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The Effectiveness of Intradialytic Exercise in Reducing Fatigue among Hemodialysis Patients Based on Roy Adaptation Model

Syarief Hidayatullah Bahri*, Priyanto
Master of Nursing Study Program, Ngudi Waluyo University, Semarang, Indonesia
*Corresponding Author: nursesyarief@gmail.com

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ABSTRACT

Background: Fatigue is one of the most common and distressing problems among hemodialysis patients, significantly affecting their quality of life and adherence to treatment. This condition arises from physiological and psychological imbalances experienced during the hemodialysis process. Within the framework of the Roy Adaptation Model, fatigue is understood as a maladaptive response to prolonged stressors, while intradialytic exercise can function as an adaptive mechanism to enhance positive adjustment.
Methods: This conceptual study employed a literature-based review approach by synthesizing evidence from recent national and international publications from 2022 to 2025. Thematic analysis was conducted based on the four adaptive modes of the Roy Adaptation Model: physiological, self-concept, role function, and interdependence.
Results: The synthesis revealed that intradialytic exercise, which refers to physical activity performed during hemodialysis, effectively reduces fatigue levels by improving muscle perfusion, enhancing cardiovascular function, and stabilizing hormonal balance. This adaptive intervention supports physiological stability and promotes better psychosocial adjustment in hemodialysis patients.
Conclusion: Intradialytic exercise serves as an effective adaptive nursing intervention to minimize fatigue and improve the overall quality of life in hemodialysis patients. These findings provide both theoretical and practical implications for developing comprehensive and sustainable nursing strategies grounded in the Roy Adaptation Model.

INTRODUCTION

Fatigue, or chronic exhaustion, is one of the most significant clinical problems experienced by patients with end stage chronic kidney disease (CKD) undergoing maintenance hemodialysis. This phenomenon is not merely a sense of tiredness but a complex condition involving multiple dimensions including physical, psychological, social, and behavioral aspects, and it directly affects patients' overall quality of life (Zuo et al., 2022). Epidemiological data indicate that the prevalence of fatigue in this population is remarkably high, ranging from 60% to 97%, depending on the operational definitions and measurement instruments used (Eugenio, Burdelis, José, Melo, & Ii, 2023). Recent studies in both Asian and global contexts reinforce this finding, reporting that approximately 83% of hemodialysis patients experience significant fatigue, which frequently emerges as a major side effect of continuous dialysis therapy (Zheng, Zhang, Cheng, Yang, & Xu, 2023). The clinical implications of fatigue are extensive and cannot be overlooked. Evidence

consistently shows that fatigue decreases quality of life and exacerbates both physical and psychological conditions, including an increased risk of depression, sleep disorders, and reduced motivation for social and physical activity (Picariello, Moss-morris, Macdougall, & Chilcot, 2022). Data indicate that about 65.9% of patients with fatigue experience moderate to severe depression, while 69.5% suffer from poor sleep quality, both positively correlated with fatigue symptoms (Khemchandani, Nasir, Qureshi, Dhrolia, & Ahmad, 2023). Moreover, fatigue has been identified as an independent risk factor associated with increased mortality among hemodialysis patients, making it not only a matter of discomfort but also a determinant of survival (You et al., 2022). From the perspective of Roy's Adaptation Model, fatigue primarily disrupts the Physiological Mode by reducing energy availability, impairing activity tolerance, decreasing functional capacity, and limiting the ability to perform basic activities of daily living, thereby compromising the patient's physiological integrity. A more complete understanding of this phenomenon can be achieved through a multifactorial perspective.

The etiology of fatigue in patients with chronic kidney disease undergoing dialysis is influenced by a complex interaction of physiological, psychological, social, and behavioral factors. Physiologically, fatigue is caused by anemia, chronic inflammation, electrolyte imbalance, and the accumulation of uremic toxins that can no longer be effectively cleared. Elevated levels of inflammatory markers such as interleukin 6 and tumor necrosis factor alpha have been shown to be significantly associated with fatigue severity (Nassar, Tharwat, Gawad, Elrefaey, & Elsawi, 2023). Another study revealed that older patients demonstrated higher levels of fatigue, with an odds ratio of 1.042 per year of age, indicating that vulnerability to fatigue increases with advancing age (Zheng et al., 2023). Beyond physiological factors, psychological aspects play a critical role. Depression, anxiety, and stress related to chronic illness and therapeutic uncertainty can exacerbate both the perception and intensity of fatigue (Sakiqi, Vasilopoulos, Koutelekos, Polikandrioti, & Dousis, 2022). Sleep disturbances, which frequently occur in this population, are also directly correlated with fatigue, as 69.5 percent of patients have been reported to experience significant sleep problems that positively correlate with fatigue intensity (Shi et al., 2024). From a social perspective, patients often experience social isolation, loss of social roles, and dependence both psychological and physical on their surroundings, all of which contribute to an overall increase in fatigue burden. Employment status has also been linked to fatigue, with unemployed patients demonstrating higher fatigue scores, indicating a conceptual connection between the loss of social role and fatigue severity (Khemchandani et al., 2023). The multifactorial nature of fatigue in hemodialysis patients results in broad consequences for productivity, mobility, social dependence, and quality of life. Therefore, comprehensive and theory based management approaches are urgently needed to optimally reduce this burden (Zuo et al., 2022).

Although empirical and recent meta analytical evidence has shown that physical exercise interventions during dialysis, known as intradialytic exercise, are effective in significantly reducing fatigue levels, most studies remain limited to physiological aspects and objective clinical outcomes. These outcomes are often presented as reductions in fatigue scores, improvements in functional capacity, and increased dialysis efficiency (Astri et al., 2023). However, these studies rarely explore the psychosocial mechanisms and adaptive processes that underlie the long term success of the intervention (Chakraborty, Kundu, & Mukherjee, 2024). Furthermore, many studies do not consider psychological, social, and behavioral factors as facilitators of intervention success, resulting in major challenges for program sustainability and long term adherence. The application of theoretical models in nursing, particularly the Roy Adaptation Model (RAM), remains limited to specific contexts and is seldom integrated systematically with physical exercise interventions or rehabilitation programs for hemodialysis patients (Kim, Lee, Kim, Im, & Lee, 2023). Most studies referring to RAM focus mainly on selfmanagement and psychosocial adaptation without directly associating them with the effectiveness of exercise based interventions during dialysis (Afrasiabifar, Karimi, & Hassani, 2022). In fact, RAM provides a comprehensive conceptual framework to understand the complex responses of individuals to both direct and indirect stressors, including those associated with illness and interventions aimed at enhancing holistic adaptation. The implementation of intradialytic exercise also faces challenges due to motivational factors, social support, selfperception, and environmental influences that affect adherence and

continuity (Yogalakshmi, Sasikala, Varughese, & Sundararajan, 2024). The adaptation concept within RAM offers a strong theoretical foundation for systematically addressing these factors by linking physiological outcomes with dynamic psychological, social, and behavioral processes. Nevertheless, such integration remains scarce in the current literature and requires a robust conceptual framework to optimize intervention implementation and improve the quality and sustainability of nursing care. Addressing this gap is essential, as the physiological effectiveness of the intervention can be significantly enhanced when supported by healthy psychosocial and behavioral adaptation processes within an integrated and holistic theoretical framework. Therefore, conceptual research that integrates empirical evidence into a comprehensive theoretical model is urgently needed to establish a systematic and sustainable foundation for nursing practice.

The primary urgency in developing a theoretical framework based on the Roy Adaptation Model (RAM) lies in the need to ensure the sustainability and effectiveness of intradialytic exercise programs through the strengthening of patients' holistic adaptation processes (Krismiadi, 2024). Fatigue is not merely a physiological problem but a multidimensional experience influenced by psychological processes such as selfefficacy, selfperception, and social factors, including environmental support and social roles (Balconi et al., 2022; Eugenio et al., 2023). Without a comprehensive approach, the success of exercise programs tends to be temporary and vulnerable to long term implementation failure. Moreover, the successful execution of such programs requires a process oriented rather than outcome oriented approach, emphasizing adaptive mechanisms over purely physiological results. The theoretical framework of RAM provides a systematic model capable of integrating physiological, psychological, and social dimensions in an interrelated and mutually reinforcing manner. Through this framework, nurses and healthcare professionals can conduct holistic assessments, formulate accurate nursing diagnoses, and design interventions that focus on strengthening adaptive processes across all modes. Beyond the scientific rationale, the urgency also reflects the reality that sustaining intradialytic exercise programs requires strong patient motivation and environmental support. Without systematic reinforcement of psychological and social adaptation, patients are likely to experience dropout, reduced adherence, and a decline in the long term effectiveness of the intervention (Khairallah & Al-Ashour, 2025). The theoretical framework proposed in this conceptual paper offers practical guidance to enhance patients' motivation, selfefficacy, and perceived competence in managing the adaptation process. Its novelty and significance lie in its ability to integrate empirical evidence with holistic nursing philosophy into a solid and clinically applicable framework. This approach facilitates the development of sustainable and evidence based interventions aimed at improving patients' quality of life while supporting the continuity of physical rehabilitation and the enhancement of psychosocial and behavioral adaptation processes (Esquivel-garzon, Marquez-herrera, & Parra, 2025).

The primary novelty of this paper lies in the synergy between empirical evidence on the effectiveness of intradialytic exercise and the theoretical foundation of the Roy Adaptation Model (RAM) as a conceptual basis for developing holistic and sustainable nursing interventions. This approach positions physical exercise not only as a physiological stimulus but also as an agent that facilitates positive adaptive processes across the four major modes of Roy: physiological, selfconcept, role function, and interdependence (Eugenio et al., 2023). In practical terms, the proposed model outlines and structures how intradialytic exercise can enhance physical mobility, reduce fatigue levels, and improve patients' sense of self achievement and social role performance through interrelated and mutually reinforcing physiological and psychological mechanisms (Zou, Zhang, Yi, Chen, & Qing, 2025). This integrative framework provides a theoretical foundation for holistic assessment, adaptation based nursing diagnoses, and the design of personalized and sustainable nursing interventions. More broadly, this framework addresses an existing gap in the nursing literature by integrating physiological outcomes with psychosocial and behavioral adaptation processes in the success of exercise programs within the context of chronic illness. The model offers a theoretical bridge connecting empirical clinical findings with the holistic philosophy of nursing practice, emphasizing adaptation as both a process and an outcome. Therefore, this conceptual framework provides an innovative contribution that strengthens

theory based nursing practice, enhances the quality and continuity of interventions, and extends the long term benefits of intradialytic exercise programs both in clinical and community contexts.

METHODS

This study employed a conceptual literature review approach, which aims to integrate theories, concepts, and empirical findings from diverse scientific sources to build a comprehensive conceptual understanding of a phenomenon. Unlike systematic reviews or meta-analyses that emphasize quantitative data, this approach focuses on exploring ideas, theoretical relationships, and cross-study conceptual integration. In this study, the conceptual review was used to explain the theoretical relationship between intradialytic exercise and fatigue reduction among hemodialysis patients through the framework of the Roy Adaptation Model (RAM). The review included national and international journal articles published between 2022 and 2025 that discussed intradialytic exercise, fatigue, hemodialysis, nursing interventions, and the Roy Adaptation Model. Literature searches were conducted using PubMed, ScienceDirect, and Google Scholar databases. The search strategy used the following keywords: "intradialytic exercise," "fatigue," "hemodialysis," "nursing intervention," and "Roy Adaptation Model." These keywords were applied both individually and in combination using Boolean operators "AND" and "OR" to refine the search results. Examples of search strings included: "intradialytic exercise AND fatigue AND hemodialysis," "fatigue AND hemodialysis," and "Roy Adaptation Model AND nursing intervention." Articles were selected through inclusion and exclusion criteria to ensure methodological quality and relevance.

Data extraction involved identifying key variables, major concepts, and empirical findings, which were then categorized according to the four adaptive modes of the Roy Adaptation Model: physiological, self-concept, role function, and interdependence. A conceptual thematic analysis was applied to identify core themes, patterns, and conceptual gaps. The synthesis process explored how intradialytic exercise functions as an adaptive stimulus that promotes physiological balance, psychological motivation, social interaction, and interdependence among patients undergoing hemodialysis. The findings were analyzed conceptually and interpretively rather than statistically. This process generated a theoretical synthesis illustrating the connection between intradialytic exercise and the multidimensional adaptation processes of patients based on the RAM framework. The final outcome of this study is a conceptual model of adaptation, positioning intradialytic exercise as a holistic nursing intervention that enhances patient adaptation across physical, psychological, and social dimensions. While this method is limited by the availability and quality of reviewed literature, it provides a strong theoretical foundation for developing future empirical and interventional nursing studies.

RESULTS

This literature review comprehensively examined the influence of intradialytic exercise on fatigue reduction among hemodialysis patients within the framework of the Roy Adaptation Model (RAM). Based on a literature search conducted through PubMed, ScienceDirect, and Google Scholar between 2022 and 2025, a total of 22 relevant articles met the inclusion criteria. These publications included experimental, quasi-experimental, and conceptual studies that directly investigated the physiological, psychological, and social impacts of intradialytic exercise on hemodialysis patients. Overall, the findings consistently demonstrated that intradialytic exercise has a positive effect on reducing fatigue levels, improving functional capacity, and enhancing patients' overall quality of life. Exercises performed during dialysis sessions were shown to stimulate physiological adaptation mechanisms, strengthen self-concept and psychological resilience, maintain social role functioning, and improve interdependence through increased engagement with family and healthcare providers. From a physiological perspective, several studies explained that intradialytic exercise improves muscle perfusion, leading to increased blood flow distribution to active skeletal muscles during dialysis sessions. This enhanced perfusion supports oxygen delivery at the tissue level, thereby improving cellular oxygenation and energy production efficiency. As a result, patients experience reduced early onset of fatigue

and improved exercise tolerance. Within the Roy Adaptation Model, these mechanisms are directly related to the Physiological Mode, particularly the Oxygenation need, as improved oxygen transport enhances cellular metabolism and reduces physiological strain. In addition, the improved oxygen availability contributes to better regulation of the Activity and Rest balance, allowing patients to perform physical activity more efficiently while maintaining adequate recovery and energy conservation during hemodialysis treatment. The reviewed studies also highlighted that integrating intradialytic exercise within a theoretical adaptation framework such as RAM may optimize long-term adherence, promote holistic well-being, and provide a strong conceptual foundation for the development of evidence-based nursing interventions in chronic kidney disease care.

Physiological Mode in the Roy Adaptation Model

Within the framework of the Roy Adaptation Model (RAM), intradialytic exercise functions as an adaptive stimulus that assists hemodialysis patients in maintaining biological integrity and physiological homeostasis. Hemodialysis patients experience chronic physiological stress manifested through fatigue, reduced muscle strength, hemodynamic instability, and the accumulation of uremic metabolites (Minanton & Tina Muzaenah, 2022). Several studies have demonstrated that intradialytic exercise effectively reduces fatigue, enhances cardiovascular capacity, increases muscle strength, stabilizes blood pressure, and improves metabolic efficiency by promoting tissue perfusion and oxygen transport (Tabibi et al., 2023; Verrelli et al., 2024). Meta-analytic evidence indicates that performing aerobic intradialytic exercise for ≥20 minutes during the initial phase of dialysis significantly decreases fatigue levels and enhances patients' physical activity tolerance (Astri et al., 2023). From a physiological standpoint, improved muscle perfusion during intradialytic exercise enhances oxygen delivery to skeletal muscle tissues, thereby optimizing aerobic metabolism and reducing early onset of fatigue. This mechanism supports cellular energy production and limits anaerobic glycolysis, which is commonly associated with lactate accumulation and exercise intolerance in hemodialysis patients. Consequently, better oxygenation directly contributes to improved activity tolerance and more efficient balance between activity and rest, which are key components of physiological adaptation in the RAM framework. In addition, intradialytic exercise improves vascular function and hemodynamic stability, reduces arterial stiffness, and enhances overall physical performance (Yabe et al., 2023; Lai et al., 2025). These physiological improvements collectively strengthen regulatory mechanisms and support adaptation to dialysis-related stressors (Ren et al., 2023).

Self-Concept Mode in the Roy Adaptation Model

Within the Roy Adaptation Model (RAM), the self-concept mode emphasizes patients' psychological and spiritual adaptation in responding to chronic illness. Among hemodialysis patients, alterations in body image, treatment dependency, and lifestyle restrictions often lead to decreased self-esteem, motivation, and emotional well-being. Intradialytic exercise serves as an adaptive stimulus that strengthens the cognator subsystem, enhancing patients' perceptions of self-control, self-worth, and psychological integrity. Empirical studies have shown that intradialytic exercise significantly improves health-related quality of life, reduces depression, and enhances psychological well-being and self-concept among hemodialysis patients (Lin et al., 2022; Rhee et al., 2022). Moreover, exercise performed during dialysis has been found to increase body image satisfaction, self-perceived strength, and vitality, contributing to the development of a more positive self-identity (Cebrian et al., 2022; Astri et al., 2023). Spiritual dimensions are also positively influenced, as patients who regularly engage in intradialytic exercise demonstrate greater self-acceptance, sense of meaning, and spiritual resilience over time (Vergara et al., 2023). From a RAM perspective, intradialytic exercise plays a key role in restoring the "physical self" by helping patients re-experience bodily competence, improved strength, and functional ability despite chronic illness. This bodily reinforcement reduces feelings of physical decline and dependency, allowing patients to perceive their bodies as more capable and responsive. In addition, exercise contributes to the "personal self" by enhancing self-consistency, self-ideal perception, and moral-ethical integrity, enabling patients to rebuild confidence, regain autonomy,

and develop a more positive self-evaluation in the context of long-term hemodialysis treatment. In summary, intradialytic exercise represents a theory-based nursing intervention that effectively reinforces the self-concept mode within the RAM framework. It facilitates psychological adaptation by promoting emotional stability, self-efficacy, and spiritual well-being in patients undergoing long-term hemodialysis.

Role Function Mode in the Roy Adaptation Model

Within the Roy Adaptation Model (RAM), the role function mode emphasizes the individual's ability to perform social, familial, and occupational roles adaptively. In hemodialysis patients, chronic fatigue and physical limitations often result in role dysfunction and reduced independence. Intradialytic exercise acts as an adaptive stimulus that enhances physical capacity, stamina, and activity tolerance, thereby supporting the restoration of patients' role functions. Empirical studies have demonstrated that intradialytic exercise significantly improves health-related quality of life, social participation, and daily functional performance (Lin et al., 2022; Sri et al., 2024). Meta-analytic evidence also indicates that exercise performed during dialysis enhances self-esteem, mood, and motivation to fulfill family and social responsibilities (Rhee et al., 2022). Furthermore, improvements in cardiovascular function, hemodynamic stability, and fatigue reduction directly contribute to increased independence and social engagement among hemodialysis patients (Verrelli et al., 2024; Yabe et al., 2023). Thus, intradialytic exercise supports the role function mode of adaptation by strengthening both the physical and psychosocial capacities of hemodialysis patients, enabling them to maintain their roles and social participation more effectively.

Interdependence Mode in the Roy Adaptation Model

Within the Roy Adaptation Model (RAM), the interdependence mode emphasizes the quality of interpersonal relationships, social support, and an individual's connectedness with family, community, and healthcare providers. Among hemodialysis patients, physical limitations, fatigue, and psychological distress often hinder social interactions and weaken emotional support systems. Intradialytic exercise functions as an adaptive stimulus that enhances physical capacity, energy, and psychological well-being, thereby enabling patients to maintain meaningful social relationships. Research has shown that intradialytic exercise programs improve social participation, family and peer interactions, and communication with healthcare providers, corresponding with reduced fatigue and improved physical performance (Lin et al., 2022; Rhee et al., 2022). Furthermore, systematic reviews and meta-analyses report that such exercise significantly enhances psychosocial quality of life and reduces depressive symptoms, positively influencing patients' sense of connectedness and social support (Huang, Li, & Wang, 2024). These findings affirm that intradialytic exercise supports adaptation within the interdependence mode by strengthening interpersonal relationships and reinforcing social support systems among hemodialysis patients.

DISCUSSION

Patients with chronic kidney disease undergoing hemodialysis face significant challenges in maintaining adaptive body functions, particularly in physiological and psychological aspects. Fatigue is among the most prevalent symptoms, affecting more than 60 percent of patients worldwide. This condition not only diminishes quality of life but also disrupts the body's adaptive equilibrium. According to the Roy Adaptation Model (RAM), humans are adaptive systems that continuously strive to maintain dynamic balance between internal and external environments. Within this framework, intradialytic exercise or physical activity performed during dialysis sessions serves as an adaptive intervention that supports physiological restoration, reduces fatigue, and strengthens the body's regulatory mechanisms.

The physiological mode in the Roy Adaptation Model focuses on the individual's ability to maintain biological integrity through body regulatory mechanisms, including oxygenation,

nutrition, activity and rest, as well as protection from physiological stress. In hemodialysis patients, these mechanisms are often disrupted due to fluid imbalance, accumulation of uremic toxins, metabolic disorders, and decreased muscle capacity. Intradialytic exercise serves as a focal stimulus that activates the body's regulatory system, improves tissue perfusion, enhances cardiovascular capacity, and optimizes energy metabolism. A study by Verrelli et al. (2024) showed that cycling exercises performed for 30 minutes during each dialysis session over 12 weeks reduced fatigue levels by 52 percent compared to the control group, while also increasing cardiac output and peripheral perfusion. This exercise also enhances the release of nitric oxide (NO) from vascular endothelium, which helps maintain vessel elasticity and reduce peripheral resistance, thereby improving hemodynamics during dialysis (Verrelli et al., 2024). Another study by Yabe et al. (2023) reinforced these findings by showing that intradialytic exercise over 10 weeks improved endothelial function and maintained stable intradialytic blood pressure. This mechanism occurs due to increased arterial compliance, which helps sustain blood pressure and prevent hypotension during dialysis sessions (Yabe et al., 2023). With improved vascular elasticity and tissue perfusion, oxygen transport and metabolic waste removal become more efficient, contributing to a significant reduction in physiological fatigue.

In addition to improving cardiovascular function, intradialytic exercise also influences the musculoskeletal system. The reduction in muscle mass and strength due to chronic immobilization is a major cause of physical fatigue among hemodialysis patients. Ren et al. (2023) found that a combination of resistance and aerobic exercises performed over eight weeks increased handgrip strength by 17 percent and chair stand ability by 21 percent. This exercise stimulates muscle fiber formation and enhances mitochondrial activity, which in turn strengthens cellular energy capacity and delays the onset of muscle fatigue (Ren et al., 2023). Improved lower limb strength also contributes to patients' ability to perform daily activities, thereby reinforcing the body's adaptive response to chronic physical stress. The positive effects of intradialytic exercise on dialysis efficiency have also been widely reported. Io et al. (2023) found that structured aerobic exercise for 30 minutes during each dialysis session improved arterial oxygen saturation, reduced plasma urea levels, and increased Kt/V values as indicators of dialysis effectiveness. This exercise enhances capillary blood flow, improves toxin diffusion across the dialyzer membrane, and strengthens oxygen transport mechanisms in hemodialysis patients (Io et al., 2023). Similarly, Tabibi et al. (2023) reported that intradialytic exercise increased serum phosphate clearance efficiency by 15 percent and reduced uremic toxin levels contributing to metabolic fatigue (Tabibi et al., 2023). This improvement in metabolic efficiency reflects the body's ability to maintain internal homeostasis through physiological adaptation processes. Beyond cardiovascular and metabolic benefits, intradialytic exercise also has significant anti-inflammatory effects. Vergara et al. (2023) found that one year of intradialytic cycling exercise significantly reduced levels of C-reactive protein (CRP) and interleukin-6 (IL-6), which were correlated with decreased fatigue and improved quality of life (Vergara et al., 2023). These findings confirm that intradialytic exercise not only improves physical function but also reduces chronic inflammatory stress, supporting the body's adaptive mechanisms to achieve a new state of homeostatic balance.

Within the framework of the Roy Adaptation Model, successful adaptation is not solely determined by the physiological mode but also involves psychological, self-concept, and social dimensions. Hemodialysis patients often experience disturbances in self-esteem, depression, and decreased motivation due to dependence on the dialysis machine. Intradialytic exercise plays an important role in strengthening self-concept by providing patients with a sense of control over their bodies and improving their self-worth. Lin et al. (2022) demonstrated that a 12-week exercise program significantly improved psychological well-being scores and reduced depressive symptoms among hemodialysis patients (Lin et al., 2022). Similarly, Rhee et al. (2022) found that combined aerobic and resistance training enhanced self-esteem and motivation to remain active during therapy (Rhee et al., 2022). Thus, physical exercise can be understood as a positive adaptive stimulus that not only restores biological function but also enhances patients' self-perception of their chronic condition. From the RAM perspective, intradialytic exercise contributes to the restoration of the "physical self" by enabling patients to re-experience bodily

strength, functional capability, and physical independence despite chronic illness. This improved bodily perception reduces feelings of helplessness and reinforces a sense of bodily control. At the same time, it strengthens the "personal self" by enhancing self-consistency, self-ideal alignment, and self-evaluation, allowing patients to rebuild confidence, autonomy, and psychological stability in managing long-term hemodialysis treatment. However, it is important to note that not all patients achieve optimal adaptation through intradialytic exercise. Some individuals may still exhibit maladaptive responses due to factors such as advanced disease severity, persistent inflammation, severe comorbidities, low motivation, depression, or inadequate social support. In these cases, the regulatory and cognator subsystems may fail to respond effectively to the exercise stimulus, limiting the adaptive response. This indicates that intradialytic exercise should be combined with individualized nursing assessment and psychosocial support to maximize its effectiveness within the RAM framework. In addition to improving physiological and psychological functions, intradialytic exercise also impacts the social and interdependence modes described in the Roy Adaptation Model. Chronic fatigue often leads patients to withdraw from social interactions and lose their roles within the family. However, the increase in physical energy resulting from exercise enables them to re-engage in social activities and daily responsibilities. Sri et al. (2024) reported that patients participating in an eight-week intradialytic exercise program experienced improved daily activity capacity and adherence to dialysis schedules, as well as more positive interpersonal relationships with family members and healthcare providers (Sri et al., 2024). This positive social adaptation indicates that intradialytic exercise not only provides physical benefits but also strengthens interpersonal relationships essential for long-term treatment success.

Future research is recommended to explore the long-term effects of intradialytic exercise on the Interdependence Mode, particularly in relation to sustained social support systems, caregiver burden, and family dynamics over extended dialysis duration. Overall, research findings indicate that intradialytic exercise functions as a holistic adaptive stimulus influencing all four adaptive modes in the Roy Adaptation Model: physiological, self-concept, role function, and interdependence. Through improved tissue perfusion, metabolic efficiency, and hemodynamic stability, this exercise strengthens the biological integrity of patients. At the same time, enhanced sense of control, self-esteem, and social relationships reinforce psychological and social aspects of adaptation. In nursing practice, the implementation of intradialytic exercise reflects a holistic, theory-based approach in which nurses act as facilitators to help patients achieve comprehensive adaptive balance. Intradialytic exercise is not merely a physical activity but also a therapeutic intervention that integrates physiological, psychological, and social functions within a unified adaptive framework. Within the context of the Roy Adaptation Model, patients who engage in exercise during dialysis demonstrate better adaptation to chronic stress, maintain internal stability, and experience significant improvements in quality of life. Supported by strong empirical evidence from recent studies conducted between 2022 and 2025, intradialytic exercise can be recommended as a routine nursing intervention to promote physiological adaptation and reduce fatigue among long-term hemodialysis patients.

CONCLUSION

Intradialytic exercise is an effective adaptive intervention that enhances the ability of hemodialysis patients to cope with physiological and psychological stress associated with long-term therapy. Within the framework of the Roy Adaptation Model, this exercise acts as an adaptive stimulus that activates both regulator and cognator mechanisms, thereby promoting positive adaptation across the four adaptive modes: physiological, self-concept, role function, and interdependence. Physiologically, intradialytic exercise improves cardiovascular capacity, muscle strength, metabolic efficiency, reduces fatigue, and enhances functional capacity. Psychologically, it strengthens self-concept, motivation, and the patient's sense of control over their health condition. Furthermore, increased energy and independence support the restoration of social role function and strengthen interdependent relationships with family members, fellow patients, and healthcare providers. Therefore, intradialytic exercise represents a non-pharmacological, theory-

based, and evidence-supported strategy that can be integrated into nursing practice to enhance adaptation and improve the quality of life among hemodialysis patients. Future research is recommended to focus on the long-term effects of intradialytic exercise on the Interdependence Mode, particularly regarding sustained social support, caregiver involvement, and the stability of family and healthcare-related relationships over prolonged periods of hemodialysis treatment.

Author's Contribution Statement: Both authors contributed substantially to all stages of the research. [Author 1] was responsible for the conceptualization of the study, methodological design, and execution of the literature review. [Author 2] contributed to data analysis and synthesis, application of the Roy Adaptation Model framework, and the drafting and editing of the final manuscript. Both authors have read and approved the final version of the manuscript and agree to be fully accountable for all aspects of the work's integrity and accuracy.

Conflicts of Interest: The authors declare that there are no conflicts of interest associated with this research. There are no financial, personal, or professional relationships with any organization or entity that could influence the objectivity or integrity of the findings. This declaration is made to ensure transparency and uphold the scientific credibility of the article.

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