted by Awang et al. (2021), the role of academicians increasingly includes administrative duties, participation in student development initiatives, engagement in community outreach, and continuous professional development activities. These additional obligations significantly extend their workload and may contribute to heightened levels of stress, time pressure, and work-life imbalance.

In the current study, academicians reported lower levels of health satisfaction compared to non-academicians, a finding that may be linked to the cumulative burden of their diverse responsibilities. The pressure to meet teaching targets, publish in reputable journals, secure research funding, fulfill committee obligations, and contribute to institutional governance may leave academicians with limited time or energy to attend to their personal well-being. However, when multiple regression analysis was conducted to evaluate the effects of various health indicators and demographic factors—including age, sex, social status, job type, years of experience, BMI, presence of chronic conditions, exercise behaviors, and smoking status—the model did not significantly predict health satisfaction. This suggests that while some individual factors may correlate with lower health satisfaction, their combined impact may not be sufficient to explain variation in health satisfaction when considered together. These findings are consistent with previous research indicating that role overload and work intensification are common stressors in academic environments, often contributing to mental fatigue and physical health deterioration (Halat et al., 2023).

Interestingly, despite their lower health satisfaction, academicians in this study were less likely to be smokers and more likely to engage in regular physical activity compared to their non-academic counterparts. This could be attributed to their higher levels of education and health literacy, which may positively influence health-related attitudes and behaviors. Academicians may be more aware of the long-term health risks associated with smoking and the benefits of physical exercise, prompting them to adopt healthier lifestyle practices even in the face of demanding schedules. However, the study found no significant differences between academicians and non-academicians across other key health indicators, such as the prevalence of chronic disease, BMI, or overall physical inactivity. This suggests that while some behavioral differences exist—particularly in smoking and exercise habits—the broader health status of both groups is similarly affected by shared workplace conditions and systemic challenges, such as sedentary work environments, limited institutional support for wellness, and cultural norms surrounding health practices.

4.1 Limitations and strengths

The limitations of this study need to be acknowledged. First, the cross-sectional nature of the research design and the absence of specific measures, such as assessing employees' responsibilities and social and psychological health measures, were not taken into consideration. Second, the sample was not nationally representative, as it only included participants from a single public university; thus, the generalization of the study's findings is limited. Third, given the voluntary nature of survey participation, there is a potential for responder bias, whereby individuals with a heightened interest in health and wellbeing—or those experiencing related concerns—may have been more inclined to participate. This may limit the generalizability of the findings to the broader university employee population. Lastly, the use of a single item to measure health satisfaction restricted the ability to explore its specific attributes. Nevertheless, the single item has been used to measure health satisfaction in numerous prior studies and has proven to have strong psychometric properties (Ashgar, 2022).

Despite these limitations, the study followed the guidelines for reporting observational studies (Von Elm et al., 2008) to strengthen the validity of the findings. To our knowledge, ours is the first study to describe health indicators and health satisfaction among university employees in Saudi Arabia. Our findings indicate that several health risks are prevalent among university employees. The data from this study may guide university management to develop preventive programs and initiatives to promote the health of their employees. These findings can also assist nursing researchers and healthcare professionals promote the quality of life in the workplace.

Future research should include an interventional and longitudinal approaches and consider a more robust research design with comparative groups, which would offer a more explanation and wider view of the phenomenon. Incorporating explicit measures of social and psychological health in future research is needed to provide a more comprehensive assessment of overall wellbeing. Universities' ability to operate effectively, grow sustainably, and achieve their intended goals require them to prioritize promoting employees' health.

4.2 Implications for Occupational Health Practice

Employees play a crucial role in the functioning of universities. As universities compete for excellence, their employees are facing increased pressure to meet stakeholders' demands. This study highlights several key implications for promoting the health of university employees. Interventions aimed at reducing risk factors and promoting health are needed. Universities could launch inclusive wellness programs that cater to various aspects of employee well-being, encompassing physical, mental, and social health. According to Lloyd et al. (2017), wellness programs to support long-term healthy behaviors that are grounded in theory are the most effective at producing positive results for employees. They outlined how a large university made use of its current resources to design, create, and carried out an extensive program for employee well-being that was grounded in theory (Lloyd et al., 2017). Such programs promise to support employees' health, thereby improving organizational productivity. These initiatives and interventions have the potential to appeal to investors who place importance on environmental, social, and governance factors (Organization for Economic Co-operation and Development, 2022).

Job type and responsibilities should be taken into consideration in designing interventions to improve health among university employees. Academicians who are overburdened with both academic and extracurricular responsibilities may experience stress related to their jobs, potentially resulting in unsatisfactory work which could harm the university's reputation. Awang et al. (2022) found that 9.3% of the variation in job-related stress among academicians is explained by non-academic responsibilities. Non-academicians may face different stressors that could compromise the quality of their work. Given that the prevalence of some health indicators differs between academicians and non-academicians (e.g., smoking status [$p < .001$], exercise habits [$p = .049$], and health satisfaction [$p = .009$]), health promotion initiatives should be targeted to specific groups.

Additionally, developing comprehensive physical, psychological, and social health services for university employees is crucial for improving their quality of life. Of the several health risk factors identified in the current study, some were social or demographic in nature: for example, having at least one chronic condition (53.4%), being overweight or obese or extremely obese (72.5%), and never exercising (48.1%). Thus, universities should provide holistic healthcare services, which adopt an interdisciplinary approach that emphasizes lifestyle changes, to promote employees' quality of life.

Given the observed differences in health indicators between academicians and non-academicians , establishing a campus climate that is favorable to health is essential. Healthy campus environments foster diverse perspectives on living, studying, and working on campus, offering opportunities for personal development and upholding democratic ideals (Northeastern Illinois University, n.d.). In such a climate, employees' workload and duties could be negotiable, improving their work satisfaction and quality of life (Faria et al., 2021).

5. Conclusions

Based on the results, it can be concluded that several health risk factors are prevalent among the sample, underscoring the potential associations between health indicators, health satisfaction, and demographic factors. To support the objectives of Saudi Vision 2030 and the university goals, attention needs to be paid to addressing employees' health and promoting the quality of health. The study findings have several implications, including developing health initiatives considering employees' job type and demographic factors; providing comprehensive physical, psychological, and social health services for university employees; and establishing a healthy campus environment. Replicating this study with a larger sample using a more robust study design would provide more understanding of the impact of health indicators and demographic factors on health satisfaction.

6. References

1. *Abdul Manaf, M. R., Mohammed Nawi, A., Mohd Tauhid, N., Othman, H., Abdul Rahman, M. R., Mohd Yusoff, H., Safian, N., Ng, P. Y., Abdul Manaf, Z., Abdul Kadir, N. B., Yanasegaran, K., Abdul Basir, S. M., Ramakrishnappa, S., Ariff, M. I., & Ganasegeran, K. (2021). Factors associated with health-related quality of life amongst employees in a Malaysian public university. International Journal of Environmental Research and Public Health, 18(20), Article 10903. https://doi.org/10.3390/ijerph182010903*
2. *Al-khawaldeh, O. (2014). Health promoting lifestyles of Jordanian university students. International Journal of Advanced Nursing Studies, 3(1), 27–31. https://doi.org/10.14419/ijans.v3i1.1931*
3. *Alsalem, H. J., & Alhaiz, A. S. (2021). Work-related Burden of Diabetes Mellitus among Employees. European Journal of Medical and Health Sciences, 3(3), 8. https://doi.org/10.24018/ejmed.2021.3.3.869*
4. *Althumiri, N. A., Basyouni, M. H., AlMousa, N., AlJuwaysim, M. F., Almubark, R. A., BinDhim, N. F., Alkhamaali, Z., & Alqahtani, S. A. (2021). Obesity in Saudi Arabia in 2020: Prevalence, distribution, and its current association with various health conditions. Healthcare, 9(3), 311. https://doi.org/10.3390/healthcare9030311*
5. *Ashgar, R. I. (2022). Personal satisfaction: A concept analysis. Nursing Forum, 57(3), 446–453. https://doi.org/10.1111/nuf.12692*
6. *Awang, Y., Mohamed, N., Ahmad, S., & Mohd Nasir, N. E. M. (2021). Examining the influence of academic and non-academic responsibilities on academicians' job-related stress in higher education. Asian Journal of University Education, 17(4), 498–510. https://doi.org/10.24191/ajue.v17i4.16197*
7. *Biman, S., Maharana, S., Metri, K. G., & Nagaratna, R. (2021). Effects of yoga on stress, fatigue, musculoskeletal pain, and the quality of life among employees of diamond industry: A new approach in employee wellness. Work, 70(2), 521–529. https://doi.org/10.3233/WOR-213589*
8. *Bonde, J. P., & Viikari-Juntura, E. (2013). The obesity epidemic in the occupational health context. Scandinavian Journal of Work, Environment & Health, 39(3), 217–219. https://doi.org/10.5271/SJWEH.3362*
9. *Caramenti, M., & Castiglioni, I. (2022). Determinants of self-perceived health: The importance of physical well-being but also of mental health and cognitive functioning. Behavioral Sciences, 12(12), 498. https://doi.org/10.3390/bs12120498*
10. *Center for Disease Control and Prevention (CDC), & National Center for Health Statistics [Internet]. Glossary; c 2017. Retrieved May 3, 2024, https://www.cdc.gov/nchs/nhis/tobacco/tobacco_glossary.htm*
11. *Centers for Disease Control and Prevention (CDC) [Internet]. Well-being concepts; c 2022. Retrieved May 2, 2024, https://archive.cdc.gov/www_cdc_gov/hrqol/wellbeing.htm*
12. *Chowdhury, S., Mok, D., & Leenen, L. P. H. (2021). Transformation of health care and the new model of care in Saudi Arabia: Kingdom's Vision 2030. Journal of Medicine and Life, 14(3), 347. https://doi.org/10.25122/jml-2021-0070*
13. *Faria, M. G. A., Fernandes, R. C., Gallasch, C. H., & Alves, L. V. V. (2021). Contributions of the health-promoting universities' movement: An integrative literature review. Journal of Education and Health Promotion, 10(1), 114. https://doi.org/10.4103/jehp.jehp_24_21*
14. *General Authority for Statistics [Internet]. (2021). Family health survey results report 2018; 2018. World Health Organization (WHO). The Kingdom of Saudi Arabia: The burden of non-communicable diseases (NCDs). Retrieved May 2, 2024, https://www.stats.gov.sa/ar/965. Retrieved May 3, 2024, https://uniatf.who.int/docs/librariesprovider22/default-document-library/ksa-ncd-infograph-en-v08-121021.pdf?sfvrsn=344dc0e9_3*
15. *Halat, D., Soltani, A., Dalli, R., Alsarraj, L., & Malki, A. (2023). Understanding and Fostering Mental Health and Well-Being among University Faculty: A Narrative Review. Journal of clinical medicine, 12(13), 4425. https://doi.org/10.3390/jcm12134425*

16. *Harvard business review analytic services [Internet]. (2013). The impact of employee engagement on performance. Harvard Business Review. https://hbr.org/resources/pdfs/comm/achievers/hbr_achievers_report_sep13.pdf*
17. *Institute for Health and Productivity Studies Johns Hopkins Bloomberg School of Public Health [Internet]. (2015, September). From evidence to practice: Workplace wellness that works. https://www.transamericainstitute.org/docs/default-source/jhu/from-evidence-to-practice---workplace-wellness-that-works.pdf?sfvrsn=dcbd5e9b_32*
18. *Ismail, A., Fauzi, N. M., Shamsuddin, N. R., & ul Hadi, A. (2013). A, Azid NN, Razali NM. The analysis of job related stress and health related quality of life (HRQoL) of lecturers: Using SPSS 16 and structural equation modeling. In IEEE Business Engineering and Industrial Applications Colloquium (BEIAC), Langkawi, Malaysia, 2013, 932–937. https://doi.org/10.1109/BEIAC.2013.6560274*
19. *Jia, W., & Liu, F. (2021). Obesity: Causes, consequences, treatments, and challenges. Journal of Molecular Cell Biology, 13(7), 463–465. https://doi.org/10.1093/jmcb/mjab056*
20. *Khalilzadeh, A., Talebi, B., & Khadivi, A. (2020). Structural analysis of the correlation between occupational stress and quality of life in university administrators using a PLS approach. Journal of Occupational Health and Epidemiology, 9(3), 180–188. https://doi.org/10.29252/johe.9.3.180*
21. *Lavallee, K. L., Zhang, X. C., Schneider, S., & Margraf, J. (2021). Obesity and mental health: A longitudinal, cross-cultural examination in Germany and China. Frontiers in Psychology, 12, Article 712567. https://doi.org/10.3389/fpsyg.2021.712567*
22. *Lee, Y. (2019). Workplace Health and Its Impact on Human Capital: Seven Key Performance Indicators of Workplace Health. In IntechOpen eBooks. IntechOpen. https://doi.org/10.5772/intechopen.85936*
23. *Liu, C., Wang, S., Shen, X., Li, M., & Wang, L. (2015). The association between organizational behavior factors and health-related quality of life among college teachers: A cross-sectional study. Health and Quality of Life Outcomes, 13, 85. https://doi.org/10.1186/s12955-015-0287-4*
24. *Lloyd, L. K., Crixell, S. H., Bezner, J. R., Forester, K., & Swearingen, C. (2017). Genesis of an employee wellness program at a large university. Health Promotion Practice, 18(6), 879–894. https://doi.org/10.1177/1524839917725500*
25. *McDonald, H., Gould, R., Delaney, D., & Vecchio, N. (2021). An investigation of the health-promoting practices of Australian universities. Health Promotion International, 36(5), 1403. https://doi.org/10.1093/heapro/daab004*
26. *Northeastern Illinois University [Internet]. What is campus climate? n.d. Retrieved November 8, 2024, https://www.neiu.edu/about/campus-climate-study/what-campus-climate*
27. *Organization for Economic Co-operation and Development. (2022). Promoting health and well-being at work: Policy and practices, OECD health policy studies. OECD Publishing. https://doi.org/10.1787/e179b2a5-en*
28. *Riza, M. F., Hutahayan, B., & Chong, H. (2025). Fostering high-performing organizations in higher education: the effect of participative leadership, organizational culture, and innovation on organizational performance and commitment. Cogent Education, 12(1). https://doi.org/10.1080/2331186x.2024.2448884*
29. *Sanchez, H. M., Sanchez, E. G. M., Barbosa, M. A., Guimarães, E. C., & Porto, C. C. (2019). Impact of health on quality of life and quality of working life of university teachers from different areas of knowledge. Ciencia e Saude Coletiva, 24(11), 4111–4123. https://doi.org/10.1590/1413-812320182411.28712017*
30. *Suleiman, A. K., & Ming, L. C. (2025). Transforming healthcare: Saudi Arabia's vision 2030 healthcare model. Journal of Pharmaceutical Policy and Practice, 18(1). https://doi.org/10.1080/20523211.2024.2449051*
31. *Vision 2030 [Internet]. Health sector transformation program; n.d. [cited 2024 August 1]. Available from: https://www.vision2030.gov.sa/en/vision-2030/vrp/health-sector-transformation-program/*
32. *Von Elm, E., Altman, D. G., Egger, M., Pocock, S. J., Gøtzsche, P. C., Vandenbroucke, J. P., & STROBE Initiative. (2008). The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: Guidelines for reporting observational studies. Journal of Clinical Epidemiology, 61(4), 344–349. https://doi.org/10.1016/j.jclinepi.2007.11.008*

33. *Walker, S. N., Sechrist, K. R., & Pender, N. J. (1987). The health-promoting lifestyle profile: Development and psychometric characteristics. Nursing Research, 36(2), 76–81. https://doi.org/10.1097/00006199-198703000-00002*
34. *World Health Organization (WHO) [Internet]. Mental health at work; c 2024. Retrieved May 4, 2024, https://www.who.int/news-room/fact-sheets/detail/mental-health-at-work*
35. *World Health Organization (WHO). (2000). Cross-national comparisons of the prevalences and correlates of mental disorders. WHO International Consortium in psychiatric epidemiology. Bulletin of the World Health Organization, 78(4), 413–426.*
36. *World Health Organization (WHO) [Internet]. (n.d.). Definition of health; c 2021. Vision 2030. Health sector transformation program. Retrieved May 2, 2024, https://www.publichealth.com.ng/world-health-organizationwho-definition-of-health/who-definition-of-health-2/. Retrieved August 1, 2024, https://www.vision2030.gov.sa/en/vision-2030/vrp/health-sector-transformation-program/*

Table 1: Comparing Demographic Characteristics of Participants by Job Type (n = 393)

Characteristics		Total number (n [%])	Academicians (n [%])	Non-Academicians (n [%])	p
Total participants		393 (100)	240 (61.1)	153 (38.9)	
Age	**Mean (SD)**	42.42 (6.19)	43 (5.87)	41.51 (6.57)	.020
Sex	**Male**	141 (35.9)	51 (13.0)	90 (22.9)	< .001
	Female	252 (64.1)	189 (48.1)	63 (16)	
Years of experience	**Mean (SD)**	12.66 (5.49)	11.89 (5.71)	13.86 (4.91)	< .001
Social status	**Single**	42 (10.6)	21 (5.3)	21 (5.3)	.003
	Married	321 (81.7)	192 (48.9)	129 (32.8)	
	Divorced	18 (4.6)	18 (4.6)	0 (0)	
	Separated	9 (2.3)	6 (1.5)	3 (0.8)	
	Widower	3 (0.8)	3 (0.8)	0 (0)	
Have at least one chronic condition	**Yes**	210 (53.4)	132 (33.6)	78 (19.8)	.436
	No	183 (46.6)	108 (27.5)	75 (19.1)	
Smoking status	**Yes**	15 (3.8)	3 (0.8)	12 (3.0)	< .001
	No	378 (96.2)	237 (60.3)	141 (35.9)	
BMI	**Under weight < 18.5**	6 (1.5)	3 (0.8)	3 (0.8)	.580
	Normal weight 18.5–24.9	102 (26.0)	57 (14.5)	45 (11.5)	.210
	Over weight 25.0–29.9	150 (38.2)	98 (25.0)	52 (13.2)	.230
	Obese 30.0–34.9	85 (21.6)	52 (13.2)	33 (8.4)	.940
	Extremely obese ≥ 35	50 (12.7)	33 (8.4)	17 (4.3)	.440
	Mean (SD)	29.14 (12.42)	28.81 (6.85)	29.65 (17.99)	.514
Exercise habits	**Never (1–1.9)**	189 (48.1)	114 (29.0)	57 (19.1)	.770
	Sometimes (2–2.9)	135 (34.4)	87 (22.2)	48 (12.2)	.320
	Often (3–3.9)	63 (16.0)	33 (8.4)	30 (7.6)	.120
	Routinely (4)	6 (1.5)	6 (1.5)	0 (0)	.049
Total exercise habits	**Mean (SD)**	2.05 (0.80)	2.06 (0.78)	2.03 (0.82)	.711
Health satisfaction	**Mean (SD)**	3.64 (0.93)	3.59 (0.98)	3.73 (0.85)	.009

Note. SD = standard deviation, BMI = body mass index.

Table 2: Health Indicators and Exercise Behaviors (n = 393)

Variable	**Mean (SD)**
BMI	29.14 (12.42)
Variable	**Total number (n [%])**
Smoking	15 (3.8)
Chronic conditions:	
1. Blood pressure	81 (20.6)
2. Diabetes	51 (13)
3. High cholesterol	54 (13.7)
4. Heart disease	9 (2.3)
5. Sickle cell anemia, Mediterranean anemia, or any blood disease	21 (5.3)
6. Thyroid gland disorders	36 (9.2)
7. Liver or kidney disease	15 (3.8)
8. Asthma or chronic lung disease	39 (9.9)
9. Arthritis	15 (3.8)
10. Depression or anxiety	36 (9.2)
11. Cancer	3 (0.8)
Exercise Behaviors:	**Mean (on a scale 1–4)**
1. Follow a planned exercise program	2
2. Exercise vigorously for 20 or more minutes at least three times a week (such as brisk walking, bicycling, aerobic dancing, using a stair climber).	2
3. Participate in light-to-moderate physical activity (such as sustained walking 30–40 minutes 5 or more times a week).	2
4. Participate in leisure-time (recreational) physical activities (such as swimming, dancing, bicycling).	2
5. Perform stretching exercises at least 3 times per week.	2
6. Engage in exercise during usual daily activities (such as walking during lunch, using stairs instead of elevators, parking car away from destination and walking).	3
7. Check pulse rate when exercising.	2
8. Reach target heart rate when exercising	2

Note. SD = standard deviation, BMI = body mass index

Table 3: Correlations Between Health Indicators and Health Satisfaction Among Employees of Jazan University (n = 393)

		Age	Sex	Social status	Job type	Years of experience	BMI	Chronic disease	Exercise behaviors	Smoking status	Health satisfaction
Age	Value p	1									
Sex	Value p	.10 < .001	1								
Social status	Value p	.16 < .001	.21 .001	1							
Job type	Value p	.12 < .001	.38 < .001	.20 .003	1						
Years of experience	Value p	.47 < .001	.009 < .001	.22 < .001	.17 < .001	1					
BMI	Value p	.23 < .001	.02 < .001	.08 < .001	.03 < .001	.17 .001	1				
Chronic disease	Value p	.06 < .001	-.20 < .001	.12 .258	-.04 .436	.03 < .001	.16 < .001	1			
Exercise behaviors	Value p	.07 .196	.11 < .001	.25 < .001	.02 < .001	.05 .343	-.05 .312	.09 < .001	1		
Smoking status	Value p	.05 .002	.27 < .001	.16 .037	.17 < .001	.017 < .001	.30 < .001	.19 < .001	.03 < .001	1	
Health satisfaction	Value p	.03 .060	.23 < .001	.13 .009	.19 .006	-.05 .32	.01 .85	.21 .003	-.04 .46	.14 .10	

Note. BMI = body mass index.

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Cysteine-rich receptor-like kinases in Arabidopsis thaliana: Properties and Functions in Stress Responses and Development

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Abstract
Cysteine-rich receptor-like kinases (CRKs) constitute a significant subfamily of receptor-like kinases (RLKs) that are essential elements in numerous signal transduction pathways. This review synthesizes current knowledge on the evolutionary background, structural characteristics, and functional diversity of the CRKs in Arabidopsis thaliana. The whole genome and tandem duplications have resulted in the emergence of 44 members of the CRKs subfamily in Arabidopsis, predominantly located on chromosome 4. Recent research increasingly demonstrates that CRK has a role in various physiological processes, including activation of immunological responses to biotic stimuli, and regulation of reactive oxygen species (ROS), abiotic stress responses, plant growth and development. The concept of functional redundancy within the CRK family is explored, proposing that closely related genes may compensate for one another's responsibilities. This work develops a fundamental understanding of CRKs, offering a baseline for subsequent research on the CRK family, including other species of agricultural significance.

Keywords: Cysteine-rich receptor-like kinases, Pathogen defense, Stress responses, Reactive oxygen species (ROS), Immunological responses.

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1. Introduction

Plants must navigate various challenges throughout their lives, including adapting to a dynamic environment and less-than-ideal growth conditions. Stress has a significant impact on reproduction. Typically, the onset of early flowering is commonly associated with environmental pressures, leading to accelerated seed maturation and successful reproduction [1,2]. Grain yield and biomass are key factors influenced by stress, making them the primary focus of plant research aimed at enhancing stress tolerance. Plants have developed various strategies to enhance growth in response to fluctuating environmental conditions. For instance, plants have the capacity to maintain reproductive fitness and buffer water/nutrient deficits by employing vacuolar storage and osmotic adjustment. Additionally, they are capable of adjusting to variations in light intensity and temperature. Programmed cell death (PCD) is employed as a defense mechanism against diseases, effectively inhibiting the entry and proliferation of pathogens. The process of leaf abscission is utilized as a means to remove infected leaves in order to protect the overall health of the plant [3-6].. In order to react to both biotic and abiotic challenges, the first and most crucial step is to perceive environmental signals. Various environmental factors trigger the activation or deactivation of distinct signal transduction pathways. Protein kinases play a crucial role in the perception of environmental signals and subsequent response at different stages. Plants possess a significantly higher number of kinases in comparison to other organisms. As an example, when comparing the human genome to that of Arabidopsis and rice, it is observed that the latter two have a significantly higher number of protein kinases. Arabidopsis has over 1000 protein kinases, while rice has over 1400 protein kinases, highlighting the significance of kinases in plants for sophisticated environmental sensing, stress response, and other developmental processes via distributed signaling networks essential for survival in the absence of mobility [7,8]. Plants have receptor-like protein kinases (RLKs) that are similar to the receptor protein kinases found in animal genomes, and function as part of signaling systems between cells and their surrounding microenvironment [9-11]. Studies have shown that Arabidopsis has over 600 members of RLK, while rice has approximately 1100 [12].

Recent studies have initiated the functional characterization of subclass-specific receptor-like kinases (RLKs) in other crops such as wheat and maize. For example, a comprehensive phylogenomic investigation revealed over 3,400 RLK genes in wheat. A number of genes were confirmed via qRT-PCR to be responsive to drought or Fusarium graminearum infection [13]. TaCrRLK1L16 has been demonstrated to be transcriptionally activated after Puccinia striiformis infection, and overexpression improves wheat resistance, supporting the subclass's mechanistic function in immunity [14]. Furthermore, 248 L-type lectin receptor-like kinases (LecRLKs) were identified in wheat, with subclass members such as TaL-LecRLK35-3D and TaL-LecRLK67-6B/A exhibiting stress-responsive expression patterns [15]. A comprehensive genome-wide investigation of maize found 205 LRR-RLKs, several of which were upregulated during Fusarium verticillioides infection [16]. Functional validation of the RLCK subclass member ZmBLK1 verified its role in pathogen defence by restoring immunological deficits in Arabidopsis bik1 mutants and increasing maize resistance to Clavibacter michiganensis [17]. Despite these advances, the subclass-specific signalling roles of RLKs in essential agricultural crops remain poorly understood. Numerous RLK subclasses remain poorly characterised in terms of essential mechanistic characteristics such as co-receptor interactions, ligand recognition, and downstream signalling cascades [9].

In recent years, there has been significant research dedicated to understanding their physiological and mechanistic roles in various aspects of plant biology. These include plant development, responses to abiotic stress, plant immunity, and symbiosis. Recent advances highlight the practical importance of RLK research in enhancing crop resilience and yield. The overexpression of Oryza sativa Large Spike S-domain Receptor-Like Kinase 1 (OsLSK1), enhanced rice panicle architecture and yield [18]. Similarly,the overexpression of Triticum aestivum Brassinosteroid-Insensitive 1 (TaBRI1) in wheat correlated with accelerated flowering and enhanced seed production [19]. Research has shown that genes like Oryza sativa Salt Tolerance Receptor-like Cytoplasmic Kinase 1(OsSTRK1), which regulates salt tolerance through ROS and Glycine soja Leucine-Rich Repeat Receptor-Like Protein Kinase (GsLRPK), which confers cold tolerance in soybean can be overexpressed or modified to improve resilience without significant yield losses [18,20] . Certain RLKs function as negative regulators; for instance, Oryza sativa Salt Intolerance 1 (OsSIT1) enhances salt sensitivity in rice, however, the natural haplotype Hap2 exhibits significantly reduced kinase activity compared to the standard haplotype (Hap1). Therefore, It was reported that the overexpression of Hap2-SIT1 in rice facilitated normal development and mitigated ROS accumulation under salt stress, while overexpression of Hap1-SIT1 detrimentally affected both growth and stress tolerance [21]. These findings emphasize the potential application of elite RLK alleles in marker-assisted breeding or transgenic approaches in crops improvement.

The majority of RLKs are located in the plasma membrane and act as sensors to detect environmental

signals such as hormones or Pathogen-Associated Molecular Patterns (PAMPs) [22,23]. Wall-Associated RLK (WAKs) are located in the cell wall, where their extracellular domains interact directly with pectin or oligogalacturonides. This allows them to monitor the cell wall's integrity while also controlling its growth and stress response [24,25]. A specific group comprises Receptor-Like Cytoplasmic Kinases (RLCKs), which are exclusively localised in the cytoplasm and function as signal carriers downstream of plasma membrane receptors, lacking of extracellular or transmembrane domains [26]. Furthermore, many RLKs are subjected to proteolytic cleavage, leading to the release of their intracellular kinase domains. This facilitates the translocation and regulation of alternative signalling pathways, potentially involving nuclear processes [27].

The three primary components of an RLK are a protein kinase catalytic domain (PKC), a transmembrane domain (TM), and an extracellular ligand-binding domain (ECLB) [28,29]. The PKC domain is located within the intracellular domain and plays a central role in the signaling cascade [30]. It contains the serine/threonine kinase domain that is responsible for its kinase activity. The TM domain, which usually consists of 22-28 amino acids, facilitates signal transduction between the extracellular and intracellular domains [30]. It is responsible for transferring signals to the intracellular realm. The ECLB domain of RLKs greatly contributes to their functional diversity, making them one of the most functionally versatile gene families in plants [30]. It exhibits significant variation between RLKs and commonly incorporates distinct motifs that facilitate the binding of ligands. The majority of RLKs possess the N-terminal signal peptide (SP) located in the ECLB domain, with the exception of those containing epidermal growth factor-like repeats (EGFs). SP is important for attaching the protein in the endoplasmic reticulum and detecting extracellular signals during protein synthesis [30]. SP variation categorizes RLKs into over 44 subclasses [31]. The Cysteine-Rich Receptor-Like (CRKs) are a significant subgroup of RLKs in higher plants. It is worth mentioning that the abbreviation CRK has also been used for a different group of protein kinases, namely the CALCIUM-DEPENDENT PROTEIN KINASE (CDPK/CPK)-RELATED KINASEs [32].

RLKs identify a variety of ligands with significant biochemical specificity; yet, their signalling outcomes may differ based on stress conditions. Examples of ligands include pathogen-associated molecular patterns (PAMPs) such as the 22–amino acid peptide epitope derived from bacterial flagellin (flg22) and the 18–amino acid peptide epitope derived from the N-terminal region of bacterial elongation factor (elf18). [25,33,34]. In Arabidopsis, under normal conditions, FLAGELLIN-SENSING 2 (FLS2) recognises the bacterial flagellin peptide flg22, while ELONGATION FACTOR Tu RECEPTOR (EFR) identifies the elongation factor elf18. In Arapidopsis, it was shown that while the specificity of ligand-receptor interactions is maintained, abiotic stresses can alter apoplastic pH, reactive oxygen species (ROS) levels, receptor concentrations, or membrane dynamics, thereby affecting the magnitude and outcomes of FLS2-flg22 and EFR-elf18 signalling without changing their specificity [33,35,36]. Further examples of ligand include peptide hormonessuch as Rapid Alkalinization Factors (RALF) peptides. FERONIA (FER) is part of the Catharanthus roseus receptor-like kinase 1-like (CrRLK1L) protein subfamily, which plays a role in plant reproduction, abiotic stress, biotic stress, and various molecular mechanisms. It mainly interacts with demethylesterified pectin. However, under stress conditions like salinity or heat, RALF peptides and pectin engage in dynamic protein interactions and phase separation. This process recruits FER along with the small co-receptor LRE-like GPI-anchored protein 1 (LLG1i) and the Leucine-Rich Repeat extensins (LRXs) [37]. This triggers various signaling pathways such as calcium influx, ROS production, and Rho-of-Plant (ROP) signaling [37].

A number of studies have addressed the roles of CRKs in various plant species; however, the majority have focused on individual members or particular stress pathways. A detailed synthesis of the evolutionary history, structural characteristics, and several functions of CRKs in Arabidopsis is currently lacking. This review will provide a detailed overview of CRKs in Arabidopsis, including their evolutionary diversification, domain organisation, and signalling roles in ROS regulation, pathogen defence, abiotic stress responses, and plant growth.

2. The evolutionary history of CRKs in Arabidopsis thaliana

CRKs are found in a wide range of vascular plants, but interestingly, they are not present in bryophytes and algae [38]. In Arabidopsis, a study revealed that a total of 38 members of the CRKs subfamily are located on chromosome 4, with 34 of them being found in tandem repeats [39]. Based on the phylogenetic relationships among CRKs genes in the tandem repeats, it was inferred that there was at least one intrachromosomal duplication event in the region containing the tandem repeats. Throughout evolution, CRKs have greatly increased their lineage, particularly through more recent tandem duplication and the selective preservation of duplicates after whole-genome duplication [38]. Several CRKs exhibit a significant degree of sequence similarity and are arranged in consecutive arrays on the chromosome, as

observed in Arabidopsis. The CRK tandem duplications primarily arose from unequal crossover or homologous recombination events. The development of CRK primarily occurred through unequal crossover or homologous recombination events [38]. These tandem repeats of CRKs have been proposed to be correlated with stress responses in order to facilitate stress-adaptive evolution. This is due to the fact that the majority of clustered CRKs are involved in the adaptation to environmental stimuli and pathogen infection.

The protein's extracellular domain consists of two copies of the DUF26 domain (the DOMAIN OF UNKNOWN FUNCTION 26) (Fig. 1). This domain contains four conserved cysteines, three of which form the C-8X-C-2X-C motif [36]. Two DUF26s are present in 41 of the 44 CRKS in Arabidopsis, while the remaining three (CRK43, CRK44, CRK45) lack either a DUF26 or a TMD and their cytoplasmic location allows them to interact with plasma membrane (PM)-localized CRKs [40]. There are two genes in the present Arabidopsis genome. The first gene, At4g11500 (CRK35), is a pseudogene. The second gene, At4g23170 (CRK9), does not have any identifiable extracellular domain, signal peptide, or full kinase domain. The DUF26 domain is present also in cysteine-rich receptor-like secreted proteins (CRRSPs) and plasmodesmata-localized proteins (PDLPs), which are grouped together with CRKs in the DUF26-containing protein family under RLKs [38]. It is highly probable that the CRKs emerged as a result of the fusion between a CRRSP containing DUF26 and LRR_clade_3 RLKs, which possess only a TM domain and a kinase domain [38]. It is widely accepted that this fusion event occurred in a shared ancestor of vascular plants [38].

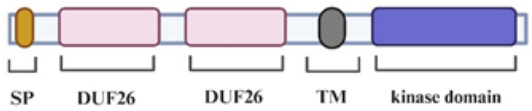

Figure 1: Typical domain structure of Cysteine-rich Receptor-like Kinases (CRKs), illustrating the extracellular DUF26 cysteine-rich motifs for redox sensing and ligand recognition, a transmembrane helix for membrane anchoring, and a serine/threonine kinase domain for signal transduction.

In various analyses, including multi-omics and molecular genetic approaches, a total of 1074 CRKs have been found in 14 different crops such as 50 CRKs have been identified in rice, while Zea mays has been found to have 30. However, a total of 63 CRKs have been identified as key players in the regulation of plant immunity, abiotic stress responses (such as salinity, osmosis, oxidation, and heat), and growth and development ([40-46].

The CRK subfamily of RLKs is often highlighted for its significant size, but this aspect has not been thoroughly explored in research. CRKs are essential for regulating a wide range of cellular processes. These include controlling the influx of Ca2+, maintaining ROS homeostasis, activating the MAPK cascade, and facilitating the deposition of callose. These processes play a crucial role in various physiological functions, including stomatal closure, expression of pathogenesis-related (PR) genes, and PCD. Based on the amino acid sequences of the coding region, the 44 Arabidopsis CRKs are categorised into five separate groups (Fig 2). Comparable groupings are recognized in evolutionary trees according to the intracellular kinase domain and the extracellular area. It is proposed that the extracellular and intracellular domains of Arabidopsis CRKs co-evolved.

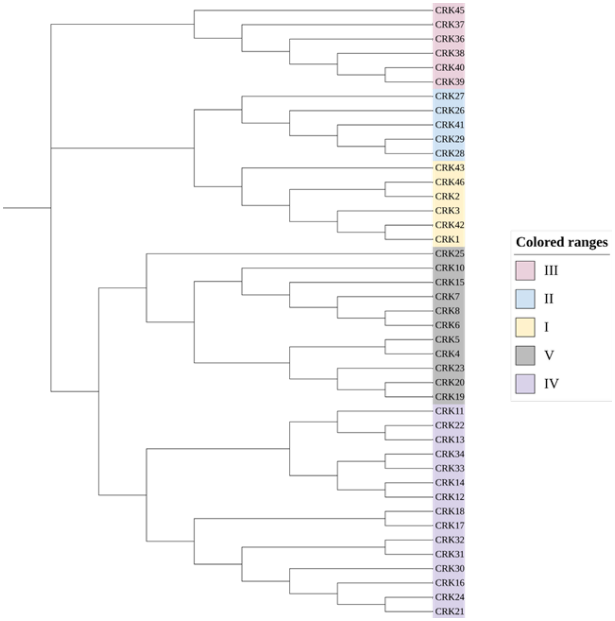

Figure. 2: Maximum-likelihood phylogenetic tree of the Arabidopsis thaliana CRK gene family. Clades are color-coded and bootstrap support values are shown at the nodes. Amino acid sequences for all A. thaliana CRKs were obtained from TAIR10 (https://www.arabidopsis.org). The tree was inferred in MEGA11 [47] using the maximum-likelihood method.

3. Structure of CRKs in Arabidopsis

3.1 Gnk2-like domain (DUF26)

In Arabidopsis, the extracellular region of CRKs is found to contain the Gnk2-like domain.

The Gnk2-like superfamily is a significant protein superfamily with a wide range of domain homology (28–31%) to the domain initially discovered in the Ginkbilobin2 (Gnk2) protein [48]. This antifungal protein is present in the endosperm of Ginkgo seeds. It specifically hinders the growth of fungus like Fusarium oxysporum [49]. Gnk2 exhibits a substantial degree of similarity, around 85%, to embryo-abundant proteins

(EAP) found in the gymnosperms Picea abies and Picea glauca [49]. Plant EAPs have a role in seed defense against stresses from the environment including drought and are expressed during the last stages of seed maturity [50]. The Gnk2-like domain is composed of two α-helices and a five-stranded β-sheet [48]. This configuration leads to a highly structured single-domain structure with an α+β-fold. The domain contains C-X (8)-C-X (2)-C motif. Cysteine residues create three intramolecular disulphide bridges: C1-C5, C2-C3, and C4-C6 [48]. DUF26 Cys residues are commonly found in the C-X8-C-X2-C motif, where they play a crucial role in the formation of inter/intramolecular disulphide bonds that contribute to the stability of protein structure [38,51]. Additionally, these residues can function as switches, effectively regulating the functions of certain CRKs [52,53]. It was suggested that Cysteine residues might have a vital function in detecting ROS and controlling redox activities [54]. Arabidopsis plants with increased CRK36 expression show enhanced hypersensitive cell death lesions and ROS production when exposed to the necrotrophic pathogen Alternaria brassicicola or the avirulent Pseudomonas syringae pv. tomato DC3000 (Pst DC3000) AvrRpm1. In a different scenario, if specific cysteine residues in CRK36 undergo mutations (CRK36C76/85/88/100/119A or CRK36C200/209/212/237A), the plants exhibit a different level of cell death or production of ROS [54].

3.2 Serine/threonine kinase domain

The serine/threonine kinase domain is the catalytic area of enzymes that phosphorylate serine or threonine residues in proteins. The phosphorylation process is considered essential for the control of cellular, with ATP being utilized as a phosphate donor [55]. The protein kinase domain is characterized by 11 conserved subdomains, labelled I through XI, which intricately fold into distinct N-terminal and C-terminal lobes [56]. The N-terminal lobe comprises the I-IV subdomains, serving to anchor and orient ATP effectively and the linker region connecting the two lobes is represented by Subdomain V [56]. The C-terminal lobe encompasses VI-XI subdomains, facilitating substrate binding and positioning them in proximity to ATP for the phosphorylation process [56]. In subdomain II, there is a conserved Lys residue that plays a crucial role in ATP binding. On the other hand, subdomain VII contains an Asp residue that is essential for catalysis. It was revealed that mutations in specific amino acids, converting Lys to Glu and Asp to Asn, impact the kinase activity of CRK2 [45,57]. Interestingly, these mutations do not seem to have any effect on the stability and subcellular localization of CRK2. This suggests that these two subdomains play a crucial role in the kinase activities of CRKs. Similarly, when Lys is replaced with glutamic acid in CRK36 or lysine is replaced with asparagine in CRK28, it impacts their function related to stomatal closure, cell death, and development [54,58]. However, the impact of mutations in the subdomains of the kinase domain has yet to be investigated.

The transmembrane domain (TM) and the N-terminal signal peptide (SP). The localization of CRK proteins in the cell is determined by both the TM domain and the N-terminal SP. TM domain plays a crucial function in attaching CRKs to the plasma membrane. On the other hand, SP plays a crucial role in directing CRKs to a specific compartment within the cell. Prior research has demonstrated that certain CRKs are situated on the plasma membrane, whereas others are situated in the endoplasmic reticulum.

A single nucleotide mutation in the TM domain can result in the relocation of proteins from the plasma membrane to the endoplasmic reticulum [59]. There is speculation that this disparity may result in a variation in hydrophobicity, which subsequently impacts the subcellular localization of proteins. The TM domain of CRK6 in Arabidopsis is composed of 23 amino acid residues. The hydrophobicity score of these residues is 3.148, and they are located in the plasma membrane, as revealed by subcellular localization studies. The key differentiating characteristic between Arabidopsis CRK6, positioned on the plasma membrane, and barley HvCRK1, situated on the endoplasmic reticulum, was the occurrence of leucine-valine-glycine (LVG) in Arabidopsis CRK6, while barley HvCRK1 consisted of a repetition of three alanine(s) (alanine-alanine-alanine, AAA) [59]. Research has demonstrated that Arabidopsis CRK4, CRK6, and CRK36 are proteins that are specifically located in the plasma membrane [51].

4. Functionals Analysis of Arabidopsis CRKs

CRKs in Arabidopsis are essential for numerous physiological functions, especially in the plant's defense against both abiotic and biotic stress as well as in plant growth and development (Table 1).

4.1 Reactive Oxygen Species (ROS) Regulation and Pathogen Defense

Numerous CRKs have been demonstrated to participate in plant defence systems, frequently by regulating ROS generation and related immunological responses. Their preserved role in defence can be ascribed to structural characteristics, including extracellular DUF26 domains with redox-sensing C-X8-C-X2-C motifs and intracellular kinase activity, which together enhance pathogen detection and immune signalling (Vaattovaara et al., 2019; Bourdais et al., 2015). For instance, several CRKs (CRK4, CRK7, CRK11, CRK12, CRK13, CRK14, CRK18, CRK24, CRK36, CRK37, and CRK45) are transcriptionally induced in Arabidopsis following oviposition by Pieris brassicae butterflies, indicating a function in detecting egg-derived elicitors

(Little et al., 2007).

CRK2 as a central regulator: CRK2 is a crucial regulator of ROS and calcium signalling in pathogen defence among the CRKs. Phosphorylation of certain residues (Ser703 and Ser862) in CRK2 facilitates its interaction with the NADPH oxidase RBOHD, thereby enhancing ROS generation [57]. The crk2 mutant exhibits diminished cytoplasmic calcium levels during pathogen invasion and compromised stomatal closure, hence affirming its function as a positive regulator of Ca^{2+} inflow and immunological signalling. Moreover, CRK2 engages with BIK1 and additional CRKs, establishing it as a central node in PTI-related signalling. CRK2 precisely regulates defence mechanisms by altering MAPK cascades, maintaining equilibrium between immunity and growth [57].

CRKs in PTI responses: Numerous CRKs enhance pattern-triggered immunity (PTI) responses downstream of pattern recognition receptors (PRRs) like FLS2 and BAK1. Proteomic investigations demonstrated that flg22 induces the upregulation of CRK11, CRK13, CRK14, CRK18, and CRK22 [58]. The overexpression of CRK4, CRK6, and CRK36 amplifies early PTI by elevating the oxidative burst in reaction to flg22 [51].

CRKs play a role in stomatal immunity: CRK4 and CRK36 inhibit pathogen-induced stomatal reopening, but CRK6 sustains stomatal closure [51]. CRK36 significantly facilitates delayed PTI by increased callose deposition, while CRK4 and CRK6 exert a minimal influence on this process [51]. Moreover, CRK4 has been recognised as a marker gene in defence priming during encounters with Pseudomonas cannabina pv. alisalensis, with its expression in systemic leaves correlating with increased immunological preparedness [60].

CRKs in immunological receptor complexes: CRK28, CRK29, and CRK36 engage with BIK1 subsequent to flg22 detection, hence affirming their function in immune signalling complexes [54,58]. Redundancy is apparent, as the individual knockouts of CRK28 or CRK29 exhibit no significant immunological deficiencies, whereas overexpression increases resistance and may trigger cell death [58].

CRKs in pathogen resistance and hypersensitive response mechanisms: In addition to PTI, several CRKs play a role in the defence against Pseudomonas syringae pv. tomato (Pst DC3000) and fungal infections. The overexpression of CRK5 enhances resistance to Pst DC3000 by triggering (Hypersensitive Response) HR-like cell death, irrespective of EDS1, NDR1, NPR1, or salicylic acid (SA) signalling [61]. CRK13 is activated by avirulent strains of Pst DC3000, providing resistance upon overexpression, and simultaneously experiences alternative splicing in response to PAMPs, together with CRK29 [62,63]. CRK20 facilitates diminished bacterial proliferation in mutant contexts [64]. CRK45 increases resistance through the activation of WRKY transcription factors and salicylic acid-related genes [65]. In fungal immunity, CRK5 and CRK22 modulate defence against Verticillium dahliae toxins through the salicylic acid pathway, functioning upstream of MPK3 and MPK6, and engaging with WRKY70 to promote the expression of salicylic acid-responsive defence genes [44].

Although the roles of individual CRKs have been elucidated, it is increasingly evident that they operate as components of integrated networks rather than as isolated entities. Besides modulating MAPK signalling and regulating calcium influx, CRK2 serves as a a central regulator by directly phosphorylating RBOHD to begin ROS generation [57]. Additional CRKs, including as CRK4, CRK6, and CRK36, appear to function collaboratively downstream of PRRs like FLS2 and BAK1, with their overexpression enhancing ROS burst, promoting stomatal immunity, and facilitating callose deposition [51]. It was suggestd that CRK28, CRK29, and CRK36 interact with BIK1 and may contribute to the sequential amplification of signals from PRRs to downstream MAPK and ROS modules [54,58]. As has been mentioned earlier, functional redundancy have been observed, particularly between CRK28 and CRK29, where overexpression enhances PTI, although individual knockouts display only slight immunological anomalies [58]. Additional CRKs, including CRK20, CRK22, and CRK45, offer supplementary defensive mechanisms by regulating SA signalling and WRKY transcription factors through parallel pathways that intersect at common nodes [40,44,65]. These findings collectively support a model in which CRKs function at multiple PTI nodes: (i) as modulators of calcium signalling and MAPK cascades (CRK2, CRK19, CRK45); (ii) as positive regulators of ROS homeostasis (CRK2, CRK4, CRK6, CRK36); and (iii) as enhancers of HR-like responses and (Salicylic Acid) SA-mediated defence (CRK5, CRK20, CRK22, CRK45). Due to the flexible and multi-layered nature of plant immunological signalling, certain CRKs operate redundantly, others synergistically, and only a few function sequentially within receptor-co-receptor complexes. This integration of ROS, Ca^{2+}, MAPK, and hormone pathways contributes to a robust, context-dependent defense mechanism.

4.2 Abiotic Stress Responses

Recent studies demonstrate the essential functions of CRKs in Arabidopsis, especially regarding their responses to environmental stresses including ozone exposure, salinity, drought, and oxidative stress, thereby indicating their essential role in plant resilience and signaling mechanisms (Fig. 3).

Ozone and oxidative stress: The impact of ozone (O3), bright light, and pathogen/elicitor therapy on the transcriptional regulation of all Arabidopsis CRKs was demonstrated to induce the production Zhao of ROS in several cellular compartments, suggesting that CRKs play a crucial role in this process [36]. The ozone-induced response of Arabidopsis CRKs showed a similarity to the pathogen-induced response, suggesting that these CRKs play a crucial role in both biotic and abiotic responses [36]. Ozone (O3) exposure was determined to induce transcriptional regulation of many CRKs. Among the 44 CRKs analyzed, 25 exhibited mRNA abundances above twofold after one hour of O3 exposure, while a similar rise was noted in 26 CRKs after six hours of O3 exposure followed by a recovery period [36]. However, mutant plants without functional CRKs showed only minor alterations when exposed to ozone, in contrast to wild-type plants, despite the pronounced transcriptional response of CRK genes to ozone. This finding implies that the plant's response to ozone is partially determined by CRKs, even though it is influenced by them [40]. Additionally, CRK6 has been identified as a crucial component of the signaling pathways in plants responsible for ROS [42]. It aids in regulating cellular responses to extracellular ROS, particularly during oxidative stress [42]. It was demonstrated that CRK6 is a protein kinase capable of phosphorylating substrates in in vitro, showing a preference for manganese (Mn^{2}□) as a divalent cation, which plays a crucial role in its enzymatic activity [42].

In contrast to CRK6, CRK7 demonstrates a preference for magnesium (Mg^{2}□) as a divalent cation in its phosphorylation activities [42]. CRK7 expression was concentrated in regions commonly impacted by O□ damage, suggesting its role in the plant's reaction to oxidative stress, specifically in relation to extracellular ROS, rather than chloroplastic ROS [42]. Furthermore, CRK20 has been identified as a regulator of plant responses to ozone stress ([64]. Although CRK20 is upregulated by ozone, the loss-of-function mutants (crk20-1 and crk20-2) do not exhibit significant differences in physiological responses to ozone treatment when compared to the wild-type, suggesting that alternative mechanisms or pathways may compensate for the absence of CRK20 in mitigating ozone stress [64].

Salt and osmotic stress: Further investigations have revealed the particular contributions of several CRK mutants in improving plant resilience to salt stress. CRK2 stimulates callose deposition at plasmodesmata to enhance plant resilience to salt stress during germination. The phosphorylation of callose synthase CALS1 regulates plasmodesmata permeability in response to osmotic stress [45]. In response to several stimuli, a reduction in stomatal closure was observed in the crk2 mutant plants [40]. The crk2 mutant plants exhibit salt tolerance, evidenced by reduced root growth and germination efficiency under saline conditions [40,45]. Plants deficient in CRK5, CRK8, CRK11, CRK28, CRK29, CRK37, and CRK45 exhibit delayed germination on salt-enriched medium, suggesting additional function in salt stress responses alongside CRK2 [40]. CRK2 and CRK3 were recognized as essential in the response to salt stress. It was shown that CRK2 and CRK3 interact with the cytoplasmic kinase PBL27, which is an essential part of the signaling cascade that starts defense responses [66]. CRK2 interacts strongly with PBL27, but CRK3 has a weaker connection, suggesting that CRK2 contributes more to the signaling network than CRK3. Additionally, CRK18 and CRK36 were identified within the downstream stress-responsive networks and as ABA-responsive genes that exhibited down-regulation in the sahy9/apum23 Arabidopsis mutant under conditions of salt stress [67]. The role of the nucleolar protein SAHY9/APUM23 in ribosome production and the abscisic acid (ABA) signaling pathway is essential for Arabidopsis's response to salt stress [67].

Drought and ABA signaling: Alongside the functions of CRKs in salt stress responses, various other CRKs contribute importantly to the regulation of stomatal functions and responses to environmental stimuli such as drought, emphasizing the intricate nature of these signaling pathways. The loss of function of CRK33 has been shown to influence the stomatal density in Arabidopsis plants. This alteration subsequently impacts transpiration and water-use efficiency, thereby enhancing the potential of the plants' drought tolerance [68]. The role of CRK5 in drought tolerance was determined by the observation of ABA-hypersensitive phenotypes, such as increased stomatal closure and inhibition of stomatal opening, upon CRK5 overexpression [69]. A study demonstrated that CRK22, CRK24, CRK37, and CRK46 mutants exhibit greater ABA-induced stomatal closure than the wild type, potentially enhancing the plant's ability to respond to environmental stimuli, including drought stress and other conditions necessitating stomatal regulation [40]. The greater stomatal closure noted in these mutants is believed to be linked to the signaling pathways that regulate the effects of ABA [40]. This reaction ensures the maintenance of water balance in plants during water shortages. The exact mechanisms by which CRK22, CRK24, CRK37, and CRK46 enhance this response are not fully elucidated, yet their involvement in ABA signaling pathways is recognized as crucial for the regulation of stomatal functions.

CRK24 was recognized as a downregulated gene and a potential ethylene-response factor in transgenic Arabidopsis plants that overexpress the XERICO gene: encodes a small protein (162 amino acids) with an N-terminal trans-membrane domain and a specific

zinc-finger motif [70]. The proposed mechanism by which these plants enhance drought tolerance involves an elevation in the biosynthesis of ABA. The observed downregulation suggests that CRK24 could play a role in the regulatory network associated with ethylene signaling pathways, potentially influenced by elevated levels of ABA [70]. In related context, the expression of CRK36 is predominantly activated in Arabidopsis leaves when subjected to drought and high-salinity stress conditions [41]. The suppression of CRK36 expression via RNA interference (RNAi) leads to an enhanced response to ABA and osmotic stress, indicating that CRK36 functions as a negative regulator within these signaling pathways [41]. The reduction of CRK36 leads to elevated transcription levels of ABA-responsive genes, suggesting its involvement in the regulation of stress responses at the transcriptional level.

During the post-germinative development phase of Arabidopsis, CRK36 engages with the Receptor-Like Cytosolic Kinase (RLCK) ARCK1, leading to the creation of a complex that inhibits ABA and osmotic stress signal transduction [41].

Nutrient and ammonium stress: CRK34 has been recognized as a regulatory gene involved in phosphate homeostasis, with a potential role in sequestering the shoot-to-root mobile miRNA miR-399 through "target mimicry" [71]. Consequently, CRK34 may establish a depletion gradient that facilitates the regulation of phosphorus transport from roots to shoots and maintains phosphorus homeostasis. This suggests that plants have the ability to adjust their responses to nutrient availability and stress conditions through the utilization of mobile RNAs, which regulate the activity of miRNAs, subsequently affecting gene expression and physiological processes.

In the initial two hours of ammonium stress, CRK39 was elevated, indicating that CRKs might be involved in modulating the plant's reaction to ammonium-induced oxidative stress [72]. The expression CRK.39 exhibits sensitivity to variations in the redox state within plant cells, which are intricately linked to the redox conditions induced by ammonium treatment [72]. This shows that CRK39 could act as a sensor or mediator in signaling networks that respond to oxidative stress.

Cold and UV stress: Regarding cold stress, transgenic Arabidopsis plants that overexpress glycine-rich RNA-binding protein 2 (GRP2) and are exposed to cold stress exhibit increased expression of CRK40 [73]. This could imply that CRK40 is involved in signaling pathways that aid plants respond to environmental stress. In addition, CRK5 is involved in the response to ultraviolet (UV) radiation, the crk5 mutant exhibits considerable oxidative damage and cell death upon exposure to UV-A and UV-B radiation [40,43]. Hence, the several roles that CRKs play in Arabidopsis highlight their critical function in mediating responses to abiotic stresses, highlighting their significance in the resilience and adaptability mechanisms of plants.

4.3 Plant Growth and Development

The CRK gene family plays a crucial role in multiple developmental processes in Arabidopsis, such as flowering, root development, stress responses, and cell wall dynamics (Fig. 3). Pollen exhibits a distinct expression of CRK1, and it is identified as a member of a gene cluster that is abundant in pollen and may play a role in the signaling pathways related to pollen germination and tube elongation [74].

It is suggested that a complex regulatory mechanism involving CRK2 controls the flowering process [75]. The expression and mRNA alternative splicing of flowering-related genes, including FLOWERING LOCUS C (FLC) and its homologs (MAFs), are modulated by the FERONIA (FER) receptor-like kinase, encoded by CRK2. This kinase also regulates the transition from vegetative to reproductive growth. The timing of flowering in Arabidopsis is regulated by Rapid Alkalinisation Factor 1, a peptide that interacts with CRK2 and suppresses flowering more significantly than FER. In addition, the features of crk2 mutant phenotype involve decreased rosette size, delayed flowering, and early senescence, suggesting a role of CRK2 in growth regulation [40]. Moreover, CRK45 has been suggested to regulate bolting and early seedling development, playing a crucial role in flowering timing and overall plant growth [65].

Besides regulating seedling growth, CRK2 may also influence root formation [45]. In addition, CRK5 regulates auxin transport in plants by phosphorylating auxin efflux carriers like PIN2 and stabilizing PIN2 in the plasma membrane, which is important for appropriate gravitropic responses [76,77]. Mutant plants lacking CRK5 had abnormal PIN2 localization, which affected root gravitropic response and root development[76]. Root development and gravitropic responses depend on ROS homeostasis, which is maintained by CRK5. [78]. Mutant plants lacking CRK5 also exhibit a reduced number of stomata, decreased stomatal conductance, and accelerated senescence, increased basal ROS levels, elevated ethylene and SA levels in the leaves, along with a greater number of transcripts responsive to these compounds, are also observed [40,43]Furthermore, CRK5 influences the stability and localization of other PIN proteins, which are involved in the transport of auxin and the development of the embryo [77]. CRK5 expression has been reported to be controlled by many WRKY transcription factors, including WRKY18, WRKY40, and WRKY60, suggesting an interaction between CRK5 and ABA signaling pathways [43,69].

Additionally, CRK5 inhibits the signaling of both ethylene and salicylic acid (SA), which are crucial for growth and senescence [44]. Hence, root hair elongation, rosette leaf formation, and seedling height have been demonstrated to be influenced [44]. Previously, when AtCRK5 was overexpressed, an increase in plant biomass is observed, suggesting a potential role in growth promotion in general [61]. CRK28-deficient plants exhibit elongated, more branching roots compared to wild-type plants, while those with CRK28 overexpression display a contrasting phenotype, marked by restricted root growth and diminished lateral root development, highlighting the role of CRK28 in root organogenesis [46]. Additionally, crk28 mutants have shorter root hairs and an increased number of trichomes, whereas overexpressing lines show longer root hairs and a reduced number of trichomes. Moreover, it was found that CRK28 acts as a regulator of lateral root formation, affecting the regulation of cell division, primary root elongation, and ABA responses during seedling development and germination [46]. As a result, a positive effect on rosette diameters, inflorescence branching, and the regulation of root hair development is observed [46].

CRK25 was detected in proteins isolated from the cell wall of 5-day-old, not 11-day-old, etiolated hypocotyls of Arabidopsis plants, indicating that it is only involved in the early stages of growth in the elongating cells of Arabidopsis [79]. The expression of CRK25 can be influenced by plant factors such as salicylic acid (SA), jasmonic acid (JA), and ethylene (ET)[36].

CRK25was shown to have a role cell wall dynamics in Arabidopsis, specifically in the elongation of hypocotyls by rearranging and modifying components of the cell wall [79]. Global proliferative arrest (GPA) in Arabidopsis was shown to be regulated by CRK14 via a unique CRK14-dependent signaling mechanism [80]. The gain-of-function mutation in CRK10 results in a dwarf phenotype and collapsed xylem vessels in the roots and hypocotyls of Arabidopsis plants, accompanied by increased resistance to the vascular pathogen Fusarium oxysporum [81]. Transcriptomic analysis indicates that the crk10 mutant exhibits a constitutive up-regulation of genes responsive to both biotic and abiotic stress [81].

The transcriptional dynamics observed during seed germination across different seed compartments, including the testa, endosperm, and embryo, in Arabidopsis suggest that CRK11 and several other genes are involved in the germination process [82]. In CRK36 knockdown plants, cotyledon greening was reduced in response to ABA treatment, which could be associated to senescence [41]. Indeed, CRK36 overexpression causes early senescence characteristics, while a loss of function leads to delayed senescence [54].

These findings highlight the promise of CRK proteins as targets for genetic engineering and breeding strategies focused on improving plant growth, development, stress resilience, and productivity in agricultural systems.

5. Functional redundancy

The analysis of the CRKs genes reveals a complicated network of functional redundancy and regulatory relationships that are crucial for plant defense and stress responses that is most clearly documented in Arabidopsis. Research indicates that after mutating certain CRKs genes in Arabidopsis, there were no noticeable changes in the plant's defense process. This indicates the presence of afunctional redundancy, where the mutation of one gene is compensated for by closely related genes in the CRK family [83]. In Arabidopsis, CRK4 and CRK19 have the ability to compensate for the role of CRK5 in the signaling pathway of ABA [69]. The overexpression of CRK4 and CRK19 elicits identical ABA responses to those observed with CRK5, indicating a potential overlap in their functions within this signaling pathway [69]. Similar to CRK5, both CRK4 and CRK19 contribute to the enhanced drought resilience observed in plants. WRKY transcription factors, including WRKY18, WRKY40, and WRKY60, regulate the expression of CRK5, and they are also likely involved in the regulation of CRK4 and CRK19, indicating that these kinases are components of a complex regulatory system [69].

CRK6 and CRK7 were identified to have similar functions and redundancies in Arabidopsis plant defense and ROS regulation. They have significant sequence similarity, indicating that these two kinases perform similar functions [42]. This complicates the task of describing their specific roles, since the loss of one position might be seamlessly covered by the other. Indeed, there were no discernible changes in Arabidopsis plant growth or disease resistance when CRK6 was constitutively expressed [61]. It is possible that the absence of evident phenotypes in transgenic Arabidopsis plants that overexpress CRK6 is an indication that it is functionally redundant with other members of the CRK family, including CRK7. CRK31 and CRK32 collectively form a low diversified duplicate gene pair [84]. The individual suppression of each gene did not markedly affect the phenotype; nevertheless, the simultaneous suppression of both low-diversity duplicates resulted in Arabidopsis transgenic plants exhibiting abnormal phenotypes [84]. It is suggested that functional redundancy, a characteristic of low diversified duplicates, is implicated in CRK31 and its copy. Thereby, diversified duplicates, such as CRK31 and CRK23, play a significant role in preserving essential functions within the plant genome due to their conservation under purifying selection and their frequent association with critical signaling pathways.

The identification of functional redundancy within

the CRK gene family carries significant implications for genetic engineering and plant biology. Initially, due to the compensatory functions of other closely related genes, altering a single CRK gene may not yield the desired phenotypic alterations. This emphasizes the need for a more comprehensive methodology in the development of genetic modifications,

Moreover, as certain CRKs have overlapping functions, altering one gene may need concurrent modifications of others to substantially change plant responses to environmental stimuli. This interplay may complicate the engineering of plants for resilience, demanding a systems biology approach to understand the entire regulatory network involved.

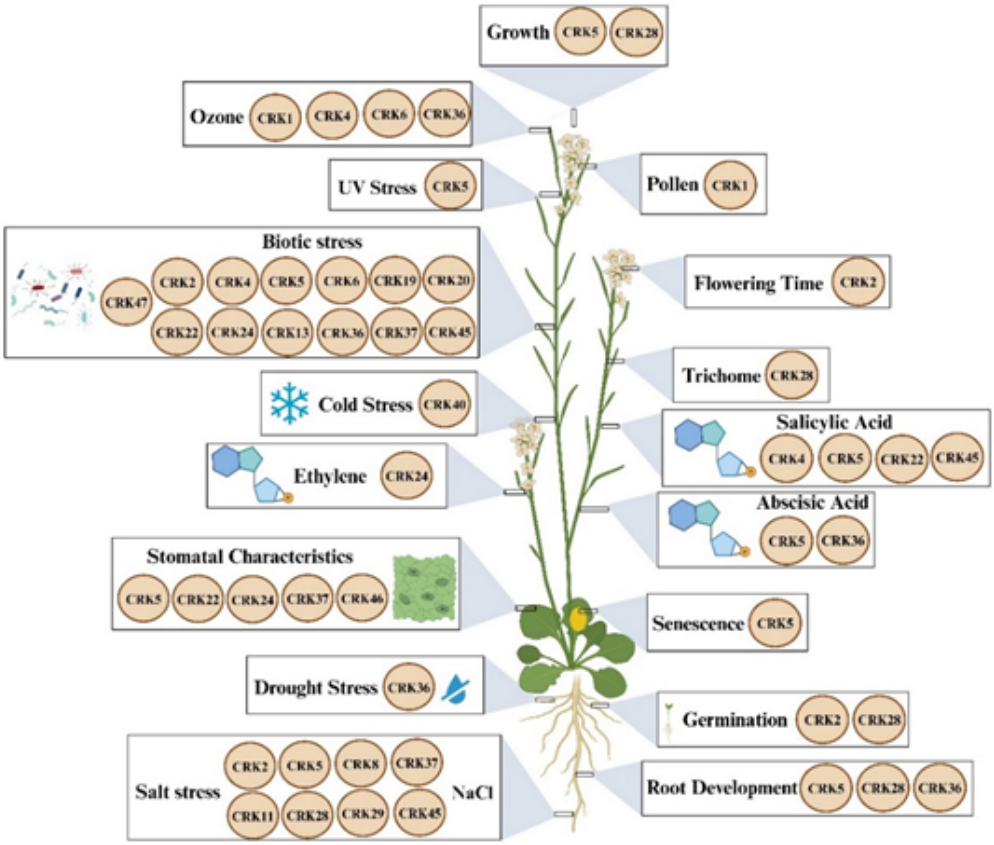

Figure 3: Functional Analysis of Cysteine-Rich Receptor-Like Kinases (CRKs) in Arabidopsis thaliana. This figure summarizes the experimentally characterized roles of CRKs in Arabidopsis, in regulating root development, seed germination, plant growth and development, and various biotic stress responses and abiotic stress.

6. Future directions

To fully understand how plants grow and develop, as well as to navigate challenges, it is essential to expand our understanding of the complete signaling pathway of CRKs in plants. Future studies should concentrate on several important areas to enhance our understanding of the significance of CRKs in plant biology. The conservation and divergence of CRKs functions in response to biotic and abiotic stresses will be determined by extending research beyond Arabidopsis to include other plant species. Investigating the complex molecular mechanisms by which CRKs affect signaling pathways, particularly regarding the interactions of each subdomain in signal transduction, can be improved through techniques such as site-directed mutagenesis, domain deletion, region exchange, and other methodologies. The manipulation of specific CRK genes, whether through overexpression or knockout, has been advanced by creating transgenic plants that exhibit modified CRK expression levels. Utilizing multi-omics approaches,

including genomics, transcriptomics, and proteomics, will enhance our understanding of CRK functions and their regulatory networks in relation to environmental stimuli, as well as evaluating their contributions to plant growth, development, and stress resilience.

7. Conclusions

The Arabidopsis CRK subfamily shows gene family evolution, expanding mainly through tandem and intrachromosomal duplications that enabled functional diversification. This evolutionary path has established a network of receptors that play both common and distinct roles in plant stress adaptation. Functional studies demonstrate that CRKs are essential regulators of ROS homeostasis, immune activation, and stress signalling, directly interacting with components like RBOHD, MAPKs, Ca^{2}□ channels, and hormone pathways. These interactions show how CRKs fit into complex signalling networks, where redundancy, synergy, and sequential activation form a strong defence against biotic and abiotic stressors. CRKs are vital targets for crop engineering, ipmroving resilience, optimising growth, and stabilising yield under environmental stress. Future research requires assessing the functional divergence of individual CRKs, their coordination within receptor complexes, and their contributions across species to facilitate targeted applications in agriculture and biotechnology.

Table 1. Functionals Analysis of Arabidopsis CRKs. The table summarizes the reported biological roles of individual CRK family members in Arabidopsis.

No.	TAIR	Name	Role	References
1	AT1g19090	CRK1	Pollen development role Plant's immune response	[58,74]
2	AT1g70520	CRK2	Modulation of ROS Regulation of calcium signaling Promotion of callose accumulation Immune responses Influence on flowering and growth regulation Salt tolerance	[40,45,57,75]
3	AT3g45860	CRK4	Activation in response to pathogen infection and salicylic acid Role in defense priming Enhancement of ROS generation Stomatal closure in response to pathogen invasion.	[66,85]
4	AT4g23130	CRK5	Enhancement of resistance to pseudomonas syringae. Regulation of drought tolerance. Influence on auxin transport. Impact on root growth and gravitropic responses. Response to ultraviolet radiation Regulation of stomatal conductance and senescence	[51,60,61]
5	AT4g23140	CRK6	ROS regulation Response to oxidative stress induced by ozone	[40,43,61,69,76]
6	AT4g23150	CRK7	ROS regulation Response to oxidative stress induced by ozone	[42,61]
7	AT4g23180	CRK10	Plant growth regulation Defense mechanisms against fusarium oxysporum Up-regulation of genes associated with both biotic and abiotic stress	[42]
8	AT4g23190	CRK11	Seed germination.	[82]
9	AT4g23210	CRK13	Initial defense signaling. Alternative splicing in response to PAMPs.	[62,63]
10	AT4g23220	CRK14	Regulation of global proliferative arrest (GPA)	[80]
11	AT4g23260	CRK18	ABA signaling under salt stress conditions	[67]
12	AT4g23270	CRK19	Activation in response to pathogen infection and salicylic acid Drought tolerance	[26,61,83]

No.	TAIR	Name	Role	References
13	AT4g23280	CRK20	Regulator of plant responses to pseudomonas syringae pv. Tomato dc3000 Response to ozone stress	[40,64]
14	AT4g23300	CRK22	Defense against toxins produced by the pathogen verticillium dahliae Involved in the signaling pathways that modify the salicylic acid	[44]
15	AT4g23320	CRK24	Involvement in ethylene signaling pathways Potential role in drought tolerance	[70]
16	AT4g05200	CRK25	Involvement in early growth phases Influence on cell wall dynamics	[79]
17	AT4g21400	CRK28	Germination and root development Involved in trichomes numbers. Involve in plant resistance to pseudomonas syringae Involved in salt stress.	[40,46,58]
18	AT4g21410	CRK29	Involvement in plant defense mechanism against pseudomonas syringae Alternative splicing in response to PAMPs.	[58]
19	AT4g11490	CRK33	Stomatal density regulation.	[68]
20	AT4g11530	CRK34	Phosphate homeostasis.	[71]
21	AT4g04490	CRK36	Drought and high-salinity stress response regulation. Influence on senescence	[41,54]
22	AT4g04500	CRK37	Modulation of pattern-triggered immunity (PTI)	[54,58]
23	AT4g04540	CRK39	Ammonium stress response.	[72]
24	AT4g04570	CRK40	Cold stress response	[73]
25	AT4g11890	CRK45	Resistance to pseudomonas syringae Modulation of bolting and early seedling development	[65]

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8. Abbreviations

The following abbreviations are used in this manuscript:

CRK Cysteine-rich receptor-like kinases

PCD Programmed cell death

RLKs receptor-like protein kinases

ROS reactive oxygen species

TM transmembrane domain

ECLB extracellular ligand-binding domain

SP signal peptide

EGFs epidermal growth factor-like repeats

DUF26 domain the DOMAIN OF UNKNOWN FUNCTION 26

PM plasma membrane

PDLPs plasmodesmata-localized proteins

9. References

1. *Xu, M.Y.; Zhang, L.; Li, W.W.; Hu, X.L.; Wang, M.; Fan, Y.L.; Zhang, C.Y.; Wang, L. Stress-induced early flowering is mediated by miR169 in Arabidopsis thaliana. J Exp Bot 2014, 65, 89–101, DOI https://doi.org/10.1093/jxb/ert353..*
2. *Wada, K.C.; Takeno, K. Stress-induced flowering. Plant signaling & behavior 2010, 5, 944–947, DOI https://doi.org/10.4161/psb.5.8.11826..*
3. *Williams, B.; Dickman, M. Plant programmed cell death: can't live with it; can't live without it. Molecular Plant Pathology 2008, 9, 531–544, DOI https://doi.org/10.1111/j.1364-3703.2008.00473.x..*
4. *Jones, J.D.; Dangl, J.L. The plant immune system. Nature 2006, 444, 323–329, DOI https://doi.org/10.1038/nature05286..*
5. *Coll, N.S.; Epple, P.; Dangl, J.L. Programmed cell death in the plant immune system. Cell Death & Differentiation 2011, 18, 1247–1256, DOI https://doi.org/10.1038/cdd.2011.37..*
6. *Bruggeman, Q.; Raynaud, C.; Benhamed, M.; Delarue, M. To die or not to die? Lessons from lesion mimic mutants. Frontiers in plant science 2015, 6, 24, DOI https://doi.org/10.3389/fpls.2015.00024..*
7. *The Arabidopsis Genome Initiative Analysis of the genome sequence of the flowering plant Arabidopsis thaliana. Nature 2000, 408, 796–815, DOI https://doi.org/10.1038/35048692..*
8. *Dardick, C.; Chen, J.; Richter, T.; Ouyang, S.; Ronald, P. The rice kinase database. A phylogenomic database for the rice kinome. Plant Physiol 2007, 143, 579–586, DOI https://doi.org/10.1104/pp.106.087270..*
9. *Krasensky-Wrzaczek, J.; Wrzaczek, M. New kids on the block—cysteine-rich receptor-like kinases in pattern-triggered immunity. Curr Opin Plant Biol 2024, 81, 102619.*
10. *Zeiner, A.; Colina, F.J.; Citterico, M.; Wrzaczek, M. CYSTEINE-RICH RECEPTOR-LIKE PROTEIN KINASES: their evolution, structure, and roles in stress response and development. J Exp Bot 2023, 74, 4910–4927.*
11. *Zhang, Y.; Tian, H.; Chen, D.; Zhang, H.; Sun, M.; Chen, S.; Qin, Z.; Ding, Z.; Dai, S. Cysteine-rich receptor-like protein kinases: emerging regulators of plant stress responses. Trends Plant Sci 2023, 28, 776–794.*
12. *Shiu, S.; Karlowski, W.M.; Pan, R.; Tzeng, Y.; Mayer, K.F.; Li, W. Comparative analysis of the receptor-like kinase family in Arabidopsis and rice. Plant Cell 2004, 16, 1220–1234, DOI https://doi.org/10.1105/tpc.020834..*
13. *Yan, J.; Su, P.; Meng, X.; Liu, P. Phylogeny of the plant receptor-like kinase (RLK) gene family and expression analysis of wheat RLK genes in response to biotic and abiotic stresses. BMC Genomics 2023, 24, 224.*
14. *Zhao, G.; Qin, S.; Wei, Z.; Bai, X.; Guo, J.; Kang, Z.; Guo, J. Evolutionary characteristics, expression patterns of wheat receptor-like kinases and functional analysis of TaCrRLK1L16. Stress Biology 2025, 5, 1–16.*
15. *Zhao, W.; Zhang, F.; Wang, J.; Fang, S.; Cheng, Z.; Ma, X.; Fan, J.; Xu, Z.; Chen, X. Comprehensive Genome-Wide Characterization of L-Type Lectin Receptor-like Kinase (L-LecRLK) Genes in Wheat (Triticum aestivum L.) and Their Response to Abiotic Stress. Plants 2025, 14, 1884.*
16. *Gao, Y.; Qu, Q.; Liu, N.; Sun, M.; Liu, X.; Cao, Z.; Dong, J. Genome identification of the LRR-RLK gene family in maize (Zea mays) and expression analysis in response to Fusarium verticillioides infection. BMC Plant Biology 2025, 25, 524.*
17. *Li, W.; Liao, C.; Bluhm, B.H.; Mengiste, T.; Woloshuk, C.P. A maize (Zea mays L.) BIK1-like receptor-like cytoplasmic kinase contributes to disease resistance. Plant Mol Biol Rep 2022, 40, 28–42.*
18. *Zou, X.; Qin, Z.; Zhang, C.; Liu, B.; Liu, J.; Zhang, C.; Lin, C.; Li, H.; Zhao, T. Over-expression of an S-domain receptor-like kinase extracellular domain improves panicle architecture and grain yield in rice. J Exp Bot 2015, 66, 7197–7209.*
19. *Singh, A.; Breja, P.; Khurana, J.P.; Khurana, P. Wheat Brassinosteroid-Insensitive1 (TaBRI1) interacts with members of TaSERK gene family and cause early flowering and seed yield enhancement in Arabidopsis. PLoS One 2016, 11, e0153273.*
20. *Yang, L.; Wu, K.; Gao, P.; Liu, X.; Li, G.; Wu, Z. GsLRPK, a novel cold-activated leucine-rich repeat receptor-like protein kinase from Glycine soja, is a positive regulator to cold stress tolerance. Plant Science 2014, 215, 19–28.*
21. *Zhang, L.; Xu, D.; Zhang, N.; Gao, P.; Zhang, J.; Zhao, J.; Han, Y.; Chen, Y.; Sun, Y.; Zhao, J. Activity-directed selection of natural variants of a receptor kinase facilitates salt-tolerant rice breeding. Plant Physiol 2024, 194, 618–622.*

22. *Sun, T.; Nitta, Y.; Zhang, Q.; Wu, D.; Tian, H.; Lee, J.S.; Zhang, Y. Antagonistic interactions between two MAP kinase cascades in plant development and immune signaling. EMBO Rep 2018, 19, e45324.*
23. *Chen, T. Identification and characterization of the LRR repeats in plant LRR-RLKs. BMC Mol Cell Biol 2021, 22, 9, DOI 10.1186/s12860-021-00344-y..*
24. *Kohorn, B.D.; Kohorn, S.L. The cell wall-associated kinases, WAKs, as pectin receptors. Frontiers in plant science 2012, 3, 88.*
25. *Liu, J.; Li, W.; Wu, G.; Ali, K. An update on evolutionary, structural, and functional studies of receptor-like kinases in plants. Frontiers in Plant Science 2024, 15, 1305599.*
26. *Lu, D.; Wu, S.; Gao, X.; Zhang, Y.; Shan, L.; He, P. A receptor-like cytoplasmic kinase, BIK1, associates with a flagellin receptor complex to initiate plant innate immunity. Proceedings of the National Academy of Sciences 2010, 107, 496–501.*
27. *Yu, M.; Nie, X.; Ke, S.; Li, L.; Li, B. Receptor-like kinase cleavage: molecular mechanism and regulatory functions in plants. New Phytol 2025, 246, 2478–2483.*
28. *Greeff, C.; Roux, M.; Mundy, J.; Petersen, M. Receptor-like kinase complexes in plant innate immunity. Frontiers in plant science 2012, 3, 209, DOI https://doi.org/10.3389/fpls.2012.00209..*
29. *Walker, J.C. Structure and function of the receptor-like protein kinases of higher plants. Plant Mol Biol 1994, 26, 1599–1609, DOI https://doi.org/10.1007/978-94-011-0239-1_20..*
30. *Dievart, A.; Gottin, C.; Périn, C.; Ranwez, V.; Chantret, N. Origin and diversity of plant receptor-like kinases. Annual Review of Plant Biology 2020, 71, 131–156, DOI https://doi.org/10.1146/annurev-arplant-073019-025927..*
31. *Gish, L.A.; Clark, S.E. The RLK/Pelle family of kinases. The Plant Journal 2011, 66, 117–127, DOI https://doi.org/10.1111/j.1365-313x.2011.04518.x..*
32. *Yip Delormel, T.; Boudsocq, M. Properties and functions of calcium-dependent protein kinases and their relatives in Arabidopsis thaliana. New Phytol 2019, 224, 585–604, DOI https://doi.org/10.1111/nph.16088..*
33. *Sun, Y.; Li, L.; Macho, A.P.; Han, Z.; Hu, Z.; Zipfel, C.; Zhou, J.; Chai, J. Structural basis for flg22-induced activation of the Arabidopsis FLS2-BAK1 immune complex. Science 2013, 342, 624–628.*
34. *Jose, J.; Ghantasala, S.; Roy Choudhury, S. Arabidopsis transmembrane receptor-like kinases (RLKs): a bridge between extracellular signal and intracellular regulatory machinery. International journal of molecular sciences 2020, 21, 4000.*
35. *Chinchilla, D.; Zipfel, C.; Robatzek, S.; Kemmerling, B.; Nürnberger, T.; Jones, J.D.; Felix, G.; Boller, T. A flagellin-induced complex of the receptor FLS2 and BAK1 initiates plant defence. Nature 2007, 448, 497–500.*
36. *Wrzaczek, M.; Brosché, M.; Salojärvi, J.; Kangasjärvi, S.; Idänheimo, N.; Mersmann, S.; Robatzek, S.; Karpiński, S.; Karpińska, B.; Kangasjärvi, J. Transcriptional regulation of the CRK/DUF26 group of receptor-like protein kinases by ozone and plant hormones in Arabidopsis. BMC plant biology 2010, 10, 1–19.*
37. *Zhang, Z.; Deng, H.; Hu, S.; Han, H. Phase separation: a new window in RALF signaling. Front Plant Sci 2024, 15, 1409770, DOI 10.3389/fpls.2024.1409770..*
38. *Vaattovaara, A.; Brandt, B.; Rajaraman, S.; Safronov, O.; Veidenberg, A.; Luklová, M.; Kangasjärvi, J.; Löytynoja, A.; Hothorn, M.; Salojärvi, J. Mechanistic insights into the evolution of DUF26-containing proteins in land plants. Communications biology 2019, 2, 56.*
39. *Shiu, S.; Bleecker, A.B. Receptor-like kinases from Arabidopsis form a monophyletic gene family related to animal receptor kinases. Proceedings of the National Academy of Sciences 2001, 98, 10763–10768, DOI https://doi.org/10.1073/pnas.181141598..*
40. *Bourdais, G.; Burdiak, P.; Gauthier, A.; Nitsch, L.; Salojärvi, J.; Rayapuram, C.; Idänheimo, N.; Hunter, K.; Kimura, S.; Merilo, E. Large-scale phenomics identifies primary and fine-tuning roles for CRKs in responses related to oxidative stress. PLoS Genetics 2015, 11, e1005373.*
41. *Tanaka, H.; Osakabe, Y.; Katsura, S.; Mizuno, S.; Maruyama, K.; Kusakabe, K.; Mizoi, J.; Shinozaki, K.; Yamaguchi-Shinozaki, K. Abiotic stress-inducible receptor-like kinases negatively control ABA signaling in Arabidopsis. The Plant Journal 2012, 70, 599–613.*
42. *Idänheimo, N.; Gauthier, A.; Salojärvi, J.; Siligato, R.; Brosché, M.; Kollist, H.; Mähönen, A.P.; Kangasjärvi, J.; Wrzaczek, M. The Arabidopsis thaliana cysteine-rich receptor-like kinases CRK6 and CRK7 protect against apoplastic oxidative stress. Biochem Biophys Res Commun 2014, 445, 457–462.*

43. *Burdiak, P.; Rusaczonek, A.; Witoń, D.; Głów, D.; Karpiński, S. Cysteine-rich receptor-like kinase CRK5 as a regulator of growth, development, and ultraviolet radiation responses in Arabidopsis thaliana. J Exp Bot 2015, 66, 3325–3337.*
44. *Zhao, J.; Sun, Y.; Li, X.; Li, Y. CYSTEINE-RICH RECEPTOR-LIKE KINASE5 (CRK5) and CRK22 regulate the response to Verticillium dahliae toxins. Plant Physiol 2022, 190, 714–731.*
45. *Hunter, K.; Kimura, S.; Rokka, A.; Tran, H.C.; Toyota, M.; Kukkonen, J.P.; Wrzaczek, M. CRK2 enhances salt tolerance by regulating callose deposition in connection with PLD α 1. Plant Physiol 2019, 180, 2004–2021.*
46. *Pelagio-Flores, R.; Muñoz-Parra, E.; Barrera-Ortiz, S.; Ortiz-Castro, R.; Saenz-Mata, J.; Ortega-Amaro, M.A.; Jiménez-Bremont, J.F.; López-Bucio, J. The cysteine-rich receptor-like protein kinase CRK28 modulates Arabidopsis growth and development and influences abscisic acid responses. Planta 2020, 251, 1–12.*
47. *Tamura, K.; Stecher, G.; Kumar, S. MEGA11: molecular evolutionary genetics analysis version 11. Mol Biol Evol 2021, 38, 3022–3027.*
48. *Miyakawa, T.; Miyazono, K.; Sawano, Y.; Hatano, K.; Tanokura, M. Crystal structure of ginkbilobin-2 with homology to the extracellular domain of plant cysteine-rich receptor-like kinases. Proteins: Structure, Function, and Bioinformatics 2009, 77, 247–251.*
49. *Sawano, Y.; Miyakawa, T.; Yamazaki, H.; Tanokura, M.; Hatano, K. Purification, characterization, and molecular gene cloning of an antifungal protein from Ginkgo biloba seeds. 2007.*
50. *Hong-Bo, S.; Zong-Suo, L.; Ming-An, S. LEA proteins in higher plants: structure, function, gene expression and regulation. Colloids and surfaces B: Biointerfaces 2005, 45, 131–135.*
51. *Yeh, Y.; Chang, Y.; Huang, P.; Huang, J.; Zimmerli, L. Enhanced Arabidopsis pattern-triggered immunity by overexpression of cysteine-rich receptor-like kinases. Frontiers in plant science 2015, 6, 322.*
52. *Nagahara, N. Intermolecular disulfide bond to modulate protein function as a redox-sensing switch. Amino Acids 2011, 41, 59–72.*
53. *Feige, M.J.; Hendershot, L.M. Disulfide bonds in ER protein folding and homeostasis. Curr Opin Cell Biol 2011, 23, 167–175.*
54. *Lee, D.S.; Kim, Y.C.; Kwon, S.J.; Ryu, C.; Park, O.K. The Arabidopsis cysteine-rich receptor-like kinase CRK36 regulates immunity through interaction with the cytoplasmic kinase BIK1. Frontiers in plant science 2017, 8, 1856.*
55. *Pereira, S.F.; Goss, L.; Dworkin, J. Eukaryote-like serine/threonine kinases and phosphatases in bacteria. Microbiology and Molecular Biology Reviews 2011, 75, 192–212.*
56. *Taylor, S.S.; Keshwani, M.M.; Steichen, J.M.; Kornev, A.P. Evolution of the eukaryotic protein kinases as dynamic molecular switches. Philosophical Transactions of the Royal Society B: Biological Sciences 2012, 367, 2517–2528.*
57. *Kimura, S.; Hunter, K.; Vaahtera, L.; Tran, H.C.; Citterico, M.; Vaattovaara, A.; Rokka, A.; Stolze, S.C.; Harzen, A.; Meißner, L. CRK2 and C-terminal phosphorylation of NADPH oxidase RBOHD regulate reactive oxygen species production in Arabidopsis. Plant Cell 2020, 32, 1063–1080.*
58. *Yadeta, K.A.; Elmore, J.M.; Creer, A.Y.; Feng, B.; Franco, J.Y.; Rufian, J.S.; He, P.; Phinney, B.; Coaker, G. A cysteine-rich protein kinase associates with a membrane immune complex and the cysteine residues are required for cell death. Plant Physiol 2017, 173, 771–787.*
59. *Rayapuram, C.; Jensen, M.K.; Maiser, F.; Shanir, J.V.; Hornshøj, H.; Rung, J.H.; Gregersen, P.L.; Schweizer, P.; Collinge, D.B.; Lyngkjaer, M.F. Regulation of basal resistance by a powdery mildew-induced cysteine-rich receptor-like protein kinase in barley. Molecular Plant Pathology 2012, 13, 135–147.*
60. *Sistenich, A.J.; Fürtauer, L.; Scheele, F.; Conrath, U. Marker and readout genes for defense priming in Pseudomonas cannabina pv. alisalensis interaction aid understanding systemic immunity in Arabidopsis. Scientific Reports 2024, 14, 3489.*
61. *Chen, K.; Du, L.; Chen, Z. Sensitization of defense responses and activation of programmed cell death by a pathogen-induced receptor-like protein kinase in Arabidopsis. Plant Mol Biol 2003, 53, 61–74.*
62. *Acharya, B.R.; Raina, S.; Maqbool, S.B.; Jagadeeswaran, G.; Mosher, S.L.; Appel, H.M.; Schultz, J.C.; Klessig, D.F.; Raina, R. Overexpression of CRK13, an Arabidopsis cysteine-rich receptor-like kinase, results in enhanced resistance to Pseudomonas syringae. The Plant Journal 2007, 50, 488–499.*

63. *Bazin, J.; Mariappan, K.; Jiang, Y.; Blein, T.; Voelz, R.; Crespi, M.; Hirt, H. Role of MPK4 in pathogen-associated molecular pattern-triggered alternative splicing in Arabidopsis. PLoS pathogens 2020, 16, e1008401.*
64. *Ederli, L.; Madeo, L.; Calderini, O.; Gehring, C.; Moretti, C.; Buonaurio, R.; Paolocci, F.; Pasqualini, S. The Arabidopsis thaliana cysteine-rich receptor-like kinase CRK20 modulates host responses to Pseudomonas syringae pv. tomato DC3000 infection. J Plant Physiol 2011, 168, 1784–1794.*
65. *Zhang, X.; Han, X.; Shi, R.; Yang, G.; Qi, L.; Wang, R.; Li, G. Arabidopsis cysteine-rich receptor-like kinase 45 positively regulates disease resistance to Pseudomonas syringae. Plant Physiology and Biochemistry 2013, 73, 383–391.*
66. *Desaki, Y.; Morishima, M.; Sano, Y.; Uemura, T.; Ito, A.; Nemoto, K.; Nozawa, A.; Sawasaki, T.; Arimura, G. Cytoplasmic kinase network mediates defense response to Spodoptera litura in Arabidopsis. Plants 2023, 12, 1747.*
67. *Huang, K.; Lin, W.; Cheng, W. Salt hypersensitive mutant 9, a nucleolar APUM23 protein, is essential for salt sensitivity in association with the ABA signaling pathway in Arabidopsis. BMC plant biology 2018, 18, 1–21.*
68. *Arellano-Villagómez, F.C.; Guevara-Olvera, L.; Zuñiga-Mayo, V.M.; E. Cerbantez-Bueno, V.; Verdugo-Perales, M.; R. Medina, H.; De Folter, S.; Acosta-García, G. Arabidopsis cysteine-rich receptor-like protein kinase CRK33 affects stomatal density and drought tolerance. Plant Signaling & Behavior 2021, 16, 1905335.*
69. *Lu, K.; Liang, S.; Wu, Z.; Bi, C.; Yu, Y.; Wang, X.; Zhang, D. Overexpression of an Arabidopsis cysteine-rich receptor-like protein kinase, CRK5, enhances abscisic acid sensitivity and confers drought tolerance. J Exp Bot 2016, 67, 5009–5027.*
70. *Ko, J.; Yang, S.H.; Han, K. Upregulation of an Arabidopsis RING-H2 gene, XERICO, confers drought tolerance through increased abscisic acid biosynthesis. The Plant Journal 2006, 47, 343–355.*
71. *Thieme, C.J.; Rojas-Triana, M.; Stecyk, E.; Schudoma, C.; Zhang, W.; Yang, L.; Miñambres, M.; Walther, D.; Schulze, W.X.; Paz-Ares, J. Endogenous Arabidopsis messenger RNAs transported to distant tissues. Nature Plants 2015, 1, 1–9.*
72. *Burian, M.; Podgórska, A.; Ostaszewska-Bugajska, M.; Kryzheuskaya, K.; Dziewit, K.; Wdowiak, A.; Laszczka, M.; Szal, B. A prospective study of short-term apoplastic responses to ammonium treatment. J Plant Physiol 2023, 286, 154008.*
73. *Kim, J.Y.; Park, S.J.; Jang, B.; Jung, C.; Ahn, S.J.; Goh, C.; Cho, K.; Han, O.; Kang, H. Functional characterization of a glycine-rich RNA-binding protein 2 in Arabidopsis thaliana under abiotic stress conditions. The Plant Journal 2007, 50, 439–451.*
74. *Becker, J.D.; Boavida, L.C.; Carneiro, J.; Haury, M.; Feijó, J.A. Transcriptional profiling of Arabidopsis tissues reveals the unique characteristics of the pollen transcriptome. Plant Physiol 2003, 133, 713–725.*
75. *Wang, L.; Yang, T.; Lin, Q.; Wang, B.; Li, X.; Luan, S.; Yu, F. Receptor kinase FERONIA regulates flowering time in Arabidopsis. BMC plant biology 2020, 20, 1–16.*
76. *Rigó, G.; Ayaydin, F.; Tietz, O.; Zsigmond, L.; Kovács, H.; Páy, A.; Salchert, K.; Darula, Z.; Medzihradszky, K.F.; Szabados, L. Inactivation of plasma membrane–localized CDPK-RELATED KINASE5 decelerates PIN2 exocytosis and root gravitropic response in Arabidopsis. Plant Cell 2013, 25, 1592–1608.*
77. *Baba, A.I.; Valkai, I.; Labhane, N.M.; Koczka, L.; Andrási, N.; Klement, É; Darula, Z.; Medzihradszky, K.F.; Szabados, L.; Fehér, A. CRK5 protein kinase contributes to the progression of embryogenesis of Arabidopsis thaliana. International Journal of Molecular Sciences 2019, 20, 6120.*
78. *Cséplő, Á; Zsigmond, L.; Andrási, N.; Baba, A.I.; Labhane, N.M.; Pető, A.; Kolbert, Z.; Kovács, H.E.; Steinbach, G.; Szabados, L. The AtCRK5 protein kinase is required to maintain the ROS NO balance affecting the PIN2-mediated root gravitropic response in Arabidopsis. International journal of molecular sciences 2021, 22, 5979.*
79. *Irshad, M.; Canut, H.; Borderies, G.; Pont-Lezica, R.; Jamet, E. A new picture of cell wall protein dynamics in elongating cells of Arabidopsis thaliana: confirmed actors and newcomers. BMC plant biology 2008, 8, 1–16.*
80. *Imai, S.; Hirozawa, H.; Sugahara, S.; Ishizaki, C.; Higuchi, M.; Matsushita, Y.; Suzuki, T.; Mochizuki, N.; Nagatani, A.; Ueguchi, C. The CRK14 gene encoding a cysteine-rich receptor-like kinase is implicated in the regulation of global proliferative arrest in Arabidopsis thaliana. Genes to Cells 2024.*

81. *Piovesana, M.; Wood, A.K.; Smith, D.P.; Deery, M.J.; Bayliss, R.; Carrera, E.; Wellner, N.; Kosik, O.; Napier, J.A.; Kurup, S. A point mutation in the kinase domain of CRK10 leads to xylem vessel collapse and activation of defence responses in Arabidopsis. J Exp Bot 2023, 74, 3104–3121.*
82. *Dekkers, B.J.; Pearce, S.; van Bolderen-Veldkamp, R.P.; Marshall, A.; Widera, P.; Gilbert, J.; Drost, H.; Bassel, G.W.; Müller, K.; King, J.R. Transcriptional dynamics of two seed compartments with opposing roles in Arabidopsis seed germination. Plant Physiol 2013, 163, 205–215.*
83. *Chen, K.; Fan, B.; Du, L.; Chen, Z. Activation of hypersensitive cell death by pathogen-induced receptor-like protein kinases from Arabidopsis. Plant Mol Biol 2004, 56, 271–283.*
84. *Ezoe, A.; Shirai, K.; Hanada, K. Degree of functional divergence in duplicates is associated with distinct roles in plant evolution. Mol Biol Evol 2021, 38, 1447–1459.*
85. *Miyamoto, T.; Uemura, T.; Nemoto, K.; Daito, M.; Nozawa, A.; Sawasaki, T.; Arimura, G. Tyrosine kinase-dependent defense responses against herbivory in Arabidopsis. Frontiers in plant science 2019, 10, 776.*

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Knowledge and Preventive Practices Regarding Dengue Fever Among Nurses at Prince Mohammed Bin Nasser Hospital, December 2022

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Abstract
Background: Dengue fever is a viral disease posing a major public health threat. Nurses are crucial in-patient education and prevention.
Aim: This study assessed the knowledge and preventive practices of nursing staff regarding dengue fever at Prince Mohammed bin Nasser Hospital, Saudi Arabia, in 2022.
Methodology: A descriptive cross-sectional design was employed, with (89) nurses randomly selected. Participants were categorized by age, educational level, work experience, and department. A structured self-administered questionnaire was used to assess knowledge and preventive practices. Data were analyzed using SPSS version (26) with descriptive and inferential statistics.
Results: The nurses demonstrated good knowledge (Mean = 2.855) and moderate preventive practices (Mean = 1.5854). A moderate positive correlation was observed between knowledge and practice ($r = 0.33$, $P = 0.001$). Knowledge was also positively correlated with qualifications and work experience ($r = 0.33$, $P < 0.001$), whereas the correlation between preventive practices and work experience was not significant ($r \approx 0.03$, $P = 0.735$).
Conclusion: Nurses possess good knowledge about dengue fever; however, preventive practices require improvement. Continuous professional training and targeted educational interventions are essential to enhance preventive measures.

Keywords: Knowledge, Practice, Dengue Fever, Nurses, Prince Mohammed bin Nasser Hospital.

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1. Introduction

Dengue virus (DENV) is transmitted to humans through the bite of an infected Aedes mosquito, chiefly Aedes aegypti and Aedes albopictus (Näslund et al., 2021). Southeast Asia, Africa, and Latin America are just a few examples of tropical and subtropical regions where it is found most frequently (Quesada-Román et al., 2022).

Dengue fever, a virus carried by mosquitoes, is characterized by intense muscular and joint stiffness, headache, nausea, weakness, lymph node swelling (lymphadenopathy), and rashes on the skin (Trivedi & Chakravarty, 2022). Dengue fever is highly characterized by gingivitis, excruciating pain in the eyes, and palms and soles. (Gerlicki, 2024)

Dengue is not harmful to everyone, but people with compromised immune systems are more susceptible (Soiza et al., 2023). Acquisition of dengue fever can occur repeatedly as it is caused by five dengue contagion stereotypes (Verma et al., 2024). Acquisition of a dengue attack, however, would grant lifetime immunity to that serotype to which an individual has been previously exposed. This disease is also known as breakbone fever and dandy fever (B. Halstead, 2023).

The aggravated form of dengue fever can be called dengue hemorrhagic fever or dengue shock syndrome. The severe form of dengue hemorrhagic fever leads to hemorrhages within the body (Trivedi & Chakravarty, 2022). It is a life-threatening disease that may progress to dengue shock syndrome, the most dangerous type (Singh et al., 2023). It is considered as being among the most contagious diseases worldwide. The virus belongs to Flavivirus genus which is a genus under the family Flaviviridae [single-strand, non-segmented RNA viruses](Varsha, 2023). Dengue is transmitted by two species of Aedes mosquitoes: Aedes aegyptian and Aedes albopictus. Cross-immunity evidence: None exists; only protection against re-infection with its own serotype is lifetime (Tsheten, 2023).

As over half the world resides in a region where dengue can be transmitted, dengue ranks among the most serious harming infections transmitted by arthropods in terms of morbidity and mortality (Sarker et al., 2024). Humans are susceptible to any of the various serotypes of dengue viruses through being bitten by an infected Aedes mosquito, most commonly Ae. Aegypti (Sarker et al., 2024).

The mosquito has a global distribution and is primarily found in tropical and subtropical regions. Dengue fever is a systemic disorder that produces acute and moderate symptoms, appears suddenly, and occurs in three phases: febrile, critical, and recovery. It may either lead to asymptomatic infection or symptomatic infection (Biswas et al., 2021).

In 2009 the Tropical Disease Research [TDR] and World Health Organization [WHO] developed the classification of dengue by severity based on the indicators under the sub category dengue to assist clinicians to treat and closely monitor the disease (Yang et al., 2023). Symptoms include fluid accumulation, stomach pain, and vomiting. Associated with platelet count plummeted sharply, mucosal bleeding, fatigue, liver enlargement, and the rising hematocrit (Held-Warmkessel, 2023).

Vector control is one of the paramount preventive measures of dengue fever without a vaccine or special antiviral medication. Prevention of dengue disease is possible in many ways (Côrtes et al., 2023). One method of controlling the vectors is environmental management which involves modifying the environment in a manner that prevents or minimizes the propagation and human contact with the pathogen by destroying, altering, removing or recycling unnecessary containers which serve as larval habitats (Ababa, 2021). The Enhancement of water storages and delivery systems to handle Aedes vectors, especially Ae. aegypti, is another applicable prevention approach. Rooftop catchments, communal standpipes, wells, and other water-storage structures cannot provide the same quality of water as piping directly in-home. Mosquitoes can be kept off ovipositors by mosquito proofing of water storage containers (Ligsay et al., 2021).

In Saudi Arabia, dengue fever is a growing public health concern, particularly in the western and southwestern regions such as Jeddah, Jazan, Makkah, Madinah, and Najran(Alalawi, 2023). Recent seroprevalence studies reported rates up to 33.6% in Jazan, while a large outbreak in Jeddah during 2022–2023 recorded nearly 10,000 confirmed cases within 31 weeks. Incidence rates in Jazan increased sharply from 7.6 per 100,000 in 2016 to about 100 per 100,000 in 2019(Zrieq et al., 2023). These figures highlight the significant health burden of dengue in the Kingdom, reflecting recurrent outbreaks, rising incidence, and persistent challenges in vector control.

Rainwater can be collected from rooftops, and mosquitoes can be prevented from entering it by using tightly sealed containers or well-fitted mesh screens (Ngugi, 2023). Removable covers should be replaced each time water is removed, and covers should be maintained clean to prevent damage that permits entries and exited by mosquitoes. Solid waste management should be well managed through collecting, storing, and disposing of so that it does not pose a threat to the health of the people with dengue (Oluwagbayide et al., 2024).

Several studies from different countries have highlighted gaps in knowledge, attitudes, and practices (KAP) regarding dengue fever among healthcare workers and the community. For example, a study in the Philippines

found that while nurses had adequate knowledge of dengue, preventive practices were inconsistent(Guad et al., 2021).Similarly, a study in Malaysia revealed significant associations between knowledge levels and preventive practices, suggesting that education directly influences behavior(Lim et al., 2021). Findings from Ethiopia also indicated that healthcare workers had knowledge gaps, particularly in identifying breeding sites, which affected their ability to implement control strategies effectively(Zerfu et al., 2023). These studies emphasize the importance of continuous training and capacity building for healthcare providers in diverse settings.

2. Significance of the Study

Dengue fever is a major public health concern in arid regions like Saudi Arabia, with recurrent outbreaks in Jeddah, Jazan, and Makkah. Nurses, as the first line of defense, play a vital role in education and prevention. However, previous studies show variable knowledge levels (60–80%) and relatively weak preventive practices (<50%). This study is significant as it identifies strengths and gaps, guiding training and preventive strategies to reduce the burden of dengue fever.

3. Aim of the Study

The study aimed to assess the knowledge and preventive practices of nurses regarding dengue fever at Prince Mohammed Bin Nasser Hospital, Saudi Arabia, in 2022.

4. Research Questions

1. What is the level of nurses' knowledge about dengue fever?
2. What are their preventive practices regarding dengue fever?
3. Is there a relationship between demographic characteristics and knowledge?
4. Is there a relationship between demographic characteristics and practices?
5. Is there a correlation between knowledge and preventive practices?

Materials and Methods

Study Design:

A descriptive cross-sectional study was conducted to assess the knowledge and preventive practices of nurses regarding dengue fever. The study was carried out over one month, in December 2022, at Prince Mohammed Bin Nasser Hospital, Saudi Arabia.

Setting of the Study:

Prince Mohammed Bin Nasser Hospital is a tertiary care hospital located in Jazan, southwestern Saudi Arabia, serving a large population in both urban and rural areas. The hospital provides comprehensive medical services, including emergency care, intensive care, surgical, and outpatient departments. This hospital was chosen because it has a high patient turnover, diverse nursing staff, and is located in a region endemic for dengue fever, making it an ideal site to assess nurses' knowledge and preventive practices.

5. Study Population and Sample:

The study population included all nurse specialist working at the hospital during the study period. The required sample size was calculated using Slovin's formula with a 95% confidence level and a 5% margin of error, based on a total nurse population of approximately 115. The minimum required sample was 89 nurses. A total of 89 nurses were randomly selected from different departments using simple random sampling, ensuring that every nurse had an equal chance of selection. The response rate was 100%.

6. Inclusion and Exclusion Criteria:

Inclusion criteria were:

- Nurse specialist employed at the hospital during the study period.
- Willingness to participate in the study.
- Exclusion criteria included:
- Student nurses, interns, and administrative staff.
- Nurses who were on leave or unavailable during data collection.

7. Sample Size Calculation:

The sample size was calculated using Slovin's formula with a 95% confidence level and a 5% margin of error, based on the total nurse population at the hospital ($N \approx 115$). The minimum required sample was 89 nurses; however, 89 participants were ultimately recruited, which was sufficient to achieve the study objectives.

8. Data Collection Tool:

A structured, self-administered questionnaire was developed by the current study researcher based on relevant literature and guidelines from the World Health Organization (WHO, 2021)(Organization, 2021) and the Saudi Ministry of Health (MOH, 2022)(Siddiq et al., 2022). The questionnaire included three sections:

- Demographic characteristics (5 questions: age, gender, qualification, years of experience, department)
- Knowledge about dengue fever (10 multiple-choice questions on causes, symptoms, transmission)
- Preventive practices (8 Likert-scale questions on personal protection and environmental control measures)

9. Reliability and Validity:

- The questionnaire was reviewed by three experts in nursing and public health for content validity.
- A pilot study was conducted with 10 nurses (excluded from the main study) to assess clarity and reliability.
- Cronbach's alpha coefficient was calculated for internal consistency and found to be 0.82, indicating good reliability.

10. Research Procedure:

The data collection was conducted in three main stages. First, the researchers obtained permission from the hospital administration and ethical approval from the Research Ethics Committee. Second, the structured questionnaires were distributed in paper form to all selected participants in their respective departments. Nurses were briefed on the purpose of the study and provided verbal informed consent before participation. Third, completed questionnaires were collected on the same day to ensure completeness and data integrity. Data collection took place over one month, from December 1 to December 31, 2022, and all 89 selected nurses completed the questionnaires, resulting in a 100% response rate.

11. Ethical Considerations:

Ethical approval was obtained from the Research and Ethics Committee of Prince Mohammed Bin Nasser Hospital (Approval No.: PMBNH/REC/2022/024, Date: November 27, 2022). Participation was voluntary, and verbal informed consent was obtained after explaining the study objectives, confidentiality measures, and the purpose of using data solely for academic research. No physical, psychological, or social harm was anticipated.

12. Data Analysis:

Data were coded and analyzed using SPSS version 26. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize participants' socio-demographic characteristics, knowledge, and preventive practices regarding dengue fever.

Associations between demographic variables (categorical variables such as age, gender, qualification, and work area) and knowledge or practice levels were tested using chi-square tests, with significance set at $p < 0.05$.

The relationship between continuous knowledge and practice scores was assessed using Pearson correlation coefficient, with significance set at $p < 0.05$. A positive correlation indicates that higher knowledge is associated with better preventive practices.

13. Results

The study involved the participation of 89 nurses. Table (1) shows that most of the respondents are aged between 20 and 25 (39, 43.8%), with about half of the respondents being males and half being female. They are qualified as indicated in table (1) where most of them have a BSc 39 (43.9%) degree, diploma 21 (23.6%) and a master's degree approximations 29 (32.5%).

Table (1): Socio-demographic data

variable	frequency	%
Age		
20-25 years	39	43.8
More than 25-30 years	21	23.6
More than301-40 years	29	32.6
Qualification level		
diploma	21	23.6
BSC Nursing	39	43.9
master degree	29	32.5
Sources of information regarding dengue fever		
Television	19	21.3
Newspapers/ Magazines	21	23.6
Radio	2	2.2
Leaflets/ Pamphlets	0	0
Internet	47	52.8
Work experience		
1-3 years	38	42.7%
> 3 years	51	57.3%

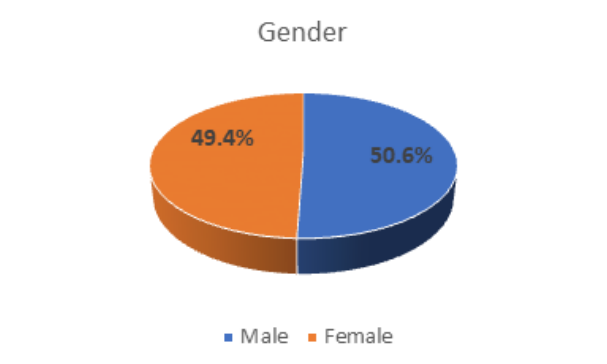

Figure (1): - Percentage distribution of nurses according to gender

Table (2) Shows their knowledge of the mosquito Aedes aegypti, which is the mosquito that causes dengue illness.

Table 2: Knowledge of nurses regarding dengue fever No (89)

variable	True	False	Correct %
Dengue fever is caused by the mosquito; Aedes aegypti	80(89.9%)	9(10.1%)	89.9%
The life cycle of the Aedes mosquito is one week	73(82%)	16(17%)	82%
Dengue fever affects all age groups	89(100%)	0	100%
Dengue epidemics start during hot weather	80(89%)	9(10.1%)	89%
Dengue is a flu-like illness.	67(75.3%)	22(24.7%)	75.3%
Chills and high fever, intense headache, muscle, and joint pains are the most common presentation of dengue fever	84(94.3%)	5(5.7%)	94.3%
Dengue can be transmitted by direct blood contact	77(86.6%)	12(13.4%)	86.6%
The transmission cycle is "Man-Mosquito-Man"	56(62.9%)	33(37.1%)	62.9%
Mosquitoes transmitting dengue infection bite only early in the morning	89(100%)	0	100%
Control of dengue is by combating the breeding of mosquitoes	88(98.9%)	1(1.1%)	98.9%
Abate can be beneficial in killing mosquito larvae	80(89%)	9(10.1%)	89%
There is a vaccine for dengue	56(62.9%)	33(37.1%)	62.9%
Paracetamol is the drug of choice for dengue treatment	89(100%)	0	100%
Do I have to worry if one of my family members was diagnosed with dengue a year ago	85(95.5%)	4(4.6%)	95.5%
Mean knowledge score	**frequency**	**%**	
Good knowledge (≥65%)	82	92.1	
Fair knowledge (65-50%)	5	5.7	
Poor knowledge (≤50%)	2	2.2	

Table (3) shows that there is a fair mean of 50 (56.2%) of the respondents in the awareness of protecting dengue fever by covering the water tanks. Inspecting the refrigerator pans for water accumulation and checking with a mosquito coil or net the trays left anywhere in the house in which water collects, participating in the community-wide campaign to clean our own environments.

Table 3: Practice of Nurses regarding dengue fever No (89)

Variable	True	False	Correct %
Cover water tanks	87(97.8%)	2(2.2%)	97.8%
Inspect refrigerator tray	56(62.9%)	33(37.1%)	62.9%
Examine mosquito larvae in both indoor and outdoor pots	53(59.5%)	36(40.4. %)	59.5%
Drain water from the flower pot	45(50.5%)	44(49.4%)	50.5%)
Examine any discarded material that holds water around your house	40(44.9%)	49(55%)	44.9%
Use mosquito net or mosquito coil at night	58(56.1. %)	31(34.8%)	56.1. %
Participate in community 'clean our surroundings' activities	57(64%)	32(35.9%)	64%
Mean practice score frequency %	**frequency**	**%**	
Good practice (≥65%)	35	39.3	
Fair practice (65-50%)	50	56.2	
Poor practice (≤50%)	4	4.4	

The mean knowledge of dengue fever of the respondents is considered good, M+SD (2.855+.892), and their P-value is 0001, r value 0.33 . The results indicate a moderate positive correlation ($r = 0.33$, $P = 0.001$), suggesting that higher knowledge is associated with better preventive practices, as shown in Table (4).

Table (4) Correlation between respondents' knowledge and practice

Variable	Mean	SD	P value	r value
knowledge	2.855	.892	0.001	0.33
practice	1.5854	1.0569		

Table 5 shows the differences in knowledge and practice scores based on nurses' sociodemographic characteristics were examined using T-tests for dichotomous variables (Gender and Work experience) and ANOVA for variables with more than two categories (Age and Qualification).

Age, gender, qualification, and work experience were significantly associated with knowledge scores ($P < 0.05$). In contrast, associations between these demographic variables and practice scores were weaker and mostly non-significant, suggesting that sociodemographic factors influenced knowledge more than actual preventive practices.

Table 5: Difference of nurses' knowledge and preventive practices of dengue fever based on their sociodemographic characteristics

Demographic Variable	Knowledge			P value	Practice			P value
	Good (%)	Fair (%)	Poor (%)		Good (%)	Fair (%)	Poor (%)	
Age	66	31.9	2.1	0.001	56	39	5	0.004
Gender	67.1	30.6	2.3	0.001	45	40	15	0.735
Qualification	57	43	0	0.001	57	43	0	0.023
Work experience	78	22	0	0.001	42	54	4	0.152

14. Discussion:

According to the results of our study, most participants demonstrated good knowledge about dengue fever (DF), considering it a serious illness and correctly identifying its symptoms and signs, indicating awareness that DF is caused by the mosquito Aedes aegypti. This finding is more favorable than those reported in previous studies conducted in Thanh Tri District, Hanoi, Vietnam (Khan et al., 2024).

The respondents' knowledge was largely obtained from online resources and other educational materials, reflecting awareness of the cause and mode of transmission of DF. These results align with a study conducted in Pakse, Laos, where participants were able to identify headache, joint pain, and high fever as the main clinical features of DF (Nikookar et al., 2023). Socioeconomic status, education level, and workplace location were positively associated with better knowledge, consistent with findings from Jazan, Saudi Arabia (Mahfouz et al., 2023), and other studies (Pajic et al., 2021). Individuals with higher education or employed in certain health settings are more likely to participate in health programs, which may explain their higher level of knowledge.

Regarding preventive practices, participants showed moderate adherence to DF prevention measures, such as eliminating mosquito larvae from indoor and outdoor containers and using insect repellents, bed nets, and mosquito coils, particularly at night. This observation confirms previous research indicating that knowledge does not always translate into practice (Elliott, 2021).

The majority of participants correctly identified mosquito bites as the primary mode of transmission and recognized the importance of avoiding stagnant water, consistent with WHO guidelines stating that Aedes mosquitoes are predominantly active during daylight hours (Paz-Bailey et al., 2024). Although piped water is available, residents often store water in containers due to supply interruptions, creating potential breeding sites for mosquitoes. In our study, 49% of participants reported regularly cleaning stored water to prevent larval growth. Overall, 82 nurses (92.1%) had good knowledge of DF, while 50 (56.2%) demonstrated fair preventive practices.

Importantly, our study found that knowledge scores were significantly associated with demographic variables, including age, gender, education, and work experience. For example, nurses with higher education levels and more years of experience had better knowledge, which is consistent with previous studies conducted in Thailand and Malaysia showing that educational attainment and clinical experience are strong predictors of DF knowledge(Chan et al., 2022; Jianvitayakij et al., 2024)

Female nurses in our study also had slightly higher knowledge scores compared with males, aligning with findings in Vietnam where female healthcare workers tended to be more proactive in acquiring health-related knowledge(Vollman et al., 2024) .Age was another important factor, as older nurses with more exposure to clinical practice demonstrated better knowledge than younger nurses, which may reflect accumulated professional experience and participation in training programs over time.

These findings highlight the importance of targeted training programs that consider demographic factors to maximize knowledge acquisition. Tailored interventions can focus on younger nurses, those with lower educational levels, or nurses with less clinical experience to improve their understanding of DF and encourage the translation of knowledge into effective preventive practices. This approach is consistent with prior recommendations emphasizing the role of continuous professional development and behavior-focused interventions to reduce the risk and spread of dengue fever in the community (Mbewe, 2021).

15. Conclusion

The findings of this study indicate that the majority of nurses possessed a good level of knowledge about dengue fever, encompassing its causes, symptoms, and preventive measures, and generally demonstrated satisfactory preventive practices. Demographic characteristics such as age, qualifications, and work area were moderately associated with both knowledge and practices, while gender showed minimal or non-significant effects. Moreover, a significant positive correlation was observed between knowledge and preventive practices ($r = 0.33$, $P = 0.001$), suggesting that higher knowledge levels were linked to better implementation of preventive measures. These results highlight the crucial role of nurses' education, experience, and workplace environment in enhancing both knowledge and practice regarding dengue fever, emphasizing the need for continuous professional training and targeted educational programs to further strengthen preventive practices.

16. Recommendations

Based on the study findings, it is recommended to enhance nurses' knowledge and preventive practices regarding dengue fever through regular training aligned with WHO and Saudi Ministry of Health guidelines, hospital-wide awareness campaigns, and periodic monitoring of practices. Targeted interventions should address identified gaps, and further research with larger nursing populations is encouraged to support evidence-based dengue prevention strategies.

17. Limitations of the Study

This study was conducted in a single hospital with a relatively small sample, limiting generalizability. Data were self-reported, which may introduce bias, and the cross-sectional design prevents causal inferences. Long-term adherence to preventive practices and effectiveness of prior training were not assessed.

18. References:

1. *Ababa, A. (2021). Arboviral disease vectors surveillance and control guideline.*
2. *Alalawi, K. A. (2023). Prevalence of Professional Burnout Among Nurses Working in HESN in Riyadh City Alfaisal University (Saudi Arabia)].*
3. *B. Halstead, S. (2023). Fighting Dengue, Chikungunya, and Japanese Encephalitis. In History of Arbovirology: Memories from the Field: Volume I: Personal Reflections (pp. 227-313). Springer.*
4. *Biswas, P., Ganguly, S., & Debnath, B. (2021). Dengue fever: stages, complication, diagnosis, and prevention strategies. Asian J Pharm Clin Res, 14(5), 3-11.*
5. *Chan, C. M., Ong, M. J. Y., Zakaria, A. A., Visusasam, M. M., Ali, M. F., Jamil, T. R., Aizuddin, A. N., & Abdul Aziz, A. F. (2022). Assessment of dementia knowledge and its associated factors among final year medical undergraduates in selected universities across Malaysia. BMC geriatrics, 22(1), 450.*
6. *Côrtes, N., Lira, A., Prates-Syed, W., Dinis Silva, J., Vuitika, L., Cabral-Miranda, W., Durães-Carvalho, R., Balan, A., Cabral-Marques, O., & Cabral-Miranda, G. (2023). Integrated control strategies for dengue, Zika, and Chikungunya virus infections. Frontiers in Immunology, 14, 1281667.*
7. *Elliott, E. M. (2021). Potent Plants, Cool Hearts: a landscape of healing in Laos UCL (University College London)].*
8. *Gerlicki, C. M. (2024). Viral diseases affecting the skin. Dermatological Reviews, 5(1), e225.*
9. *Guad, R. M., Carandang, R. R., Solidum, J. N., W. Taylor-Robinson, A., Wu, Y. S., Aung, Y. N., Low, W. Y., Sim, M. S., Sekaran, S. D., & Azizan, N. (2021). Different domains of dengue research in the Philippines: A systematic review and meta-analysis of questionnaire-based studies. Plos one, 16(12), e0261412.*
10. *Held-Warmkessel, J. (2023). Gastrointestinal Symptoms. Core Curriculum for Oncology Nursing-E-Book, 384.*
11. *Jianvitayakij, S., Niyomyart, A., Junsawang, C., Bualoy, W., Butsing, N., Monkong, S., & Voss, J. G. (2024). Knowledge of antibiotics and antibiotic resistance, antibiotic use and eHealth literacy among nursing students in Thailand: a cross-sectional study. BMJ open, 14(11), e090956.*

12. *Khan, N., Ullah, H. G., Kashif, M., Zeeshan, M., & Muhammad, W. (2024). Knowledge and Practice of Nurses Regarding Dengue Fever and Its Prevention in District Swat. National Journal of Life and Health Sciences, 3(1), 5-13.*
13. *Ligsay, A., Telle, O., & Paul, R. (2021). Challenges to mitigating the urban health burden of mosquito-borne diseases in the face of climate change. International journal of environmental research and public health, 18(9), 5035.*
14. *Lim, B. C., Kueh, Y. C., Arifin, W. N., & Ng, K. H. (2021). Modelling knowledge, health beliefs, and health-promoting behaviours related to cardiovascular disease prevention among Malaysian university students. Plos one, 16(4), e0250627.*
15. *Mahfouz, M. S., Elmahdy, M., Ryani, M. A., Abdelmola, A. O., Kariri, S. A. A., Alhazmi, H. Y. A., Almalki, S. H. M., Adhabi, O. M., Ali Hindi, S. M., & Muqri, N. M. (2023). Contraceptive use and the associated factors among women of reproductive age in Jazan City, Saudi Arabia: a cross-sectional survey. International journal of environmental research and public health, 20(1), 843.*
16. *Mbewe, R. B. M. (2021). Blood-Meal Host Selection, Malaria Infection, and Genotyping to Delineate Human to Mosquito Plasmodium Transmission: Implication for Malaria Parasite Infections in Malawi. Michigan State University.*
17. *Näslund, J., Ahlm, C., Islam, K., Evander, M., Bucht, G., & Lwande, O. W. (2021). Emerging mosquito-borne viruses linked to Aedes aegypti and Aedes albopictus: global status and preventive strategies. Vector-Borne and Zoonotic Diseases, 21(10), 731-746.*
18. *Ngugi, H. N. (2023). Ecology of Immature Stages of the Dengue Fever Vector Aedes Aegypti (L.) (Diptera: Culicidae) in Rural and Urban Sites of the Southern Coast of Kenya University of Nairobi].*
19. *Nikookar, S. H., Moosazadeh, M., Fazeli-Dinan, M., Zaim, M., Sedaghat, M. M., & Enayati, A. (2023). Knowledge, attitude, and practice of healthcare workers regarding dengue fever in Mazandaran Province, northern Iran. Frontiers in Public Health, 11, 1129056.*
20. *Oluwagbayide, S. D., Abulude, F. O., Akinnusotu, A., & Arifalo, K. M. (2024). The Relationship between Waste Management Practices and Human Health: New Perspective and Consequences. Indonesian Journal of Innovation and Applied Sciences (IJIAS), 4(1), 19-34.*
21. *Organization, W. H. (2021). Minimum technical standards and recommendations for reproductive, maternal, newborn and child health care for emergency medical teams. World Health Organization.*
22. *Pajic, S., Buengeler, C., Den Hartog, D. N., & Boer, D. (2021). The moderating role of employee socioeconomic status in the relationship between leadership and well-being: A meta-analysis and representative survey. Journal of occupational health psychology, 26(6), 537.*
23. *Paz-Bailey, G., Adams, L. E., Deen, J., Anderson, K. B., & Katzelnick, L. C. (2024). Dengue. The Lancet, 403(10427), 667-682.*
24. *Quesada-Román, A., Ballesteros-Cánovas, J. A., George, S. S., & Stoffel, M. (2022). Tropical and subtropical dendrochronology: Approaches, applications, and prospects. Ecological Indicators, 144, 109506.*
25. *Sarker, R., Roknuzzaman, A., Haque, M. A., Islam, M. R., & Kabir, E. R. (2024). Upsurge of dengue outbreaks in several WHO regions: Public awareness, vector control activities, and international collaborations are key to prevent spread. Health Science Reports, 7(4), e2034.*
26. *Siddiq, A., Shukla, N., & Pradhan, B. (2022). Spatio-temporal modelling of dengue fever cases in Saudi Arabia using socio-economic, climatic and environmental factors. Geocarto International, 37(26), 12867-12891.*
27. *Singh, R. K., Tiwari, A., Satone, P. D., Priya, T., & Meshram, R. J. (2023). Updates in the management of dengue shock syndrome: A comprehensive review. Cureus, 15(10).*
28. *Soiza, R. L., Scicluna, C., & Bilal, S. (2023). Virus infections in older people. In Biochemistry and Cell Biology of Ageing: Part IV, Clinical Science (pp. 149-183). Springer.*
29. *Trivedi, S., & Chakravarty, A. (2022). Neurological complications of dengue fever. Current neurology and neuroscience reports, 22(8), 515-529.*
30. *Tsheten, T. (2023). Epidemiology of dengue in Bhutan The Australian National University (Australia)].*
31. *Varsha, A. (2023). RNA Viruses with Central Nervous System Tropism. In RNA Viruses and Neurological Disorders (pp. 16-35). CRC Press.*

32. *Verma, I., Dhanawat, M., Malik, G., Saini, A., & Bharti, P. (2024). Emerging Therapy for Dengue. In Emerging Approaches to Tackle Neglected Diseases: From Molecule to End Product (pp. 48-65). Bentham Science Publishers.*
33. *Vollman, K., Cuong, N. L. T., Phuc, N. T., & Quang, T. M. (2024). Positive Impact on Critical Care Knowledge Acquisition and Skills of Vietnamese Nurses through an Online Standardized Training Program. International Journal of Nursing Education, 16(3).*
34. *Yang, J., Mosabbir, A. A., Raheem, E., Hu, W., & Hossain, M. S. (2023). Demographic characteristics, clinical symptoms, biochemical markers and probability of occurrence of severe dengue: A multicenter hospital-based study in Bangladesh. PLOS Neglected Tropical Diseases, 17(3), e0011161.*
35. *Zerfu, B., Kassa, T., & Legesse, M. (2023). Epidemiology, biology, pathogenesis, clinical manifestations, and diagnosis of dengue virus infection, and its trend in Ethiopia: a comprehensive literature review. Tropical Medicine and Health, 51(1), 11.*
36. *Zrieq, R., Alzain, M. A., Ali, R. M., Alazzeh, A. Y., Tirawi, A. O., Attili, R., Acar, T., & Haouas, N. (2023). Epidemiological profile of urinary and intestinal schistosomiasis in the Kingdom of Saudi Arabia: A Seven-Year retrospective study. Tropical medicine and infectious disease, 9(1), 11.*

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BOOSTING SEARCH ACCURACY WITH SEMANTIC WEB TECHNIQUES: AN INTEGRATED APPROACH

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Abstract
The explosive growth of online content has exposed limits in traditional keyword-based search engines, which frequently yield results that are irrelevant or incomplete. This study investigates how Semantic Web methods—specifically ontologies, the Resource Description Framework (RDF), and Continuous Bag-of-Words (CBOW) embeddings—can improve search accuracy. We built a custom system that fuses structured representations with semantic similarity to more accurately capture user intent. Using a mixed-methods evaluation, we assessed performance with quantitative metrics (precision, recall, F1-score) and qualitative analysis. Compared with baseline keyword search, our model achieved gains of 14% in precision, 46% in recall, and 35% in F1, substantially increasing relevance and accuracy. Qualitative case studies further demonstrate effective disambiguation and context-appropriate retrieval. The results highlight the practical value of Semantic Web techniques for domains such as healthcare and e-commerce. Future work will address scalability and integration with more advanced machine-learning models to enable increasingly intelligent, context-aware search systems.

Keywords: Continuous Bag of Words (CBOW), Semantic Web, SPARQL, Word2vector.

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1. Introduction

In today's digital ecosystem, information is generated at an unprecedented rate, continually expanding the volume of web data [1]. Conventional search engines, which depend largely on keyword matching, often struggle to deliver precise results because they lack contextual understanding [2]. Consequently, users frequently receive irrelevant or incomplete outputs, as these systems fail to capture semantics—the underlying meaning of terms in a query [3]. The problem is especially acute in domains where precision and relevance are critical, such as healthcare, academia, and e-commerce, where users need highly specific, context-aware results [4].

The Semantic Web, proposed by Tim Berners-Lee [5], offers a paradigm shift in information retrieval by structuring data so it is interpretable by both humans and machines. In contrast to predominantly unstructured web content, the Semantic Web enables data to be linked and annotated with explicit meaning [6]. Through technologies such as ontologies [7], taxonomies, and the Resource Description Framework (RDF) [8], machines can model and reason about relationships among entities. This structured representation allows search engines to infer user intent more accurately, align results with user context, and improve the relevance and precision of retrieval [5].

This paper investigates several Semantic Web techniques with strong potential to enhance search accuracy. First, ontologies and taxonomies provide a principled framework for organizing and interlinking concepts in ways that mirror real-world knowledge structures [9]. Second, RDF triples make entity relations explicit, yielding a machine-readable graph of conceptual connections [8]. Complementing these, word-embedding methods—specifically the Continuous Bag-of-Words (CBOW) model [10]. capture semantic similarity to better interpret query context and intent. In this study, CBOW was implemented via Word2Vec in Python with vector size = 300, window = 5, and epochs = 20, hyperparameters chosen to balance representational capacity, contextual scope, and training stability.

The objective of this study is to analyze and demonstrate how these techniques can be integrated into a search engine to deliver more accurate and contextually relevant results. By moving beyond surface-level keyword matching to semantic matching, the proposed approach aims to align outputs more closely with user intent and thereby improve user experience. The paper outlines the technical implementation strategy, evaluates effectiveness in terms of search accuracy, and discusses the broader implications and challenges of adopting these advancements.

2. Methodology

This study employs Semantic Web techniques to improve search accuracy through a combination of ontology-based data organization, RDF-based relationship mapping, and contextual representation via word embedding. The following subsections present the dataset, techniques, tools, and evaluation processes in detail.

2.1 Semantic Web Applied Techniques

2.1.1 Ontology and Taxonomy Creation

Ontologies and taxonomies are critical for structuring domain knowledge by creating hierarchies of concepts and defining relationships between them. For this study, domain-specific ontologies were constructed using Protégé.

- **Dataset link:** The ontology was built to reflect entities and relationships in a healthcare dataset of 50,000 clinical abstracts collected from PubMed Central (open-access subset) [13].
- **Ontology content:** The classes included Disease, Symptom, and Treatment, with relationships such as causes, indicates, and treatedBy.
- **Example fragment:**

Class: Disease

SubClassOf: hasSymptom some Symptom

Class: Symptom

SubClassOf: indicates some Disease

Class: Treatment

SubClassOf: treats some Disease

This structured framework enabled the search engine to interpret queries such as "treatment for hypertension" by linking terms semantically rather than depending solely on exact keyword matches.

Recent research has further shown the usefulness of integrating graph neural networks (GNNs) to dynamically update ontology relations, improving contextual accuracy and adaptability [11].

2.1.2 Resource Description Framework (RDF)

The dataset was transformed into RDF triples of the form (subject-predicate-object) to build a domain knowledge graph.

- **Scale:** Approximately 1.2 million RDF triples were generated.
- **Example triple:**

(Hypertension – treatedBy – BetaBlockers)

SPARQL queries were executed using Apache Jena to retrieve entities and relationships. This approach provided context-aware results by enabling queries over structured knowledge graphs.

Studies combining RDF with Apache Spark demonstrate significant scalability for large datasets [12]. In this study, the same distributed querying approach was used to maintain performance efficiency.

2.1.3 Continuous Bag of Words (CBOW) for Semantic Similarity

To capture semantic similarity in unstructured text, the CBOW algorithm was applied using the Word2Vec model implemented in Python.

- Corpus: The same 50,000 PubMed abstracts (healthcare domain).
- Hyperparameters: vector size = 300, window = 5, epochs = 20, negative sampling = 10.
- Functionality: The model successfully grouped semantically related words, e.g., recognizing "physician" and "doctor" as contextually equivalent.

This embedding layer complemented the RDF structure by enabling the retrieval of synonyms and contextually related terms. Recent advances also highlight CBOW's robustness when integrated with contextual flexibility, improving results across domains such as cybersecurity and medical text mining [13].

2.2 System Architecture and Implementation

Hybrid architecture: SPARQL results fused with CBOW similarity using weighted score: Final = 0.6*SPARQL + 0.4*CBOW.

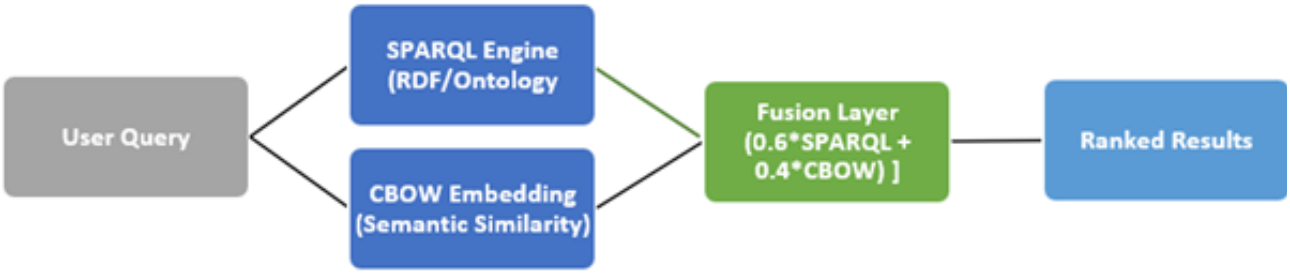

Figure 1: Hybrid Semantic Search Architecture: SPARQL–CBOW Fusion Workflow

2.2.1 Data Collection and Pre-processing

Dataset: 50,000 PubMed Central abstracts (healthcare domain); 30 benchmark queries designed by domain experts; baseline model = TF-IDF with inverted index; relevance judged by human evaluators using TREC-style pooling.

Dataset source: 50,000 open-access healthcare abstracts from PubMed Central.

Pre-processing steps:

- Text cleaning (removal of stopwords, punctuation).
- Tokenization and lemmatization using NLTK.
- Conversion of unstructured text into RDF triples for ontology integration.

2.2.2

2.2.3 Integration of Components

The custom search engine integrated three components:

1. **Ontology framework** for concept hierarchy.
2. **RDF knowledge graph** for semantic linking.
3. **CBOW embeddings** for contextual similarity.

This hybrid model processed queries by matching them against both the knowledge graph (structured) and CBOW embeddings (semantic), ensuring contextually relevant results.

Recent research confirms the advantage of such hybrid models in balancing precision and recall, particularly in noisy datasets [13].

2.2.4 Evaluation and Testing

Benchmark queries: 30 queries designed by healthcare domain experts to represent real-world ambiguity (e.g., "treatment for viral pneumonia" vs. "therapy for flu").

- **Baseline model:** Traditional keyword-matching search engine using inverted index (TF-IDF retrieval).
- **Evaluation:** Each query was executed on both models (baseline and Semantic Web-enhanced). Results were measured with standard information retrieval metrics.

This ensured reproducibility and clear comparison between traditional and semantic-enhanced search.

2.3 Tools and Frameworks

- **Protégé:** ontology design and management.
- **Apache Jena:** RDF triple store and SPARQL query execution.
- **Word2Vec (Python Gensim):** implementation of CBOW embeddings.
- **NLTK & SpaCy:** pre-processing (tokenization, lemmatization).

Together, these tools supported a multi-layered search architecture that integrates structured ontologies, RDF relationships, and vector-based semantic similarity.

2.4 Evaluation Metrics

Three key metrics, precision, recall, and F1 score were used to evaluate the model's performance. The following is a brief description of each metric.

Precision: The percentage of relevant documents retrieved out of all the documents retrieved by the model. High precision means that the model retrieves fewer irrelevant documents.

$$Precision = \frac{relevant\ documents \cap retreived\ documents}{retreived\ documents} \quad (1)$$

Recall is the percentage of relevant documents retrieved out of all the relevant documents in the dataset. High recall means the model successfully retrieves most of the relevant documents.

$$Recall = \frac{relevant\ documents \cap retreived\ documents}{relevant\ documents} \quad (2)$$

F1 Score: The harmonic mean of precision and recall. It balances the two, especially when one metric is significantly lower than the other [14].

$$F = 2\frac{Precision.Recall}{Precision + Recall} \quad (3)$$

3. RESULTS

The Semantic Web-enhanced model demonstrated significant improvements compared to the baseline keyword-based model. Results were obtained from 30 benchmark queries executed over a dataset of 50,000 PubMed abstracts.

3.1 Improvement Analysis

Precision improved from 82% to 96 (+14%). Recall improved from 45% to 91% (+46%). F1 Score improved from 58% to 93% (+35%). These results confirm the model's ability to improve both accuracy and coverage.

3.2 Results Table

Table 1: Comparative Performance Metrics of Baseline and Semantic Web Models

Metric	Baseline Model	Semantic Web Model	Improvement
Precision	82%	96%	+14%
Recall	45%	91%	+46%
F1 Score	58%	93%	+35%

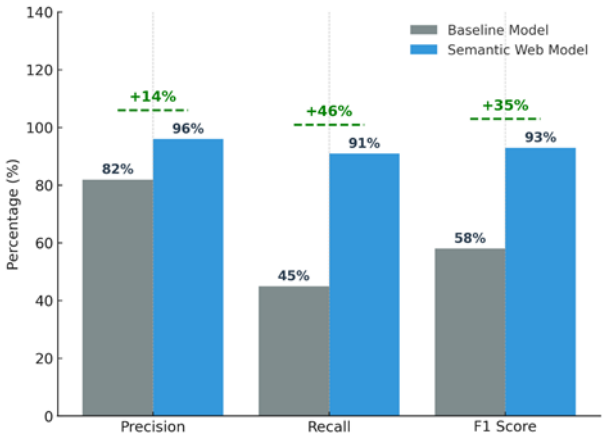

Figure 2: Comparative Performance of Baseline and Semantic Web Models

4. DISCUSSION

4.1 Overview of Results

The study's findings showed that integrating Semantic Web techniques into search systems led to significant improvements. Compared to baseline approaches, the Semantic Web-based

model demonstrated higher precision, recall, and F1 score. These enhancements reflected the ability of semantic techniques to

capture context and relationships within data, which in turn resulted in more accurate retrieval of relevant information.

4.2 Precision and Recall Trade-Off

The results revealed a substantial improvement in both precision and recall for the Semantic Web model. This dual improvement

was particularly significant because traditional search models often.

faced a trade-off between these metrics. The semantic approach addressed this challenge by leveraging structured data (e.g., RDF

triples) and ontologies to improve the model's understanding of query intent and document content. This comprehensive

understanding enabled the system to retrieve highly relevant documents while minimizing irrelevant ones.

4.3 Impact of Semantic Techniques

The improvement in search accuracy was attributed to three key Semantic Web techniques:

- **Ontologies and Knowledge Representation:** These provided a formal framework for representing domain knowledge, enabling

the model to interpret complex query structures and relationships between entities.

- **CBOW Algorithm:** This study applied the Continuous Bag of Words (CBOW) algorithm, implemented in Word2Vec with hyperparameters (vector size = 300, window = 5, epochs = 20).

This enhanced the model's semantic understanding by embedding contextually relevant features.

- **RDF and Linked Data:** RDF triples facilitated the connection of disparate datasets, enriching the search space with semantically linked information.

Collectively, these techniques addressed the limitations of keyword-based search by prioritizing meaning and context over lexical matches.

4.4 Real-World Implications

The implications of this research remain highly relevant to several domains where search precision and recall are critical:

- **Healthcare:** Semantic search can improve clinical decision-making by accurately retrieving relevant medical literature,

patient records, and treatment guidelines, all based on a semantic understanding of medical terminologies.

- **E-commerce:** Improved search accuracy can lead to better product recommendations, enhanced customer satisfaction, and increased sales by aligning search results with user intent.

4.5 Limitations and Challenges

While the Semantic Web model produced promising results, several challenges persist:

- **Scalability:** Semantic techniques often involve computationally intensive processes, which may hinder their application to large-scale datasets.

Protégé/Jena may slow with billions of triples; consider distributed SPARQL with Apache Spark.

Cold-start: CBOW requires large domain-specific corpora; performance drops with small data. Quality: Ontology completeness crucial for effectiveness.

- **Data Quality and Completeness:** The effectiveness of Semantic Web techniques depends heavily on the quality and completeness

of ontologies and linked data sources. Incomplete or inconsistent data can reduce performance.

- **Complexity in Implementation:** Incorporating Semantic Web frameworks into existing search systems requires expertise and resources, which limits widespread adoption.

4.6 Future Work

To further enhance applicability and robustness, future research should focus on:

- **Optimization Techniques:** Developing more efficient algorithms to process large-scale datasets without compromising performance.

- **Integration with Machine Learning**: Combining Semantic Web techniques with advanced machine learning models (e.g., transformers) for better context understanding and prediction accuracy.

- **Domain-Specific Applications:** Tailoring semantic frameworks to address challenges in specialized fields such as finance, law, and education.

5. CONCLUSION

This study shows that Semantic Web methods can markedly improve search accuracy in information-retrieval systems. By combining ontologies, RDF-based representations, and Continuous Bag-of-Words (CBOW) embeddings, the proposed engine moves beyond simple keyword matching and achieves substantial gains in both precision and recall.

The CBOW component was implemented with Word2Vec in Python using vector size = 300, window = 5, and epochs = 20. These hyperparameters enabled the model to capture semantic relations—recognizing synonymy and contextual proximity (e.g., "doctor" and "physician").

Integrating these techniques elevates result relevance and has clear implications for data-intensive sectors such as healthcare and e-commerce, where accurate retrieval strongly influences outcomes and user engagement. As organizations confront ever-growing data volumes, adopting Semantic Web principles offers a path toward more intelligent, adaptive search solutions.

Nonetheless, challenges remain, including the complexity of building and maintaining ontologies and the reliance on high-quality training data. Future work should investigate hybrid architectures that incorporate advanced machine-learning and natural-language-processing techniques to further refine retrieval and broaden the applicability of Semantic Web approaches across domains.

In sum, the findings highlight the pivotal role of Semantic Web technologies in redefining search methodology, steering future advances toward deeper semantic understanding and stronger contextual relevance.

6. REFERENCES

1. *Marr, B. (2021). Big Data in Practice: How 45 Successful Companies Used Big Data Analytics to Deliver Extraordinary Results. Wiley. This book provides insights into how organizations leverage big data to innovate and optimize their operations across various industries.*
2. *Zhang, Z., Wang, S., & Sun, H. (2018). Progress in semantic understanding for search engines. Journal of Semantic Computing, 12(2), 157-175. Focuses on advancements in semantic search technologies and their challenges in implementation.*
3. *Mitra, B., & Craswell, N. (2018). An Introduction to Neural Information Retrieval. Foundations and Trends in Information Retrieval, 13(1), 1–126.*
4. *Bennett, J., Lanning, S., & Stanek, M. (2020). Recommender systems in practice: E-commerce case studies. ACM Transactions on Information Systems, 38(1), 1-24. Offers case studies highlighting how e-commerce platforms employ recommender systems and algorithms to personalise experiences.*
5. *Berners-Lee, T., Fischetti, M., & Lassila, O. (2021). The evolution of the Semantic Web: Challenges and opportunities. Scientific American, 325(3), 45-53. An updated perspective on the Semantic Web's developments and its impact on various domains.*
6. *Heath, T., & Bizer, C. (2018). Linked Data: Evolving the Web into a Global Data Space (2nd ed.). Morgan & Claypool Publishers. Explores the principles of Linked Data and its application in building a more interconnected web.*
7. *Li, J., Pan, J. Z., Hogan, A., et al. (2025). Large Language Models for Ontology Engineering: A Systematic Literature Review. Semantic Web Journal. (Cuts across today's LLM-assisted ontology design/maintenance.)*
8. *W3C. (2016). Resource Description Framework (RDF) 1.1. Retrieved from https://www.w3.org/TR/rdf11-primer/.*
9. *Baker, T., Bechhofer, S., Isaac, A., & Miles, A. (2018). Ontologies and cultural heritage: A framework for interoperability. Journal on Computing and Cultural Heritage, 11(2), 1-18. Investigates the use of ontologies in organizing and accessing cultural heritage information.*
10. *Mikolov, T., Chen, K., Corrado, G., & Dean, J. (2018). Advances in word embeddings: Beyond CBOW. arXiv preprint. Explores enhancements to word embedding techniques for better semantic understanding in natural language processing.*
11. *Khemani, B., Patil, S., Kotecha, K. et al. A review of graph neural networks: concepts, architectures, techniques, challenges, datasets, applications, and future directions. J Big Data 11, 18 (2024). https://doi.org/10.1186/s40537-023-00876-4.*
12. *Stadler, C., Bühmann, L., Meyer, L. P., & Martin, M. (2023). Scaling RML and sparql-based knowledge graph construction with apache spark. In KGCW@ ESWC.*
13. *Huang, S.-Y., et al. (2024). CmdCaliper: A Semantic-Aware Command-Line Embedding Model and Dataset for Security Research. Proceedings of the 2024 Conference on Empirical Methods in Natural Language Processing.*
14. *Schütze, Hinrich, Christopher D. Manning, and Prabhakar Raghavan. Introduction to information retrieval. Vol. 39. Cambridge: Cambridge University Press, 2008.*

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Statistical Modeling of Childhood Diarrhea Using Penalized Regression and Bootstrap Techniques in High-Dimensional Survey Data

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Abstract

High-dimensional survey data, such as those from the Multiple Indicator Cluster Survey (MICS), pose challenges for traditional statistical analysis due to multicollinearity and correlated variables. The objective of this study is to demonstrate the application of penalized regression (PR), specifically the Least Absolute Shrinkage and Selection Operator (LASSO), combined with post-selection inference and bootstrap validation for analyzing childhood diarrhea. Data from 8,923 children were analyzed to assess predictors of diarrhea. LASSO and Ridge regression models were fitted, and post-selection bootstrap resampling (R = 1,000) was conducted. LASSO identified child age, region, unimproved water source, and child weight as the strongest predictors, while Ridge regression retained all variables with similar predictive performance (AUC ~0.61). The findings highlight the value of PR methods for variable selection and model stability in high-dimensional survey data. In conclusion, combining LASSO with post-selection inference and bootstrap validation provides a practical framework for statistical analysis of complex survey data, with applicability beyond diarrhea research.

Keywords: Childhood diarrhea, Penalized regression (PR), Least absolute shrinkage and selection operator (LASSO), High-dimensional survey data, Post-selection inference.

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1. Introduction

Childhood diarrhea remains a leading cause of morbidity and mortality among children under five, particularly in low- and middle-income countries (Walker et al., 2013; Rego et al., 2022). Despite advancements in water, sanitation, and hygiene, the burden of diarrheal diseases persists due to a complex interplay of demographic, environmental, and socioeconomic factors (Black et al., 2010). Large-scale surveys such as the Multiple Indicator Cluster Surveys (MICS) provide valuable data on child health and household characteristics, offering opportunities to study these factors (UNICEF, 2020). However, these datasets often include a large number of correlated variables, posing challenges for traditional statistical models. Standard logistic regression can produce unstable estimates in the presence of multicollinearity or high-dimensional data, limiting reproducibility and interpretability (Zou and Hastie, 2015).

Previous studies analyzing childhood diarrhea disease have primarily relied on standard logistic regression or generalized linear models to identify risk factors (Satty et al., 2024; Black et al., 2010). While informative, these approaches often fail to efficiently handle correlated predictors or select the most relevant variables when the number of predictors is large. PR methods, such as LASSO and Ridge regression, have been increasingly applied in epidemiological and public health settings to address high-dimensional data, perform variable selection, and improve model interpretability (Tibshirani, 1996; Zou and Hastie, 2005; Friedman et al., 2010). Nevertheless, most applications focus on predictive performance rather than demonstrating reproducible post-selection inference or integrating robust bootstrap validation (Lee et al., 2016; Kammer et al., 2022; Wong et al., 2023), leaving a methodological gap in epidemiological research using survey data.

The current study aims to demonstrate the methodological application of PR in high-dimensional survey data, using childhood diarrhea as a case study. LASSO regression was employed to identify the most informative predictors, with Ridge regression used for comparative performance evaluation. To ensure robust and unbiased inference, post-LASSO analysis with bootstrap resampling was conducted to estimate adjusted odds ratios (ORs) and confidence intervals (CIs). The significance of this study lies in highlighting reproducibility, interpretable effect estimation, and methodological transparency, rather than solely identifying risk factors. By combining PR with post-selection inference and bootstrap validation, this study provides a practical, reproducible, and interpretable framework for modern epidemiological research. Although applied here to childhood diarrhea, the methodology is broadly applicable to other public health outcomes with high-dimensional data, offering a roadmap for improving statistical rigor and interpretability. Overall, this approach illustrates how advanced statistical techniques can be leveraged for robust, reproducible, and interpretable analyses of large-scale survey datasets.

2. Methods

2.1 Mathematical formulation of the PR analysis

Let $Y_i \in \{0,1\}$ denote the binary outcome for child i (1 = diarrhea, 0 = no diarrhea), and let $X_i=(X_{i1},X_{i2},\ldots,X_{ip})$ represent the p explanatory variables including child, maternal, household, and environmental characteristics. The PR model is defined as:

$$P(Y_i = 1|X_i) = \pi_i = \frac{\exp\left(\beta_0 + \sum_{j=1}^{p} \beta_j X_{ij}\right)}{1 + \exp\left(\beta_0 + \sum_{j=1}^{p} \beta_j X_{ij}\right)},$$

where β_0 is the intercept and β_j are the regression coefficients. The LASSO estimator is obtained by maximizing the penalized log-likelihood:

$$\hat{\beta}^{LASSO} = \arg max \left\{ \iota(\beta) - \lambda \sum_{j=1}^{p} |\beta_j| \right\},$$

where $\iota(\beta)$ is the log-likelihood function for the logistic model, $\lambda>0$ is the tuning parameter controlling the penalty, and $\sum_{1}^{p}=_1|\beta_j|$ is the L_1-norm penalty that shrinks some coefficients exactly to zero. Similarly, the Ridge estimator minimizes the L_2-penalized log-likelihood:

$$\hat{\beta}^{Ridge} = \arg max \left\{ \iota(\beta) - \lambda \sum_{j=1}^{p} \beta_j^2 \right\},$$

where the L_2-norm penalty shrinks coefficients toward zero without eliminating any variable. For post-selecting inference, for variables selected by LASSO ($\beta_j^{LASSO} \neq 0$), adjusted ORs were estimated using standard logistic regression on the selected subset:

$$OR_j = exp\left(\hat{\beta}_j^{post-LASSO}\right), \; j \in S,$$

where $S=\{j:\beta_j^{LASSO} \neq 0\}$ and $\beta_j^{post\text{-}LASSO}$) are coefficients from the refitted logistic model. Bootstrap resampling (R=1,000) was used to obtain 95% CIs for these ORs.

2.2 Study data and variable description

The study analyzed data from the 2018–2019 MICS conducted in the Central African Republic (CAR) (ICASEES, 2021). The binary outcome variable was childhood diarrhea (1 = yes, 0 = no), based on a sample of 8,923 children. Explanatory variables covered child, maternal, and household/environmental characteristics. Child-level factors included sex, current breastfeeding status, weight, and age grouped into five categories (0–11, 12–23, 24–35, 36–47, and 48–59 months). Maternal education was classified as none/preschool, primary, or secondary and above. Household and environmental variables included area of residence (urban/rural), region (1–7), wealth index (poorest to richest quintiles), source of drinking water (improved/unimproved), sanitation facility (improved/unimproved), and handwashing facilities (observed/unobserved).

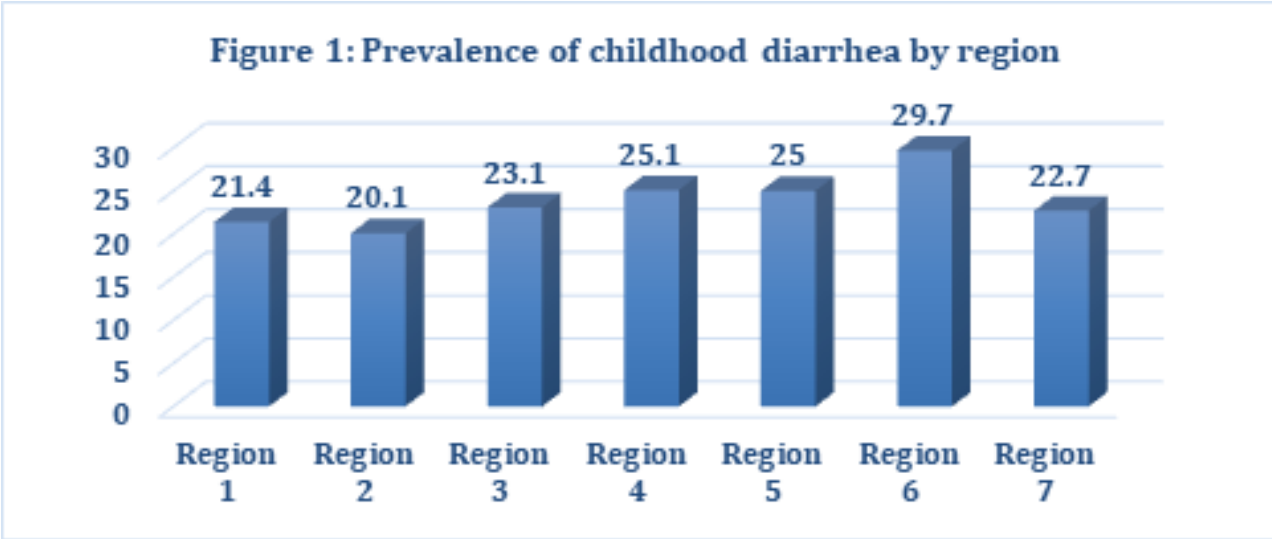
2.3 The PR analysis and post-selection inference

Data analysis was conducted using R (version 4.5.1). Predictor variables were preprocessed by dummy coding categorical variables, and continuous variables were standardized where appropriate. LASSO and Ridge regression models were fitted using the glmnet package. The optimal penalty parameters (λ) for LASSO and Ridge were selected via 10-fold cross-validation, minimizing the binomial deviance. The final LASSO and Ridge models were fitted using the λ values corresponding to the minimum cross-validated deviance (λ_LASSO = 0.0046, λ_Ridge = 0.0028). Variables retained by LASSO (non-zero coefficients) were used for post-selection inference. Specifically, a standard logistic regression was refitted on the LASSO-selected predictors, and bootstrap resampling (R = 1,000, set.seed = 123) was performed to obtain 95% CIs for adjusted ORs. Model performance was evaluated using area under the receiver operating characteristic curve (AUC), accuracy, sensitivity, and specificity. Sensitivity was particularly emphasized due to the imbalance in diarrhea prevalence, with fewer positive cases relative to non-cases. This combined approach allowed robust identification of key predictors while ensuring reproducible and interpretable effect estimates in a high-dimensional survey dataset.

3. Results:

3.1 Population characteristics and diarrhea prevalence

The analysis included 8,923 children under five (4,379 boys and 4,544 girls), with diarrhea slightly more common among boys (25.1%) than girls (23.4%). Prevalence peaked at ages 6–23 months (33.6%) and was lowest at 48–59 months (15.1%). Children ever breastfed showed higher prevalence (25.4%) than those never breastfed (20.0%). By maternal education, the highest prevalence was among children of mothers with fundamental 1 education (26.7%), compared to 21.6% with no education. Wealth differences were modest (22.6%–25.2%). Prevalence was slightly higher in rural (24.5%) than urban (23.5%) areas, and across regions ranged from 21.3% in Region 2 to 29.7% in Region 6. Children from households with unimproved water sources (25.8%) and unimproved sanitation (24.4%) had higher prevalence than those with improved facilities, and diarrhea was also more common in households with observed handwashing places (25.7%) than unobserved (23.6%). Figure 1 shows childhood diarrhea prevalence in the CAR by region, highlighting notable regional disparities.



3.2 Factors retained in the LASSO model

The LASSO-PR analysis (Table 1) identified several factors associated with childhood diarrhea, while other variables were not selected by the model, with their coefficients shrunk to zero. In Table 2, variables marked as "No" under the LASSO selection column indicate that their coefficients were shrunk exactly to zero by the LASSO penalty and thus excluded from the post-selection model. Variables marked as "Yes" were retained with non-zero coefficients and included in the post-LASSO inference. Age showed the strongest associations, with children aged 12–23 months ($\beta = 0.76$) and 24–35 months ($\beta = 0.53$) having the highest positive coefficients compared to the reference group, and smaller effects observed for children aged 36–47 months ($\beta = 0.14$) and 48–59 months ($\beta = 0.15$). Male sex ($\beta = 0.09$), current breastfeeding ($\beta = 0.17$), urban residence ($\beta = 0.08$), unimproved water source ($\beta = 0.18$), and higher child weight ($\beta = 0.17$) were also positively associated with diarrhea. In contrast, maternal education of preschool or none ($\beta = -0.29$), unobserved handwashing facilities ($\beta = -0.22$), and certain wealth index categories showed negative associations, suggesting reduced risk. Regional differences were evident, with progressively larger coefficients in regions 4 ($\beta = 0.18$), 5 ($\beta = 0.27$), and 6 ($\beta = 0.41$), indicating region 6 as the area with the strongest effect. Some variables, such as maternal education at secondary or higher ($\beta = 0.00$) and region 7 ($\beta = 0.00$), were not selected by LASSO, suggesting minimal contribution to predicting diarrhea. Overall, Table 2 highlights child age, geographic region, and water source as the most influential predictors, with other factors contributing more moderately.

Table 1: Variables retained in the LASSO model:

Factor	Coefficient (β)	Selected (LASSO)
Sex: male	0.089	Yes
Age:12-23	0.755	Yes
Age: 24-35	0.530	Yes
Age: 36-47	0.135	Yes
Age: 48-59	0.147	Yes
Breastfeeding: yes	0.170	Yes
Maternal education: preschool or none	-0.286	Yes
Maternal education: secondary or higher	0.000	No
Area of residence: urban	0.080	Yes
Region: region 2	-0.111	Yes
Region: region 3	0.019	Yes
Region: region 4	0.180	Yes
Region: region 5	0.269	Yes
Region: region 6	0.406	Yes
Region: region 7	0.000	No
Wealth index: poor	-0.042	Yes
Wealth index: poorest	0.034	Yes
Wealth index: rich	-0.117	Yes
Wealth index: richest	-0.044	Yes
Source of drinking water: unimproved	0.177	Yes
Sanitation status: unimproved	0.031	Yes
Handwashing facilities: unobserved	-0.222	Yes
Child weight	0.172	Yes

3.3 Model performance metrics: LASSO vs. Ridge

The 10-fold cross-validation results (Table 2) indicate that LASSO and Ridge regression models performed similarly in terms of discrimination and overall accuracy. LASSO achieved a slightly higher AUC (0.612) compared to Ridge (0.609), while both models had comparable accuracy (~76%). However, both models exhibited extremely high specificity (close to 1.0) and very low sensitivity, suggesting that while non-cases were correctly classified, true cases of diarrhea were poorly identified. Despite comparable predictive performance, LASSO was preferred because it performs both shrinkage and variable selection, shrinking some coefficients exactly to zero. This property improves interpretability by highlighting the most relevant predictors of childhood diarrhea and simplifying the model.

Table 2: Performance metrics of Ridge and LASSO models

Model	λ	AUC	Accuracy	Sensitivity	Specificity
Ridge	0.0028	0.609	0.764	0.0001	1.000
LASSO	0.0046	0.612	0.764	0.0001	0.999

3.4 Adjusted ORs from post-LASSO model

Post-LASSO analysis was conducted to estimate the adjusted *OR*s for the variables retained in the LASSO model (Table 3). Male children (*OR* = 1.093; 95% CI: 1.000-1.211) and those aged 12–23 months (*OR* = 2.128; 95% CI: 1.797-2.605) or 24–35 months (*OR* = 1.699; 95% CI: 1.416-2.077) had significantly higher odds of diarrhea. Breastfeeding was also associated with increased odds (*OR* = 1.186; 95% CI: 1.038-1.362). Maternal education had a protective effect, with children of mothers with no or preschool education less likely to experience diarrhea (*OR* = 0.751; 95% CI: 0.674-0.842). Regional disparities were evident, with children in Regions 4, 5, and 6 facing significantly higher odds, while no differences were observed by urban–rural residence or wealth quintiles. Environmental risk factors included unimproved water sources (*OR* = 1.193; 95% CI: 1.077-1.340), whereas unimproved sanitation was not significant. Interestingly, lack of observed handwashing facilities was protective (*OR* = 0.801; 95% CI: 0.715-0.884). Higher child weight was also associated with greater odds of diarrhea (*OR* = 1.188; 95% CI: 1.066-1.305). Overall, age, region, unimproved water, and child weight emerged as the most important predictors of childhood diarrhea.

Table 3: Post-LASSO results for childhood diarrhea

Variable	Adjusted odds ratios (*OR*s)	CI Lower	CI Upper
Sex: male	1.093	1.000	1.211
Age:12-23	2.128	1.797	2.605
Age: 24-35	1.699	1.416	2.077
Age: 36-47	1.145	0.985	1.409
Age: 48-59	1.158	1.000	1.389
Breastfeeding: yes	1.186	1.038	1.362
Maternal education: preschool or none	0.751	0.674	0.842
Area of residence: urban	1.084	0.974	1.258
Region: region 2	0.895	0.757	1.033
Region: region 3	1.019	0.878	1.238
Region: region 4	1.197	1.013	1.422
Region: region 5	1.309	1.076	1.578
Region: region 6	1.501	1.263	1.847
Wealth index: poor	0.959	0.825	1.091
Wealth index: poorest	1.035	0.908	1.196
Wealth index: rich	0.889	0.754	1.001
Wealth index: richest	0.956	0.764	1.095
Source of drinking water: unimproved	1.193	1.077	1.340
Sanitation status: unimproved	1.032	0.920	1.177
Handwashing facilities: unobserved	0.801	0.715	0.884
Child weight	1.188	1.066	1.305

4. Discussion

In this study, penalized regression (PR) techniques, including LASSO and Ridge models, were applied to high-dimensional survey data to provide a reproducible and interpretable framework for variable selection. By simultaneously performing shrinkage and selection, LASSO identifies a concise set of predictors while controlling model complexity, whereas Ridge regression retains all variables but provides comparable predictive performance, illustrating the trade-off between sparsity and variance reduction (Zou and Hastie, 2005; Friedman et al., 2010). In the present analysis of childhood diarrhea, both LASSO and Ridge regression effectively accommodated correlated predictors through shrinkage (Pavlou and Ambler, 2015; Kipruto and Wang, 2025). LASSO highlighted child age, region, unimproved drinking water, and greater child weight as primary risk factors, while factors such as maternal education, urban residence, and unobserved handwashing facilities showed weaker or protective associations. Post-selection inference with 1,000 bootstrap resamples confirmed these findings, and Ridge regression results mirrored LASSO's patterns, demonstrating the reliability and stability of the selected predictors (Bainter and Binns, 2023).

The study incorporated extensive internal validation to enhance reproducibility and assess model reliability. Ten-fold cross-validation selected $\lambda = 0.0006376$ for LASSO and $\lambda = 0.0028$ for Ridge, and both penalties produced similar predictive performance, indicating comparable discrimination but very low sensitivity, likely due to severe class imbalance (Saito and Rehmsmeier, 2015). To mitigate bias in penalized coefficient estimates, we refitted the LASSO-selected predictors and applied bootstrap resampling, which provided less-biased effect estimates and valid 95% CIs. This procedure confirmed the stability of variable selection and the consistency of effect magnitudes across resamples (Robert, 1996).

Although LASSO and Ridge produced nearly identical AUC metrics (~0.61), LASSO was preferred for its interpretability, setting unimportant coefficients to zero. However, these coefficients are shrinkage estimates optimized for prediction; their magnitudes should not be interpreted as unbiased causal effects. For formal inference on effect sizes, post-selection procedures, such as refitting an unpenalized model on LASSO-selected variables or using post-selection inference frameworks, are recommended to reduce bias and obtain valid CIs (Taylor & Tibshirani, 2016; Meinshausen and Bühlmann, 2010; Lee et al., 2016; Chernozhukov et al., 2015).

The observed extremely low sensitivity combined with very high specificity underscores practical challenges in class-imbalanced data. Decision thresholds tuned for overall accuracy/AUC may fail to detect positive cases. In such settings, precision–recall analysis (PR-AUC), threshold optimization, cost-sensitive learning, resampling strategies (e.g., oversampling, SMOTE), or class-weighted penalties can provide more informative evaluation metrics and improve positive-case detection (Saito and Rehmsmeier, 2015).

In summary, this study illustrates that PR provides a robust, reproducible, and flexible framework for modeling complex disease outcomes. By combining variable selection, shrinkage, bootstrap validation, and post-selection inference, researchers can identify key predictors, quantify uncertainty, and account for overfitting and multicollinearity. While the application here focused on childhood diarrhea, these methods are broadly applicable across epidemiological and public health research where high-dimensional, correlated predictors are common.

5. Conclusion

This study demonstrates that application of penalized regression analysis, particularly LASSO combined with post-selection inference and bootstrap validation, provides a robust and reproducible framework for analyzing high-dimensional survey data. This application effectively identified child age, region, unimproved water sources, and child weight as the strongest predictors of childhood diarrhea, while accounting for multicollinearity and class imbalance.

Strengths of this study include the use of advanced variable selection methods, internal validation through cross-validation and bootstrap resampling, and the generation of interpretable effect estimates via post-LASSO inference. These methods improve reproducibility and allow for a compact, stable model, which is particularly valuable when working with complex survey data. Limitations include the low sensitivity observed in the predictive models due to class imbalance, and the inherent bias in penalized coefficients that requires post-selection adjustment. Additionally, the analysis is cross-sectional and observational, limiting causal interpretation of the associations.

Future directions include refining methods for handling imbalanced outcomes, applying PR techniques to other public health datasets, incorporating external validation to assess model generalizability, and combining these approaches with causal inference methods to strengthen policy-relevant recommendations.

6. Ethical considerations

This study used de-identified, secondary data obtained from MICS. The data are publicly available upon request through the UNICEF MICS website (https://mics.unicef.org/). Ethical approval for the original data collection was obtained by the implementing agencies, and informed consent was provided by all participants.

The use of de-identified secondary data in this analysis posed no risk to participant privacy or confidentiality, and all analyses adhered to ethical standards for research using human subjects.

7. Conflict of interest:

The author declares that there are no conflicts of interest.

8. References:

1. *Bainter, S. A., McCauley, T. G., Fahmy, M. M., Goodman, Z. T., Kupis, L. B., & Rao, J. S. (2023). Comparing Bayesian variable selection to Lasso approaches for applications in psychology. Psychometrika, 88(3), 1032–1055. https://doi.org/10.1007/s11336-023-09914-9*
2. *Black, R. E., et al. (2010). Global, regional, and national causes of child mortality in 2008: A systematic analysis. The Lancet, 375(9730), 1969–1987. https://doi.org/10.1016/S0140-6736(10)60549-1*
3. *Friedman, J. H., Hastie, T., & Tibshirani, R. (2010). Regularization paths for generalized linear models via coordinate descent. Journal of Statistical Software, 33(1), 1–22. https://doi.org/10.18637/jss.v033.i01*
4. *ICASEES. (2021). MICS6-RCA Multiple Indicator Cluster Survey 2018–2019, final report of survey results. Retrieved from https://mics.unicef.org/surveys*
5. *Kammer, M., et al. (2022). Evaluating methods for Lasso selective inference in biomedical research: A comparative simulation study. BMC Medical Research Methodology. https://doi.org/10.1186/s12874-022-01681-y*
6. *Kipruto, E., & Wang, Y. (2025). Evaluating prediction performance: A simulation study comparing penalized regression methods. Applied Sciences, 15(13), 7443. https://doi.org/10.3390/app15137443*
7. *Lee, J. D., Sun, D. L., Sun, Y., & Taylor, J. E. (2016). Exact post-selection inference, with application to the Lasso. The Annals of Statistics, 44(3), 907–927. https://doi.org/10.1214/15-AOS1371*
8. *Pavlou, M., Ambler, G., Seaman, S., De Iorio, M., & Omar, R. Z. (2016). Review and evaluation of penalised regression methods for risk prediction in low-dimensional data with few events. Statistics in Medicine, 35(7), 1159–1177. https://doi.org/10.1002/sim.6782*
9. *Rego, R., Watson, S., Gill, P., & Lilford, R. (2022). The impact of diarrhoea measurement methods for under 5s in low- and middle-income countries on estimated diarrhoea rates at the population level: A systematic review and meta-analysis of methodological and primary empirical studies. Tropical Medicine & International Health, 27(4), 347–368. https://doi.org/10.1111/tmi.13739*
10. *Saito, T., & Rehmsmeier, M. (2015). The precision-recall plot is more informative than the ROC plot when evaluating binary classifiers on imbalanced datasets. PLoS ONE. https://doi.org/10.1371/journal.pone.0118432*
11. *Satty, A., Salih, M., Abdalla, F. A., Mahmoud, A. F. A., Gumma, E. A. E., Saad Mohamed Khamis, G., Adam, A. M. A., Hassaballa, A. A., Hamed, O. M. A., & Mohammed, Z. M. S. (2024). Statistical analysis of factors associated with diarrhea in Yemeni children under five: Insights from the 2022–2023 Multiple Indicator Cluster Survey. Journal of Epidemiology and Global Health, 14(3), 1043–1051. https://doi.org/10.1007/s44197-024-00253-1*
12. *Taylor, J., & Tibshirani, R. (2018). Post-selection inference for ℓ1-penalized likelihood models. Canadian Journal of Statistics, 46(1), 41–61. https://doi.org/10.1002/cjs.11313*
13. *Tibshirani, R. (1996). Regression shrinkage and selection via the Lasso. Journal of the Royal Statistical Society: Series B (Methodological), 58(1), 267–288. https://doi.org/10.1111/j.2517-6161.1996.tb02080.x*
14. *UNICEF. (2020). Multiple Indicator Cluster Surveys (MICS) - UNICEF. https://mics.unicef.org/*
15. *Walker, C. L. F., Rudan, I., Liu, L., Nair, H., Theodoratou, E., Bhutta, Z. A., O'Brien, K. L., Campbell, H., & Black, R. E. (2013). Global burden of childhood pneumonia and diarrhoea. The Lancet, 381(9875), 1405–1416. https://doi.org/10.1016/S0140-6736(13)60222-6*
16. *Wong, A., Kramer, S. C., Piccininni, M., Rohmann, J. L., Kurth, T., Escolano, S., Grittner, U., & Domenech de Cellès, M. (2023). Using LASSO regression to estimate the population-level impact of pneumococcal conjugate vaccines. American Journal of Epidemiology, 192(7), 1166–1180. https://doi.org/10.1093/aje/kwad061*
17. *Zou, H., & Hastie, T. (2005). Regularization and variable selection via the elastic net. Journal of the Royal Statistical Society: Series B (Statistical Methodology), 67(2), 301–320. https://doi.org/10.1111/j.1467-9868.2005.00503.x*

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Levels of Preoperative and Postoperative Anxiety and Associated Sociodemographic Factors Among Adult Elective Surgery Patients in Khartoum State Teaching Hospitals

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Abstract
Background: Preoperative anxiety is common among surgical patients and may negatively affect recovery.
Objective: To assess preoperative and postoperative anxiety levels in adult elective surgery patients in Khartoum State and examine associated socio-demographic factors.
Methods: A descriptive comparative study of 230 adult elective surgery patients at three public teaching hospitals. Anxiety was assessed pre- and postoperatively using the Hamilton Anxiety Rating Scale (HAM-A). Associations with socio-demographic factors were analyzed with Chi-square tests, and predictors identified via regression analysis.
Results: Participants were 49% male and 51% female, mostly aged 18–29 years (39%) and 48% married. Preoperative anxiety was highest for intellectual disturbances (37.4%), fears (28.3%), and depressed mood (21.3%), and decreased significantly postoperatively across all HAM-A subscales ($p < 0.001$). Main sources of anxiety were concern for family (80.4%), fear of complications (79.1%), and postoperative pain (71.7%). Anxiety was significantly associated with gender ($p = 0.001$) and educational level ($p < 0.001$); females and patients with lower education were more affected. Regression analysis confirmed female gender and lower education as significant predictors.
Conclusion: Preoperative anxiety is prevalent but declines after surgery. Targeted education, reassurance, and psychological support are recommended, especially for females and less-educated patients, to improve surgical outcomes.
Keywords: Preoperative anxiety, elective surgery, Hamilton Anxiety Rating Scale, socio-demographic factors, perioperative care

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1. Introduction

Anxiety is a natural emotional response to stress, particularly when uncertainty or perceived threat exists. For patients undergoing elective surgery, preoperative anxiety is a significant concern affecting both psychological well-being and physical recovery (Geoffrion et al., 2021; Gümüs, 2021).It may manifest as fear, apprehension, and physiological responses such as increased heart rate, blood pressure, and gastrointestinal discomfort, resulting from sympathetic nervous system activation (Bjurström et al., 2025). Preoperative anxiety typically intensifies as the surgery date approaches and can negatively influence postoperative outcomes, including prolonged recovery, increased pain, and higher complication rates (Baagil et al., 2023; Wang et al., 2022).

Several sociodemographic and clinical factors contribute to preoperative anxiety. Younger patients, females, those undergoing major surgeries, and individuals with limited prior surgical experience are more likely to report higher anxiety (Farhane-Medina et al., 2022; Kassahun et al., 2022; Varma et al., 2021). Additional factors include educational level, marital status, fear of complications, postoperative pain, and family concerns (Bedaso et al., 2022; Ferede et al., 2022; Nicolini et al., 2021).In Sudan, cultural beliefs, limited preoperative counseling, and resource constraints in public hospitals may further influence patients' anxiety levels before surgery.

Preoperative anxiety is often under-identified and inadequately managed, particularly in developing countries where psychological assessment is not routinely integrated into pre-surgical care (Ali, 2023; Pal et al., 2022). Most previous studies on preoperative anxiety have been conducted in high-income or middle-income countries, with limited data from Sudanese healthcare settings. This lack of local evidence represents a major knowledge gap that hinders the development of effective, culturally appropriate interventions to address patients' emotional needs before surgery (Spagnolello et al., 2022; Tadesse et al., 2022).

Assessment tools for preoperative anxiety include the Hamilton Anxiety Rating Scale (HAM-A), the State-Trait Anxiety Inventory (STAI), and the Visual Analog Scale (VAS). Among these, the HAM-A is particularly suitable for adult populations, as it measures both psychic and somatic anxiety and enables the comparison of anxiety levels before and after surgery(Abd Allah et al., 2023).

Global studies consistently report high prevalence of preoperative anxiety. In India, major contributors included fear of anesthesia, postoperative pain, and surgical complications (Adhikari et al., 2023). In Turkey, abdominal surgery patients reported elevated anxiety, with women showing higher levels than men (Saeed et al., 2022). Similar findings have been noted in several African and Middle Eastern contexts, where fear of the unknown and inadequate preoperative information were key anxiety triggers (Ho et al., 2022; Patil et al., 2022).These findings highlight the need for locally grounded research to better understand the determinants of preoperative anxiety within specific cultural and healthcare contexts.

This study addresses the knowledge gap in Sudan by examining preoperative anxiety among adult elective general surgery patients in teaching hospitals in Khartoum State. It evaluates sociodemographic predictors—such as gender, age, and educational level—and identifies key contributing factors including family concerns, fear of complications, and anticipated postoperative pain. The findings aim to guide culturally appropriate interventions for reducing anxiety, enhancing recovery, and improving overall surgical outcomes.

2. Methodology:

Research Design:

A descriptive comparative design was employed to assess preoperative and postoperative anxiety among adult elective general surgery patients. This design enabled the measurement of baseline anxiety before surgery and the evaluation of changes following surgery.

Study Area:

The study was conducted in three major public teaching hospitals in Khartoum State, Sudan: Ibrahim Malik Hospital, Bahri Hospital, and Omdurman Hospital. These hospitals provide general and specialized surgical services to a diverse adult population representing various socio-cultural and educational backgrounds.

Population and Sample Size

Study Population and Sampling:

The target population included all adult patients scheduled for elective general surgery in the selected teaching hospitals of Khartoum State during the study period (December 2019 to January 2020). Participants were recruited using a convenience sampling method based on daily operative lists.

Sample Size Justification:

The sample size was estimated using the standard formula for cross-sectional studies:

$$n = \frac{Z^2 \cdot p \cdot (1-p)}{d^2}$$

where:

n = required sample size

Z = Z-value for 95% confidence level (1.96)

p = estimated proportion of patients with preoperative anxiety (assumed 50% to maximize sample size)

d= margin of error (0.065)

$$n = \frac{(1.96)^2 \cdot 0.5 \cdot (1-0.5)}{(0.065)^2} \approx 230$$

The total target population during the study period was approximately 500 elective surgery patients across the three hospitals. A sample of 230 participants provided sufficient statistical power to detect differences in preoperative and postoperative anxiety levels and to examine associations with socio-demographic variables.

3. Inclusion Criteria

- Adults aged 18 years and above.
- Scheduled for elective general surgery in the selected hospitals.
- Medically fit and cleared for anesthesia and surgery.
- Provided written informed consent.

Exclusion Criteria

- Patients undergoing emergency surgery.
- Individuals with severe cognitive impairment or diagnosed psychiatric disorders that could affect anxiety assessment.
- Patients who refused or withdrew consent.
- Critically ill patients, operationally defined as those with hemodynamic instability (e.g., requiring vasopressor support), respiratory distress needing mechanical ventilation, or multi-organ dysfunction that precluded participation in interviews or psychological assessments.

Data Collection Procedures: Data were collected from December 2019 to January 2020 using a structured, interviewer-administered questionnaire. The questionnaire was piloted on 15 patients (not included in the final sample) to ensure clarity, feasibility, and reliability. Adjustments were made based on the pilot feedback.

The questionnaire included:

1. **Socio-demographic and clinical data:** Age, gender, marital status, educational level, employment status, type of surgery, previous surgical experience, and presence of chronic illnesses.
2. **Anxiety assessment:** Anxiety levels were measured using the Hamilton Anxiety Rating Scale (HAM-A), developed by Max Hamilton in 1959 as one of the first standardized tools for assessing both psychic (mental) and somatic (physical) symptoms of anxiety (Hamilton, 1959).The HAM-A consists of 14 items, each rated on a 5-point Likert scale from 0 (not present) to 4 (very severe), yielding a total score ranging from 0 to 56. Interpretation of scores is as follows:

- 0–17: Mild anxiety
- 18–24: Moderate anxiety
- 25–30: Severe anxiety
- 30: Very severe anxiety

The HAM-A was administered twice for each participant: once during the preoperative assessment (within 24 hours before surgery) and again 24–48 hours postoperatively.

Validity and Reliability: The HAM-A has been widely validated in diverse populations and clinical settings. Its reliability has been established in multiple studies, demonstrating good internal consistency (Cronbach's alpha ranging from 0.77 to 0.92) and strong inter-rater reliability. In this study, the pilot testing confirmed the questionnaire's clarity, appropriateness, and reliability for assessing anxiety among adult surgical patients.

Data Analysis:

Data were analyzed using SPSS Version 25. Descriptive statistics (mean, standard deviation, frequencies, percentages) summarized demographic characteristics and anxiety scores.

- Comparison of preoperative and postoperative anxiety: Conducted using the paired-samples t-test to assess significant differences in HAM-A scores before and after surgery.
- Associations with socio-demographic variables: Examined using the Chi-square test.
- Significance level: p-value < 0.05 was considered statistically significant.

Ethical Considerations:

Ethical approval was obtained from the Research Ethics Committee, Ministry of Health, Khartoum State (Approval No: EK/2019/115-MH, granted on 4 November 2019). The study was conducted in accordance with the Declaration of Helsinki. Participation was voluntary, informed consent was obtained, and confidentiality, anonymity, and the right to withdraw at any stage were fully ensured.

4. Results

The study included 230 adult patients undergoing elective general surgery at three public teaching hospitals in Khartoum State: Bahri Hospital (n=115, 50%), Omdurman Hospital (n=74, 32%), and Ibrahim Malik Hospital (n=41, 18%). Socio-demographic variables examined included gender, age, marital status, educational level, previous surgical history, and health insurance coverage.

The study population had a nearly equal gender distribution (49% males, 51% females). The majority were aged 18–29 years (39%), followed by 30–49 years (33%), and ≥50 years (28%). Most patients were married (48%), while 36% were single, and a small proportion were separated, widowed, or divorced. Educationally, nearly half had low education levels (illiterate or primary education, 47%). About 41% had previous surgical experience, and 55% were insured. Most patients (69%) had a hospital stay of less than one week, shown in table

Table 1: Socio-Demographic Characteristics of Study Participants

Item	Frequency	Percent
Gender		
Male	113	49%
Female	117	51%
Age		
18–29 years	89	39%
30–49 years	76	33%
≥50 years	65	28%
Marital Status		
Single	82	36%
Married	110	48%
Separated	16	7%
Widowed	17	7%
Divorced	5	2%
Educational Level		
Illiterate	44	19%
Primary school	65	28%
Secondary school	52	23%
Undergraduate	55	24%
Postgraduate	14	6%
Previous Surgery		
Yes	95	41%
No	135	59%
Health Insurance		
Yes	127	55%
No	103	45%

Table 2 presents the preoperative and postoperative anxiety levels among adult elective surgery patients, assessed using the Hamilton Anxiety Rating Scale (HAM-A). Overall, anxiety decreased postoperatively across most domains, including anxious mood, tension, fears, insomnia, depressed mood, somatic (muscular and sensory), respiratory, and gastrointestinal symptoms.

Table 2: Comparison Between Preoperative and Postoperative Anxiety Levels

N			NP		Mi		M		S		VS	
			Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	Anxious mood	F	41	170	36	54	66	4	50	1	37	1
		%	17.8%	73.9%	15.7%	23.5%	28.7%	1.7%	21.7%	0.4%	16.1%	0.4%
2	Tension	F	19	153	49	71	55	4	53	2	54	0
		%	8.3%	66.5%	21.3%	30.9%	23.9%	1.7%	23.0%	0.9%	23.5%	0.0%
3	Fears	F	65	158	56	69	39	3	29	0	41	0
		%	28.3%	68.7%	24.3%	30.0%	17.0%	1.3%	12.6%	0.0%	17.8%	0.0%
4	Insomnia	F	24	143	50	77	56	8	45	2	55	0
		%	10.4%	62.2%	21.7%	33.5%	24.3%	3.5%	19.6%	0.9%	23.9%	0.0%
5	Intellectual	F	86	181	65	46	41	3	21	0	17	0
		%	37.4%	78.7%	28.3%	20.0%	17.8%	1.3%	9.1%	0.0%	7.4%	0.0%
6	Depressed mood	F	49	184	64	40	64	4	27	1	26	1
		%	21.3%	80.0%	27.8%	17.4%	27.8%	1.7%	11.7%	0.4%	11.3%	0.4%
7	Somatic (muscular)	F	40	173	63	50	56	7	29	0	42	0
		%	17.4%	75.2%	27.4%	21.7%	24.3%	3.0%	12.6%	0.0%	18.3%	0.0%
8	Somatic (sensory)	F	51	185	72	40	62	5	19	0	26	0
		%	22.2%	80.4%	31.3%	17.4%	27.0%	2.2%	8.3%	0.0%	11.3%	0.0%
9	Respiratory symptoms	F	67	173	37	55	35	2	32	0	59	0
		%	29.1%	75.2%	16.1%	23.9%	15.2%	0.9%	13.9%	0.0%	25.7%	0.0%
10	Gastrointestinal	F	37	167	42	56	46	5	47	2	58	0
		%	16.1%	72.6%	18.3%	24.3%	20%	2.2%	20.4%	0.9%	25.2%	0.0%

NP – Not Present, **Mi** – Mild, **M** – Moderate, **S** – Severe, **VS** – Very Severe

Table 3 presents the mean anxiety scores for each HAM-A subscale before and after elective surgery. Overall, there was a marked decrease in anxiety levels postoperatively across all subscales. The largest reductions were observed in Intellectual disturbances (↓ 2.5), Fears (↓ 2.2), and Anxious mood (↓ 2.1). These findings indicate that elective surgery was associated with substantial improvement in patient-reported anxiety, emphasizing the need for perioperative psychological support to optimize patient outcomes.

Table 3: Mean Anxiety Scores Pre- and Postoperatively

Subscale	Preoperative Mean ± SD	Postoperative Mean ± SD	Change (Pre – Post)
Anxious mood	3.2 ± 1.1	1.1 ± 0.8	↓ 2.1
Tension	2.8 ± 1.0	1.0 ± 0.7	↓ 1.8
Fears	3.5 ± 1.2	1.3 ± 0.9	↓ 2.2
Insomnia	2.1 ± 0.9	0.8 ± 0.6	↓ 1.3
Intellectual	3.7 ± 1.3	1.2 ± 0.8	↓ 2.5
Depressed mood	3.0 ± 1.1	1.1 ± 0.7	↓ 1.9
Somatic (muscular)	2.9 ± 1.0	1.0 ± 0.7	↓ 1.9
Somatic (sensory)	3.2 ± 1.1	1.2 ± 0.8	↓ 2.0
Respiratory	2.5 ± 0.9	1.0 ± 0.7	↓ 1.5
Gastrointestinal	2.7 ± 1.0	1.1 ± 0.7	↓ 1.6

Legend: ↓ indicates a decrease in mean anxiety scores postoperatively.

Family concerns, fear of complications, and postoperative pain were the primary sources of anxiety (>70%). Less common sources included nil per mouth, body image concerns, and negative prior hospital experiences. Anxiety is multifactorial, involving psychological, physical, and social aspects, shown in table 4.

Table 4: Associated Factors with Preoperative Anxiety

Factor	Frequency	Percent
Concern about family	185	80.4%
Fear of complications	182	79.1%
Postoperative pain	165	71.7%
Fear of physical disability	148	64.3%
Waiting for operation	156	67.8%
Not awakening from anesthesia	145	63.0%
Financial loss	132	57.4%
Familiarity with facilities	131	57.0%
Harm from medical error	122	53.0%
Postoperative nausea and vomiting	127	55.2%
Alteration in body image	113	49.1%
Absence from work	114	49.6%
Negative prior hospital experiences	108	47.0%
Nil per mouth	103	44.8%

Significant associations were found between preoperative anxiety and both gender ($p < 0.01$) and educational level ($p < 0.001$), indicating that females and patients with lower education levels were more likely to experience elevated preoperative anxiety. No significant associations were found for age, marital status, previous surgery, or health insurance shown in table 5.

Data were analyzed using Chi-Square tests to explore associations between preoperative anxiety and socio-demographic variables.

Table 5: Association Between Preoperative Anxiety and Socio-Demographic Characteristics of Participants (n = 230)

Variable	χ^2	df	p-value	Significance
Gender	10.89	2	0.001	Significant
Educational level	14.76	3	0.000	Significant
Age	2.45	2	0.294	Not significant
Marital status	1.73	3	0.421	Not significant
Previous surgery	0.87	1	0.352	Not significant
Health insurance	0.61	1	0.436	Not significant

A regression analysis identified female gender and lower educational level as significant predictors of higher preoperative anxiety ($p < 0.05$). Other variables, including age, marital status, previous surgery, and health insurance, were not significant predictors.

5. Discussion

The findings of this study regarding preoperative anxiety are consistent with research worldwide, highlighting the common psychological challenges patients face when undergoing surgery. Key factors contributing to preoperative anxiety include concern for family, fear of complications, and worry about postoperative pain. In this study, the most frequently reported concerns were worry about family (80%), fear of complications (79.1%), and worry about pain after surgery (71.7%), consistent with findings from previous studies (Grocott et al., 2023; Kefelegn et al., 2023).These studies similarly reported that uncertainty about surgical outcomes, family well-being, and fear of discomfort were major sources of anxiety.

Studies from India, Turkey, and Nigeria similarly identified fear of complications, family-related concerns, and uncertainty regarding surgical outcomes as significant predictors of preoperative anxiety (Lami et al., 2025). Additionally, in this study, patients reported anxiety related to potential physical disability and financial loss, which aligns with prior research indicating these as notable stressors for surgical patients (Van Beek et al., 2021).These cross-cultural similarities suggest that the emotional experiences of surgical patients are influenced by universal psychological and social factors, irrespective of geographic or cultural context (Sikakulya et al., 2024).

A notable finding of this study is the substantial reduction in anxiety following surgery. Before surgery, 30.4% of patients reported very severe anxiety, whereas after surgery, 97% reported only mild anxiety, with no patients experiencing severe or very severe anxiety. This pattern aligns with previous studies showing that successful surgery alleviates the fear of uncertainty and provides psychological relief (Jenkins et al., 2024; Lanini et al., 2022; Obuchowska & Konopinska, 2021). Postoperative reduction in anxiety is supported by effective postoperative care, including pain management, complication monitoring, and psychological support (Niyonkuru et al., 2025).Nonetheless, not all patients experience the same degree of relief, and some may continue to worry about recovery or complications, highlighting the need for ongoing postoperative support and education (Newman, 2022; Saludes & Sardan, 2025).

Regarding demographic factors, this study found that preoperative anxiety was significantly associated with gender and educational level. Female patients reported higher anxiety, which aligns with prior research suggesting that women are generally more prone to anxiety due to psychological, biological, and social factors (Yang et al., 2024). Patients with lower educational levels also experienced greater preoperative anxiety, likely due to less understanding of surgical procedures and associated risks. Higher educational attainment may provide patients with better health literacy and the ability to seek information, which can reduce uncertainty and anxiety. These findings emphasize the importance of tailoring preoperative education and interventions to patients' educational backgrounds to effectively reduce anxiety.

No significant associations were observed between anxiety and age, marital status, or previous surgical experience. Although some literature suggests younger patients may experience higher anxiety, this study indicates that factors such as gender and educational level may have a stronger influence (Civilotti et al., 2021).

Overall, the findings highlight the importance of comprehensive preoperative assessment, individualized patient education, and supportive interventions to address anxiety, considering both psychological and socio-demographic factors.

6. Conclusion

The current study demonstrates that preoperative anxiety is a significant issue among patients undergoing elective general surgery in public teaching hospitals in Khartoum State. Anxiety levels were substantially higher before surgery compared to after surgery, with a marked reduction following the procedure. Female patients and those with lower educational levels were more likely to experience higher preoperative anxiety. The most common sources of anxiety included concern for family, fear of complications, and worry about postoperative pain.

These findings underscore the importance of implementing preoperative interventions to reduce anxiety. Addressing patients' psychological concerns before surgery can not only improve mental well-being but also enhance surgical outcomes, such as faster recovery and reduced postoperative discomfort. Targeted strategies, including patient education, psychological support, and clear communication about surgical procedures, are essential, particularly for vulnerable groups with lower education levels.

Overall, effective management of preoperative anxiety is crucial for improving patient care, optimizing surgical outcomes, and increasing overall patient satisfaction.

7. Limitations

This study has several limitations that should be considered when interpreting the findings. First, the sample was selected using convenience sampling, which may introduce selection bias, as it does not represent the entire population of patients undergoing elective surgery. The study was limited to three public teaching hospitals in Khartoum State, so the findings may not be generalizable to other regions or private hospitals. Additionally, although the sample included 230 patients, a larger sample size in future studies could provide more statistical power and a more representative understanding of preoperative anxiety across diverse patient populations.

Second, data were collected through self-reported measures using a structured questionnaire and the Hamilton Anxiety Rating Scale (HAM-A). Self-reported data may be subject to response bias, such as underreporting or overreporting of anxiety, which could affect the accuracy of the findings.

Third, certain patient categories were not included, such as individuals with severe cognitive impairments or psychiatric conditions, who might experience anxiety differently. Inclusion of these groups in future studies

could provide a more comprehensive understanding of preoperative anxiety.

Overall, these limitations suggest that future research should include a larger and more diverse sample and consider objective or complementary measures of anxiety to improve the validity and generalizability of findings.

8. Future Recommendations

The most effective way to reduce preoperative anxiety is to evaluate the effectiveness of interventions (preoperative education, relaxation methods, psychological counselling) that should be implemented in future research. These interventions can be conducted in other hospitals to establish their effect on the level of patient anxiety and postoperative outcomes. The studies may be conducted to study the timing, format, and content of educational programs to determine what methods are the most effective in reducing anxiety. Also, longer follow-up measures after the surgery would be beneficial to understand the long-term outcomes of such interventions on anxiety measures and general healing.

Medical staff should be taught to identify the symptoms of preoperative anxiety early during the surgery. Specific interventions, including clear and detailed information on the surgery, clarifying key fears and anxieties, and psychological support, can go a long way in relieving anxiety. The collaboration between the nurses, surgeons, and anesthesiologists can be used to provide assurance and engage the patients in conversations that reduce uncertainty. Moreover, healthcare professionals need to think about incorporating some relaxation activities, including guided imagery or breathing exercises, into the preoperative process to help diminish anxiety. These methods can increase patient comfort, better surgical results and results in an overall more positive surgical experience.

9. References

1. *Abd Allah, A.-e. N., Ahmed, R., Mourad, G. M., & Abd El-Fatah, W. O. (2023). Effectiveness of Mindfulness-Based Interventions for Reducing Anxiety among Breast Cancer Women at Nasser Institute-Egypt. Egyptian Journal of Nursing and Health Sciences, 4(4), 274-297.*
2. *Adhikari, S. P., Pathak, B. D., Ghimire, B., Baniya, S., Joshi, P., Kafle, P., Adhikari, P., Rana, A., Regmi, L., & Dhakal, B. (2023). Prevalence of pre-operative anxiety and associated risk factors among patients awaiting elective surgery in a tertiary care hospital. F1000Research, 12, 1207. https://doi.org/10.12688/f1000research.136320.2*
3. *Ali, N. N. (2023). Assessment of preoperative anxiety, its contributing factors, and impact on immediate postoperative outcomes among cardiac surgery patients-A cross-sectional study. https://ecommons.aku.edu/theses_dissertations/2169/*
4. *Baagil, H., Baagil, H., & Gerbershagen, M. U. (2023). Preoperative anxiety impact on anesthetic and analgesic use. Medicina, 59(12), 2069. https://doi.org/10.3390/medicina59122069*
5. *Bedaso, A., Mekonnen, N., & Duko, B. (2022). Prevalence and factors associated with preoperative anxiety among patients undergoing surgery in low-income and middle-income countries: a systematic review and meta-analysis. BMJ open, 12(3), e058187. https://doi.org/10.1136/bmjopen-2021-058187*
6. *Bjurström, M. F., Bothelius, K., Maathz, P., Jernelöv, S., Kraepelien, M., Rosenström, A. H., Niklasson, A., Smith, M. T., Olmstead, R., & Irwin, M. R. (2025). Randomised, controlled clinical trial evaluating the effects of preoperative insomnia treatment on postoperative pain control and recovery: a protocol for the Promoting Sleep to Alleviate Pain-Arthroplasty (PROSAP-A) trial. BMJ open, 15(7), e099785. https://doi.org/10.1136/bmjopen-2025-099785*
7. *Civilotti, C., Botto, R., Maran, D. A., Leonardis, B. D., Bianciotto, B., & Stanizzo, M. R. (2021). Anxiety and depression in women newly diagnosed with breast cancer and waiting for surgery: prevalence and associations with socio-demographic variables. Medicina, 57(5), 454. https://doi.org/10.3390/medicina57050454*
8. *Farhane-Medina, N. Z., Luque, B., Tabernero, C., & Castillo-Mayén, R. (2022). Factors associated with gender and sex differences in anxiety prevalence and comorbidity: A systematic review. Science Progress, 105(4), 00368504221135469.*
9. *Ferede, Y. A., Bizuneh, Y. B., Workie, M. M., & Admass, B. A. (2022). "Prevalence and associated factors of preoperative anxiety among obstetric patients who underwent cesarean section": A cross-sectional study. Annals of Medicine and Surgery, 74, 103272. https://doi.org/10.1016/j.amsu.2022.103272*
10. *Geoffrion, R., Koenig, N. A., Zheng, M., Sinclair, N., Brotto, L. A., Lee, T., & Larouche, M. (2021). Preoperative depression and anxiety impact on inpatient surgery outcomes: a prospective cohort study. Annals of Surgery Open, 2(1), e049. https://doi.org/ 10.1097/AS9.0000000000000049*

11. *Grocott, B., Reynolds, K., Logan, G., Hebbard, P., & El-Gabalawy, R. (2023). Breast cancer patient experiences of perioperative distress and anxiety: A qualitative study. European Journal of Oncology Nursing, 63, 102299. https://doi.org/10.1016/j.ejon.2023.102299*
12. *Gümüs, K. (2021). The effects of preoperative and postoperative anxiety on the quality of recovery in patients undergoing abdominal surgery. Journal of PeriAnesthesia Nursing, 36(2), 174-178. https://doi.org/10.1016/j.jopan.2020.08.016*
13. *Hamilton, M. (1959). The assessment of anxiety states by rating. British journal of medical psychology.*
14. *Ho, C.-J., Chen, Y.-T., Wu, H.-L., Huang, H.-T., & Lin, S.-Y. (2022). The effects of a patient-specific integrated education program on pain, perioperative anxiety, and functional recovery following total knee replacement. Journal of personalized medicine, 12(5), 719. https://doi.org/10.3390/jpm12050719*
15. *Jenkins, E. S., Crooks, R., Sauro, K., & Nelson, G. (2024). Enhanced recovery after surgery (ERAS) guided gynecologic/oncology surgery–The patient's perspective. Gynecologic Oncology Reports, 55, 101510. https://doi.org/10.1016/j.gore.2024.101510*
16. *Kassahun, W. T., Mehdorn, M., Wagner, T. C., Babel, J., Danker, H., & Gockel, I. (2022). The effect of preoperative patient-reported anxiety on morbidity and mortality outcomes in patients undergoing major general surgery. Scientific Reports, 12(1), 6312. https://www.nature.com/articles/s41598-022-10302-z*
17. *Kefelegn, R., Tolera, A., Ali, T., & Assebe, T. (2023). Preoperative anxiety and associated factors among adult surgical patients in public hospitals, eastern Ethiopia. SAGE Open Medicine, 11, 20503121231211648. https://doi.org/10.1177/20503121231211648*
18. *Lami, M., Negash, A., Dereje, J., Hiko, A., Mesfin, S., Gebreyesus, A., Belama, N., Ahmed Omer, N., Balis, B., & Jibro, U. (2025). Prevalence of Preoperative Anxiety and Associated Factors Among Surgical Patients: Systematic Review and Meta-Analysis in Ethiopia. Health Services Insights, 18, 11786329251316748. https://doi.org/10.1177/11786329251316748*
19. *Lanini, I., Amass, T., Calabrisotto, C. S., Fabbri, S., Falsini, S., Adembri, C., Di Filippo, A., Romagnoli, S., & Villa, G. (2022). The influence of psychological interventions on surgical outcomes: a systematic review. Journal of anesthesia, analgesia and critical care, 2(1), 31. https://link.springer.com/article/10.1186/s44158-022-00057-4*
20. *Newman, S. (2022). Anxiety, hospitalization, and surgery. In The experience of illness (pp. 132-153). Routledge. https://www.taylorfrancis.com/chapters/edit/10.4324/9781003283966-7/anxiety-hospitalization-surgery-stanton-newman*
21. *Nicolini, P., Abbate, C., Inglese, S., Rossi, P. D., Mari, D., & Cesari, M. (2021). Different dimensions of social support differentially predict psychological well-being in late life: Opposite effects of perceived emotional support and marital status on symptoms of anxiety and of depression in older outpatients in Italy. Psychogeriatrics, 21(1), 42-53. https://doi.org/10.1111/psyg.12633*
22. *Niyonkuru, E., Iqbal, M. A., Zhang, X., & Ma, P. (2025). Complementary approaches to postoperative pain management: a review of non-pharmacological interventions. Pain and therapy, 14(1), 121-144. https://link.springer.com/article/10.1007/s40122-024-00688-1*
23. *Obuchowska, I., & Konopinska, J. (2021). Fear and anxiety associated with cataract surgery under local anesthesia in adults: a systematic review. Psychology Research and Behavior Management, 781-793. https://doi.org/10.2147/PRBM.S314214*
24. *Pal, J., Taywade, M., Pal, R., & Sethi, D. (2022). Noise pollution in intensive care unit: a hidden enemy affecting the physical and mental health of patients and caregivers. Noise and Health, 24(114), 130-136. https://doi.org/10.4103/nah.nah_79_21*
25. *Patil, J. D., Sefen, J. A. N., & Fredericks, S. (2022). Exploring non-pharmacological methods for pre-operative Pain Management. Frontiers in Surgery, 9, 801742. https://doi.org/10.3389/fsurg.2022.801742*
26. *Saeed, H., Eslami, A., Nassif, N. T., Simpson, A. M., & Lal, S. (2022). Anxiety linked to COVID-19: a systematic review comparing anxiety rates in different populations. International journal of environmental research and public health, 19(4), 2189. https://doi.org/10.3390/ijerph19042189*

27. *Saludes, P. R., & Sardan, E. (2025). Perioperative Anxiety in Adult Surgical Patients: Identifying the Common Causes and Nursing Interventions for Anxiety Reduction.*
28. *Sikakulya, F. K., Muhumuza, J., Vivalya, B. M. N., Mambo, S. B., Kamabu, L. K., Muteke, J. K., Lussy, J. P., Ilumbulumbu, M. K., Emmanuel, T., & Kiyaka, S. M. (2024). Psychosocial impact of surgical complications and the coping mechanisms among surgeons in Uganda and Eastern Democratic Republic of the Congo. PLOS Global Public Health, 4(4), e0003180. https://doi.org/10.1371/journal.pgph.0003180*
29. *Spagnolello, O., Fabris, S., Portella, G., Raafat Shafig Saber, D., Giovanella, E., Badr Saad, M., Langer, M., Ciccozzi, M., d'Ettorre, G., & Ceccarelli, G. (2022). Rates and determinants of hospital-Acquired infection among ICU patients undergoing cardiac surgery in developing countries: results from emergency'ngo's hospital in Sudan. Antibiotics, 11(9), 1227. https://doi.org/10.3390/antibiotics11091227*
30. *Tadesse, M., Ahmed, S., Regassa, T., Girma, T., Hailu, S., Mohammed, A., & Mohammed, S. (2022). Effect of preoperative anxiety on postoperative pain on patients undergoing elective surgery: Prospective cohort study. Annals of Medicine and Surgery, 73, 103190. https://doi.org/10.1016/j.amsu.2021.103190*
31. *Van Beek, F. E., Wijnhoven, L. M., Holtmaat, K., Custers, J. A., Prins, J. B., Verdonck-de Leeuw, I. M., & Jansen, F. (2021). Psychological problems among cancer patients in relation to healthcare and societal costs: a systematic review. Psycho-Oncology, 30(11), 1801-1835. https://doi.org/0.1002/pon.5753*
32. *Varma, P., Junge, M., Meaklim, H., & Jackson, M. L. (2021). Younger people are more vulnerable to stress, anxiety and depression during COVID-19 pandemic: A global cross-sectional survey. Progress in Neuro-Psychopharmacology and Biological Psychiatry, 109, 110236. https://doi.org/10.1016/j.pnpbp.2020.110236*
33. *Wang, R., Huang, X., Wang, Y., & Akbari, M. (2022). Non-pharmacologic approaches in preoperative anxiety, a comprehensive review. Frontiers in Public health, 10, 854673. https://doi.org/10.3389/fpubh.2022.854673*
34. *Yang, Y., Qian, X., Tang, X., Shen, C., Zhou, Y., Pan, X., & Li, Y. (2024). The links between symptom burden, illness perception, psychological resilience, social support, coping modes, and cancer-related worry in Chinese early-stage lung cancer patients after surgery: a cross-sectional study. BMC psychology, 12(1), 463. https://link.springer.com/article/10.1186/s40359-024-01946-9*

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تطوير نموذج تقييمي لقياس تأثير النظم الإنشائية على الأداء الوظيفي والجمالي للفراغات المعمارية الداخلية – دراسة تطبيقية

Developing an Evaluation Model to Measure the Impact of Structural Systems on the Functional and Aesthetic Performance of Interior Architectural Spaces – An Applied Study

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ملخص البحث: يتناول هذا البحث تأثير النظم الإنشائية على الأداءين الوظيفي والجمالي للفراغات المعمارية الداخلية، من خلال تطوير نموذج تقييمي يتكوّن من 288 نقطة قياس موزعة على عناصر وظيفية وجمالية. تم تطبيق النموذج على ثلاث مبانٍ مختلفة من حيث نوع النظام الإنشائي والاستخدام والموقع الجغرافي داخل المملكة العربية السعودية، وهي: مركز الملك عبد الله للدراسات والبحوث البترولية، مسجد جامعة تبوك، ومبنى كلية الهندسة وعلوم الحاسب بجامعة جازان. أظهرت النتائج تفاوتًا ملحوظًا في درجات التفاعل بين النظام الإنشائي ومتطلبات الفراغات الداخلية، حيث حقق مركز الملك عبد الله للدراسات والبحوث البترولية أعلى تقييم (254 نقطة)، يليه مسجد جامعة تبوك (230 نقطة)، ثم مبنى كلية الهندسة (199 نقطة). يُعد النموذج أداة تحليلية يمكن استخدامها لتقييم المشروعات المعمارية أثناء التصميم أو بعد التنفيذ، كما يوفّر مدخلاً علميًا لدعم القرارات التصميمية وتوجيه اختيار الأنظمة الإنشائية بما يحقق التوازن بين الوظيفة والجمال. يقدّم البحث مساهمة نوعية في مجال التصميم التكاملي، ويقترح إطارًا قابلاً للتطوير والتطبيق في سياقات معمارية متنوعة

الكلمات المفتاحية: (المنظومة الانشائية، الجوانب الوظيفية، الجوانب الجماليه، الفراغات الداخلية الرئيسية، الفراغ المعماري)

Abstract: This study examines the impact of structural systems on the functional and aesthetic performance of interior architectural spaces by developing an evaluation model comprising 288 measurement points distributed across functional and aesthetic elements. The model was applied to three buildings in Saudi Arabia, differing in structural system type, function, and geographic location: The King Abdullah Petroleum Studies and Research Center, the University of Tabuk Mosque, and the College of Engineering and Computer Science building at Jazan University. The results revealed significant variations in the interaction scores between structural systems and interior spatial requirements. The King Abdullah Petroleum Studies and Research Center achieved the highest evaluation score (254 points), followed by the University of Tabuk Mosque (230 points), and the College of Engineering building (199 points). The model serves as an analytical tool for assessing architectural projects during the design phase or post-implementation. It provides a scientific foundation to support design decisions and guide the selection of structural systems to achieve a balance between functionality and aesthetics. The research contributes qualitatively to the field of integrative design and proposes a scalable framework applicable to diverse architectural contexts.

Keywords: (Structural systems, Functional aspects, Aesthetic aspects, Main internal spaces, Architectural space)

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1. المقدمة

يلعب النظام الإنشائي دورًا جوهريًا في تشكيل الفراغات المعمارية الداخلية، ليس فقط من ناحية تحقيق الاستقرار البنيوي، بل ومن حيث التأثير المباشر على أداء الفراغ ووظيفته وجمالياته، فالعناصر الإنشائية لم تعد تُعامل كخلفية صامتة للتصميم الداخلي، بل أصبحت أدوات تصميمية تُسهم في خلق هوية المكان وتعزيز تجربة المستخدم، وتزداد الحاجة اليوم إلى أدوات تقييم موضوعية تساعد المعماريين على فهم العلاقة المعقدة بين النظام الإنشائي ومتطلبات التصميم الداخلي، خاصة في ظل تعاظم التحديات البيئية والتقنية التي تواجه المباني الحديثة، في هذا السياق، يأتي هذا البحث ليقترح نموذجًا تقييميًا مكونًا من 288 نقطة، يهدف إلى قياس تفاعل النظم الإنشائية مع الأبعاد الوظيفية والجمالية للفراغ الداخلي بشكل دقيق وقابل للتطبيق

تتمثل أهمية البحث في قدرته على دعم اتخاذ القرار التصميمي في مراحل التخطيط الأولي أو عند تقييم المباني القائمة بغرض تطويرها. وقد تم اختبار النموذج على ثلاث حالات دراسية متنوعة ضمن بيئات مناخية ووظيفية مختلفة داخل المملكة العربية السعودية، بما يعزز من موثوقية النتائج وإمكانية تعميمها

1-1 اشكالية البحث:

على امتداد تاريخ العمارة، ظل تأثير النظام الإنشائي على الفراغ المعماري محل جدل بين من يراه محددًا مباشرًا للوظيفة والجمال، ومن يسعى إلى إخفاء حضوره خلف عناصر التصميم الأخرى. تبرز الإشكالية في مدى قدرة النظام الإنشائي على دعم كفاءة استخدام الفراغ الداخلي دون أن يطغى على هويته الجمالية أو يُقيد مرونته الوظيفية. وتتمثل مشكلة البحث في غياب أداة منهجية دقيقة ترصد هذا التأثير وتقدّره بشكل موضوعي في السياقات التصميمية المعاصرة

2-1 الدراسات السابقة والفجوة البحثية:

أشارت الدراسات السابقة إلى غياب أداة منهجية شاملة وقابلة للتطبيق الكمي لقياس التفاعل بين الأنظمة الإنشائية ومتطلبات الفراغات المعمارية الداخلية من الناحيتين الوظيفية (كالكفاءة، المرونة، الراحة البيئية) والجمالية (كالاتزان البصري، التفاعل مع التراث، التعبير الرمزي). ركزت الأبحاث السابقة على جوانب محددة مثل المتانة أو الكفاءة الاقتصادية، لكنها لم تقدم نموذجًا تكامليًا يُقيِّم العلاقة التبادلية بين النظام الإنشائي والفراغ الداخلي بشكل دقيق وقابل للتعميم (1)

ويقدم البحث دراسة لهذه الفجوة البحثية من خلال تطوير نموذج تقييمي، يربط بين تأثير الأنظمة الإنشائية والأداء الوظيفي والجمالي للفراغات الداخلية بشكل منهجي. اعتمد النموذج على نقط قياس موزعة على معايير محددة (كالكفاءة الوظيفية، الاتزان البصري، التفاعل مع الإضاءة)، مما وفَّر أداة موضوعية قابلة للتطبيق على مختلف المشاريع

3-1 فرضية البحث :

يفترض البحث إمكانية تطوير نموذج تقييمي فعّال لقياس أثر النظام الإنشائي وعناصره على جودة وكفاءة الفراغات المعمارية الداخلية من النواحي الوظيفية والجمالية. ويُتوقع أن يُستخدم هذا النموذج كأداة دعم تصميمي في اختيار النظم الإنشائية الملائمة للمشاريع الجديدة، أو لتقييم وتحديث المباني القائمة بما يواكب المتغيرات الوظيفية والتقنية والبيئية. كما تُفترض مرونة النموذج في التكيف مع تنوع أنماط المباني والسياقات

4-1 اهداف البحث :

الهدف الرئيس للبحث هو تصميم وتطبيق نموذج تقييمي يُحدّد العلاقة التبادلية بين العناصر الإنشائية والفراغ الداخلي على المستويين الوظيفي والجمالي. وتندرج تحته الأهداف الفرعية التالية:

- فهم مكونات المنظومة الفراغية وعلاقتها بالمنظومة الإنشائية.
- تحليل تأثير العناصر الإنشائية على تشكيل واستخدام الفراغ الداخلي.
- توثيق العلاقة بين خصائص النظام الإنشائي ومتطلبات الراحة والأداء البصري والنفسي للمستخدم.

5-1 منهجية البحث:

هو نفس المنهج العلمي المستخدم في الدراسة التحليلية وهو المنهج الوصفي التحليلي.

حيث سيتم رصد وتوثيق عينات الدراسة من الطبيعة باستخدام التصوير الفوتوغرافي وبواسطة الرسومات المعمارية لكل مشروع، وباستخدام التحليل الاحصائي سيتم استخراج النتائج المطلوبة

تم استخدام المنهج الوصفي التحليلي الذي يهتم بدراسة ووصف خصائص وأبعاد تأثير النظام الانشائي على الاداء الوظيفي وجماليات الفراغ من خلال نموذج تقييمي يرصد هذه العلاقة مع المكونات الوظيفية والجماليه كل على حده لعدة مباني تختلف في طبيعة انشائها ووظائفها، مثل مبني كلية الهندسة وعلوم الحاسب بجامعة جازان ومبني مسجد جامعة تبوك ومركز الملك عبد الله للدراسات والبحوث البترولية، وبالتالي استخلاص نتائج قيميه ترصد قيمه تفصيليه وقيمه نهائيه واضحه ومحددة، ويمكن تطبيق هذا النموزج لرصد هذه العلاقة في مباني مختلفة في مرحلة التصميم أو حتي مباني قائمه، مما يفيد المصمم في اتخاذ القرارات التصميمية في الحاله الاولي أو في تطوير الاداء الجمالي والوظيفي في الحاله الثانيه

2. الفراغ المعماري الداخلي

هو ذاك الوعاء الذي يحوي الانشطة الإنسانية المختلفة وشكل المبني الخارجي ما هو إلا غلاف للانشطة المتنوعة بداخله، (2) وكل نشاط يحتاج إلي متطلبات فراغية وبيئية خاصة بالاضافة الي الابعاد الجمالية التي تميز الفراغ وتحفز علي أداء الانشطه، لذا يجب علي المعماري قبل أن يبدأ في العملية التصميمية أن يكون ملما بمتطلبات الراحة الفسيولوجية والنفسية والاحتياجات الوظيفية داخل الفراغ أو بين الفراغات وبعضها (3)، والهدف هنا دراسة منظومة العلاقات الفراغية الداخلية والتأثير المتبادل بين العناصر الانشائية وهذه المنظومة

2-1 العناصر المادية للفراغ الداخلي

تعتبر هذه العناصر أدوات المصمم للوصول بأي فراغ إلي شخصية مستقلة بذاتها، وهذه العناصر هي (4) :

1-1-2 العناصر المعمارية

وهي عناصر الفراغ المسؤلة عن تشكيله النهائي وهي عبارة عن (الأرضيات – الحوائط - الأسقف) .

2-1-2 العناصر الإنشائية

وهي عناصر النظام الانشائي والتي تؤثر بشكل كبير علي تشكيل الفراغ، حيث يلعب الإنشاء دورا أساسيا في تحقيق المتطلبات الفراغية المعمارية بكفاءة، وتتمثل هذه العناصر في العناصر الرأسية كالاعمدة والافقية كالكمرات والاسطح كبلاطات الاسقف بالاضافة الي العناصر المائلة والتي قد تكون أعمدة أو كمرات أو أسقف بالاضافة الي الشدادات الفولاذية وغيرها

3-1-2 عناصر الانتقال الفراغي

هي العناصر الناقلة في التصميم الداخلي (ممرات – سلالم – شبابيك - ابواب) حيث تنقل بصريا وماديا العلاقة بين فراغ وآخر وبين الفراغ الداخلي والخارج، ويؤثر حجم الفتحات وشكلها علي التكامل البصري لسطح الحائط والإحساس بالمحتوي الذي يغطيه.

4-1-2 عناصر التأثيث

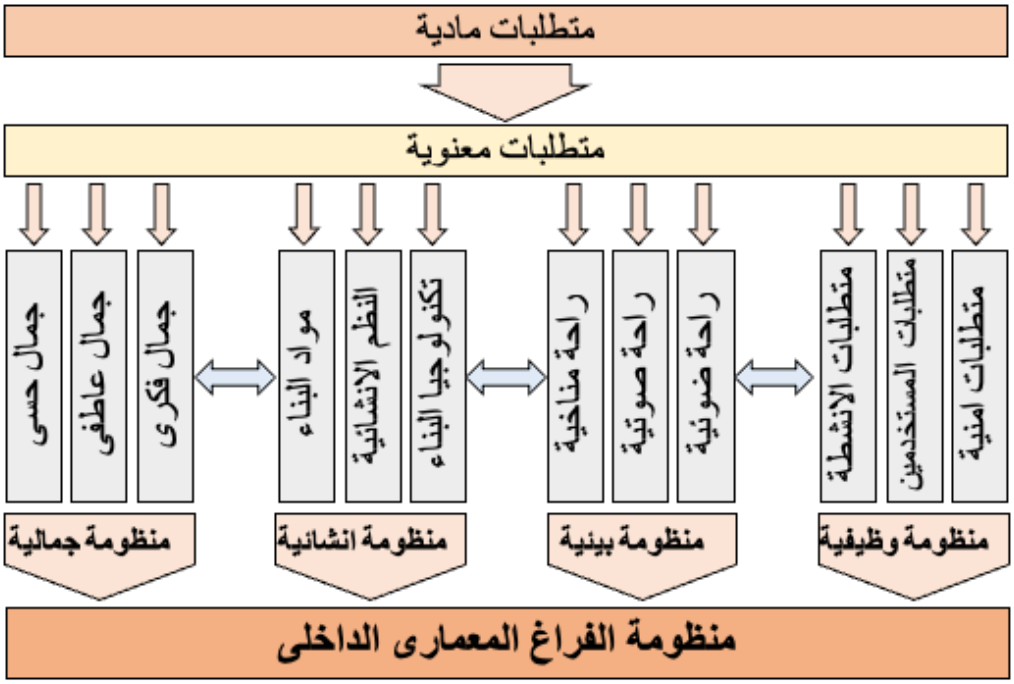
ويعتبر اختيار وترتيب عناصر الفرش في كل فراغ من فراغات المبني هو من أهم عناصر التصميم الداخلي، والطريقة التي يوضع بها الفرش تؤثر علي كيفية إدراك واستخدام الفراغ

5-1-2 الأنظمة الفنية

هي عناصر الانظمة الميكانيكية والكهربية بالمبني كالمصاعد والسلالم المتحركة وأنظمة التكييف والحريق وغرف التحكم وهي من عناصر الفراغات الداخلية والتي تأثر بشكل كبير على شكل الفراغات ووظيفتها.

3. منظومة الفراغ المعماري الداخلي

تعرف المنظومة بأنها تفاعل أجزاء مرتبطة ببعضها البعض لتحقيق أهداف معينة، والمنظومة الفراغية هي مجموعة المتطلبات المطلوبة لتكوين الفراغ الداخلي من اجل راحة الإنسان المادية والمعنوية،(5) وهذه المنظومة تتكون في حد ذاتها من عدد من المنظومات كما يعبر عنها شكل (1) وهي:



شكل (1) منظومة الفراغ المعمارى الداخلى

1-3 المنظومة الإنسانية Human System :

المقصود بالمنظومة الإنسانية هي تلك المنظومة التي تشكل الفكر العام للإنسان في المجتمع، وتتشكل تلك المنظومة من الاتي :

1-1-3 البيئة الإنسانية Human Environment:

وهي البيئة التي تشكل فكر وشخصية الفرد حتي تكوينه الفسيولوجي والعقلي والاجتماعي، وهي بدورها تنقسم إلي بيئتين الايكولوجية والحضارية

2-1-3 البنية الإنسانية Human Anatomy:

وهي تنقسم إلي البنية المادية (الأنظمة والأجهزة الداخلية للجسم التي تتكامل مع بعضها في اتزان وظيفي) والنفسية (الظواهر النفسية والغريزية في الإنسان) والعقلية (الفكر الذي يفرق الإنسان عن باقي المخلوقات) وكيفية تعاملها مع الظروف البيئية، وذلك لتحديد دور الغلاف والفراغ المعماري الداخلي والخارجي في تهيئة هذه الظروف بما يناسب الإنسان (6).

2-3 المنظومة الوظيفية Functional System :

المعيار الأول للحكم علي نجاح الفراغ الداخلي هو وظيفته، ولتحقيق الوظيفة المثلي داخل الفراغ يجب تحليل متطلبات المستخدمين والأنشطة التي ستمارس داخله وهي (7) :

أ- متطلبات المستعملين Users Requirement

ب- متطلبات الأنشطة Activity Requirements

ج- متطلبات الأبعاد Dimensions Requirement

د- متطلبات التأثيث furnishing requirement

هـ- متطلبات الأمن Safety Requirements

3-3 منظومة الراحة البيئية Environment Comfort System :

يحتاج الإنسان إلي التحكم في المحيط الداخلي للفراغ بوسائل طبيعية أو صناعية وذلك للوصول إلي راحته المادية من خلال:

أ- راحة مناخية Climatic Comfort

ب- راحة ضوئية Lighting Comfort

ج- راحة صوتية Acoustical Comfort

4-3 المنظومة الجمالية Aesthetic System:

بقدر ما كان الغرض من الفراغ المعماري الداخلي الحماية من الظروف الطبيعية وأداء وظيفة معينة فانه بنفس القدر في حاجة إلي تحقيق متعة بصرية ونفسية، وهذه المنظومة الجمالية هي التي ترقي بالعمل المعماري من مجرد بناء الي عمل متكامل متوازن يحقق الاحتياجات الوظيفية والجماليه وتنقسم منظومة الجمال إلي ثلاثة أنواع وهي (8) : (الجمال الحسي - الجمال العاطفي - الجمال الفكري).

ومن الأمثلة التي توضح أنواع الجمال الثلاثة تغطية صحن المسجد النبوي فيظهر الجمال الحسي في استخدام مواد معروفة لهذه البيئة مع استخدام لون محايد وهو الأبيض، ويظهر الجمال العاطفي التراثي في استخدام أسلوب انشائي وهو الخيام وما له من موروث ثقافي تاريخي بيئي،كما يظهر الجمال الفكري في تأديتها الناجحة لوظيفتها من عناصر إنشائية بسيطه وتكنولوجيا متطورة وتظهر في انطباق الغشاء وفتحه مع استخدام مفردات تشكيل نابعة من مفردات تشكيل المسجد كالتيجان ووحدات الاضاءة وقواعد الاعمدة كما في شكل (2).

شكل (2) تغطية صحن المسجد النبوى يؤكد التكامل بين الجمال الحسى والعاطفى والفكرى

5-3 المنظومة الإنشائية Structural System:

الإنشاء مكون أساسي من مكونات الفراغ المعماري، حيث انه المسؤول الأول عن حمل المحتوي الفراغي لأداء الوظيفة المطلوبة بما يحقق المتانة والاقتصاد، وتتكون العناصر المادية للمنظومة الإنشائية من (9)

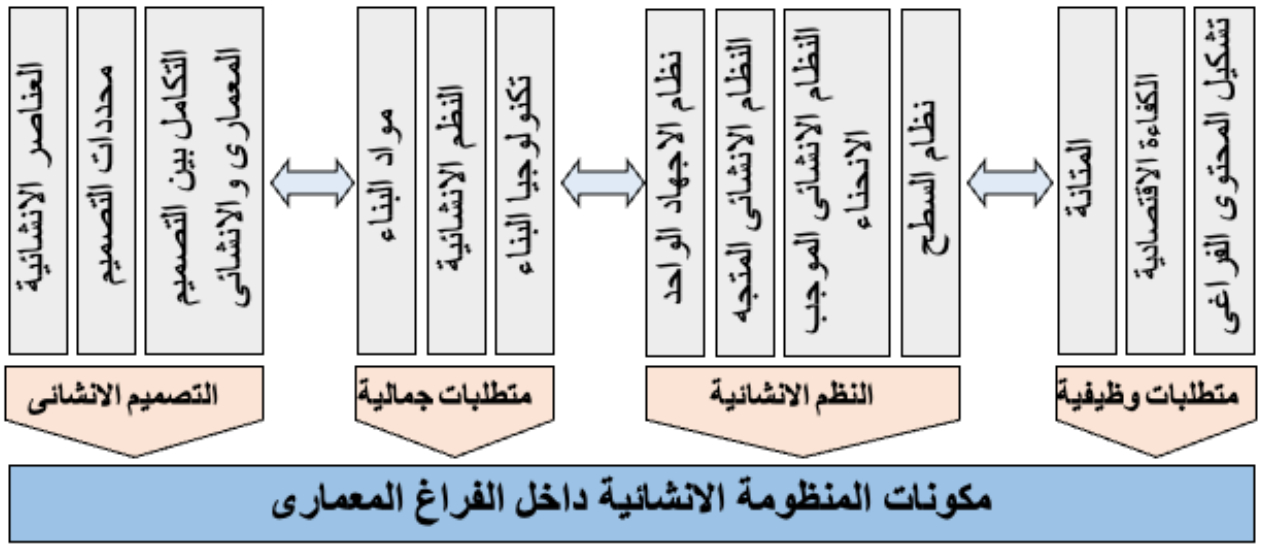
مواد البناء : تعتبر مواد البناء هي المكون المادي للإنشاء وخواصها هي المسؤولة عن التكوينات الإنشائية الناتجة، وكلما تطورت مواد البناء تحسنت خصائصها وتطورت الإمكانيات الإنشائية لها وبالتالي ظهور تشكيلات فراغية جديدة أكثر جمالاً وأفضل أداءاً

النظم الإنشائية: هي الأساليب الإنشائية المختلفة التي تم إبداعها حتي الآن كنظم لتغطية الفراغات المختلفة، ولكل نظام خصائصه التي تميزه عن الآخر، وتقسم هذه الأنظمة تبعا للاجهادات الناتجة منها

تكنولوجيا البناء: ترتبط تكنولوجيا البناء وطرق التنفيذ المستخدمة في انتاج المباني ارتباطا وثيقا بنظم الانشاء والمواد المستخدمة، فهي تعتبر الوسيلة التي يتم بها تشكيل الهيكل العام للمبني

4. مكونات المنظومة الإنشائية:

يمر التصميم الإنشائي بمرحلتان، مرحلة الكيف التي يتم فيها تحديد نوع الإنشاء المتوقع استخدامه ومادته وشكله، وهي مرحلة خاصة بالمعماري، (10) و مرحلة الكم التي يتم فيها عمل الحسابات اللازمة للنظام الإنشائي السابق اقتراحه، وهي مرحلة خاصة بالمصممالإنشائي، ولكي يستطيع المعماري القيام بدوره يجب ان يعرف علي متطلبات المنظومة الانشائية شكل(3) :



شكل (3) المنظومة الانشائية داخل الفراغ المعمارى

4-1 المتطلبات الوظيفية والجمالية:

علي كل نظام إنشائي تحقيق نقطتان اساسيتان وهما الجمال "متطلبات معنوية" مع تحقيق التكنولوجيا والوظيفة "متطلبات مادية "

4-1-1 المتطلبات المادية :

المقصود بالمتطلبات المادية هو توافق الإنشاء مع وظائف المبني أو مواصفات الفراغات كما وكيفا من خلال تحقيق الاتي:

أ- المتانة: وهي تعبر عن قدرة المبني علي تحمل متطلبات وظيفته وعدم تعرض أي جذء منه للانهيار سواءا في الحالات العادية أو حالات الطوارئ، ومتانة المبني قد تكون في مرونته أو صلابته، ولا يوجد تعارض بين الصلابة والمرونة، وذلك مثل القوس فهو قوي ومرن في نفس الوقت

ب- الوظيفة: الوظيفة هي العامل الأساسي الذي يحدد شكل المبني، ويلاحظ أن هناك نوعية من المباني الوظيفية البحتة مثل مباني الجراجات وأخري ليس للوظيفة مكان يذكر مثل النصب التذكاري، ومثال لذلك القطاعات في ساق الأشجار يقل سمكها كلما اتجهنا لأعلي لمقاومة الرياح، كما أن اغلب الأشجار تسقط أوراقها في الشتاء حتي تقلل المساحة المعرضة للرياح وتخفيف الحمل كما يسمح للشمس بالوصول إلي الشجرة نفسها لأداء وظيفتها (11)

ج- الكفاءة الاقتصادية: تعتبر الكفاءة الاقتصادية من أهم العوامل المؤثرة في تصميم المنشأ واختيار مادة البناء، والنظام الإنشائي المثالي اقتصاديا هو الذي يحقق الفراغ المطلوب مع مراعاة الاتي (12)

- الكفاءة في استعمال المادة
- توافق متطلبات التنفيذ مع العمالة والمواد والتكنولوجيا المتوفرة
- اختصار وقت تنفيذ المشروع
- عمر المنشأ
- الوزن الذاتي

4-1-2 المتطلبات الجمالية:

وهي المتطلبات التي تعمل علي تنمية المتعة البصرية والنفسية لدي المتلقي وهي كالأتي:(13).

4-1-3 الجماليات الحسية:

الاتزان الإستاتيكي والديناميكي: الإحساس بالاتزان هو إحساس فطري في الإنسان يشعر به في نفسه وفيما حوله، وخاصة اتزان المبني إنشائيا يجب أن يكون واضحا للعامة والخاصة لإعطاء الشعور بالأمان وله عدة صور:

الاتزان الاستاتيكي بالتراكم: وفيه ينتقل الوزن عن طريق التراكم المباشر بفعل الوزن الناتج من الجاذبية الأرضية

الاتزان بالجساءة: ويطلق عليها أيضا التماسك أو الاستمرارية المادية، بمعني أن المبني بمكوناته من كمرات وأعمدة متماسكة تقاوم الأحمال الواقعة علي إحداها وتنقلها إلي القواعد ثم إلي الأرض(مثل الإنشاء الهيكلي)

الاتزان من خلال الوحدة المستمرة هندسيا: حيث تتحول الأحمال إلي اجهادات محورية تنساب داخل قطاع المنشأ المتزن إلي الأرض مثل الإنشاء المعقود

الاتزان بالليونة وانعدام الجساءة: حيث تكون المادة المغلفة لينة بحيث تأخذ الوضع المناسب والملائم لها لنقل الاجهادات المحورية بالضغط أو بالشد إلي الأرض مثل الكابلات المشدودة أو الأغشية المشدودة

الاتزان التكنولوجي: مثل المصدات الميكانيكية أو الزنبركات المخروطية أو الاسطوانية التي تكتسب قوة رافعة أو ضاغطة نتيجة الشد أو الضغط السابق في اتجاه التحميل

الإحساس بالأمان : النظام الإنشائي للمنشأ المعماري هو المسؤول الأول في إعطاء الإحساس بالأمان للمتلقي عند رؤية أو استخدام المنشأ

المرونة : من أهم متطلبات الفراغات الحديثة هي المرونة في استعمالها كما وكيفا لذا يفضل في النظام الإنشائي أن يحقق إمكانية الفك والتركيب والنقل والحذف والإضافة .

الإضاءة والتهوية : استخدم المعماري الإنشاء الاساسي واحياناً إنشاء مساعد في تحقيق الاضاءة والتهوية من خلال وحدات الاضاءة العلوية والجانبية وفتحات التهوية سواء في جزء من المبني أو حتي لكامل المبني

4-1-4 الجماليات الفكرية:

وتتضح بصورة أكبرفي المباني ذات الرمزية والعلامات المميزة (Land Mark) مثل النصب التذكاري والأبراج، ويمكن تحقيق الجمال بعدة طرق مثل اندماج الوظيفة داخل الإنشاء او اندماج الإنشاء داخل الوظيفة

5-1-4 الجماليات العاطفية:

ليس كل ما ينتجه الإنشاء مقبول جماليا إلا بإضافة الحس الفني المعماري إليه، كما انه ليس كل ما هو غير مناسب إنشائيا يكون غير مقبول جماليا مثل العمارة الفرعونية فهي ذات قيمة فنية عالية لكنها غير مناسبة إنشائيا، والعلاقة التعبيرية بين الهيكل الإنشائي والمنشأ متأرجحة علي مر العصور

6-1-4 النظم الإنشائية Structural Systems: (14)

تصنف النظم الانشائية تبعا لنوع الإجهاد المتولد في النظام: عند تعرض اي هيكل إنشائي إلي أحمال معينة فأنه يقوم بتحويلها الي اجهادات معينة (شد - ضغط – انحناء) ويتم تصنيف النظم الإنشائية تبعا لنوع الاجهادات التي تنتجها ويعتبر هذا الأسلوب هو أدق التصنيفات والتي ستتناولها الدراسة، وبالتالي فأن أنواع النظم الإنشائية هي (15):

1. نظام الإجهاد الواحد Single Stress: (16) وهو إنشاء يعمل بطريقة أساسية من خلال تكوين" تشكيل المادة، وفكرة هذا النظام هو تفادي كل الاجهادات في العنصر الانشائي مثل اجهاد الشد واجهاد الضغط والانحناء عن طريق تحقيق اجهادات من النوع الفردي، وذلك بتصميم الهيكل الانشائي علي شكل خطوط القوي أو عكسها، مثل العقود والخيام والمنشأت الهوائية المنفوخة والمنشأت المعلقة شكل(4)

شكل (4) نظام الاجهاد الواحد Single Stress العقود والخيام والمنشأت الهوائية المنفوخة والمنشأت المعلقة

2. نظام ثنائي الاجهاد علي مستوي النظام Victor Active Structural: " وهو إنشاء يعمل بطريقة أساسية من خلال أعضاء الشد والضغط "، وفكرة عمله تقوم علي الغاء قوي العزوم وتحويل القوي الي اجهادات شد وضغط داخل العناصر الانشائية وذلك عن طريق تكوين الهيكل الانشائي من أجزاء خطية لها قطاع صغير بالمقارنة بطولها لذا تنقل القوي باتجاه طولها إما شد أو ضغط، (17) ويتم تجميع الاعضاء علي شكل مثلثات، والامثله علي ذلك الجمالونات المستوية والجمالونات الفراغية شكل(5).

شكل (5) نظام ثنائي الاجهاد علي مستوي النظام Victor Active Structural الجمالونات المستوية والجمالونات الفراغية

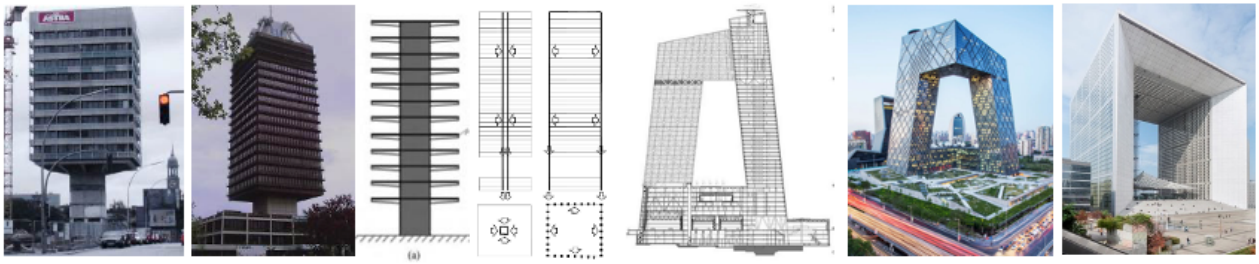
3. نظام ثنائي الاجهاد في العنصر الواحد (تحت تأثير العزوم) Bulk Active Structural: ويتكون هذا النظام من عناصر انشائية مستقيمة كالاعمدة والكمرات وهي تقاوم القوي عن طريق مقاومة المادة المكونة لقطاعها الانشائي، وتحويل هذه القوي الي اجهادات ضغط علي أطرافها العلوية واجهادات شد علي أطرافها السفلية، وتتدرج هذه الاجهادات حتي تنعدم عند المحور المحايد وهو منتصف الكمرة، مع تولد عزم انحناء داخلي، مقاوم لعزوم القوي، (18) وينطبق هذا النظام علي نظم الكمرات والاطارات، الاطارات المتقاطعة، ونظم الكمرات المتقاطعة، بلاطات الوافل،البلاطات المجوفة او الطوب المفرغ، والكمرات المتقاطعة، شكل(6).

شكل (6) نظام ثنائي الاجهاد في العنصر الواحد (تحت تأثير العزوم) Bulk Active Structuralنظم الكمرات والاطارات.

4. النظام السطحي Service Active Structure: " إنشاء يؤثر من خلال استمرارية السطح "، وفي هذا النظام تكون البلاطه هي السطح والإنشاء معاً، (19) وميكانيكية عمل البلاطه أنها مجموعة من الكمرات المتلاصقة والتي تتشارك في مقاومة القوي المؤثرة عليها كجسم واحد متجانس من خلال التوزيع المتساوي للاحمال واجهادات الشد والضغط والعزوم علي كامل البلاطه، وكلما زادت نقاط الارتكاز زادت قدرتها وكفائتها، وتتميز هذه الاسطح بقدرتها علي تغطية بحور واسعه جدا، وتزداد قوة مادة الإنشاء بتغير شكل السطح، سواءاً كان منحنياً كالقشريات أو منكسراً شكل (7).

شكل (7) النظام السطحي Service Active Structure البلاطه هي السطح والإنشاء معاً.

النظام الرأسي Vertical Structure System : "إنشاء يؤثر من خلال انتقال الأحمال الرأسية " وفكرة عمله تعتمد علي تحميل المنشآت المتعددة الطوابق، (20) حيث أنها تعمل تحت تأثير الأحمال العرضية كوحدات كابولية، وتميل هذه الأحمال إلي توليد عزم انحناء دوراني مع عزم انحناء مقاوم يوجده الإنشاء ذاته، ويصمم الهيكل الانشائي كحلقة جاسئة خارجية او داخلية لها القدرة علي نقل الاحمال العرضية في أي اتجاه بالاضافة الي الاحمال الرأسية كما يوضح شكل(8).



شكل (8) النظام الرأسي Vertical Structure System تحميل المنشآت المتعددة الطوابق

5. العلاقة بين المنظومة الفراغية والإنشائية في العمارة

وتتكون هذه الدراسة بمرحلتين:

الأولي: رصد وتوثيق العلاقة بين المنظومتين.

الثانية: تحليل العلاقة بين المنظومتين نظريا من خلال الدراسة التحليلية للخروج بالعناصر ذات الارتباط بين المنظومة الفراغية والمنظومة الإنشائية، والتي سيتكون منها النموذج التقييمي المقترح.

5-1 العلاقة التاريخية بين الإنشاء والفراغ المعماري

مرت العلاقة بين الفراغ المعماري الداخلي والإنشاء بثلاث مراحل فكرية وهي(21):

مرحلة أحادية الفكر:

كان تطور الفكر التصميمي للفراغ المعماري من حيث الارتفاع والبحور والنسب الداخلية للعناصر المكونة للفراغ نابعا من إمكانيات مادة البناء والنظم الإنشائية المستخدمة، وفي اغلب حقب أحادية الفكر كان السلوك الإنشائي مسيطرا علي الفراغ الداخلي، وقد كان النظام الإنشائي المستخدم عبارة عن مادة لتحمل الضغط " للأعمدة " مثل الحجر او الطوب او الخرسانة العادية ومادة لتحمل الشد مثل الخشب " للأسقف " وقد تطورت نظم الأسقف من أسقف بلاطات حجرية ثم جمالونات مستوية محمل عليها أسقف خشبية ثم القباب والقبوات من الطوب أو الحجر أو الخرسانة العادية

مرحلة الازدواجية الفكرية:

ظهر في هذه المرحلة اتجاهان في العمارة

أ- الاتجاه الأول هم المعماريين التقليديين الذين حاولوا الحفاظ علي التراث السابق كما هو واستخدام المواد المحلية الطبيعية في الإنشاء، وهو اتجاه لو يدم طويلا نتيجة الحاجة إلي فراغات وظيفية ذات أنشطة مختلفة وبحور مختلفة

ب- الاتجاه الثاني قام بعمل ثورة تكنولوجية جديدة باكتشاف مواد انشائية حديثة هي الخرسانة المسلحة والحديد لما لها من إمكانيات عالية في مقاومة الشد والضغط معا عكس العصور السابقة، مما فتح أفاق معمارية جديدة وظهور نظم انشائية جديدة تناسب إمكانيات هذه المواد التي أصبحت مواد ذات صبغة عالمية مما ساعد علي إعادة تشكيل الفراغات بفكر جديد أساسه الفكر الإنشائي

مرحلة التعددية الفكرية: (22)

تم انتزاع النظرة الميكانيكية من المجتمع وظهرت التعددية الشخصية في كافة مجالات الحياة وأصبح لكل جماعة فكرها الخاص وقد اثر ذلك في العمارة في ظهور توجهات عديدة مختلفة الفكر مثل

أ- استمرار للتفاعل الصريح بين الفراغ والإنشاء مع استخدام مواد البناء والتكنولوجيا العالمية في الإنشاء

ب- تفاعل غير صريح مع الفراغ المعماري الداخلي مع التعبير الكاذب عن مواد البناء

ج- تأرجح العلاقة بين الفراغ المعماري والإنشاء تبعا للفكر الشخصي للمصمم المعماري

2-5 النموذج التقييمي المقترح

من التحليل النظري السابق أمكن تحديد العناصر ذات الارتباط بين المنظومة الإنشائية ومنظومة الفراغ المعماري الداخلي، والتي يمكن من خلالها عمل نموذج تقييمي لهذه العلاقة يجمع كل العناصر السابقة يمكن استخدامه في تقييم وقياس المردود التصميمي للإنشاء علي الفراغ المعماري الداخلي لأي منشأ معماري سواء قائما او في مرحلة التصميم، ويتكون النموذج المقترح من ثلاث عناصر أساسية محددة لرصد العلاقة بين المنظومة الانشائية والمنظومة الفراغية كالأتي:

1. البيانات الإنشائية: وفيها كافة البيانات للنظام الانشائي وتحوى 8 عناصر بكل عنصر 3 نقاط وهي نقاط مساعده في استنتاج التقييمات للعنصرين التاليين وهما المتطلبات الوظيفية والجمالية.
2. تفاعل الإنشاء مع المتطلبات الوظيفية وهي تحوي 16 عنصر قياس بقيمة 48 نقطه كل عنصر قياس من 9 درجات تقسم احيانا فى بعض المعايير بواقع ثلاث درجات لكل نقطة قياس، واحيانا توضع من 7الى 9 بالحاله الجيدة أو من 4 الى 6 بالحالة المتوسطة ومن 1 الى 3 بالحاله الضعيفه كما هو موضح باستمارات التقييم .
3. تفاعل الإنشاء مع المتطلبات الجمالية وهي تحوي 16 عنصر قياس بقيمة 48 نقطه كل عنصر قياس من 9 درجات تقسم احيانا فى بعض المعايير بواقع ثلاث درجات لكل نقطة قياس، واحيانا توضع من 7الى 9 بالحاله الجيدة أو من 4الى 6 بالحالة المتوسطة ومن 1الى 3 بالحاله الضعيفه كما هو موضح بنماذج التقييم .
4. اجمالى درجات التقييم للنموذج المقترح 288 درجة.
5. والنتائج المتوقع الحصول عليها من تطبيق النموذج هي:

- قياس مستوي علاقة التفاعل بين الإنشاء والفراغ الداخلي بطريقة اجمالية .
- قياس مدي تفاعل كل متطلب من متطلبات التفاعل الوظيفية والجمالية.
- التعرف علي مستوي اداء كل عنصر من عناصر القياس
- عمل دراسة إحصائية مقارنة بين المباني المعمارية المختلفة الخاضعة لتطبيق النموذج وتفترض الدراسة
- إمكانية تطبيق ذلك النموذج علي المشاريع القائمة اوعلي المشاريع أثناء مراحل التصميم الأولية للوصول الي الحل الأمثل.

6. اختبار النموذج التقييمي

1-6 تمهيد

تم استخدام المنهج الوصفي التحليلي الذي يهتم بدراسة ووصف خصائص وأبعاد ظاهرة من الظواهر في اطار معين او في وضع معين يتم من خلاله تجميع البيانات والمعلومات اللازمة عن هذه الظاهرة وتنظيم هذه البيانات وتحليلها للوصول الي أسبابها ومسبباتها والعوامل التي تتحكم فيها وبالتالي استخلاص نتائج يمكن تعميمها مستقبلا وتفسير هذه النتائج التي تم التوصل إليها سواء لتأييد أو لنفي اقتراحات معينة.

2-6 عينات الدراسة

وقد تم تحديد ملامح ومواصفات العينات التي سيتم اختبار النموذج بها كالأتي :

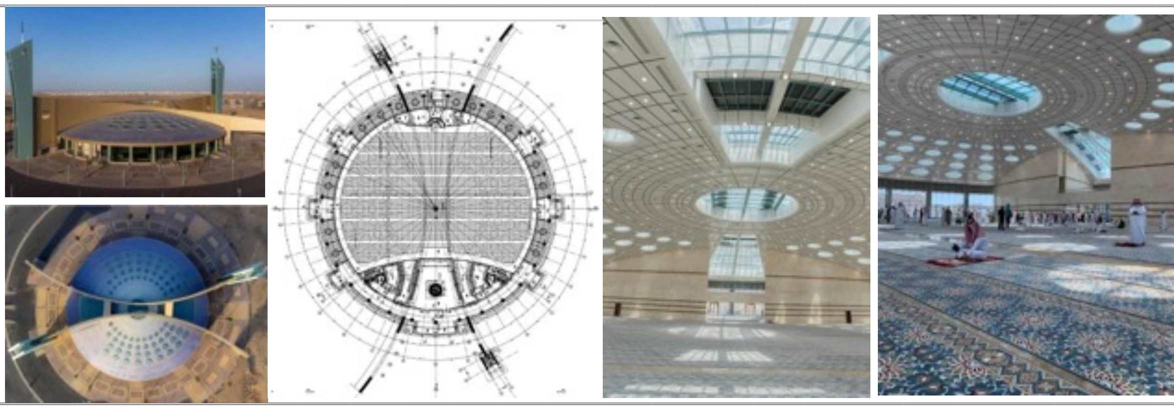
المشاريع المختارة ذات الأنشطة العامة مثل الفراغات التعليمية ودور العباده والمراكز البحثية مع عدم إغفال الجوانب الثقافية والتراثية .

أن تكون هذه المشروعات رائدة وذات قيمه معمارية وتمثل أقاليم مناخية وثقافية متنوعة داخل المملكة العربية السعودية.

جدول (1) تقييم مشروع مسجد جامعة تبوك على النموذج التقييمى المقترح – المملكة العربية السعودية (23 - 24)

نموذج تقييمي لقياس المردود التصميمي للمنظومة الانشائية علي الفراغ المعماري الداخلي (مسجد جامعة تبوك)

التعريف بالمبني: الانشاء 2006 وهو يمزج بين الطراز الإسلامي الكلاسيكي واللمسات العصرية ويقع بجامعة تبوك بالمملكة العربية السعودية



وصف المبني : تبلغ المساحة الإجمالية للمسجد 7100 متر مربع، وتبلغ سعته 3450 مصلٍ، ويحتوي علي مئذنتين بارتفاع 50 متراً، أما سقفه علي شكل قبة بقطر 90 متر بها فتحات للاضاءة وترتكز علي كمرة دائرية (Rigid Beam) ترتكز علي 29 عامود تقع خارج صحن الصلاة مما يوفر مساحة داخلية كاملة بدون اعمدة مع واجهات زجاجية مزدوجة لتحقيق الاضاءة والعزل

التوصيف الانشائي للمبني – الكفاءة الاقتصادية

العنصر	المعيار	التقييم
التوافق الانشائي	ضعيف	
	متوسط	
	قوي	■
الهيكل الانشائي	خرساني	■
	معدني	
	مختلط	
بحر الإنشاء	صغيرة	
	متوسطة	
	كبيرة	■
تكنولوجيا البناء	تقليدية	■
	مختلطة	
	متطورة	
توافق الإنشاء	غير متوافق	
	الي حد ما	
	متوافق	■
عمر المبني بالسنة	من (1 - 10)	
	من (11 - 20)	■
	من (21 - 30)	
الشبكة الانشائية	لا يوجد	
	احيانا	
	واضحة	■
الانظمة الانشائية	تقليدية	
	مختلطة	■
	متطورة	

تفاعل الإنشاء مع المتطلبات الوظيفية للفراغات الداخلية

المجموعة	العنصر	المعيار	التقييم
المرونة الوظيفية	الحذف والاضافة	ضعيف	3
		متوسط	
		جيد	
	المرونة الفراغية	ضعيف	
		متوسط	5
		جيد	
	الاتصال الفراغي	ضعيف	
		متوسط	
		جيد	9
التوزيع الحركي		إيقاع الاعمدة	3
		تغير شكل السقف	3
		تغير ارتفاعات السقف	3
الراحة البيئية	راحة صوتية	ضعيف	
		متوسط	5
		جيد	
	راحة حرارية	ضعيف	
		متوسط	6
		جيد	
	راحة ضوئية	ضعيف	
		متوسط	
		جيد	7
العلاقات الوظيفية		غير واضحه	
		واضحه احيانا	
		واضحة	8
طبيعة وظيفة الفراغ	الشبكة المعمارية	صغير	3
		متوسط	3
		كبير	3
	العزل	صوتي	1
		حراري	2
		مائي	3
	اتجاه التأثير	راسي	3
		افقي	3
		متداخل	3
	الحركة والاستقرار	استاتيكي	3
		ديناميكي	3
		متداخل	3
	الاستدامة	غير متحققة	
		الي حد ما	5
		متحققة	
الامن والسلامة	امان وظيفي	ضعيف	3
		متوسط	3
		جيد	3
	امان نفسي	ضعيف	
		متوسط	
		جيد	8
التفاعل		ضعيف	
		متوسط	
		قوي	8

تفاعل الإنشاء مع المتطلبات الجمالية للفراغات الداخلية

المجموعة	العنصر	المعيار	التقييم
التفاعل بين الشكل الانشائي والمعماري	التفاعل الثقافي	غير متفاعل	
		الي حد ما	
		متفاعل	8
	التفاعل الشكلي	غير متفاعل	
		الي حد ما	
		متفاعل	7
الجمال الحسي	الاتزان البصري	لا يوجد	
		احيانا	
		متزن ومتوافق	8
	المقياس	غير مناسب	
		الي حد ما	
		مناسب ومعبر	8
	التفاعل مع الاضاءة	إضاءة سماوية	2
		إضاءة جانبية	2
		إضاءة صناعية	3
الجمال العاطفي		التفاعل مع التراث	1
		تعبير رمزي	2
		تعبير عاطفي	2
الجمال الفكري	فكري وظيفي	غير معبر	
		الي حدا ما	
		معبر	8
	فكري تجريدي	غير واضح	
		الي حدا ما	
		واضح	7
عناصر التفاعل		عناصر أفقية	2
		عناصر راسية	2
		اسقف	2
السلوك الإنشائي		كامن	
		نسبي	
		مسيطر	9
الإيقاع		غير منتظم	
		متداخل	
		منتظم	8
الاتزان الكتلي		غير متزن	
		الي حدا ما	
		متزن	8
النسب		متناقض	
		الي حدا ما	
		متناسقة	7
عناصر الجذب		غير واضح	
		الي حدا ما	
		واضح	8
الالوان		متناقض	
		الي حدا ما	
		متناسقة	8
الملمس		غير معبر	
		الي حدا ما	
		معبر	8

(■) رمز تحديد منظومة الإنشاء، والرقم يعبر عن التقييم بواقع 9 درجات لكل عنصر مجتمعه أو مقسمه

جدول(2) تقييم مشروع مركز الملك عبد الله للدراسات والبحوث البترولية على النموذج التقييمى المقترح (25 - 26)

نموذج تقييمي لقياس المردود التصميمي للمنظومة الانشائية علي الفراغ المعماري الداخلي (مركز الملك عبد الله للدراسات والبحوث البترولية)

التعريف بالمبني : يقع المشروع في الرياض وانشأ عام 2017 من تصميم زها حديد، ويهدف إلي دعم الابحاث في مجال الطاقة المستدامة. يتميز التصميم ببنية خلّيّة تشبه البلورات الطبيعية، مما يعكس فلسفة الاستدامة والكفاءة

وصف المبني : المشروع بمساحة 70000 متر ويتكون من خمسة مبانٍ: مركز في مجال الطاقة؛ ومركز حاسوب الطاقة؛ ومركز مؤتمرات مع قاعة عرض وقاعة تتسع لـ 300 مقعد؛ ومكتبة أبحاث تحتوي 100 ألف مجلد؛ والمصلي ، يُقسّم كل مبني إلي وظائفه المختلفة، ويمكن تعديله لتلبية متطلبات وأساليب العمل المتغيرة، وحاصل علي شهادة LEED البلاتينية من مجلس المباني الخضراء الأمريكي

التوصيف الإنشائي للمبني	الكفاءة الاقتصادية																										
	التوافق الانشائي			الهيكل الانشائي			بحر الإنشاء			تكنولوجيا البناء			توافق الإنشاء			عمر المبني بالسنة			الشبكة الانشائية			الانظمة الانشائية		
	ضعيف	قوي	متوسط	خرساني	معدني	مختلط	صغيرة	متوسطة	كبيرة	تقليدية	مختلطة	متطورة	غير متوافق	الي حد ما	متوافق	من (1 - 10)	من (11 - 20)	من (21 - 30)	لا يوجد	احيانا	واضحة	تقليدية	مختلطة	متطورة
		■				■			■			■			■					■					■

تفاعل الإنشاء مع المتطلبات الوظيفية للفراغات الداخلية	المرونة الوظيفية									التوزيع الحركي			الراحة البيئية									العلاقات الوظيفية		
	الحذف والاضافة			المرونة الفراغية			الاتصال الفراغي						راحة صوتية			راحة حرارية			راحة ضوئية					
	ضعيف	متوسط	جيد	ضعيف	متوسط	جيد	ضعيف	متوسط	جيد	ابتداع الاعمدة	تغير شكل السقف	تغير ارتفاعات السقف	ضعيف	متوسط	جيد	ضعيف	متوسط	جيد	ضعيف	متوسط	جيد	غير واضحه	واضحة احيانا	واضحة
	3				5		7			3	3	3			7			7			8			8

تفاعل الإنشاء مع المتطلبات الوظيفية للفراغات الداخلية	طبيعة وظيفة الفراغ																							
	الشبكة المعمارية			العزل			اتجاه التأثير			الحركة والاستقرار			الاستدامة			امان وظيفي			امان نفسي			التفاعل		
	صغير	متوسط	كبير	صوتي	حراري	مائي	راسي	افقي	متداخل	استاتيكي	ديناميكي	متداخل	غير متحققة	الي حد ما	متحققة	ضعيف	متوسط	جيد	ضعيف	متوسط	جيد	ضعيف	متوسط	قوي
	3	3	3	2	2	3	3	3	3	3	3	3			8			8			8			8

تفاعل الإنشاء مع المتطلبات الجمالية للفراغات الداخلية	التفاعل بين الشكل الانشائي والمعماري																							
	التفاعل الثقافي			التفاعل الشكلي			الاتزان البصري			الجمال الحسي المقياس			التفاعل مع الإضاءة			الجمال العاطفي			الجمال الفكري فكري وظيفي			الجمال الفكري فكري تجريدي		
	غير متفاعل	الي حد ما	متفاعل	غير متفاعل	الي حد ما	متفاعل	لا يوجد	احيانا	متزن ومتوافق	غير مناسب	الي حد ما	مناسب ومعبر	إضاءة سماوية	إضاءة جانبية	إضاءة صناعية	التفاعل مع التراث	تعبير رمزي	تعبير عاطفي	غير معبر	الي حد ما	معبر	غير واضح	الي حد ما	واضح
			9			9			8			9	3	3	3	3	2	3		6					9

تفاعل الإنشاء مع المتطلبات الجمالية للفراغات الداخلية	عناصر التفاعل			السلوك الإنشائي			الإيقاع			الاتزان الكتلي			النسب			عناصر الجذب			الالوان			الملمس		
	عناصر أفقية	عناصر راسية	اسقف	كامن	نسبي	مسيطر	غير منتظم	متداخل	منتظم	غير متزن	الي حد ما	متزن	متناقض	الي حد ما	متناسقة	غير واضح	الي حد ما	واضح	متناقض	الي حد ما	متناسقة	غير معبر	الي حد ما	معبر
	3	2	3			9			9			8			9			8			8			8

(■) رمز تحديد منظومة الإنشاء، والرقم يعبر عن التقييم بواقع 9 درجات لكل عنصر مجتمعه أو مقسمه

جدول(3) تقييم مشروع مبني كلية الهندسة وعلوم الحاسب – جامعة جازان على النموذج التقييمي المقترح (27)

نموذج تقييمي لقياس المردود التصميمي للمنظومة الانشائية علي الفراغ المعماري الداخلي (مبني كلية الهندسة وعلوم الحاسب)

التعريف بالمبني: يقع المبني بالحرم الجامعي لجامعة جازان وقد انشا علم 2016 تقريبا ويجمع في تصميميه بين الحداثة والهوية المحلية، وكسوات الواجهات بالجرانيت لتقليل امتصاص الحرارة.

وصف المبني: المبني مكون من ثلاث ادور يحتوي علي قاعة مؤتمرات تتسح لحدود 150 شخص وقاعات دراسية ومعامل ومكاتب اعضاء هئية التدريس والمبني منشأ بنظام Waffle slap لتحقيق فراغات ببحور متوسطه، ويتميز المبني ببهو المدخل وممر بارتفاع الثلاث بشكل مميز واضاءة مباشرة جانبية وعلوية وتستعمل في مناقشة مشروعات التخرج والاحتفالات بالمناسبات الوطنية والفاعليات والانشطة المختلفة .

التوصيف الانشائي للمبني	الكفاءة الاقتصادية																								
	التوافق الانشائي			الهيكل الانشائي			بحر الإنشاء			تكنولوجيا البناء			توافق الإنشاء			عمر المبني بالسنة			الشبكة الانشائية			الانظمة الانشائية		
	ضعيف	متوسط	قوي	خرساني	معدني	مختلط	صغيرة	متوسطة	كبيرة	تقليدية	مختلطة	متطورة	غير متوافق	الي حد ما	متوافق	من (1 - 10)	من (11 - 20)	من (21 - 30)	لا يوجد	احيانا	واضحة	تقليدية	مختلطة	متطورة
			■			■	■	■			■			■			■			■				■	

تفاعل الإنشاء مع المتطلبات الوظيفية للفراغات الداخلية	المرونة الوظيفية									التوزيع الحركي			الراحة البيئية									العلاقات الوظيفية		
	الحذف والاضافة			المرونة الفراغية			الاتصال الفراغي			ايقاع الاعمدة	تغير شكل السقف	تغير ارتفاعات السقف	راحة صوتية			راحة حرارية			راحة ضوئية			غير واضحه	واضحه احيانا	واضحة
	ضعيف	متوسط	جيد	ضعيف	متوسط	جيد	ضعيف	متوسط	جيد				ضعيف	متوسط	جيد	ضعيف	متوسط	جيد	ضعيف	متوسط	جيد			
		7			6		7			2	2	2		5		3				6			5	

تفاعل الإنشاء مع المتطلبات الوظيفية للفراغات الداخلية	طبيعة وظيفة الفراغ																		التفاعل		
	الشبكة المعمارية			العزل			اتجاه التأثير			الحركة والاستقرار			الاستدامة			امان وظيفي			امان نفسي			ضعيف	متوسط	قوي
	صغير	متوسط	كبير	صوتي	حراري	مائي	راسي	افقي	متداخل	استاتيكي	ديناميكي	متداخل	غير متحققة	الي حد ما	متحققة	ضعيف	متوسط	جيد	ضعيف	متوسط	جيد			
	3	3	3	2	1	2	3	3	3	3	3	3		5				7		5				7

تفاعل الإنشاء مع المتطلبات الجمالية للفراغات الداخلية	التفاعل بين الشكل الانشائي والمعماري									الجمال الحسي									الجمال العاطفي			الجمال الفكري					
	التفاعل الثقافي			التفاعل الشكلي			الاتزان البصري			المقياس			التفاعل مع الاضاءة			الاتزان الكتلي			التفاعل مع التراث	تعبير رمزي	تعبير عاطفي	فكري وظيفي			فكري تجريدي		
	غير متفاعل	الي حد ما	متفاعل	غير متفاعل	الي حد ما	متفاعل	لا يوجد	احيانا	متزن ومتوافق	غير مناسب	الى حد ما	مناسب ومعبر	إضاءة سماوية	إضاءة جانبية	إضاءة صناعية	غير متزن	الى حد ما	متزن	1	2	1	غير معبر	الي حدا ما	معبر	غير واضح	الي حدا ما	واضح
	3			6			7				6		3	3	3				1	2	1		5			6	

	عناصر التفاعل			السلوك الإنشائي			الإيقاع			الاتزان الكتلي			النسب			عناصر الجذب			الالوان			الملمس		
	عناصر أفقية	عناصر راسية	اسقف	كامن	نسبي	مسيطر	غير منتظم	متداخل	منتظم	غير متزن	الى حدا ما	متزن	متناقض	الي حدا ما	متناسقة	غير واضح	الي حدا ما	واضح	متناقض	الي حدا ما	متناسقة	غير معبر	الي حدا ما	معبر
	3	3	2		6			6				7			8		6			5			6	

(■) رمز تحديد منظومة الإنشاء، والرقم يعبر عن التقييم بواقع 9 درجات لكل عنصر مجتمعه أو مقسمه

3-6 نتائج اختبار النموذج التقييمي

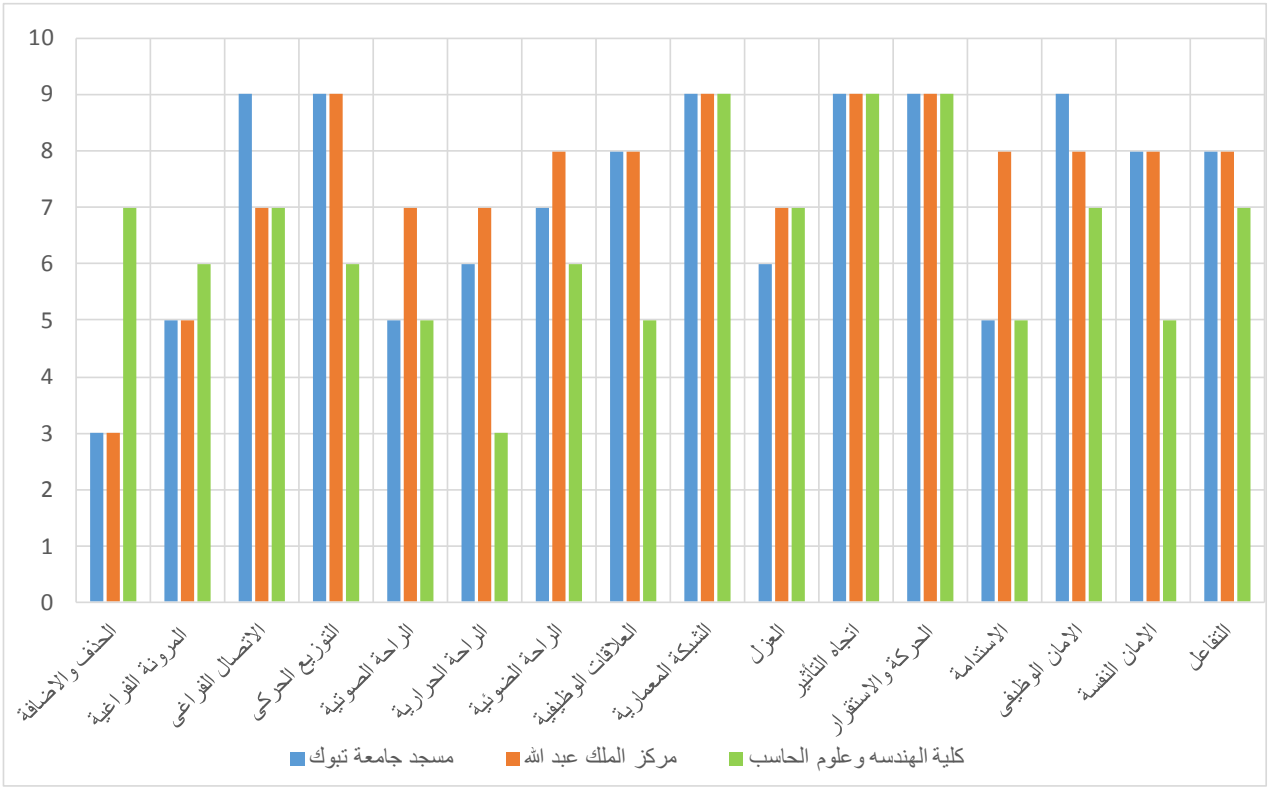
تُمثّل نتائج اختبار النموذج التقييمي محورًا رئيسيًا في تقييم فرضية البحث، حيث تم تطبيق النموذج على ثلاث عيّنات معمارية متنوعة الوظائف والأنظمة الإنشائية. تهدف هذه النتائج إلى قياس مدى تفاعل الأنظمة الإنشائية مع متطلبات الفراغات الداخلية وظيفيًا وجماليًا، عبر تحليل كمّي يعكس أداء كل مبنى وفق معايير مُحددة. تعكس هذه المرحلة التحليلية ربط الجوانب النظرية بالتطبيق العملي، مُقدِّمةً رؤيةً واضحةً حول كفاءة النموذج في دعم عملية اتخاذ القرارات التصميمية أو تطوير المباني القائمة

1-3-6 متوسطات المتطلبات الوظيفية التفصيلية

عند تحليل متوسطات قيم عناصر تفاعل الإنشاء والمتطلبات الوظيفية للفراغ لعيّنات الدراسة المختارة مقارنةً بالنموذج القياسي، شكل (9)، تُظهر النتائج ما يلي:

تتصدر عناصر التوزيع الحركي، واتجاه التأثير، والحركة، والاستقرار قائمةَ العناصر الأكثر تفاعليةً، في حين تُعد عمليتا الحذف والإضافة إلى جانب المرونة الفراغية أقلَّها تفاعليةً

1. سجّل مركز الملك عبد الله قيمًا متوسطةً أعلى في مؤشرات التفاعل، بينما احتل مبنى كلية الهندسة المرتبةَ الدنيا وفقًا للمتوسطات المُقاسَة.
2. أسفر تحليل الرسوم البيانية عن النتائج الآتية:
   - تقييم الكفاءة الفردية لعناصر التفاعل.
   - مقارنة الأداء النسبي لعناصر العيّنات المختارة.

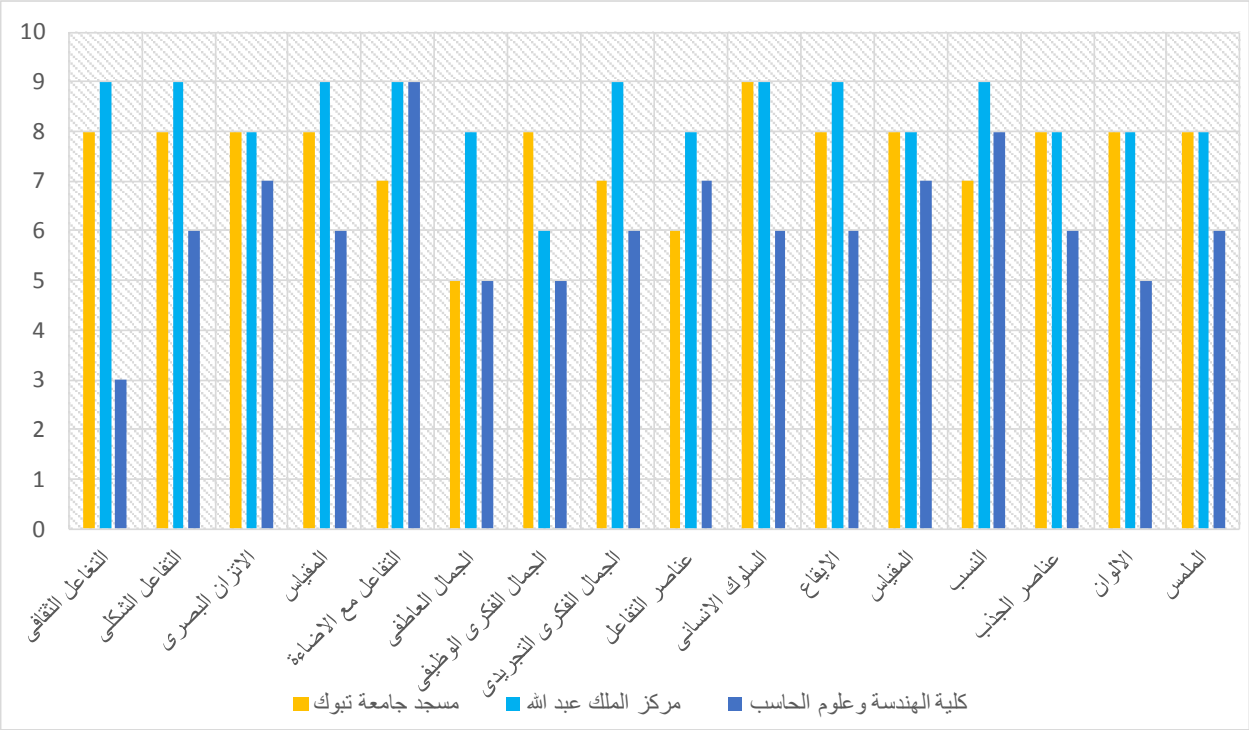


شكل (9) يوضح تأثير الإنشاء على العناصر الوظيفية للفراغات الداخليه الرئيسية للمبانى المقيمة.

6-3-2 متوسطات المتطلبات الجمالية التفصيلية:

وعند التحليل الإحصائي لمتوسطات قيم عناصر تفاعل الإنشاء والمتطلبات الجمالية للفراغ في العينات المُختارة مقارنةً بالنموذج القياسي، شكل (10)، تُظهر النتائج ما يلي:

4. تصدَّرَت عناصر المقياس والتفاعل مع الإضاءة والسلوك الانساني قائمة العناصر الأكثر تفاعليةً، بينما احتلت عناصر الجمال العاطفي والجمال الفكري والكفاءة الوظيفية المراتب الأقل تأثيرًا وفقًا للتحليل الكمّي.
5. مكَّن التمثيل البصري للبيانات من:
   - تقييم كفاءة كل عنصر تفاعلي على حدة.
   - إجراء مقارنة إحصائية بين أداء عناصر العينات المختلفة.



شكل (10) يوضح تأثير الإنشاء على العناصر الجمالية للفراغات الداخليه الرئيسية للمباني المقيمة.

6-3-3 متوسطات إجمالية:

بعد تحليل مدى تأثير النظام الإنشائي على تحقيق الجوانب الوظيفية والجمالية، كما هو موضح في الجداول (1، 2، 3) والأشكال (9، 10)، توضح النتائج ما يلي:

من حيث إجمالي النقاط: تصدَّر مبنى مركز الملك عبد الله للدراسات والبحوث البترولية بأعلى مجموع نقاط (254 نقطة من أصل 288)، يليه مبنى مسجد جامعة تبوك (230 نقطة)، ثم مبنى كلية الهندسة وعلوم الحاسب بجامعة جازان (199 نقطة) بنسبة تراجع قدرها 21.5% مقارنة بالأول

في الجوانب الوظيفية: حصل مبنى مركز الملك عبد الله للدراسات والبحوث البترولية على المرتبة الأولى (120 نقطة من أصل 144)، فيما حلَّ مبنى مسجد جامعة تبوك في المرتبة الثانية (116 نقطة)، ثم مبنى كلية الهندسة وعلوم الحاسب بجامعة جازان بالمرتبة الثالثة (100 نقطة)

في الجوانب الجمالية: سجَّل مبنى مركز الملك عبد الله للدراسات والبحوث البترولية تفوقاً واضحاً (134 نقطة من أصل 144)، بينما حقق مبنى مسجد جامعة تبوك (114 نقطة)، في حين جاء مبنى كلية الهندسة وعلوم الحاسب بجامعة جازان في المرتبة الأخيرة (99 نقطة)

7. النتائج والتوصيات:

7-1 النتائج:

1. أكدت الدراسة البحثية على صحة الفرضية في إمكانية عمل نموذج تقييمي لقياس العلاقة التبادلية بين المنظومة الفراغية والإنشائية سواء على المباني القائمة أو أثناء العملية التصميمية لمقارنة البدائل أو تقييم المقترح.
2. المكونات المادية للمنظومة الفراغية الداخلية هي (العناصر المعمارية - العناصر الانشائية -عناصر الانتقال الفراغي - عناصر التأثيث - الانظمة الفنية)
3. تتكون المنظومة الفراغية من عدة منظومات هي:
   - المنظومة الوظيفية " متطلبات المستعملين – متطلبات الأنشطة – متطلبات الأبعاد – متطلبات التأثيث ".

- منظومة الراحة البيئية " راحة مناخية – راحة ضوئية – راحة صوتية " .
- المنظومة الإنشائية " مواد البناء – النظم الإنشائية – الكفاءة الاقتصادية – تكنولوجيا البناء " .
- المنظومة الجمالية " الجمال العاطفي - الجمال الفكري - الجمال الحسي " .

4. المكونات المادية للمنظومة الانشائية هي (مواد البناء - النظم الانشائية - تكنولوجيا البناء)
5. تصنف النظم الإنشائية إلي خمس نظم أساسية تبعا لنوع الاجهاد وهي : (نظام الإجهاد الواحد - نظام ثنائي الإجهاد علي مستوي النظام - نظام ثنائي الإجهاد في العنصر الواحد - النظام السطحي - النظام الرأسي)
6. أظهرت نتائج التقييم أن النموذج يتمتع بقدرة فعالة على قياس مدى تفاعل النظام الإنشائي مع متطلبات الفراغ المعماري، من الجانبين الوظيفي والجمالي، عبر مؤشرات كمية واضحة. وقد استطاع النموذج الكشف عن تباينات دقيقة بين المشاريع المدروسة، مما يعكس صلاحيته كأداة تقييم موضوعية يمكن الاعتماد عليها في تحليل الأداء الداخلي للمباني.
7. يتميز النموذج بتحليل تفصيلي لـ 32 مؤشرًا، بواقع 16 مؤشرًا وظيفيًا و16 مؤشرًا جماليًا، موزعة على مقياس تدرجي مكون من 9 نقاط. هذا التدرج أتاح تصنيفًا دقيقًا لمستويات الأداء داخل كل مشروع، وسهّل تحديد مواضع القوة والقصور في الأنظمة الإنشائية وتأثيرها على بيئة الاستخدام، سواء من حيث الراحة أو التنظيم أو الجماليات المعمارية.
8. قدّم البحث من خلال هذا النموذج إطارًا منهجيًا عمليًا يُترجم مفاهيم التصميم التكاملي إلى أداة قابلة للتطبيق في الواقع المعماري. وقد تجلت قوة النموذج في قدرته على التعامل مع مكونات متعددة تتداخل بين البنية الإنشائية، متطلبات المستخدم، والاعتبارات الجمالية، ما يعزز من دوره كحلقة وصل بين الجانب النظري والممارسة المهنية.
9. كما أظهرت الدراسة أن النموذج يمتلك إمكانات تطبيقية في دعم صُنّاع القرار، لاسيما فيما يخص مراجعة وتحديث اللوائح البنائية المحلية. إذ يُوفر مؤشرات كمية قابلة للقياس يمكن أن تُستخدم في صياغة معايير تصميمية تضمن تحسين كفاءة الأداء الوظيفي والجمالي للمباني في المملكة العربية السعودية.

2-7 التوصيات:

1. استخدام النموذج التقييمي كأداة منهجية لمقارنة البدائل التصميمية المُقترحة خلال مرحلة التصميم للمشروعات المختلفة في مرحلة التصميم وذلك بهدف تحديد الحل الأمثل بناءً على معايير محددة. كما يساهم هذا النموذج في الكشف عن العيوب والقيود المرتبطة بكل مقترح.
2. استخدام النموذج التقييمي من تحليل الوضع الراهن للمباني القائمة، وتقييم كفاءة أدائها الوظيفي والتصميمي. ويُستخدم هذا التحليل لدعم قرارات التطوير، سواء عبر إعادة توزيع وظائف الفراغات الداخلية لتعزيز المرونة الوظيفية، أو عبر تحسين أداء الوظائف الحالية لتتوافق مع المتطلبات الحديثة والمعايير المستدامة.
3. ترسيخ مبدأ المشاركة الفعالة في اتخاذ القرارات الإنشائية لدي المعماري من حيث تناسب النظام الإنشائي مع الفكر المعماري.
4. اختبار النموذج على أنواع مختلفة من الفراغات (كالمنشآت الصحية، المراكز التجارية، والمباني السكنية) لقياس مدى شموليته.
5. دراسة تأثير الأنظمة الإنشائية المبتكرة كالخرسانة ذاتية الإصلاح، الهياكل القابلة للتحويل على الفراغات المعمارية.
6. تحسين كفاءة النموذج في تقييم أداء الأنظمة الإنشائية في المناطق ذات الظروف المناخية القاسية كالحرارة العالية، الرطوبة.
7. استخدام تقنيات الذكاء الاصطناعي لمحاكاة التفاعل بين الأنظمة الإنشائية والفراغات المعمارية وتوليد حلول تصميمية مُحسَّنة.
8. تطبيق النموذج في مراجعة اللوائح البنائية المحلية لضمان توافقها مع أهداف البحث (كفاءة وظيفية-جمالية).

الخلاصه:

أوضحت الدراسة تأثير النظم الانشائية ومكوناتها على الاداء الوظيفي للفراغات المعمارية، كما أوضحت التأثير الرئيسي للنظم الانشائية على جماليات وأنسنة الفراغات الداخلية، حتي أن العناصر الانشائية كالاعمدة قد تكون من أهم عناصر جماليات الفراغات والتي قد تعكس مفردات التراث المعماري للبيئة ومثال على ذلك مشروع مركز أبحاث ودراسات البترول بالرياض، واقترح البحث نموذج تقييمي لتأثير العناصر الانشائية على وظائف وجماليات الفراغات الداخلية، وتم تطبيقه على العديد من المباني داخل المملكة العربية السعوديه، وهي مباني قائمة، واوضحت الدراسة انه يمكن تطبيق هذا النموذج لتقييم المشروعات في مرحلة التصميم للمساعدة في اتخاذ القرارات التصميمية المعمارية والانشائية وانتهي البحث بتحليل النتائج للاستفاده بها في الدراسات المستقبلية في هذا المجال

8. المراجع :

1. *Ahmed, M. (2006). The Interrelation Challenges Between Spatial and Structural Systems in Architecture: A Critical Study on Architectural Spaces in Public Buildings. Mataria, Egypt: Faculty of Engineering, Helwan University.*
2. *حسن، م. س. (2018). العمارة والإنشاء: التكامل بين الجمال والوظيفة. القاهرة: دار النهضة العربية.*
3. *Wang, Q., et al. (2023). "Sustainable Steel-Concrete Composite Structures: A Review of Architectural Applications." Sustainable Materials and Technologies, 37, e00675. DOI: 10.1016/j.susmat.2023.e00675*
4. *Gissen, D. (2020). The Architecture of Disability: Buildings, Cities, and Landscapes Beyond Access. University of Minnesota Press. ISBN: 978-1517906650*

5. *Steemers, K., & Baker, W. (2021). Architecture and Environment: Designing for Climate Resilience. DOI: 10.4324/9781003096744*
6. *محمود، ن. (2020). التفاعل بين الهيكل الإنشائي والتصميم الداخلي في العمارة المعاصر. رسالة دكتوراة، جامعة القاهرة.*
7. *السيد عثمان: طاقة الفراغ والراحة الحرارية الكلية – رسالة دكتوراة –قسم العمارة- كلية الهندسة- جامعة القاهرة، 2004.*
8. *Li, B., & Yu, X. (2022). "Seismic Design of Reinforced Concrete Structures: Balancing Safety and Aesthetic Flexibility." Earthquake Engineering & Structural Dynamics, 51(8), DOI: 10.1002/eqe.3641*
9. *Bille, M., & Sørensen, T. F. (2023). The Anthropology of Space and Place: Locating Culture. Wiley-Blackwell. ISBN: 978-1119898410*
10. *ArchDaily. (2023). How Structure Shapes Space. Retrieved May 5, from https://www.archdaily.com/1012345*
11. *K. Michael Hays. (2023) "Theories of Architecture: A Critical Anthology" 10.5749/j.ctv2t8b7b9*
12. *على رأفت : الإبداع الانشائى فى العمارة – ثلاثية الإبداع المعماري – مركز أبحاث انتر كونسلت، مطابع الأهرام، القاهرة، 1996.*
13. *A.Blanc&M.Mcevoy&R.plank: "Architecture & Construction in Steel ,E&FN Spon,London,1993c.*
14. *Steane, M. A. (2021). The Architecture of Light: Recent Approaches to Designing with Natural Light. Taylor & Francis. DOI: 10.1201/9781003183889*
15. *Salvadori, M. (2002). Why Buildings Stand Up: The Strength of Architecture. W.W. Norton & Company. ISBN: 978-0393306767.*
16. *Engel, H. (2015). Structure Systems. Deutsche Verlags-Anstalt. DOI: 10.1515/9783035606556*
17. *Ahmad, S., et al. (2023). "Smart Materials in Concrete Construction: Future Directions for Architectural Innovation." Materials Today: Proceedings, 82(Part 3), 231–238. DOI: 10.1016/j.matpr.2023.03.522*
18. *https://alwadiadas.blogspot.com/2018/01/types-of-concrete-slabs-advantages-and.html*
19. *Smith, B., & Killa, S. (2021). "Adaptive Structural Systems: A Review of Emerging Technologies." Journal of Architectural Engineering, 27(3), 04021020. DOI: 10.1061/(ASCE)AE.1943-5568.0000489*
20. *American Society of Civil Engineers (ASCE). (2022). *Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE/SEI 7-22)*. ASCE.*
21. *Schodek, D., & Bechthold, M. (2014). Structures (7th ed.). Pearson. Chapter 4: "Structural Systems: Types and Configurations."*
22. *Babič, A., & Čuš, F. (2024). "Adaptive Reuse of Industrial Steel Structures: Architectural and Structural Synergy." Engineering Structures, 300, 117201. DOI: 10.1016/j.engstruct.2023.117201*
23. *https://www.astucestopo.net/2017/11/blog-post.html*
24. *Ahmad, S., et al. (2023). "Smart Materials in Concrete Construction: Future Directions for Architectural Innovation." Materials Today: Proceedings, 82(Part 3), 231–238. DOI: 10.1016/j.matpr.2023.03.522*
25. *https://www.archdaily.com/882341/king-abdullah-petroleum-studies-and-research-centre-zaha-hadid-architects*
26. *Almusallam, T., et al. (2023). "Innovations in Hybrid Steel-Concrete Structural Systems for High-Rise Buildings." Journal of Building Engineering, 76, 107301. DOI: 10.1016/j.jobe.2023.107301*
27. *https://www.jazanu.edu.sa/ar/colleges/college-engineering-and-computer-science.*

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☒ *The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.*

☐*The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:*

الأبحاث باللغة العربية

مجلة الشمال للعلوم الأساسية والتطبيقية (JNBAS)

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الأبحـاث باللغة العربية

- **الاقتباس من كتاب لأكثر من مؤلف:**

نيوباي، تيموثي؛ ستيبتش، دونالد؛ راس، جيمس. (1434هـ/2013م). ***التقنية التعليمية للتعليم والتعلم***. الرياض، المملكة العربية السعودية: دار جامعة الملك سعود للنشر.

- **الاقتباس من دورية:**

النافع، عبداللطيف حمود. (1427هـ). أثر قيادة السيارات خارج الطرق المعبدة في الغطاء النباتي بالمنتزهات البرية: دارسة في حماية البيئة، في وسط المملكة العربية السعودية. ***المجلة السعودية في علوم الحياة***، *14*(1)، 53-72.

- **الاقتباس من رسالة ماجستير أو دكتوراه:**

القاضي، إيمان عبدالله. (1429هـ). ***النباتات الطبيعية للبيئة الساحلية بين رأسي تنورة والملوح بالمنطقة الشرقية: دراسة في الجغرافيا النباتية وحماية البيئة***. رسالة دكتوراه غير منشورة، كلية الآداب للبنات، الدمام، المملكة العربية السعودية: جامعة الملك فيصل.

- **الاقتباس من الشبكة العنكبوتية (الإنترنت):**

- الاقتباس من كتاب:

المزروعي، م.ر. و المدني، م.ف. (2010م). ***تقييم الأداء في مؤسسات التعليم العالي***. المعرِّف الرقمي (DOI:10.xxxx/xxxx-xxxxxxxx-x)، أو برتوكول نقل النصوص التشعبي (http://www...)، أو الرقم المعياري الدولي للكتاب (ISBN : 000-0- 00 - 000000-0)

– الاقتباس من مقالة في دورية:

المدني، م.ف. (2014). مفهوم الحوار في تقريب وجهات النظر. ***المجلة البريطانية لتكنولوجيا التعليم***، *11*(6)، 225-260. المعرِّف الرقمي (DOI:10.xxxx/xxxx-xxxxxxxx-x) أو برتوكول نقل النصوص التشعبي (http://onlinelibrary.wiley.com/journal/10.1111)، أو الرقم المعياري التسلسلي الدولي للمجلة (ISSN: 1467 - 8535).

14) يلتزم الباحث بترجمة (أو رومنة) أسماء المصادر والمراجع العربية إلى اللغة الإنجليزية في قائمة المصادر والمراجع. وعلى سبيل المثال:

الجبر، سليمان. (1991م). تقويم طرق تدريس الجغرافيا ومدى اختلافها باختلاف خبرات المدرسين وجنسياتهم وتخصصاتهم في المرحلة المتوسطة بالمملكة العربية السعودية. ***مجلة جامعة الملك سعود- العلوم التربوية***، *3*(1)، 143-170.

Al-Gabr, S. (1991). The Evaluation of Geography Instruction and the Variety of its Teaching Concerning the Experience, Nationality, and the Field of Study in Intermediate Schools in Saudi Arabia *(in Arabic). Journal of King Saud University- Educational Sciences, 3*(1), 143-170.

15) تستخدم الأرقام العربية الأصلية (0، 1، 2، 3، ...) في البحث.

16) تؤول جميع حقوق النشر للمجلة في حال إرسال البحث للتحكيم وقبوله للنشر.

ثانياً: الملفات المطلوب تسليمها

1) نسخة إلكترونية من البحث بصيغتي (WORD) و (PDF)، وترسلان على البريد الإلكتروني الآتي:

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2) السيرة الذاتية للباحث، متضمنة اسمه باللغتين العربية والإنجليزية، وعنوان البريد الإلكتروني الحالي، ورتبته العلمية.

3) تعبئة النماذج الآتية:

أ - نموذج طلب نشر بحث في المجلة.

ب - نموذج تعهد بأن البحث غير منشور أو مقدم للنشر في مكان آخر.

ثالثاً: تنبيهات عامة

1) أصول البحث التي تصل إلى المجلة لا تردّ سواء أُنْشِرَتْ أم لم تنشر.

2) الآراء الواردة في البحوث المنشورة تعبر عن وجهة نظر أصحابها.

شروط النشر

أولاً: ضوابط النص المقدم للنشر

1) ألا تزيد صفحاته عن (35) صفحة من القطع العادي (A4).
2) أن يحتوي على عنوان البحث وملخصه باللغتين العربية والإنجليزية في صفحة واحدة، بحيث لا يزيد عن (250) كلمة للملخص، وأن يتضمن البحث كلمات مفتاحية دالة على التخصص الدقيق للبحث باللغتين، بحيث لا يتجاوز عددها (6) كلمات، توضع بعد نهاية كل ملخص.
3) أن يذكر اسم المؤلف وجهة عمله بعد عنوان البحث مباشرة باللغتين العربية والإنجليزية.
4) أن تقدم البحوث العربية مطبوعة بخط (Simplified Arabic)، بحجم (14) للنصوص في المتن، وبالخط نفسه بحجم (12) للهوامش.
5) أن تقدم البحوث الإنجليزية مطبوعة بخط (Times New Roman) بحجم (12) للنصوص في المتن، وبالخط نفسه بحجم (9) للهوامش.
6) كتابة البحث على وجه واحد من الصفحة، مع ترك مسافة سطر واحد بين السطور، وتكون الحواشي 2.5 سم على الجوانب الأربعة للصفحة، بما يعادل 1.00 إنش (بوصة).
7) التزام الترتيب الموضوعي الآتي:

المقدمة: تكون دالة على موضوع البحث، والهدف منه، ومنسجمة مع ما يَرِدُ في البحث من معلومات وأفكار وحقائق علمية، كما تشير باختصار إلى مشكلة البحث، وأهمية الدراسات السابقة.

العرض: يتضمن التفاصيل الأساسية لمنهجية البحث، والأدوات والطرق التي تخدم الهدف، وترتب المعلومات حسب أولويتها.

النتائج والمناقشة: يجب أن تكون واضحة موجزة، مع بيان دلالاتها دون تكرار.

الخاتمة: تتضمن تلخيصًا موجزًا للموضوع، وما توصل إليه الباحث من نتائج، مع ذكر التوصيات والمقترحات.

8) أن تدرج الرسوم البيانية والأشكال التوضيحية في النص، وترقم ترقيماً متسلسلاً، وتكتب أسماؤها والملاحظات التوضيحية أسفلها.
9) أن تدرج الجداول في النص، وترقم ترقيماً متسلسلاً، وتكتب أسماؤها أعلاها، وأما الملاحظات التوضيحية فتكتب أسفل الجدول.
10) ألا توضع الهوامش أسفل الصفحة إلا عند الضرورة فقط، ويشار إليها برقم أو نجمة، ويكون الخط فيها بحجم (12) للعربي و (9) للإنجليزي.
11) لا تنشر المجلة أدوات البحث والقياس، وتقوم بحذفها عند طباعة المجلة.
12) أن يُراعى في منهج توثيق المصادر والمراجع داخل النص نظام (APA)، وهو نظام يعتمد ذكر الاسم والتاريخ (name/year) داخل المتن، ولا يقبل نظام ترقيم المراجع داخل النص مع وضع الحاشية أسفل الصفحة، وتوضع المصادر والمراجع داخل المتن بين قوسين حسب الأمثلة الآتية: يذكر اسم عائلة المؤلف متبوعا بفاصلة، فسنة النشر، مثلا: (مجاهد، 1988م). وفي حالة الاقتباس المباشر يضاف رقم الصفحة مباشرة بعد تاريخ النشر مثلا: (خيري، 1985م، ص:33). أما إذا كان للمصدر مؤلفان فيذكران مع اتباع الخطوات السابقة مثلا: (الفالح وعياش، 1424هـ). وفي حالة وجود أكثر من مؤلفين فتذكر أسماء عوائلهم أول مرة، مثلا: (مجاهد والعودات والشيخ، 1408هـ)، وإذا تكرر الاقتباس من المصدر نفسه فيشار إلى اسم عائلة المؤلف الأول فقط، ويكتب بعده وآخرون مثل: (مجاهد وآخرون، 1408هـ)، على أن تكتب معلومات النشر كاملة في قائمة المصادر والمراجع.
13) توضع قائمة المصادر والمراجع في نهاية البحث مرتبة ترتيباً هجائياً حسب اسم العائلة، ووفق نظام جمعية علم النفس الأمريكية (APA) الإصدار السادس، وبحجم (12) للعربي و(9) للإنجليزي، وترتب البيانات الببليوغرافية على النحو الآتي:

- **الاقتباس من كتاب لمؤلف واحد:**

الخوجلي، أحمد. (2004م). ***مبادئ فيزياء الجوامد***. الخرطوم، السودان: عزة للنشر والتوزيع

مجلة الشمال للعلوم الأساسية والتطبيقية (JNBAS)

التعريف بالمجلة

تعنى المجلة بنشر البحوث والدراسات العلمية الأصيلة في مجال العلوم الأساسية والتطبيقية، باللغتين العربية والإنجليزية، كما تهتم بنشر جميع ما له علاقة بعرض الكتب ومراجعتها أو ترجمتها، وملخصات الرسائل العلمية، وتقارير المؤتمرات والندوات العلمية، وتصدر مرتين في السنة (مايو - نوفمبر).

الرؤية

الريادة في نشر البحوث العلمية المحكمة، وتصنيف المجلة ضمن أشهر الدوريات العلمية العالمية.

الرسالة

نشر البحوث العلمية المحكمة في مجال العلوم الأساسية والتطبيقية وفق معايير عالمية متميزة.

أهداف المجلة

1) أن تكون المجلة مرجعًا علميًا للباحثين في العلوم الأساسية والتطبيقية.
2) تلبية حاجة الباحثين إلى نشر بحوثهم العلمية، وإبراز مجهوداتهم البحثية على المستويات المحلية والإقليمية والعالمية.
3) المشاركة في بناء مجتمع المعرفة بنشر البحوث الرصينة التي تؤدي إلى تنمية المجتمع.
4) تغطية أعمال المؤتمرات العلمية المحكمة.

شروط قبول البحث

1) الأصالة والابتكار وسلامة المنهج والاتجاه.
2) الالتزام بالمناهج والأدوات والوسائل العلمية المتبعة في مجاله.
3) الدقة في التوثيق والمصادر والمراجع والتخريج.
4) سلامة اللغة.
5) أن يكون البحث غير منشور أو مقدم للنشر في أي مكان آخر.
6) أن يكون البحث المستل من الرسائل العلمية غير منشور أو مقدم للنشر، وأن يشير الباحث إلى أنه مستلٌ.

للمراسلة

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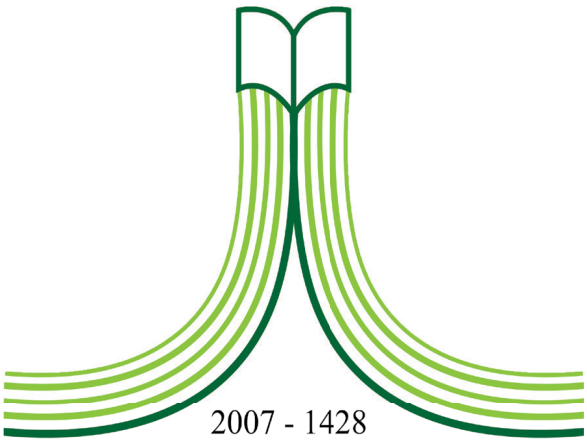

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