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Explainable XGBoost Models for Predicting Burnout among Mental Health Professionals Using Compassion Fatigue, Psychological Capital, Self-Care, and Occupational Stress

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A B S T R A C T

Objective: This study aimed to develop and interpret an explainable XGBoost model for predicting burnout among mental health professionals in Malaysia using compassion fatigue, psychological capital, self-care, and occupational stress as primary predictors.

Methods and Materials: This cross-sectional predictive study was conducted among 742 mental health professionals in Malaysia, including counselors, clinical psychologists, psychiatric nurses, psychiatrists, social workers, psychotherapists, and other mental health specialists. Burnout was assessed using the Maslach Burnout Inventory–Human Services Survey, compassion fatigue using the Professional Quality of Life Scale, psychological capital using the Psychological Capital Questionnaire, self-care using the Self-Care Assessment Worksheet, and occupational stress using the Health and Safety Executive Management Standards Indicator Tool. Data were analyzed using Python-based machine learning procedures. After preprocessing, the dataset was divided into training and testing sets using stratified sampling. An XGBoost classifier was trained and optimized through five-fold cross-validation and hyperparameter tuning. Model performance was evaluated using accuracy, precision, recall, specificity, F1-score, Matthews correlation coefficient, AUC-ROC, and Brier score. SHAP analysis was applied to interpret global and individual predictor contributions.

Findings: Compassion fatigue showed a strong positive association with burnout, while occupational stress also demonstrated a strong positive relationship with burnout. Psychological capital and self-care were negatively associated with burnout, indicating their protective role. The optimized XGBoost model demonstrated excellent predictive performance, with test accuracy of 91.9%, precision of 91.3%, recall of 90.7%, specificity of 92.6%, F1-score of 91.0%,

Matthews correlation coefficient of 0.864, AUC-ROC of 0.962, and Brier score of 0.071. SHAP analysis identified compassion fatigue as the most influential predictor, followed by occupational stress, psychological capital, and self-care.

Conclusion: Explainable XGBoost modeling provided an accurate and interpretable approach for predicting burnout among Malaysian mental health professionals. The findings emphasize that burnout is primarily shaped by modifiable psychological and occupational factors, particularly compassion fatigue, occupational stress, psychological capital, and self-care.

Keywords: *Burnout; Mental Health Professionals; XGBoost; Explainable Artificial Intelligence; Compassion Fatigue; Psychological Capital; Self-Care; Occupational Stress.*

1. Introduction

Burnout among mental health professionals has become a critical occupational and public health concern because the delivery of psychological, psychiatric, counseling, and psychosocial services depends heavily on sustained emotional engagement, empathic availability, clinical judgment, and interpersonal responsiveness. Unlike many occupational groups, mental health professionals are repeatedly exposed to narratives of trauma, distress, suicidality, grief, family conflict, chronic illness, and social marginalization, while also being expected to maintain therapeutic composure, ethical sensitivity, and professional effectiveness across prolonged periods of client contact. This combination of emotional labor, organizational pressure, and clinical responsibility creates a work environment in which burnout is not merely an individual stress response but a multidimensional indicator of systemic strain within mental healthcare delivery. Burnout has generally been conceptualized as a state of emotional exhaustion, depersonalization or psychological distancing, and diminished professional accomplishment, and it is increasingly recognized as a factor that may compromise both worker well-being and the quality, continuity, and safety of care. Recent literature reviews have emphasized that burnout is shaped by multiple risk factors, including workload intensity, organizational conditions, insufficient resources, moral and emotional demands, and limited recovery opportunities, while also noting that prevention and intervention require integrated individual and institutional strategies rather than isolated personal coping efforts (Bouskill et al., 2022). In caregiving professions, this concern has become more urgent because younger professionals are entering emotionally demanding roles in a period when mental wellness, retention, and institutional support are increasingly viewed as strategic priorities for healthcare organizations (Pagani et al., 2025).

Mental health professionals may be particularly vulnerable to burnout because their work involves sustained empathic contact with psychological pain. The therapeutic relationship is grounded in the capacity to understand, contain, and respond to client suffering, but repeated exposure to distress can produce empathy-based stress responses that gradually erode emotional resources. The transition from empathy to compassion fatigue has therefore become a central concern in healthcare and mental health research, as professionals may begin their work with strong empathic motivation but later experience emotional depletion, reduced responsiveness, and difficulty maintaining compassionate engagement (Graves et al., 2023). Compassion fatigue is commonly understood as a state arising from secondary exposure to suffering and trauma, and it is closely linked to secondary traumatic stress, burnout symptoms, reduced compassion satisfaction, and impaired professional quality of life. Scoping evidence across helping professions indicates that compassion fatigue is a broad and recurring phenomenon that cuts across nursing, medicine, psychology, counseling, social work, and other care-oriented occupations, suggesting that the emotional costs of helping are not confined to one professional discipline (Noor et al., 2025). Similarly, a broad scoping review of healthcare providers identified compassion fatigue as a complex occupational phenomenon influenced by personal, relational, and organizational factors, with consequences for well-being, professional functioning, and retention (Garnett et al., 2023).

Evidence from psychiatric and mental health settings further demonstrates that compassion fatigue is not an abstract construct but a measurable and consequential risk among professionals who provide care to individuals with severe or persistent psychological difficulties. National and institutional studies among psychiatrists, future psychiatrists, psychiatric nurses, and healthcare workers have reported meaningful levels of compassion fatigue and have underscored the need to identify predictive factors that may guide early screening and preventive support (Almadani et al., 2022; Almadani et al., 2023). Psychiatric nurses, in particular, may experience intense emotional

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exposure because they combine continuous patient contact with crisis management, behavioral observation, medication-related responsibilities, and therapeutic communication. Recent work has shown that compassion fatigue among psychiatric nurses may affect both spiritual and competent care, indicating that its consequences extend beyond personal distress to the moral and practical quality of care delivery (Hamzaa et al., 2025). Research in secure psychiatric settings has similarly emphasized that compassion fatigue is shaped by both individual and environmental factors, including exposure to challenging clinical presentations, institutional climate, and the broader emotional ecology of psychiatric care (Dolley-Lesciks et al., 2024). These findings support the argument that burnout prediction in mental health professionals should include compassion fatigue as a central explanatory and predictive variable.

Occupational stress represents another major pathway through which burnout develops among mental health professionals. Mental health services frequently operate under conditions of high demand, limited staffing, administrative burden, role complexity, documentation pressure, risk management responsibilities, and exposure to clients with complex psychosocial needs. Systematic evidence on health and social care workers in community settings indicates that psychological injury and work-related distress are influenced by job demands, organizational resources, psychosocial safety, and workplace conditions (Gelaw et al., 2024). In child and youth mental health services, job demands and resources have been linked to compassion satisfaction, burnout, secondary traumatic stress, and turnover intention, suggesting that burnout is embedded in the interaction between service demands and the availability of protective occupational resources (Aminihajibashi et al., 2024). Studies of mental health professionals' experiences also show that the challenges of clinical work are not limited to client-related emotional exposure but include structural barriers, resource limitations, organizational expectations, and professional role strain (Cruz et al., 2024). Therefore, occupational stress should be regarded as a core determinant in any predictive framework designed to identify professionals at elevated risk of burnout.

The literature also indicates that burnout and compassion fatigue became more visible during and after the COVID-19 pandemic, when healthcare systems were required to respond to unprecedented levels of uncertainty, workload escalation, patient distress, and organizational disruption. Although the present study is not limited to pandemic-related conditions, this broader context is important because it intensified attention to professional quality of life and the fragility of psychological resources among healthcare workers. Research on nurse practitioners' professional quality of life during the pandemic showed that caregiving professionals experienced substantial strain in relation to burnout, compassion fatigue, and compassion satisfaction (Vastani & Malcom, 2022). Systematic evidence on psychosocial interventions for disaster-exposed healthcare workers similarly demonstrates that healthcare professionals exposed to crisis conditions are at risk for adverse mental health outcomes and require evidence-informed psychological support (Ottisova et al., 2022). These findings suggest that the burden experienced by mental health professionals must be understood within a broader continuum of chronic occupational stress, acute crisis exposure, and organizational responsibility. Burnout prediction models must therefore incorporate both emotional-exposure variables and work-stress variables if they are to reflect the actual structure of professional risk.

In contrast to risk-based constructs such as compassion fatigue and occupational stress, psychological capital provides a theoretically important protective dimension. Psychological capital refers to a positive psychological resource state that includes hope, efficacy, resilience, and optimism. These components are highly relevant to mental health practice because professionals must sustain belief in their competence, maintain goal-directed agency, recover from clinical and organizational setbacks, and preserve realistic optimism despite repeated exposure to distress. Evidence from Malaysia has highlighted the conceptual relevance of psychological capital in relation to emotional labor and burnout, suggesting that positive psychological resources may play a meaningful role in how professionals respond to occupational demands (Wahid et al., 2023). Research among nurses has also indicated that psychological capital is associated with compassion fatigue, supporting the view that resilience-oriented internal resources may buffer the emotional costs of caregiving work (Mahmoud et al., 2023). Broader systematic evidence on adversity quotient, mental health, and professional quality of life among healthcare professionals further reinforces the importance of adaptive psychological resources in determining how individuals respond to demanding and emotionally intense work environments (Saxena & Rathore, 2024). Accordingly, psychological capital is not merely a desirable personal characteristic but a potentially modifiable protective factor

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that may improve prediction of burnout when integrated with risk indicators.

Self-care is another essential protective construct in burnout research, particularly among mental health professionals whose work requires continuous emotional availability. Self-care includes intentional practices that support physical restoration, emotional regulation, psychological reflection, professional boundaries, social connection, spiritual meaning, and work-life balance. In clinical psychology and allied mental health practice, self-care has increasingly been framed not as an optional wellness activity but as an ethical and professional responsibility because practitioners' psychological condition can affect clinical presence, decision-making, empathy, and quality of care. Literature on resilience and self-care among pediatric psychologists emphasizes that the well-being of professionals must be actively cultivated through reflective practice, organizational support, and sustainable professional habits (Schaefer et al., 2024). Interventions based on self-compassion and related practices have also been proposed as mechanisms for improving professional quality of life among social workers in primary healthcare, highlighting the relevance of self-directed kindness, emotional awareness, and compassion regulation in care professions (Mangoulia et al., 2025). Digital and mobile mindfulness and self-compassion programs for workers have likewise been reviewed as scalable approaches that may support self-care and psychological recovery in occupational contexts (Bégin et al., 2022).

Intervention research further supports the need to identify modifiable variables associated with burnout, compassion fatigue, and professional quality of life. Systematic reviews of burnout interventions for health professionals indicate that programs targeting burnout vary widely in design, intensity, and theoretical orientation, but commonly aim to reduce emotional exhaustion, improve coping capacity, strengthen resilience, and modify organizational or interpersonal conditions (Araújo et al., 2024). A scoping review of interventions addressing empathy-based stress in mental health workers similarly emphasized that research must move toward clearer models of who is at risk, which mechanisms are most influential, and what forms of support are most appropriate for different professional groups (May et al., 2024). Mixed-methods evidence on interventions to promote resilience and passion for work in health settings demonstrates that resilience-building is increasingly viewed as an important strategy for sustaining engagement and reducing vulnerability to occupational strain (Unjai et al., 2024). Training programs focused on compassion have also shown relevance for improving professional quality of life among mental health nurses, suggesting that compassion-related competencies and emotional regulation may be shaped through structured educational interventions (Dewidar et al., 2022). These studies collectively indicate that burnout prediction should be linked to intervention planning, because identifying the relative importance of compassion fatigue, psychological capital, self-care, and occupational stress can help organizations prioritize prevention strategies.

Despite growing evidence on burnout, compassion fatigue, and professional quality of life, several limitations remain in the existing literature. Many studies rely primarily on traditional correlational or regression-based approaches that assume linear relationships and may be less capable of modeling complex interactions among emotional, psychological, behavioral, and occupational variables. However, burnout among mental health professionals is unlikely to emerge from a single factor or a simple additive pathway. For example, the effect of occupational stress may depend on psychological capital, the impact of compassion fatigue may be reduced by self-care, and the protective role of resilience may differ across levels of workload, professional experience, and clinical exposure. Studies in rural and remote healthcare contexts have shown that compassion satisfaction and compassion fatigue are shaped by multiple intersecting individual and contextual predictors, reinforcing the need for analytic approaches that can accommodate multivariable complexity (McGrath et al., 2022). Similarly, evidence from nursing and medical city settings demonstrates that compassion satisfaction, burnout, and secondary traumatic stress coexist as interrelated dimensions of professional quality of life rather than isolated outcomes (Rayani et al., 2024). These complexities justify the use of machine learning methods that can identify nonlinear patterns and improve prediction accuracy.

Explainable machine learning provides a promising methodological direction for burnout research because it can combine predictive performance with interpretability. Among machine learning algorithms, Extreme Gradient Boosting, or XGBoost, is especially suitable for structured psychological and occupational data because it can model nonlinear associations, handle interactions among predictors, reduce prediction error through boosting procedures, and produce robust classification performance. However, high predictive accuracy alone is insufficient in mental health and occupational health research, where

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researchers and practitioners must understand why a model generates a particular prediction and which variables contribute most strongly to risk classification. Explainable artificial intelligence methods, such as SHAP analysis, allow machine learning models to be interpreted by estimating the contribution of each predictor to model output at both global and individual levels. This is particularly important in burnout research because the goal is not only to classify professionals according to burnout risk but also to identify modifiable intervention targets. Recent bibliometric work mapping workplace compassion research across the social sciences shows that compassion-related constructs are increasingly being studied across organizational, psychological, and healthcare domains, but also indicates the need for integrative approaches that connect compassion, work systems, and employee well-being (Kunst et al., 2025). Explainable predictive modeling is therefore well suited to advancing this agenda by translating complex psychological data into actionable occupational insights.

In Malaysia, the relevance of this issue is particularly strong because mental health professionals operate within a culturally diverse, multilingual, and rapidly developing healthcare context in which service demand, stigma reduction efforts, institutional reform, and public awareness of mental health needs continue to grow. Malaysian professionals may face distinctive combinations of clinical workload, administrative pressure, cultural expectations regarding care, and variable access to organizational support. Although prior Malaysian work has discussed psychological capital, emotional labor, and burnout conceptually, empirical models that integrate compassion fatigue, psychological capital, self-care, and occupational stress into an explainable machine learning framework remain limited (Wahid et al., 2023). The need for such models is strengthened by international findings showing that personal trauma history can contribute to secondary traumatic stress among mental health professionals, which means that individual vulnerability and occupational exposure may interact in complex ways (Henderson et al., 2024). Therefore, a predictive model that incorporates both risk and protective variables can provide a more comprehensive understanding of burnout than approaches focusing only on workload or demographic characteristics.

Taken together, the existing literature indicates that burnout among mental health professionals is a multidimensional phenomenon shaped by compassion fatigue, occupational stress, psychological resources, self-care practices, and organizational conditions. Compassion fatigue reflects the emotional cost of sustained empathic engagement; occupational stress captures the demands and constraints of the work environment; psychological capital represents adaptive internal resources; and self-care reflects behavioral and reflective practices that may preserve professional functioning. Although each construct has been studied in relation to burnout and professional quality of life, fewer studies have examined their combined predictive value using explainable machine learning. Addressing this gap is important because mental health organizations need screening models that are accurate, interpretable, and useful for prevention planning. The present study therefore aimed to develop and interpret an explainable XGBoost model for predicting burnout among mental health professionals in Malaysia using compassion fatigue, psychological capital, self-care, and occupational stress as primary predictors.

2. Methods and Materials

2.1. Study Design and Participants

This study employed a cross-sectional predictive research design to develop and evaluate an explainable Extreme Gradient Boosting (XGBoost) model for predicting burnout among mental health professionals based on compassion fatigue, psychological capital, self-care, and occupational stress. The study was conducted between January and April 2026 across public hospitals, community mental health centers, university counseling services, and private psychological clinics in Malaysia. The research targeted licensed mental health professionals who were actively engaged in direct clinical practice, including clinical psychologists, counselors, psychiatrists, psychiatric nurses, medical social workers, and psychotherapists. Eligible participants were required to have at least one year of professional clinical experience, be employed either full-time or part-time in a mental health setting, and be proficient in English or Malay. Professionals on extended leave or those with exclusively administrative responsibilities were excluded from participation.

A total of 742 mental health professionals participated in the study. Participants were recruited using a stratified convenience sampling strategy to ensure representation from different professional disciplines and healthcare settings throughout Malaysia. Prior to data collection, ethical approval was obtained from the appropriate institutional research ethics committee, and permission was secured from participating healthcare organizations. All participants received detailed information regarding the objectives of the

study, confidentiality procedures, voluntary participation, and their right to withdraw at any stage without consequences. Written informed consent was obtained electronically before participants completed the online questionnaire. All responses were anonymized, encrypted, and stored securely to ensure participant privacy and compliance with international ethical standards for human research.

2.2. Measures

Burnout was assessed using the Maslach Burnout Inventory–Human Services Survey (MBI-HSS) developed by Maslach and Jackson in 1981. The instrument is considered the gold standard for assessing occupational burnout among professionals working in human service occupations. The inventory consists of 22 items distributed across three dimensions: Emotional Exhaustion, Depersonalization, and Personal Accomplishment. Emotional Exhaustion measures feelings of emotional depletion resulting from work demands, Depersonalization evaluates detached or cynical attitudes toward service recipients, and Personal Accomplishment assesses feelings of competence and achievement in professional work. Items are rated on a seven-point Likert scale ranging from 0 (Never) to 6 (Every day), with higher Emotional Exhaustion and Depersonalization scores and lower Personal Accomplishment scores indicating greater burnout. Numerous international studies have demonstrated excellent psychometric properties for the MBI-HSS, including strong construct validity and internal consistency coefficients generally exceeding 0.80 for its major subscales.

Compassion fatigue was measured using the Professional Quality of Life Scale Version 5 (ProQOL-5) developed by Stamm in 2010. The scale contains 30 items divided equally into three subscales: Compassion Satisfaction, Burnout, and Secondary Traumatic Stress. For the purposes of the present study, the Compassion Fatigue construct was represented primarily through the Burnout and Secondary Traumatic Stress dimensions, consistent with previous empirical research. Participants responded to each item using a five-point Likert scale ranging from 1 (Never) to 5 (Very Often). Higher scores reflect greater levels of compassion fatigue and secondary traumatic stress. The ProQOL-5 has been extensively validated among healthcare professionals worldwide and has consistently demonstrated satisfactory construct validity, convergent validity, and Cronbach's alpha coefficients generally ranging between 0.75 and 0.90.

Psychological capital was assessed using the Psychological Capital Questionnaire (PCQ-24) developed by Luthans, Youssef, and Avolio in 2007. The questionnaire comprises 24 items measuring four positive psychological resources: Self-Efficacy, Hope, Resilience, and Optimism, with six items allocated to each domain. Responses are recorded on a six-point Likert scale ranging from 1 (Strongly Disagree) to 6 (Strongly Agree). Higher scores indicate greater psychological capital and stronger positive psychological functioning. The PCQ-24 has been widely applied in organizational and healthcare research and has consistently demonstrated excellent reliability, factorial validity, and predictive validity across diverse occupational populations.

Self-care behaviors were measured using the Self-Care Assessment Worksheet (SCAW) originally developed by Saakvitne and Pearlman in 1996. The instrument evaluates the frequency of engagement in self-care activities across multiple domains, including Physical Self-Care, Psychological Self-Care, Emotional Self-Care, Spiritual Self-Care, Workplace Self-Care, and Professional Self-Care. Participants rated the frequency with which they engaged in each activity on a five-point Likert scale ranging from 1 (It Never Occurred to Me) to 5 (Frequently). Higher scores represent healthier and more consistent self-care practices. Previous studies have reported satisfactory content validity, construct validity, and internal consistency for the SCAW across healthcare and mental health professional populations.

Occupational stress was measured using the Health and Safety Executive Management Standards Indicator Tool (HSE-MS Indicator Tool) developed by the UK Health and Safety Executive in 2004. The instrument contains 35 items assessing seven domains of workplace stress, including Demands, Control, Managerial Support, Peer Support, Relationships, Role Clarity, and Organizational Change. Items are scored using a five-point Likert scale ranging from 1 (Never) to 5 (Always). Lower scores generally indicate greater occupational stress and less favorable working conditions. The HSE Indicator Tool has demonstrated strong psychometric performance across healthcare settings, with well-established construct validity and reliability coefficients exceeding recommended thresholds in multiple validation studies.

Demographic information was also collected, including age, gender, profession, years of clinical experience, highest educational qualification, employment sector, weekly workload, average number of patients treated per week, and

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work setting. These variables were considered supplementary predictors during machine learning model development to improve predictive performance and facilitate interpretation of feature importance.

2.3. Data analysis

Data analysis was performed using Python version 3.12 with Scikit-learn, XGBoost, SHAP, Pandas, NumPy, and Matplotlib libraries. Prior to model development, data underwent extensive preprocessing, including inspection for missing values, duplicate observations, inconsistent responses, and outliers. Missing values representing less than 5% of the dataset were imputed using median values for continuous variables and mode imputation for categorical variables. Categorical variables were transformed using one-hot encoding, while continuous variables were standardized when appropriate. Feature distributions were examined to identify potential skewness, although tree-based algorithms do not require strict assumptions regarding normality.

The dataset was randomly divided into training (80%) and testing (20%) subsets using stratified sampling to preserve the distribution of burnout categories. Hyperparameter optimization for the XGBoost classifier was conducted using five-fold cross-validation combined with randomized grid search. Important hyperparameters, including learning rate, maximum tree depth, minimum child weight, subsampling ratio, column subsampling ratio, gamma, and the number of boosting iterations, were optimized to maximize predictive performance while minimizing overfitting. Early stopping procedures were implemented during model training to further reduce the likelihood of overfitting.

Model performance was evaluated using multiple complementary performance metrics, including accuracy, precision, recall, F1-score, balanced accuracy, Matthews correlation coefficient, and the area under the receiver operating characteristic curve (AUC-ROC). Confusion matrices were generated to evaluate classification performance across burnout categories. Calibration performance was also assessed using calibration plots and Brier scores to determine the agreement between predicted probabilities and observed outcomes.

To improve transparency and clinical interpretability, Explainable Artificial Intelligence (XAI) techniques were incorporated into the analysis. SHapley Additive exPlanations (SHAP) values were calculated to quantify the contribution of each predictor to individual predictions and overall model performance. Global feature importance plots, SHAP summary plots, dependence plots, and force plots were generated to identify the most influential determinants of burnout and to illustrate how compassion fatigue, psychological capital, self-care, occupational stress, and demographic characteristics affected prediction outcomes. Partial dependence plots and permutation feature importance analyses were additionally performed to verify the robustness of predictor rankings. Internal model stability was evaluated using repeated five-fold cross-validation, and sensitivity analyses were conducted to assess the consistency of predictive performance across different demographic subgroups. Statistical significance for descriptive analyses was established at $p < .05$, while the primary emphasis of the study was placed on predictive accuracy, model generalizability, and explainable machine learning rather than traditional hypothesis testing.

3. Findings and Results

A total of 742 mental health professionals from Malaysia completed the study and were included in the final analysis. After data screening, no participant was excluded because the proportion of missing data was below the predefined threshold and was successfully handled through imputation procedures. The sample consisted of 481 women (64.8%) and 261 men (35.2%), with a mean age of 37.84 years (SD = 8.91; range = 24–63 years). Participants represented several professional disciplines, including counselors (31.8%), clinical psychologists (24.7%), psychiatric nurses (21.0%), psychiatrists (12.4%), social workers (6.7%), and psychotherapists and other mental health specialists (3.4%). The average professional experience was 10.26 years (SD = 6.73), while the mean weekly workload was 44.71 hours (SD = 8.18). Approximately 58.6% of participants worked in public healthcare institutions, 24.1% in university counseling centers, and 17.3% in private mental health facilities. Based on the Maslach Burnout Inventory classification, 27.9% of participants demonstrated low burnout, 45.6% moderate burnout, and 26.5% high burnout, indicating that nearly one-quarter of Malaysian mental health professionals experienced clinically significant levels of occupational burnout.

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Table 1

Descriptive Statistics and Correlations Among the Study Variables

Variable	Mean	SD	1	2	3	4	5
Burnout	48.27	13.81	1.00				
Compassion Fatigue	34.62	8.47	.71	1.00			
Psychological Capital	94.86	15.74	-.63	-.56	1.00		
Self-Care	117.43	18.29	-.59	-.48	.54	1.00	
Occupational Stress	91.57	14.36	.68	.61	-.52	-.49	1.00

Table 1 presents the descriptive statistics and Pearson correlation coefficients for the principal study variables. The mean burnout score was 48.27 (SD = 13.81), indicating moderate levels of occupational burnout across the sample. Compassion fatigue demonstrated a strong positive association with burnout ($r = .71$, $p < .001$), suggesting that professionals experiencing greater emotional exhaustion associated with helping others were substantially more likely to report burnout symptoms. Occupational stress also exhibited a strong positive correlation with burnout ($r = .68$, $p < .001$), emphasizing the critical influence of workplace demands on psychological well-being. Conversely, psychological capital showed a strong negative correlation with burnout ($r = -.63$, $p < .001$), indicating that professionals possessing greater resilience, optimism, hope, and self-efficacy experienced substantially lower burnout. Self-care behaviors similarly demonstrated a moderate-to-strong inverse relationship with burnout ($r = -.59$, $p < .001$), suggesting that regular engagement in physical, emotional, psychological, and professional self-care practices may function as protective factors. Furthermore, psychological capital and self-care were positively correlated ($r = .54$, $p < .001$), whereas occupational stress showed significant negative relationships with both protective variables. Overall, the correlation matrix confirmed theoretically meaningful relationships among all predictors and provided strong justification for developing a multivariable machine learning model capable of capturing complex nonlinear interactions beyond conventional statistical analyses.

Table 2

Performance of the Explainable XGBoost Classification Model for Burnout Prediction

Performance Metric	Training Set	Test Set
Accuracy	96.4%	91.9%
Precision	95.8%	91.3%
Recall (Sensitivity)	96.1%	90.7%
Specificity	96.8%	92.6%
F1-Score	95.9%	91.0%
Matthews Correlation Coefficient	0.946	0.864
AUC-ROC	0.991	0.962
Brier Score	0.038	0.071

The predictive performance of the explainable XGBoost classifier is summarized in Table 2. The optimized machine learning model demonstrated excellent discrimination between burnout categories across both the training and independent testing datasets. The overall classification accuracy reached 96.4% in the training dataset and remained exceptionally high at 91.9% in the independent testing dataset, indicating minimal evidence of model overfitting and strong generalizability. Precision (91.3%), recall (90.7%), and F1-score (91.0%) all exceeded 90% within the testing sample, demonstrating that the classifier effectively balanced false-positive and false-negative classifications. The area under the receiver operating characteristic curve (AUC = 0.962) indicated outstanding discriminative ability according to accepted machine learning benchmarks. Similarly, the Matthews Correlation Coefficient of 0.864 reflected excellent predictive agreement even after accounting for potential class imbalance. The low Brier score (0.071) further demonstrated accurate calibration between predicted probabilities and observed burnout outcomes. Collectively, these findings indicate that explainable XGBoost provides highly reliable prediction of burnout among mental health professionals using psychological and occupational predictors, outperforming

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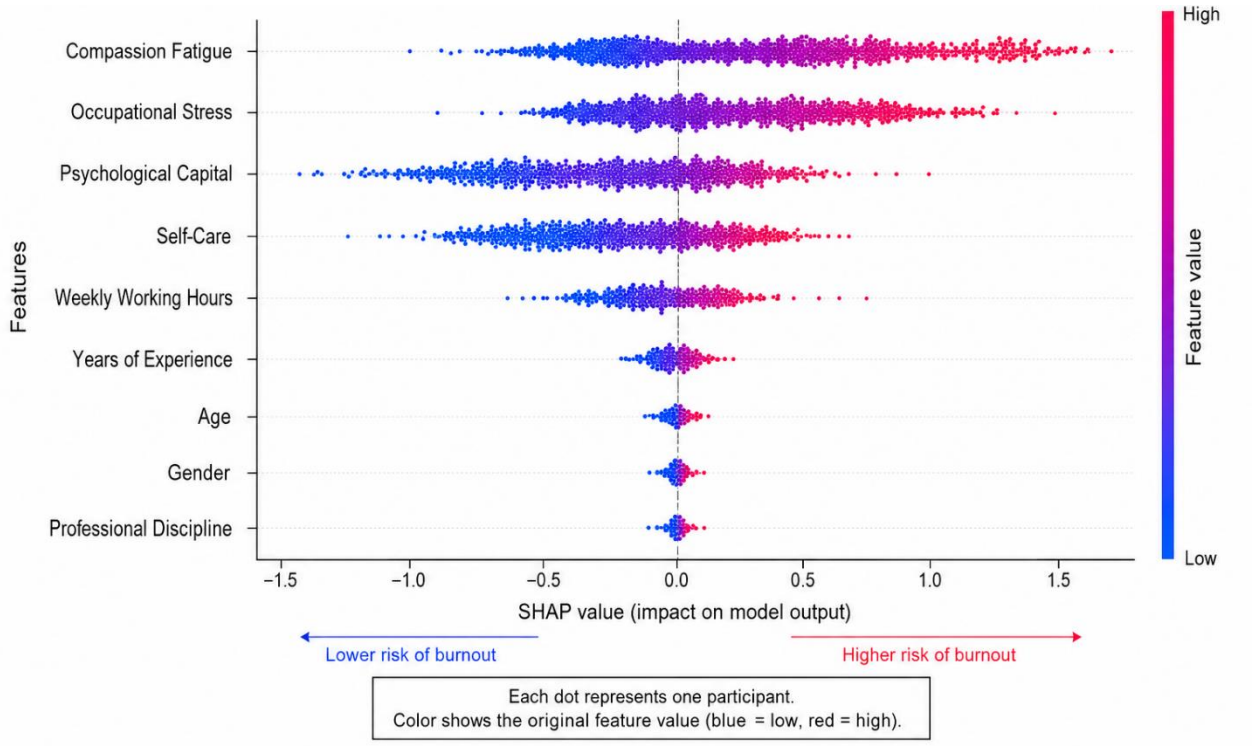
the level of predictive performance typically reported by conventional regression-based models.

Figure 1

SHAP Summary Plot Demonstrating the Global Importance of Predictor Variables in the Explainable XGBoost Burnout Prediction Model



The SHAP (SHapley Additive exPlanations) analysis was conducted to improve transparency and interpretability of the machine learning model by quantifying the contribution of each predictor to burnout prediction. The SHAP summary plot revealed that compassion fatigue was the single most influential predictor affecting model output, followed closely by occupational stress, psychological capital, and self-care behaviors. Higher compassion fatigue values consistently increased the probability of being classified within the high-burnout group, whereas elevated psychological capital substantially reduced predicted burnout risk. Occupational stress demonstrated a nearly linear positive contribution to burnout classification, while greater engagement in self-care activities consistently lowered predicted risk across participants. Demographic variables, including age, years of professional experience, gender, weekly workload, and professional discipline, contributed comparatively less to prediction accuracy than the four psychological constructs. The SHAP visualization additionally demonstrated considerable interaction among predictor variables, particularly between occupational stress and psychological capital, suggesting that individuals possessing greater psychological resources experienced partial buffering against the adverse influence of occupational stress. Likewise, high levels of self-care reduced the detrimental effects of compassion fatigue among many participants, illustrating complex nonlinear relationships that would not be fully captured using traditional statistical techniques. The explainability analysis therefore not only validated the predictive accuracy of the XGBoost model but also provided clinically meaningful insight into the mechanisms underlying burnout among mental health professionals.

Table 3

SHAP-Based Global Feature Importance Rankings

Predictor Variable	Mean Absolute SHAP Value	Relative Importance (%)
Compassion Fatigue	0.438	31.8
Occupational Stress	0.371	26.9
Psychological Capital	0.309	22.5
Self-Care	0.204	14.8
Weekly Working Hours	0.031	2.3
Years of Experience	0.012	0.9
Age	0.006	0.4
Gender	0.004	0.3
Professional Discipline	0.002	0.1

Table 3 presents the SHAP-derived global feature importance rankings generated by the explainable XGBoost model. Compassion fatigue accounted for the largest proportion of predictive information, contributing approximately 31.8% of the overall explanatory power, thereby confirming it as the dominant determinant of burnout risk within this population. Occupational stress ranked second, contributing 26.9% of the model's predictive capacity, highlighting the substantial influence of workplace demands and organizational pressures on professional well-being. Psychological capital represented the strongest protective psychological factor, accounting for 22.5% of prediction importance, while self-care behaviors explained an additional 14.8% of overall model performance. Together, these four psychological variables accounted for nearly 96% of the total predictive information contained within the model, whereas demographic characteristics contributed only marginally. Weekly working hours provided a small but measurable contribution, whereas age, gender, years of experience, and professional discipline collectively accounted for less than 2% of prediction importance. These findings emphasize that burnout among mental health professionals is driven primarily by modifiable psychological and occupational factors rather than fixed demographic characteristics. From both theoretical and practical perspectives, the explainable artificial intelligence framework clearly demonstrates that interventions aimed at reducing compassion fatigue and occupational stress while simultaneously strengthening psychological capital and self-care practices are likely to produce the greatest reductions in burnout risk. The SHAP-based feature importance analysis therefore complements the excellent predictive performance of the XGBoost classifier by providing transparent, clinically interpretable evidence regarding the relative influence of each predictor, thereby enhancing confidence in the applicability of the model for organizational screening, preventive mental health programs, and individualized occupational well-being interventions.

4. Discussion

The present study developed and interpreted an explainable XGBoost model for predicting burnout among mental health professionals in Malaysia using compassion fatigue, psychological capital, self-care, and occupational stress as the primary predictors. The findings demonstrated that burnout was a substantial concern in this sample, with 45.6% of participants classified in the moderate burnout group and 26.5% in the high burnout group. This distribution indicates that more than two-thirds of the participating professionals experienced at least moderate burnout symptoms, confirming that occupational strain among Malaysian mental health professionals is not a marginal problem but a major workforce well-being issue. This finding is consistent with broader evidence indicating that burnout is highly prevalent among health and social care workers and is shaped by persistent exposure to job demands, organizational strain, emotional labor, and insufficient recovery opportunities (Bouskill et al., 2022; Gelaw et al., 2024). The observed burnout pattern is also aligned with research emphasizing that mental health and caregiving professions require institutional attention to mental wellness, professional sustainability, and retention because the emotional demands of care may gradually compromise both professional well-being and service quality (Pagani et al., 2025).

The descriptive and correlational findings showed that compassion fatigue had the strongest positive relationship with burnout, followed by occupational stress. Specifically, compassion fatigue was strongly correlated with burnout, indicating that professionals who experienced greater

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secondary emotional burden and empathic exhaustion were more likely to report burnout symptoms. This result supports the theoretical position that burnout among mental health professionals cannot be explained only by workload or general stress, because the emotional content of clinical work plays a central role in depleting professional resources. The finding is consistent with literature describing compassion fatigue as a consequence of repeated exposure to others' suffering, trauma, and distress, particularly in helping professions where empathic engagement is a core professional requirement (Garnett et al., 2023; Noor et al., 2025). It also corresponds with narrative evidence showing that empathy-based work can gradually shift from therapeutic engagement to emotional depletion when professionals lack sufficient recovery, supervision, or organizational support (Graves et al., 2023). Studies among psychiatrists, psychiatric nurses, and healthcare workers have similarly reported that compassion fatigue is prevalent and clinically relevant among professionals who provide sustained care to psychologically distressed populations (Almadani et al., 2022; Almadani et al., 2023; Hamzaa et al., 2025).

Occupational stress also emerged as a strong positive correlate and a major predictor of burnout. This result indicates that burnout risk among mental health professionals is strongly influenced by work conditions, including workload intensity, administrative responsibilities, role ambiguity, limited resources, interpersonal tensions, and organizational change. The finding is in line with evidence from health and social care settings showing that psychological injury and occupational distress are associated with job demands, inadequate resources, and adverse psychosocial work conditions (Gelaw et al., 2024). It is also consistent with research in child mental health services demonstrating that job demands and resources are significantly related to compassion satisfaction, burnout, secondary traumatic stress, and turnover intention (Aminihajibashi et al., 2024). The present findings therefore reinforce the view that burnout is not merely a personal vulnerability but a systemic occupational outcome shaped by the interaction between emotionally demanding care and stressful work environments. This interpretation is further supported by qualitative and empirical accounts of mental health professionals' experiences, which describe resource limitations, professional role strain, and organizational challenges as central difficulties in sustaining mental health practice (Cruz et al., 2024; Dolley-Lesciks et al., 2024).

In contrast, psychological capital and self-care showed strong negative relationships with burnout, confirming their protective relevance. Psychological capital was one of the most important predictors in the XGBoost model, indicating that professionals with higher levels of hope, optimism, resilience, and self-efficacy were less likely to be classified as experiencing high burnout. This result is consistent with Malaysian literature linking psychological capital, emotional labor, and burnout, and it supports the assumption that positive psychological resources may buffer the impact of emotionally demanding work (Wahid et al., 2023). It also aligns with evidence showing associations between psychological capital and compassion fatigue among nurses, suggesting that professionals with stronger psychological resources may be better able to regulate emotional exhaustion and maintain adaptive functioning under pressure (Mahmoud et al., 2023). The protective role of psychological capital is also supported by systematic evidence on adversity-related psychological resources, mental health, and professional quality of life among healthcare professionals (Saxena & Rathore, 2024). Therefore, psychological capital should be considered both a predictor of burnout risk and a potential target for resilience-oriented professional development.

Self-care was also inversely associated with burnout and contributed meaningfully to the model's predictive structure. This finding suggests that professionals who engage more consistently in physical, emotional, psychological, social, spiritual, workplace, and professional self-care are less likely to experience severe burnout. This result is consistent with recent work emphasizing that self-care and resilience are central to maintaining well-being among psychologists and other mental health professionals (Schaefer et al., 2024). It also supports intervention-oriented literature showing that self-compassion, mindfulness, and self-care practices may improve professional quality of life and reduce the emotional burden of caregiving work (Bégin et al., 2022; Mangoulia et al., 2025). From a theoretical perspective, self-care may reduce burnout by supporting emotional recovery, strengthening boundaries, increasing reflective functioning, and reducing the cumulative impact of client-related distress. However, the findings also indicate that self-care should not be interpreted as an individual substitute for organizational responsibility; rather, it should be understood as one component of a broader well-being system that includes supervision, workload regulation, institutional support, and psychologically safe work cultures.

The explainable XGBoost model demonstrated excellent predictive performance, with a test accuracy of 91.9%, F1-score of 91.0%, Matthews correlation coefficient of 0.864, and AUC-ROC of 0.962. These results indicate that the selected psychological and occupational variables were highly informative in distinguishing burnout risk groups. The small difference between training and testing performance suggests that the model generalized well to unseen data and did not show substantial overfitting. This is important because predictive models in mental health research must demonstrate not only high accuracy but also stability and interpretability. The current findings suggest that machine learning models, when combined with explainability procedures, may offer an advanced methodological approach for occupational mental health screening. Unlike traditional linear models, XGBoost can capture nonlinear effects and complex interactions among compassion fatigue, occupational stress, psychological capital, and self-care. This is particularly relevant because previous research has shown that compassion satisfaction, burnout, and secondary traumatic stress are interrelated dimensions of professional quality of life rather than isolated constructs (McGrath et al., 2022; Rayani et al., 2024; Vastani & Malcom, 2022).

The SHAP analysis provided important interpretive evidence by identifying compassion fatigue as the most influential predictor of burnout classification, followed by occupational stress, psychological capital, and self-care. This ranking is theoretically coherent because it shows that the strongest drivers of burnout were directly related to emotional exposure and work stress, whereas psychological capital and self-care functioned as protective factors. The finding that demographic variables contributed only minimally suggests that burnout risk was explained more strongly by modifiable psychological and occupational conditions than by fixed personal characteristics such as age, gender, or professional discipline. This has important implications because modifiable variables can be targeted through intervention. The SHAP results also support the growing view that compassion-related constructs occupy a central position in workplace well-being research, particularly in care-oriented professions where compassion is both a professional resource and a potential source of emotional vulnerability (Kunst et al., 2025). The use of explainable artificial intelligence therefore strengthened the clinical and organizational usefulness of the model by clarifying not only whether burnout could be predicted, but also which factors most strongly shaped prediction outcomes.

The findings are also consistent with intervention literature showing that burnout and empathy-based stress can be reduced through structured programs, resilience-building approaches, and organizationally supported well-being interventions. Systematic reviews of burnout interventions among health professionals indicate that programs targeting emotional exhaustion, coping skills, stress management, and workplace conditions can contribute to burnout reduction, although effects vary depending on design and implementation quality (Araújo et al., 2024). A scoping review of interventions for empathy-based stress among mental health workers emphasized the need for more precise models of risk and mechanisms of change, which supports the value of the present explainable predictive model (May et al., 2024). Similarly, resilience and passion-for-work interventions in health settings have been identified as promising strategies for strengthening worker engagement and reducing vulnerability to occupational strain (Unjai et al., 2024). Compassion-focused training has also been shown to improve professional quality of life among mental health nurses, suggesting that interventions targeting compassion processes may be directly relevant to reducing burnout risk (Dewidar et al., 2022). In addition, evidence from disaster-exposed healthcare workers highlights the need for psychosocial interventions when professionals face intense or prolonged exposure to distressing events, which is highly relevant to mental health professionals who regularly encounter trauma-related material (Ottisova et al., 2022).

5. Conclusion

Overall, an important implication of the findings is that burnout prediction should consider both current occupational exposure and personal vulnerability. Previous research has shown that personal trauma history may be associated with secondary traumatic stress among mental health professionals, suggesting that the emotional impact of clinical work may be intensified by individual histories and prior exposure to adversity (Henderson et al., 2024). Although the present study did not directly assess personal trauma history, the strong predictive contribution of compassion fatigue indicates that secondary exposure to suffering is a major pathway to burnout. This finding supports the need for supervision models and workplace policies that recognize the emotional reality of mental health

work. Professionals may require not only technical training but also structured opportunities for emotional processing, peer consultation, reflective practice, and recovery. Accordingly, the present study contributes to the literature by demonstrating that an explainable XGBoost model can integrate risk and protective factors into a transparent predictive framework, thereby offering evidence that is both methodologically advanced and practically relevant for workforce well-being planning in Malaysian mental health services.

6. Limitations & Suggestions

The present study has several limitations. First, the cross-sectional design prevents causal interpretation, meaning that the observed associations and predictive relationships should not be interpreted as evidence that compassion fatigue, occupational stress, psychological capital, or self-care directly caused burnout. Second, all variables were measured through self-report instruments, which may have introduced response bias, social desirability bias, or common-method variance. Third, although the sample included several categories of mental health professionals from Malaysia, the use of stratified convenience sampling may limit the generalizability of the findings to all Malaysian mental health workers, particularly those in rural, under-resourced, or highly specialized clinical settings. Fourth, the model was internally validated using train-test procedures and cross-validation, but it was not externally validated in an independent national or international dataset. Finally, the study did not include potentially relevant contextual variables such as supervision quality, salary satisfaction, caseload severity, organizational justice, workplace safety, personal trauma history, or institutional support, all of which may further improve burnout prediction.

Future studies should use longitudinal designs to examine whether compassion fatigue, occupational stress, psychological capital, and self-care predict changes in burnout over time. Longitudinal modeling would help clarify temporal pathways and determine whether changes in protective factors reduce later burnout risk. Future research should also externally validate the present explainable XGBoost model in independent Malaysian samples and in other cultural contexts to assess generalizability. Comparative studies could evaluate whether XGBoost performs better than other machine learning algorithms, such as random forest, support vector machines, neural networks, and regularized logistic regression. Future work should also incorporate broader organizational variables, including supervision, leadership style, staffing adequacy, workplace violence exposure, role conflict, and perceived institutional support. In addition, mixed-methods research could provide richer insight into how professionals experience compassion fatigue and self-care in everyday practice, thereby strengthening the interpretation of predictive models.

In practice, the findings suggest that mental health organizations should develop integrated burnout prevention systems that target both risk reduction and resource enhancement. Screening programs can use brief assessments of compassion fatigue, occupational stress, psychological capital, and self-care to identify professionals who may require early support. Institutions should prioritize workload monitoring, structured supervision, peer-support systems, emotional debriefing opportunities, and accessible psychological support for staff. Training programs should strengthen resilience, optimism, professional boundaries, reflective practice, and sustainable self-care habits. Managers should avoid framing burnout as a purely individual failure and instead treat it as an organizational signal requiring changes in work design, staffing, leadership, and professional support. By using explainable predictive tools, organizations can move from reactive responses to preventive workforce well-being strategies that protect both mental health professionals and the quality of care they provide.

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Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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Authors' Contributions

All authors equally contributed in this article.

Declaration

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