Review Article Open Access

Archives Of Breast Cancer

DOI: 10.32768/abc.202512115-22

Prediction of Distress Tolerance in Patients with Breast Cancer based on Anger Rumination and Physical Health: Using an Artificial Neural Network

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ARTICLE INFO

Received:
24 February 2024
Revised:
5 May 2024
Accepted:
6 May 2024

Keywords:
Breast cancer, Distress, health, Anger, Women, Artificial Intelligence

ABSTRACT

Background: Breast cancer is a common cancer in women, causing significant psychological consequences. Traditionally, researchers have relied on statistical methods to predict factors influencing distress in cancer patients. However, this study explores the potential of artificial neural networks (ANNs) as a novel approach for predicting distress tolerance in women with breast cancer. This study aims to explore the use of ANNs in predicting distress tolerance in women with breast cancer based on anger rumination and physical health.

Methods: The research method was descriptive and correlational. The statistical population of this study consisted of 207 women with breast cancer admitted to the hematology-oncology department of Shafa Hospital in Ahvaz in 2023, selected using convenience sampling. Data were collected using Distress Tolerance Scale (DTS), Anger Rumination Scale (ARS), and Physical Health Questionnaire (PHQ). Data analysis involved the Pearson correlation coefficient and ANN. SPSS-27 was used for initial analyses and MATLAB-2019 was used for ANN modeling.

Results: The results showed a negative relationship between anger rumination and distress tolerance, and a positive one between physical health and distress tolerance in women with breast cancer ($P<0.001$). Furthermore, a significant correlation was found among anger rumination, physical health, and distress tolerance in these women ($P<0.001$). The ANN analysis also showed that anger rumination had the most significant connection with distress tolerance in the patients, followed by physical health.

Conclusion: This study identified significant associations between anger rumination, physical health, and distress tolerance in women with breast cancer. These findings add to our understanding of distress tolerance in women with breast cancer, emphasizing the need to address psychological and physical health in interventions to improve well-being.

INTRODUCTION

Breast cancer is a leading global health concern, affecting roughly one in eight new cancer diagnoses in women worldwide.[1] Each year, over 2.5 million women receive a breast cancer diagnosis, with projections suggesting this number will continue to rise.[2-4] Beyond the physical threat, breast cancer significantly impacts patients and their families. The disease can challenge a woman's identity and disrupt family dynamics, as women often play central roles within the household.[5,6] Recognizing the broader impact of breast cancer, including its psychological effects, is crucial for effective patient care.[7]

A diagnosis of breast cancer, similar to many other cancers, can be life-altering and lead to significant emotional distress.[8] Patients exhibiting low distress

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tolerance, characterized by reduced emotional flexibility and a perceived lack of control, often experience difficulty coping with the challenges associated with the disease.[9] Unique challenges faced by women with breast cancer, such as the uncertainty surrounding treatment outcomes, body image alterations, and the fear of recurrence, can further exacerbate this emotional distress. Distress tolerance, defined as an individual's capacity to tolerate emotional distress[10,11], is particularly relevant in this population as it plays a critical role in understanding these challenges. For women with breast cancer, distress tolerance can be instrumental in managing increased irritability, anxiety, and difficulties in processing negative emotions that may arise throughout their treatment and survival. One factor influencing distress tolerance in this population is anger rumination.

Research suggests a stronger correlation between anger and blood pressure in patients with low distress tolerance compared to those with high distress tolerance.[12] This implies that individuals with lower distress tolerance may experience more frequent anger and engage in anger rumination. Anger rumination is a form of negative self-referential thinking that hinders an individual's ability to cope effectively with life experiences, impacting both self-perception and future outlook.[13] It can impair information processing and lead to cognitive biases towards oneself and others, potentially increasing the risk of developing psychological disorders.[14] Similar to anger rumination, cognitive rumination involves repetitive, passive thoughts focused on the causes of negative outcomes. This type of rumination, encompassing both anger and self-criticism, acts as a barrier to problem-solving and fuels negative emotions like anger and distress.[15] Supporting these findings, Sedighi Arfaee *et al.*[16] identified a significant association between rumination (including anger) and distress tolerance.

Physical health also emerges as a significant factor related to distress tolerance. Throughout life, individuals encounter both physical and emotional pain, with pain itself being an unpredictable and inevitable aspect of the human experience.[17] Some individuals struggling with pain exhibit unhealthy coping mechanisms, such as disengaging from activities or experiencing a loss of rational thinking, which can ultimately exacerbate their distress.[18,19] Notably, those with lower distress tolerance may be particularly susceptible to these unproductive coping strategies. Aware of their limited tolerance for discomfort, they might believe others possess better resources for managing negative emotions, leading to feelings of overwhelm.[20] Supporting this notion, research by Vujanovic *et al.*[21] and Li *et al.*[22] demonstrates a significant link between mental and physical health, and distress tolerance.

In the existing literature, there is a notable gap in the methods used to assess distress tolerance in women with breast cancer. Current approaches often struggle to effectively capture the complex interplay between anger rumination, physical health, and distress tolerance in this specific patient population. Women with breast cancer face unique challenges and limitations in controlling and regulating their emotions, particularly in dealing with stress, fear, and anger. The proposed approach in this study aims to address this gap by investigating the potential utility of artificial neural networks (ANNs) as a novel method for predicting distress tolerance in women diagnosed with breast cancer. ANNs offer a novel solution due to their capacity to mimic the human brain's architecture, enabling them to learn and model complex, non-linear relationships between variables. By leveraging this capability, the study seeks to surpass traditional methods and provide a more comprehensive understanding of distress tolerance within this specific population, ultimately aiming to predict distress tolerance based on anger rumination and physical health in women with breast cancer using an ANN.

METHODS

The current study was a descriptive correlational study employing ANN. The statistical population comprised all female women with breast cancer in the hematology department of Shafa Hospital in Ahvaz in 2023. Using convenience sampling, a total of 207 individuals were selected as the sample for this study. The sample size was estimated based on the research variables. Inclusion criteria consisted of having been diagnosed with breast cancer for at least one year, responding to all questions, being aged between 22 and 50 years (this age range has been chosen because studies suggest younger women with breast cancer often experience unique challenges in coping with the disease compared to older populations)[23], and providing informed consent to participate in the study. The exclusion criteria included failure to answer all the questions in the questionnaire and lack of satisfaction with continued participation in the study. To ensure adherence to ethical principles, informed consent was obtained from all participants after a thorough explanation of the study procedures and potential risks and benefits. Participant confidentiality and anonymity were safeguarded. All the collected information was maintained confidentially, and the study results are reported in an aggregate manner that precludes the identification of individual participants. The study protocol was reviewed and approved by the university's ethics

committee. At the end of the research, the participants received a small gift certificate for their time and contribution to the research.

Instruments

The Distress Tolerance Scale (DTS)

This scale is a self-report measure of emotional distress tolerance developed by Simons and Gaher.[24] The items of this scale assess distress tolerance based on an individual's abilities to tolerate emotional distress; cognitive appraisal of distress, attention to negative emotions when they occur, and regulatory actions for distress relief. The DTS consists of 15 items and 4 subscales: Tolerance (emotional distress tolerance), Absorption (being absorbed by negative emotions), Appraisal (cognitive appraisals of distress), and Regulation (regulating efforts for distress relief). The items in this instrument are scored on a 5-point Likert scale. completely agree (1), somewhat agree (2), neutral (3), somewhat disagree (4), completely disagree (5). The minimum and maximum scores on this scale are 15 and 75, respectively. Higher scores on this scale indicate higher distress tolerance. The internal consistency of the instruments was assessed using Cronbach's alpha coefficient. The DTS demonstrated acceptable reliability with a coefficient of 0.77.[25] In this study, the Cronbach's alpha for the entire scale was found to be 0.82.

The Anger Rumination Scale (ARS)

The ARS by Sukhodolsky *et al.*[26] is a 19-item test that measures the tendency to contemplate current anger-provoking situations and recall past anger-provoking experiences. The items of this scale assess angry afterthoughts, thoughts of revenge, angry memories, and understanding of causes on a 4-point Likert scale ranging from 1 (very low) to 4 (very high). The possible range of scores on the ARS in this study would be 19 (minimum score), indicating almost no anger rumination, to 76 (maximum score), indicating very frequent anger rumination. The ARS exhibited good internal consistency ($\alpha = 0.85$) (27). In the present study, the scale's reliability was assessed using a Cronbach's alpha coefficient, which was determined to be 0.83.

The Physical Health Questionnaire

The PHQ was designed by Schat *et al.*[28], consisting of 14 questions and 4 dimensions of physical health including headaches, sleep disturbances, gastrointestinal, and respiratory problems. The items in this questionnaire are scored on a 7-point Likert scale. Scores range from 14 to 98, with lower scores indicating better physical health. The PHQ demonstrated satisfactory reliability based on the findings of Abasi *et al.*[29] ($\alpha = 0.80$). In the present study, Cronbach's alpha was used to determine the reliability of the PHQ, yielding a value of 0.81.

Statistical analyses

Data analysis involved a combination of SPSS-27 for initial analyses and MATLAB-2019 for the development and training of an ANN model. Descriptive statistics (mean, standard deviation) were calculated using SPSS-27 to summarize the data. Pearson correlation coefficients were also computed to assess the linear relationships between the study variables (anger rumination, physical health, and distress tolerance).

For the ANN modeling, MATLAB-2019 was used. The data was pre-processed by normalizing the input variables to ensure that all input features were on a similar scale. The research question focused on the ability of the ANN to predict distress tolerance in women with breast cancer based on anger rumination and physical health. The pre-processed data was then divided into training (70.0%), validation (15.0%), and test sets (15.0%) for model training and evaluation. The input layer of the ANN consisted of two nodes representing anger rumination and physical health scores, while the output layer had one node representing the predicted distress tolerance score. The performance of the ANN model was evaluated using metrics such as the mean squared error to assess the accuracy of the model's predictions. To determine the optimal network architecture, different configurations were explored, and the best performing model utilized a two-hidden layer structure with 7 neurons in the first layer and 9 neurons in the second layer.

RESULTS

The study sample comprised 207 women diagnosed with breast cancer. The mean age of the participants was 42.38 years (SD= 6.52). The findings related to demographic variables showed that 171 (82.61%) patients were married, and 36 (17.39%) were single. In terms of education, 41 (19.80%) women had middle school education, 77 (37.20%) had high school education, and 89 (43.0%) had university education. A total of 169 (81.64%) individuals had been diagnosed with breast cancer for over 3 years, while 38 (18.36%) individuals had been diagnosed with the disease for less than 3 years. Table 1 presents the mean, standard deviation (SD), and correlation coefficients of the research variables. The Pearson correlation analysis revealed significant associations between the study variables. Anger rumination exhibited a moderate negative correlation with distress tolerance ($r= -0.57$, $P < 0.001$), indicating that higher levels of anger rumination were associated with lower distress tolerance in women

with breast cancer. Conversely, physical health demonstrated a moderate positive correlation with distress tolerance (r= 0.52, P < 0.001). This suggests that better physical health is associated with greater distress tolerance in this population. Therefore, the research hypothesis was confirmed as follows: 1) Distress tolerance could be predicted based on anger rumination in women with breast cancer. 2) Distress tolerance could be predicted based on physical health in women with breast cancer.

Table 1. Mean, standard deviation (SD), and Pearson correlation coefficients of the research variables

Variables	Mean	SD	Correlation coefficients
Distress tolerance	44.75	8.01	1
Anger rumination	50.26	9.87	-0.57**
Physical health	55.06	14.47	0.52**

**: P<0.01

In this study, an ANN was designed using MATLAB software. The research question was: Can distress tolerance be predicted based on anger rumination and physical health in women with breast cancer using an ANN? Initially, the data were divided as follows for input to the network: 70.0% as the training set, 15.0% as the validation set, and 15.0% as the test set. Two inputs and one output in the form of an Excel file were provided to the network as a matrix. Based on the obtained results, the best outcome was achieved using two hidden layers, with the first layer consisting of 7 neurons and the second layer consisting of 9 neurons. The structure of the ANN with the best possible estimation is presented in Figure 1.

Due to the uncertainty of the optimal training iteration count, the early stopping method is employed to simultaneously present the training dataset and optimize the network weights, using the evaluation dataset exclusively for prediction until the error improvement is negligible.

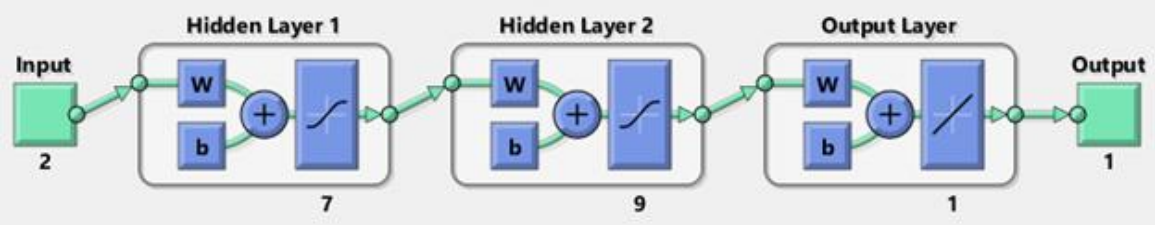

Figure 1. The structure of the ANN with the most accurate estimate

Training iterations persist until the optimal number is determined based on the minimum sum of the training dataset. As depicted in Figure 2, the neural network training process progresses from input data. Based on the settings applied, the network ceased training after 9 consecutive iterations with the evaluation set error, with the halt occurring at iteration 15.

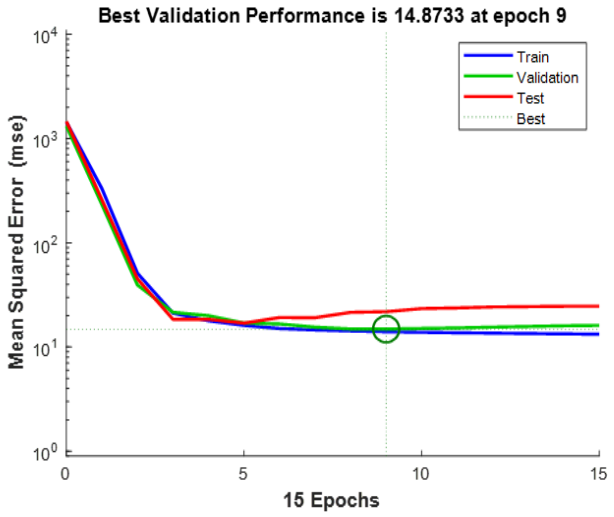

Figure 2. Diagram of the network efficiency

As illustrated in the Figure 2, the following observations were made: 1) The final mean squared error value is minimized. 2) The test set error exhibits behavior and characteristics comparable to the evaluation set error. 3) No overfitting occurred up to the 9th iteration, which corresponds to the optimal performance regarding the evaluation set.

The precise relationship between anger rumination and physical health with distress tolerance in women with breast cancer was estimated using an ANN. The results, as depicted in Figure 3, indicated that anger rumination had the strongest relationship with distress tolerance in women with breast cancer, followed by physical health. Therefore, it can be stated that the ANN provided a suitable estimation in predicting distress tolerance in women with breast cancer.

DISCUSSION

The aim of this study was to predict distress tolerance in women with breast cancer based on anger rumination and physical health. The finding indicated that distress tolerance can be predicted based on anger rumination in women with breast cancer. This finding aligns with the results of similar studies, such as those

by Shadara *et al.*[30] The high prevalence of breast cancer across diverse societies necessitates a deeper understanding of its impact on patients' mental and emotional well-being. Studies have shown that breast cancer diagnosis and treatment can lead to increased stress, worry, anxiety, and even depression.[8]

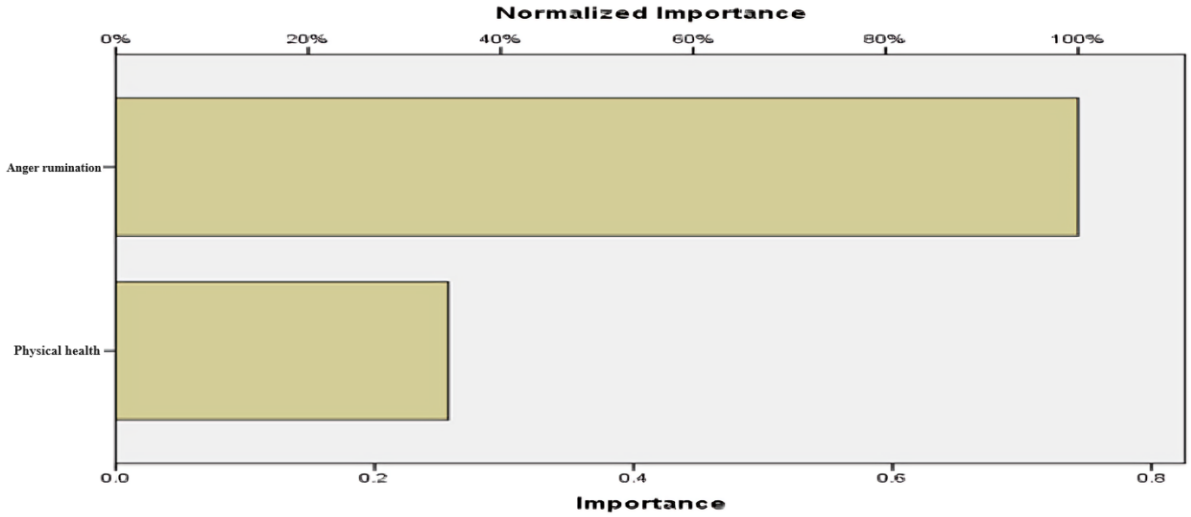

Figure 3. The relative importance of predictor variables for distress tolerance in women with breast cancer

These psychological and emotional challenges significantly contribute to diminished distress tolerance in women with breast cancer. Distress tolerance, defined as the capacity to manage negative emotions, influences how individuals react to stress. Patients with lower distress tolerance exhibit more pronounced negative reactions compared to those with higher tolerance.[31] In this context, anger rumination emerges as a potentially detrimental coping strategy. Characterized by repetitive thoughts and feelings about anger-provoking experiences, anger rumination can alter emotions, thoughts, behaviors, and physiological responses. One potential mechanism involves the activation of the amygdala, a brain region central to processing emotions like anger. Rumination on anger-related events may keep the amygdala in a heightened state, leading to sustained feelings of anger and difficulty regulating them. Furthermore, anger rumination can negatively impact the prefrontal cortex, which plays a crucial role in cognitive control and emotional regulation. By fixating on anger-provoking experiences, rumination may impair the prefrontal cortex's ability to inhibit negative emotions and promote more adaptive coping strategies.[30] These neurobiological changes can ultimately reduce distress tolerance, making it even harder for women with breast cancer to manage the emotional challenges associated with their diagnosis and treatment. Therefore, anger rumination becomes a self-perpetuating cycle that amplifies negative emotions and hinders a patient's ability to manage them effectively. By understanding the mechanisms by which anger rumination influences distress tolerance, we can develop more targeted interventions to help women with breast cancer cope with the emotional challenges of their illness.

The finding demonstrated that distress tolerance can be predicted based on physical health in women with breast cancer. This finding is consistent with the results of studies by Corkum *et al.*[32] In explicating this mechanism, we can explore the interplay between physical health and biological factors that influence emotional regulation. Good physical health is often characterized by a well-functioning immune system, a balanced hormonal profile, and adequate sleep.[33] These factors can influence distress tolerance through several pathways. Chronic inflammation, often associated with some cancers and poorer physical health, can negatively impact mood and emotional regulation. Inflammatory markers in the bloodstream are linked to increased activity in brain regions associated with negative emotions.[34] Physical health can also influence the production and availability of neurotransmitters like serotonin and dopamine, which play a crucial role in mood regulation. For example, some studies suggest that exercise, a key component of physical health, can promote the release of these neurotransmitters, potentially improving emotional well-being.[35] Adequate sleep is vital for emotional regulation and cognitive functioning. Disrupted sleep patterns, common in some cancer patients due to pain or treatment side effects, can exacerbate negative emotions and reduce distress tolerance.[33] Therefore, by promoting good physical health through a healthy diet, exercise, and adequate sleep, we may be able to improve emotional regulation and enhance distress tolerance in women with breast cancer.

The results also indicated that anger rumination exhibited the strongest correlation with distress tolerance in women with breast cancer, followed by physical health. Therefore, it can be said that the ANN provided an adequate estimation in predicting distress tolerance in women with breast cancer. In explicating this hypothesis, it can be stated that breast cancer is one of the serious health issues for women, which has significant impacts on the women themselves and their families. Breast cancer may lead to increased stress, anxiety, and depression in women, resulting in reduced quality of life and strained family relationships. Breast cancer treatment brings changes to a woman's daily life, potentially reducing her daily activities, efficiency, and independence. It may also alter her relationships with her spouse, children, and close relatives.[36] Therefore, appropriate support for these patients can be effective in increasing distress tolerance and coping with the stress of having the disease.

Cancer diagnosis and treatment can be immensely stressful experiences.[36] However, how individuals respond to this distress and their willingness to engage in treatment interventions can be significantly shaped by cultural norms, beliefs, and social support systems. Different cultures have varying expectations regarding the expression of emotions. In some cultures, stoicism and emotional control might be emphasized, leading individuals to suppress their distress and potentially delay seeking help. Conversely, other cultures may encourage open expression of emotions, facilitating earlier help-seeking behavior. Cultural values surrounding body image can influence how individuals perceive cancer treatments that may alter their appearance (e.g., surgery, or hair loss).[37] These perceptions can impact treatment adherence and emotional well-being. Cultural beliefs about the cause of illness can influence treatment choices. For instance, some cultures may favor traditional healing practices alongside conventional medicine, while others may prioritize allopathic medicine. Religious faith can provide a strong coping mechanism and social support network for cancer patients. Beliefs in a higher power or afterlife can offer comfort and hope, influencing treatment decisions and emotional responses.

This research on distress tolerance in breast cancer holds significant value for clinical practice. By understanding the interplay between anger rumination, physical health, and distress tolerance, healthcare providers can tailor interventions and support services for each patient. Early screening for emotional distress and anger rumination becomes crucial. Clinicians can then create personalized treatment plans that might involve referrals for therapies like cognitive behavioral therapy or mindfulness training to address rumination, or incorporate nutritional counseling and exercise programs to promote physical health, a factor influencing distress tolerance. Support groups can also be a powerful tool. The importance lies in early detection and intervention. By proactively managing emotional distress, patients are more likely to adhere to treatment plans, potentially leading to better clinical outcomes. Furthermore, effectively managing distress allows patients to cope better with the emotional challenges of cancer, ultimately improving their overall quality of life. This shift towards a more holistic approach that addresses both physical and emotional well-being has the potential to empower women with breast cancer and significantly impact their fight against the disease.

The present study was accompanied by certain limitations, understanding of which appears rational for conducting further research and efforts to reduce or eliminate these limitations. Since this research was conducted among females with breast cancer in the city of Ahvaz, the obtained results may not be generalizable to women with breast cancer and other chronic diseases in other regions with different cultural and personality characteristics. Non-cooperation and reluctance of some women to participate in the study were among other research limitations.

Future research could address these limitations by recruiting participants from multiple healthcare centers across different regions to enhance the generalizability of the findings. Investigating the influence of additional factors on distress tolerance, such as social support networks, coping mechanisms, cultural background, and access to mental health services. Employing longitudinal designs to examine how these factors and distress tolerance change over time during the breast cancer experience is recommended. Exploring potential interactive effects between the identified variables (anger rumination, physical health) and other factors can be beneficial in order to gain a more comprehensive understanding of distress tolerance in women with breast cancer.

CONCLUSION

In conclusion, this study revealed significant associations between anger rumination, physical health, and distress tolerance in women with breast cancer. The inverse relationship between anger rumination and distress tolerance, alongside the positive correlation with physical health, highlights the complex interplay between psychological and physical factors. This underscores the importance of considering both aspects in managing distress for this patient population. However, traditional statistical

methods often assume linear relationships, potentially missing intricate details. ANNs offer a unique perspective by modeling non-linear relationships and uncovering hidden patterns within the data. In this study, the ANN analysis corroborated the significant influence of anger rumination and further emphasized the role of physical health in predicting distress tolerance. These findings, informed by the strengths of ANNs, enhance our understanding of the multifaceted nature of distress tolerance in women with breast cancer. The importance of addressing both psychological and physical aspects in interventions designed to improve distress tolerance and overall quality of life is further emphasized. Women with breast cancer experiencing distress can benefit from a multi-pronged approach to improve their ability to manage negative emotions. Clinicians can incorporate evidence-based interventions like cognitive behavioral therapy to address anger rumination, and encourage healthy habits like exercise and proper sleep to promote physical health. Additionally, stress management techniques and social support groups can enhance overall coping skills. A collaborative effort between mental health professionals, oncologists, and supportive care providers is crucial to delivering comprehensive care that addresses both the physical and emotional challenges of breast cancer.

ETHICAL CONSIDERATIONS

The study was approved by the Ethical Committee of Islamic Azad University- Ahvaz Branch (code: IR.IAU.AHVAZ.REC.1401.011).

FUNDING

This research did not receive any funding grants from public, commercial, or nonprofit agencies.

CONFLICT OF INTEREST

No conflicts of interest exist regarding the publication of the present study.

ACKNOWLEDGEMENTS

None.

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How to Cite This Article

Azarnia M, Naderi F, Makvandi B. Prediction of Distress Tolerance in Patients with Breast Cancer based on Anger Rumination and Physical Health: Using an Artificial Neural Network. Arch Breast Cancer. 2024; 11(3):15-22.
Available from: https://www.archbreastcancer.com/index.php/abc/article/view/902