KMAN PUBLISHING INSTITUTE
Journal Website

Article history:
Received 13 April 2025
Revised 24 July 2025
Accepted 01 August 2025
Published online 01 October 2025

Psychology of Woman Journal

Volume 6, Issue 4, pp 1-8

E-ISSN: 3041-8515

Investigating the Mediating Role of Negative Repetitive Thoughts in the Relationship Between Behavioral Brain Systems and Sleep Quality With Mental Fatigue in Women With Type 2 Diabetes

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Article Info

Article type:
Original Research

How to cite this article:
Talaei Kahjugh, M., Nikmanesh, A., & Pourmohammad Ghouchani, K. (2025). Investigating the Mediating Role of Negative Repetitive Thoughts in the Relationship Between Behavioral Brain Systems and Sleep Quality With Mental Fatigue in Women With Type 2 Diabetes. *Psychology of Woman Journal, 6*(4), 1-8.
http://dx.doi.org/10.61838/kman.pwj.4288

ABSTRACT

Objective: The present study aimed to determine the mediating role of negative repetitive thoughts in the relationship between behavioral brain systems and sleep quality with mental fatigue in women with type 2 diabetes.

Materials and Methods: This study was a correlational design using structural equation modeling. The statistical population included all women with type 2 diabetes who were members of the Diabetes Patients Support Association in Tehran Province in 2025. A total of 265 women were selected as the research sample through convenience sampling. The instruments used in this study included the Negative Repetitive Thoughts Questionnaire (McEvoy, Mahoney, & Moulds, 2012), the Behavioral Inhibition/Activation Systems Scale (Carver & White, 1994), the Pittsburgh Sleep Quality Index (Buysse et al., 1989), and the Mental Fatigue Questionnaire (Smets, 1996). The data were analyzed using path analysis.

Findings: The results showed that there was a significant and positive relationship between behavioral brain systems and sleep quality with mental fatigue through the mediation of negative repetitive thoughts. However, negative repetitive thoughts did not play a significant mediating role in the relationship between the behavioral activation system and mental fatigue.

Conclusion: Our findings suggest that negative repetitive thoughts, behavioral brain systems, and sleep quality can be considered fundamental constructs in chronic illnesses such as type 2 diabetes. It can be concluded that these mechanisms may play a critical role in the persistence of the disease, and considering these relationships could be beneficial for the etiology and treatment of individuals with type 2 diabetes.

Keywords: *Negative repetitive thoughts, behavioral brain systems, sleep quality, mental fatigue, type 2 diabetes*

1. Introduction

Mental fatigue, characterized by a persistent sense of cognitive tiredness, low motivation, and diminished mental performance, is increasingly recognized as a significant health issue among individuals with chronic medical conditions, including type 2 diabetes. Type 2 diabetes is not only a metabolic disorder but also a condition deeply intertwined with psychological and neurocognitive dimensions that affect patients' quality of life and functional capacities (Foroghian-Yazdi et al., 2020; Pourmohammad Ghouchani et al., 2023). Among the many psychological constructs associated with mental fatigue in chronic illness populations, sleep disturbances, neurobehavioral regulation, and maladaptive cognitive patterns have received considerable attention in recent empirical research (Clancy et al., 2020; Cox & Olatunji, 2020; Harris et al., 2021).

Sleep quality, which encompasses both subjective and objective aspects of sleep experience, is a central factor influencing mental and physical health outcomes. Numerous studies have demonstrated that poor sleep quality is strongly associated with greater fatigue, impaired emotional regulation, and a higher risk of mood and anxiety disorders (Buysse et al., 1989; Li et al., 2021; Soleimany et al., 2008). In the context of type 2 diabetes, sleep disturbances are highly prevalent and may arise due to physiological changes, medication effects, or comorbid psychological symptoms such as anxiety and rumination (Spitzer et al., 2006; Tsay et al., 2004). Importantly, individuals experiencing chronic conditions often report cyclical patterns of poor sleep and daytime fatigue, with each exacerbating the other over time (Harris et al., 2021; McCallum et al., 2019). These bidirectional dynamics necessitate a deeper examination of the mediating mechanisms that may explain how sleep disturbances contribute to mental fatigue in diabetic populations.

From a neuropsychological perspective, individual differences in brain-behavioral systems, as conceptualized by Gray's reinforcement sensitivity theory (RST), offer a theoretical basis for understanding susceptibility to cognitive-emotional dysfunction in the face of stressors (Carver & White, 1994; Gray & McNaughton, 2003). According to RST, two major systems regulate behavioral responses: the behavioral inhibition system (BIS), which governs sensitivity to punishment and threat, and the behavioral activation system (BAS), which regulates responsiveness to reward. High BIS sensitivity has been consistently linked with heightened anxiety, excessive worry, and cognitive inflexibility—all of which can contribute to sustained mental fatigue (Che et al., 2020; Sun et al., 2020). Conversely, low BAS activity is associated with diminished motivation and reduced engagement in rewarding activities, potentially leading to emotional exhaustion and fatigue (Ghanbarizarandi et al., 2018; Mafsari et al., 2022).

In recent years, researchers have increasingly focused on repetitive negative thinking (RNT), such as worry and rumination, as key cognitive processes that mediate the relationship between emotional regulation systems and mental health outcomes. RNT is characterized by a passive, recurrent focus on negative content and its implications, often leading to emotional dysregulation, sleep disturbances, and cognitive strain (McEvoy et al., 2010; Wahl et al., 2019; Zhang et al., 2024). It is conceptualized as a transdiagnostic factor that cuts across mood, anxiety, and somatic symptom disorders and is associated with both increased BIS activity and decreased BAS functioning (Chang et al., 2023; Forgan, 2010). Among diabetic individuals, RNT has been shown to mediate the relationship between emotional dysregulation and adverse health behaviors, including poor sleep hygiene and impaired glucose control (Foroghian-Yazdi et al., 2020; Pourmohammad Ghouchani et al., 2023).

Moreover, multiple studies have confirmed the detrimental role of RNT in exacerbating the link between stress and sleep disturbances. For instance, Zhang et al. (2024) identified rumination as a significant mediator between stress and sleep quality in a sample of adult women, further modulated by social anxiety symptoms (Zhang et al., 2024). Similarly, Clancy et al. (2020) found that both worry and rumination were robustly associated with sleep difficulties in non-clinical populations, with meta-analytic evidence supporting a medium to large effect size (Clancy et al., 2020). In the clinical context, individuals with chronic illness such as diabetes may experience prolonged cognitive engagement with illness-related concerns, thereby enhancing susceptibility to mental fatigue via disrupted sleep and increased cognitive load (Cox & Olatunji, 2020; Dittner et al., 2004).

The psychophysiological mechanisms through which BIS/BAS sensitivities and sleep quality interact with RNT to predict fatigue have been further elucidated in empirical studies. For example, Sun et al. (2020) reported that cognitive emotion regulation strategies significantly mediated the effects of BIS and BAS on symptoms of anxiety and depression, highlighting the central role of cognitive intermediaries in neurobehavioral models of

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E-ISSN: 3041-8515

emotional distress (Sun et al., 2020). This finding is particularly relevant in light of data from McCallum et al. (2019), who reported strong comorbidities between sleep disturbance, fatigue, and a variety of mental disorders, with RNT operating as a potential underlying process across diagnostic categories (McCallum et al., 2019). These studies underscore the importance of examining repetitive thought patterns not as isolated symptoms but as central mechanisms linking neurobehavioral systems and sleep-related processes to broader psychological dysfunction.

Given the convergence of evidence across neuropsychological, cognitive, and behavioral domains, the present study investigates the mediating role of negative repetitive thoughts in the relationship between behavioral brain systems and sleep quality with mental fatigue in women with type 2 diabetes.

2. Methods and Materials

2.1. Study design and Participant

The present study is a correlational research based on structural equation modeling (SEM). The statistical population included all women diagnosed with type 2 diabetes who were members of the Diabetes Patients Support Association of Tehran Province in 2025 and who had visited medical and counseling centers in Tehran during the first half of 2025. In SEM, the minimum sample size is determined based on the number of factors rather than the number of variables, and a minimum of 200 participants is recommended for ten factors. To achieve more robust results, 265 women aged between 20 and 40 were selected through convenience sampling based on inclusion criteria, including a confirmed diagnosis of type 2 diabetes and a clinical interview.

Inclusion criteria were: informed consent, ability to participate in the study, at least a high school diploma, diagnosis of type 2 diabetes, assessment through the GAD-7, and a structured clinical interview based on DSM-5 to detect symptoms of repetitive negative thinking, and no psychological intervention received within the past six months. Exclusion criteria were: a diagnosis of borderline personality disorder, antisocial personality disorder, or schizotypal personality disorder based on structured interviews, presence of psychotic symptoms, substance addiction, severe psychomotor retardation or history thereof, history or current episode of manic disorder based on a structured diagnostic interview for psychiatric disorders, and the presence of brain damage or other physical illnesses.

Following administrative coordination and after gaining access to counseling centers in Tehran through the Diabetes Association (using convenience sampling), 500 eligible women diagnosed with type 2 diabetes were invited to participate in the study. Of these, 105 declined participation. Among the remaining 395 individuals, based on questionnaire screening criteria, 265 participants were selected using clinical interviews and the DSM-5, meeting the inclusion and exclusion criteria. Participants completed a demographic form, the Repetitive Negative Thinking Questionnaire, the Behavioral Brain Systems Questionnaire, the Mental Fatigue Inventory, and the Pittsburgh Sleep Quality Index.

2.2. Measures

10-Item Version of the Repetitive Negative Thinking Questionnaire (RNTQ): This is a 10-item version of the Repetitive Negative Thinking Questionnaire developed by McEvoy, Mahoney, and Moulds (2012), which was selected from the original 27-item version based on highest factor loadings. It is rated on a 5-point Likert scale ranging from 1 (completely false) to 5 (completely true). Psychometric evaluation of the 10-item version in both non-clinical (McEvoy et al., 2010) and clinical populations (McEvoy et al., 2012) demonstrated high internal consistency (Cronbach's alpha > .89) and strong correlation with the full 27-item version. Convergent validity was established through significant correlations with various negative affect constructs, including anxiety, depression, shame, anger, and general distress.

Behavioral Inhibition/Activation System Questionnaire (BIS/BAS): Developed by Carver and White (1994), this 24-item questionnaire uses a 4-point Likert scale ranging from 1 (strongly disagree) to 4 (strongly agree). It includes two subscales: the Behavioral Inhibition System (BIS) and the Behavioral Activation System (BAS). The BAS consists of three components: drive, fun-seeking, and reward responsiveness. Internal consistency for the total scale and subscales was reported between .66 and .76 (Carver & White, 1994).

Mental Fatigue Inventory (MFI): The MFI was developed by Smets (1996) and contains 20 items covering five subscales: general fatigue (4 items), physical fatigue (4 items), reduced activity (4 items), reduced motivation (4 items), and mental fatigue (4 items). Concurrent validity studies indicated strong correlations with the Fatigue Symptoms Checklist and the Vitality Scale (Stein et al.,

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2004). Cronbach's alpha values for subscales ranged from .85 to .96, and test-retest reliability exceeded .85 (Dittner et al., 2004). In Iran, Hafezi and Mahmoudi (2010) confirmed the construct validity and internal consistency of the scale, with alpha coefficients above .80 for general, physical, and mental fatigue subscales, and above .65 for reduced activity and motivation (Hafezi et al., 2010).

Pittsburgh Sleep Quality Index (PSQI): Developed by Buysse et al. (1989), this 19-item self-report scale evaluates sleep quality across seven domains over the past month: subjective sleep quality (1 item), sleep latency (2 items), sleep duration (1 item), sleep efficiency (3 items), sleep disturbances (9 items), use of sleep medication (1 item), and daytime dysfunction (2 items). Each subscale is scored from 0 (no difficulty) to 3 (severe difficulty), with total scores ranging from 0 to 21. Scores above 5 indicate poor sleep quality. Completion takes approximately 5 to 10 minutes. The PSQI has demonstrated high reliability and validity in numerous studies. Buysse et al. (1989) reported sensitivity and specificity rates of 89.6% and 86.5%, respectively, and Cronbach's alpha of .83. Test-retest reliability was reported at .85 (Tsay et al., 2004). In Iran, Soleymani et al. (2008) reported test-retest reliability of .88 (Soleimany et al., 2008).

2.3. *Data Analysis*

The collected data were analyzed using descriptive statistics and path analysis. Given the presence of a mediating variable and indirect relationships among the constructs, path analysis was chosen for data analysis using LISREL 8.8 software.

3. Findings and Results

The mean and standard deviation scores for mental fatigue were 56.92 and 16.86, respectively; for negative repetitive thoughts, 27.03 and 8.79; for the behavioral inhibition system, 16.09 and 5.11; for the behavioral activation system, 26.12 and 9.32; and for sleep quality, 10.06 and 6.57. As observed, the skewness and kurtosis values of the research variables are between +1.5 and -1.5, indicating that the variables are normally distributed (Table 1).

Table 1

Descriptive Statistics and Pearson Correlation Coefficients Among Research Variables

Variables	1	2	3	4	Mean	SD	Skewness	Kurtosis
1. Mental Fatigue	1.00				56.92	16.86	-0.33	1.39
2. Negative Repetitive Thoughts	.406	1.00			27.03	8.79	0.37	-0.81
3. Behavioral Inhibition System	.558	.373	1.00		16.09	5.11	0.28	-0.90
4. Behavioral Activation System	-.512	-.343	-.485	1.00	26.12	9.32	0.58	-0.79
5. Sleep Quality	.408	.357	.302	-.334	10.06	6.57	0.64	1.07

Fit indices indicated that the proposed model for predicting mental fatigue in women with type 2 diabetes, based on behavioral brain systems and sleep quality mediated by negative repetitive thoughts, had acceptable model fit. The CFI, TLI, and NFI values were all greater than .90, indicating satisfactory fit. The chi-square to degrees of freedom ratio was 1.95, further confirming model adequacy. The Root Mean Square Error of Approximation (RMSEA) was .062, which is within acceptable limits, and was nonsignificant with a p-value of .64. The confidence interval for RMSEA ranged from .042 to .092.

Table 2

Direct and Indirect Effects

Predictor → Outcome	Direct B	Direct T	Indirect B	Indirect T	Total B	Total T
Behavioral Inhibition → Mental Fatigue	.34	6.10	*.03	2.08	.37	6.73
Behavioral Activation → Mental Fatigue	-.24	-4.42	-.02	-1.75	-.26	-4.79
Sleep Quality → Mental Fatigue	.18	3.45	*.03	2.16	.21	4.15
Repetitive Thoughts → Mental Fatigue	*.13	2.55	-	-	*.13	2.55
Behavioral Inhibition → Repetitive Thoughts	.23	3.57	-	-	.23	3.57
Behavioral Activation → Repetitive Thoughts	*-.15	-2.40	-	-	*-.15	-2.40
Sleep Quality → Repetitive Thoughts	.24	4.05	-	-	.24	4.05

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There was a significant and positive relationship between the behavioral inhibition system and mental fatigue ($\beta = .34$, $p < .01$), and between sleep quality and mental fatigue ($\beta = .18$, $p < .01$). A significant negative relationship was found between the behavioral activation system and mental fatigue ($\beta = -.24$, $p < .01$). Additionally, there were significant positive relationships between the behavioral inhibition system ($\beta = .23$, $p < .01$) and sleep quality ($\beta = .24$, $p < .01$) with negative repetitive thoughts. A significant negative relationship was observed between the behavioral activation system and negative repetitive thoughts ($\beta = -.15$, $p < .05$). Furthermore, a significant positive relationship was found between negative repetitive thoughts and mental fatigue ($\beta = .13$, $p < .05$).

There were also significant indirect effects of the behavioral inhibition system ($\beta = .03$, $p < .05$) and sleep quality ($\beta = .03$, $p < .05$) on mental fatigue through the mediation of negative repetitive thoughts. However, negative repetitive thoughts did not significantly mediate the relationship between the behavioral activation system and mental fatigue.

The combined linear model of the behavioral inhibition system, behavioral activation system, sleep quality, and negative repetitive thoughts predicted 44% of the variance in mental fatigue. The combined model of behavioral inhibition system, behavioral activation system, and sleep quality explained 42% of the variance in mental fatigue. Additionally, the combined model of these variables predicted 22% of the variance in negative repetitive thoughts.

4. Discussion and Conclusion

The aim of the present study was to investigate the mediating role of negative repetitive thoughts in the relationship between behavioral brain systems and sleep quality with mental fatigue in women with type 2 diabetes. The results of path analysis revealed significant direct and indirect effects between the key variables. Specifically, the behavioral inhibition system (BIS) and sleep quality demonstrated significant positive relationships with mental fatigue, while the behavioral activation system (BAS) showed a significant negative association. Moreover, negative repetitive thoughts significantly mediated the relationship between BIS and sleep quality with mental fatigue but did not mediate the relationship between BAS and mental fatigue. These findings highlight the crucial role of maladaptive cognitive processes in explaining how neurobehavioral sensitivities and sleep disturbances contribute to the experience of mental fatigue in diabetic individuals.

The positive relationship between BIS sensitivity and mental fatigue aligns with theoretical assumptions rooted in reinforcement sensitivity theory (RST), which posits that high BIS activity is associated with increased vigilance toward threat, heightened emotional reactivity, and elevated levels of worry and anxiety (Carver & White, 1994; Gray & McNaughton, 2003). These characteristics are cognitively demanding and deplete psychological resources over time, leading to fatigue. Several empirical studies have corroborated this pathway. For instance, Sun et al. (2020) demonstrated that high BIS sensitivity was associated with anxiety and depressive symptoms, and this relationship was partially mediated by maladaptive cognitive emotion regulation strategies (Sun et al., 2020). Similarly, Ghanbarizarandi et al. (2018) found that individuals with high BIS sensitivity reported greater difficulties in emotion regulation and more intense cognitive engagement with negative stimuli, factors that contribute to sustained mental fatigue (Ghanbarizarandi et al., 2018).

Conversely, the negative relationship between BAS and mental fatigue suggests that individuals with greater behavioral activation tendencies may be better equipped to engage in rewarding and goal-directed activities, thus experiencing lower levels of exhaustion. This finding supports previous work showing that higher BAS activity is linked to resilience and adaptive coping strategies (Che et al., 2020; Mafsari et al., 2022). For example, Mafsari et al. (2022) reported that high BAS activation was inversely related to illness anxiety disorder and helped reduce intolerance of uncertainty, a cognitive feature closely related to mental fatigue (Mafsari et al., 2022). These results indicate that BAS not only functions as a motivational system but also serves as a protective factor against cognitive-emotional depletion.

The results also confirmed that poor sleep quality significantly predicted higher levels of mental fatigue, which is consistent with a well-established body of literature documenting the relationship between sleep and psychological well-being (Buysse et al., 1989; Dittner et al., 2004; Tsay et al., 2004). Specifically, Buysse et al. (1989) emphasized that impaired sleep architecture and fragmented sleep patterns can lead to reduced cognitive performance, poor emotional regulation, and increased daytime fatigue in clinical and non-clinical populations (Buysse et al., 1989). These findings are echoed by Harris et al. (2021), who found

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that sleep disturbances were strongly linked to fluctuations in subjective fatigue and emotional distress in individuals with chronic health conditions (Harris et al., 2021). Furthermore, McCallum et al. (2019) found that sleep disturbances were a common transdiagnostic feature across various psychiatric conditions and strongly correlated with self-reported fatigue (McCallum et al., 2019).

Crucially, the mediation analysis indicated that negative repetitive thoughts significantly explained the indirect effect of BIS and sleep quality on mental fatigue. This suggests that individuals with heightened threat sensitivity and poor sleep may engage more frequently in repetitive cognitive patterns such as worry and rumination, which in turn intensify feelings of mental exhaustion. This finding is consistent with the transdiagnostic perspective of repetitive negative thinking (RNT), which posits that RNT acts as a central mechanism linking cognitive vulnerability and affective dysfunction (McEvoy et al., 2010; Wahl et al., 2019). McEvoy et al. (2010) defined RNT as a cognitive process that is abstract, passive, and difficult to disengage from, making it a potent contributor to sustained emotional and mental strain (McEvoy et al., 2010). Wahl et al. (2019) further demonstrated that RNT contributes similarly to symptom expression across disorders such as depression, generalized anxiety disorder (GAD), and obsessive-compulsive disorder (OCD), suggesting its pervasive role in psychological dysfunction (Wahl et al., 2019).

The mediating role of RNT in the relationship between poor sleep and fatigue is also well supported. Clancy et al. (2020) conducted a meta-analysis showing that worry and rumination significantly contributed to disrupted sleep across multiple studies (Clancy et al., 2020). Similarly, Zhang et al. (2024) found that the effect of stress on sleep quality was mediated by rumination and moderated by social anxiety, indicating that RNT is not only a consequence of sleep disruption but also a factor that perpetuates it (Zhang et al., 2024). In clinical populations, RNT has been found to exacerbate insomnia symptoms and predict poor sleep quality over time, reinforcing its role as a self-perpetuating cycle that drains psychological energy and elevates fatigue levels (Chang et al., 2023; Cox & Olatunji, 2020).

It is notable, however, that RNT did not significantly mediate the relationship between BAS and mental fatigue. One plausible explanation for this is that high BAS individuals are less likely to engage in negative rumination due to their approach-oriented disposition and tendency to focus on positive reinforcement and goal pursuit. This aligns with evidence from studies showing that BAS-related traits are associated with positive affect, resilience, and a lower likelihood of engaging in maladaptive cognitive processes (Forgan, 2010; Sun et al., 2020). Therefore, while BIS and poor sleep may indirectly increase fatigue through their impact on RNT, BAS appears to exert a more direct protective influence, perhaps by promoting engagement with rewarding stimuli and distraction from repetitive thought cycles.

Collectively, the present findings support an integrative model in which both neurobiological sensitivity (BIS/BAS) and behavioral factors (sleep quality) interact with cognitive mediators (RNT) to influence mental fatigue in women with type 2 diabetes. These results offer a multi-layered perspective on how individual differences in motivational systems and sleep patterns can either exacerbate or buffer psychological distress via cognitive-emotional pathways. The implications are clinically significant, suggesting that addressing RNT and sleep disturbances may be particularly beneficial for patients with high BIS sensitivity or those experiencing chronic fatigue symptoms. Furthermore, the finding that the model explained a substantial proportion of variance in both mental fatigue (44%) and RNT (22%) highlights the robustness and utility of this framework in understanding the psychological burden of chronic illness.

5. Limitations and Suggestions

Despite the valuable insights provided by this study, several limitations should be acknowledged. First, the cross-sectional design of the study precludes causal inference. Although structural equation modeling allows for the testing of complex relationships, it cannot establish temporal precedence between variables. Second, all data were collected through self-report questionnaires, which may introduce biases such as social desirability and recall error. Third, the study sample was limited to women with type 2 diabetes in Tehran, which limits the generalizability of findings to other populations, including males or individuals from different cultural or socioeconomic backgrounds. Fourth, although the instruments used demonstrated good psychometric properties, the absence of objective measures of sleep (e.g., actigraphy or polysomnography) limits the precision with which sleep quality was assessed. Lastly, potential confounding variables such as physical activity, glycemic control, and medication adherence were not controlled, which may have influenced levels of fatigue and sleep disturbance.

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E-ISSN: 3041-8515

Future research should employ longitudinal designs to investigate the directional and causal relationships among the behavioral brain systems, sleep quality, RNT, and mental fatigue over time. This approach would help clarify whether sleep disturbances lead to increased RNT or vice versa. Additionally, it would be beneficial to replicate this study in more diverse samples, including males, younger populations, and patients with other chronic conditions. Incorporating biological and behavioral indices—such as cortisol levels, neuroimaging, or wearable sleep trackers—could also provide more comprehensive and objective assessments of the proposed mechanisms. Further exploration of moderating variables, such as emotional resilience, coping style, or spiritual well-being, may help refine the model and improve its predictive power across different clinical contexts.

The findings underscore the importance of integrating cognitive-behavioral and neurobiological considerations into the treatment of mental fatigue in diabetic populations. Interventions targeting repetitive negative thinking, such as mindfulness-based cognitive therapy or metacognitive training, may be especially beneficial for individuals with high BIS sensitivity or those with chronic sleep issues. Clinicians should also consider screening for sleep disturbances and RNT in routine assessments, as these factors contribute substantially to fatigue and overall psychological distress. In addition, psychoeducation programs that increase awareness of the link between thought patterns, neurobehavioral tendencies, and fatigue could empower patients to adopt healthier cognitive strategies. Finally, promoting behavioral activation and reinforcing reward-seeking behaviors may help reduce fatigue by enhancing positive affect and engagement with meaningful activities.

Authors' Contributions

Authors contributed equally to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

Acknowledgments

We would like to express our gratitude to all individuals helped us to do the project.

Declaration of Interest

The authors report no conflict of interest.

Funding

According to the authors, this article has no financial support.

Ethical Considerations

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

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Psychology of Woman Journal
E-ISSN: 3041-8515