



Review

Exercise as a stress buffer in cancer patients: a review of the mechanisms and psychological outcomes

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Abstract: Background: Cancer diagnosis and treatment impose significant psychological stress on patients, which can negatively impact treatment adherence and overall quality of life. Exercise has emerged as a potential stress buffer against this stress, providing both psychological and physiological benefits; **Objective:** The aim of this article is to conduct an integrative review that summarizes the mechanisms through which exercise alleviates stress in cancer patients and the associated psychological outcomes; **Methods:** A literature search was conducted using the PubMed, Google Scholar, Elsevier ScienceDirect, and Web of Science databases for systematic reviews published up to October 2024. Additionally, a manual search of reference lists was performed; **Results:** By reviewing the existing literature, we found that exercise can enhance the psychological well-being of cancer patients by modulating physiological and psychological stress responses, thereby reducing their overall stress levels; **Conclusions:** The evidence indicates promising trends regarding the use of exercise as a potential intervention for enhancing cognitive function following cancer and cancer its treatment. However, questions persist concerning the type of exercise, timing of initiation, intensity, frequency, and duration. We examine the role of exercise in modulating stress hormones, immune function, and inflammation, as well as its effects on mood, cognitive function, and overall well-being. The paper concludes with recommendations for incorporating exercise into cancer care and outlines directions for future research.

Keywords: cancer patients; exercise; psychological outcomes; psycho-oncology; stress buffering

1. Introduction

Cancer is a chronic disease that can affect individuals of all ages[1]. It can impact any part of the body and is primarily categorized into two main types: hematologic (blood) cancers and solid tumor cancers[2]. Cancer originates from genetic alterations in individual cells, which subsequently proliferate into a mass, known as a tumor. This mass has the potential to invade other parts of the body, posing a significant risk to the individual's life if left untreated[2].

The stress associated with cancer is multifaceted, encompassing fears of mortality, altered body image, treatment-related side effects, and the uncertainty of recurrence[3]. The psychological burden of cancer extends beyond the individual to their social networks, affecting family dynamics and work life, and often leading to social isolation and economic hardship. Psychological stress has been linked to poorer treatment outcomes, increased mortality, and decreased quality of life in cancer patients[4,5]. Therefore, identifying effective stress management interventions is crucial.

In this context, exercise emerges as a promising adjunct to conventional

cancer care. It is a non-pharmacological intervention with the potential to mitigate stress, improve mood, enhance physical function, and bolster the immune system—a complex interplay of physiological and psychological benefits that can positively influence cancer outcomes[6-8]. Exercise and physical activity, in general, are considered safe and can serve as a beneficial complementary therapy for alleviating adverse effects, even during the most aggressive phases of treatment[9,10].

The physiological benefits of exercise are well-documented, with evidence supporting its role in reducing fatigue, improving cardiovascular health, and increasing muscular strength in cancer patients[11,12]. These physical improvements can trigger a cascade of psychological benefits, including enhanced self-efficacy, a sense of mastery, and greater control over one's health, all of which are essential for stress reduction[13,14].

Moreover, exercise has been shown to modulate the neuroendocrine response to stress. It can reduce the production of stress hormones such as cortisol and adrenaline, which, when chronically elevated, can suppress immune function and contribute to anxiety and depression[15,16]. By normalizing these hormonal imbalances, exercise may provide a natural counterbalance to the stress associated with cancer. The psychological benefits of exercise for cancer patients are multifaceted. In addition to reducing stress and improving mood, exercise has been linked to enhanced cognitive function, including improved memory and attention, which can be particularly beneficial for patients experiencing “chemo brain”[17,18]. It also contributes to an overall sense of well-being, which is closely tied to mental health.

Although numerous systematic reviews investigate the effects of exercise and physical activity interventions on cancer, a clear understanding of the physiological and psychological outcomes experienced by these cancer patients and survivors remains elusive. This review aims to provide a comprehensive overview of exercise as a stress buffer for cancer patients, exploring the mechanisms through which exercise alleviates stress and the resulting psychological outcomes. By synthesizing the current evidence, we seek to contribute to the expanding body of research that advocates for the integration of exercise as a standard component of cancer care.

2. Methods

Literature searches were conducted using PubMed, Google Scholar, Elsevier ScienceDirect, and Web of Science. The search strategy employed the following terms: “training”, “exercise”, “exercise interventions”, “cancer”, “tumor”, “cancer patients”, “stress”, “psychological health”, “mechanisms”, “exercise AND cancer”, “cancer patients AND psychological health”, “exercise AND pressure” and “cancer AND pressure” among others.

3. Sources and effects of stress on cancer patients

Cancer patients encounter a range of stressors during diagnosis and treatment, which arise from various physical, psychological, social, and environmental factors.

Physical stress associated with cancer diagnosis and treatment

The diagnosis and treatment of cancer can impose significant physical stress on patients. To confirm a cancer diagnosis, patients may need to undergo a series of invasive tests, such as biopsies and endoscopies, which can result in pain and discomfort. During cancer treatment, modalities such as chemotherapy and radiotherapy may lead to side effects, including nausea, vomiting, hair loss, fatigue, mucositis, and anemia, all of which can severely impact the patient's daily life[19]. Additionally, surgical interventions may carry risks such as pain, postoperative infections, and impaired physical functioning[20]. Over the

long term, cancer treatments can lead to complications, such as cardiac issues associated with chemotherapy[21] and potential organ damage resulting from radiotherapy[22].

Cancer-related psychological stress

The diagnosis and treatment of cancer can cause significant psychological stress for patients[23], including feelings of panic, uncertainty, anxiety, depression, and low self-esteem. Generally, the diagnostic process for cancer patients is often accompanied by worries and fears regarding their future health status[24]. Additionally, once diagnosed, patients may experience anxiety, depression, and other mood disorders, which can exacerbate their physical symptoms[25]. During long-term cancer treatment, patients may undergo changes in body image, such as weight fluctuations and hair loss, which can negatively impact their self-esteem and sense of identity[4].

Stress due to social and environmental factors

Social and environmental factors are significant sources of stress for cancer patients, including financial burdens, inadequate social support, and disruptions to their normal work life. The high cost of cancer treatment, particularly the long-term use of certain chemotherapeutic drugs, can impose financial pressure on both patients and their families[26,27]. Additionally, patients may experience a lack of support from family, friends, and the community, which can adversely affect their psychological well-being[28]. Furthermore, cancer treatment may necessitate a reduction in working hours or even a complete cessation of work, impacting patients' social roles and overall quality of life. The effects of cancer treatment on patients' quality of life represent a major source of stress[29]. These physical, psychological, and social sources of stress and their effects are summarized in **Table 1**.

Table 1. Sources and Effects of Stress in Cancer Patients

Sources of stress	concrete expression	Effects
Physical Stress [19]	Invasive tests conducted during diagnostic procedures (e.g., biopsy, endoscopy, etc.)	Decrease in Quality of Life
	Treatment-related side effects (e.g., chemotherapy-induced nausea, vomiting, hair loss, and fatigue)	Increased Psychological Burden
	Surgical risks (e.g., pain, postoperative infections, and dysfunction)	Leads to a decline in physical function and an increase in dependence.
	Long-term complications, such as heart problems resulting from chemotherapy and organ damage caused by radiation therapy, can occur.	Impact on the Ability to Perform Daily Activities
Psychological Stress [25]	Fear of Death	The impact on treatment adherence
	Concerns Regarding Treatment Uncertainty	Decreases psychological resilience.
	Body image changes (e.g., fluctuations in weight, hair loss)	Increases psychological stress.
	Emotional disorders (e.g., anxiety, depression, and low self-esteem)	Social isolation and loneliness can result from this.
Social and environmental pressures [26, 27]	The financial burden resulting from the high cost of treatment.	Increase psychological stress.
	Job Interruption or Unemployment	The impact on family and social relationships
	Changes in Social Roles	Reduces overall quality of life.
	Lack of support from family, friends, or the community.	Leads to economic hardship and social isolation.
Impact on quality of life [28]	Limited Physical Functioning	Decreased Overall Quality of Life
	Impaired Mental Health	Treatment outcomes may be adversely affected.

Continued table:

Sources of stress	concrete expression	Effects
	Decreased Socialization Decreased treatment adherence.	Prolonged Recovery Process Exacerbation of Mental Health Issues

4. Exercise for stress relief in cancer patientsdiscussion

Exercise has consistently been shown to improve mood in cancer patients by reducing symptoms of depression and anxiety. The release of endorphins and other mood-enhancing neurotransmitters during physical activity may contribute to these positive effects. Recent research indicates that exercise may also influence mood by affecting inflammation and oxidative stress, both of which are often elevated in cancer patients and can lead to negative emotional states. By reducing inflammation and oxidative stress, exercise may foster a more favorable physiological environment for emotional well-being.

Exercise for physical stress relief in cancer patients

Exercise can assist cancer patients in alleviating physiological stress through various mechanisms. Halle et al. found that regular aerobic exercise improves cardiac function, increases cardiorespiratory endurance, and reduces fatigue induced by chemotherapy and radiotherapy[30,31]. Resistance training enhances muscle strength and endurance[32], enabling patients to better manage the physical demands of daily life and minimizing activity limitations due to muscle weakness. Additionally, exercise can mitigate fatigue associated with chemotherapy and radiation therapy[33]. It also helps alleviate the side effects of these treatments, such as reducing nausea, increasing appetite, and improving digestion. Furthermore, exercise promotes better blood circulation and decreases the risk of treatment-induced blood clots, facilitating nutrient transport and the removal of metabolic waste[34]. Moderate exercise enhances immune system function and improves the body's resistance to disease, which may support host defense; however, a direct effect on tumor growth should not be inferred from this evidence[35].

Exercise for psychological stress relief in cancer patients

Patients frequently experience depression during cancer diagnosis and treatment, which significantly impacts their treatment adherence and overall quality of life. Exercise, as a non-pharmacological intervention, has been demonstrated to effectively alleviate depressive symptoms in cancer patients. On one hand, exercise elevates mood by increasing the concentration of neurotransmitters in the brain, such as serotonin and dopamine, which directly influence the mood regulation center. On the other hand, exercise enhances patients' sense of self-efficacy, fosters a greater sense of control over their lives, and diminishes feelings of helplessness and hopelessness.

Elias et al. found that exercise promotes the release of such endorphins[36,37], which can help reduce anxiety and depression while improving mental health. Additionally, exercise can enhance self-efficacy. By engaging in physical activity, patients may experience a greater sense of control over their bodies, boost their self-efficacy[38], and increase their confidence in overcoming their illnesses[39].

Cancer patients frequently experience symptoms of anxiety, which may stem from the uncertainty surrounding their illness and fears related to treatment[40]. Exercise can alleviate anxiety in several ways. First, as a relaxation technique, exercise helps patients divert their attention and lessen excessive preoccupation with their condition. Second, it mitigates the body's stress response and diminishes anxiety-related physiological symptoms, such as palpitations and

muscle tension[41]. Studies have demonstrated that even low-intensity exercises, such as walking or yoga, can significantly lower anxiety levels in cancer patients[42]. Additionally, exercise enhances the quality of sleep, and a restful night's sleep is crucial for alleviating anxiety. Furthermore, exercise is known to reduce the risk of anxiety in individuals with cancer[43].

Mental toughness refers to an individual's capacity to effectively cope with and adapt to stress and adversity[44]. This quality is crucial for maintaining a positive psychological state in cancer patients throughout the treatment process. Engaging in exercise can significantly enhance the mental toughness of these patients in various ways. Cancer patients who exhibit higher levels of mental toughness are more likely to participate in exercise and can reap greater psychological benefits from their physical activity[45].

Social interaction is a crucial element for cancer patients[46]. Group exercise or fitness activities offer these individuals the opportunity to engage with others, which helps to establish a social support network and alleviate feelings of isolation[47]. Additionally, exercise can enhance the quality of sleep for cancer patients by aiding in the regulation of the sleep cycle, thereby reducing the psychological stress associated with sleep disturbances[48,49].

The effect of exercise on the quality of life of cancer patients

Quality of life is a crucial indicator for assessing the psychosocial well-being of cancer patients. Generally, exercise has a beneficial effect on the quality of life for these individuals. Engaging in physical activity enhances patients' physical functioning, allowing them to participate more fully in daily activities and increasing their capacity for self-care[50]. Additionally, exercise can enhance the overall quality of life of cancer patients across multiple dimensions[51], including physical, psychological, social, and emotional aspects[52]. Regular physical activity can expedite the recovery process, enabling patients to return to their normal lives and work more swiftly. Furthermore, exercise can foster a more positive attitude toward treatment and improve adherence to treatment protocols, which may lead to better treatment outcomes[53].

In conclusion, exercise serves as a low-cost intervention with minimal side effects and plays a crucial role in the treatment and rehabilitation of cancer patients. However, it is important to note that exercise programs for cancer patients should be tailored to the individual's health status, stage of treatment, and level of physical strength, and should be conducted under the supervision of a healthcare professional.

5. Mechanisms of exercise for stress relief in cancer patients

Exercise has a multifaceted mechanism of action in alleviating stress in cancer patients, encompassing three dimensions: neurobiology, the endocrine and immune systems, and psychosocial factors.

Neuroendocrine mechanisms of stress relief

One of the primary mechanisms through which exercise enhances mood is the release of endorphins and other neurotransmitters. During physical activity, the body releases endorphins, which are natural painkillers and mood elevators[54]. This phenomenon is often referred to as the "runner's high," and it can lead to immediate feelings of euphoria and well-being. Additionally, exercise increases the levels of serotonin and dopamine, neurotransmitters that play crucial roles in regulating mood and emotional responses[55,56].

The hypothalamic-pituitary-adrenal (HPA) axis is a crucial component of the stress response system, integrating perceived stressful events into a series of autonomic neuroendocrine changes necessary for restoring physiological homeostasis[57]. In response to stress, corticotropin-releasing hormone (CRH) is released from the paraventricular nucleus of the hypothalamus, which

subsequently stimulates the secretion of adrenocorticotrophic hormone (ACTH) from the anterior pituitary gland. The sustained release of cortisol, driven by adrenocorticotrophic hormone, is regarded as the primary stress response, as it induces various physiological changes aimed at meeting increased demands and mitigating further HPA activity through feedback inhibition[58]. Although the dynamic responsiveness of the HPA axis is vital for adapting to stress, prolonged over-activation or under-activation can be detrimental to both physical and mental health.

Prolonged activation of the HPA axis in cancer patients can result in elevated cortisol levels, immune suppression, and cognitive impairments[59]. Exercise is known to influence the HPA axis, which plays a central role in the body's stress response. Physical activity has been shown to decrease cortisol levels[60], a marker of HPA axis activity[61], and improve autonomic nervous system function, thereby mitigating stress responses.

Long-term exercise fosters plastic changes in the brain, including enhanced neuronal connectivity and the generation of new nerve cells, which can contribute to improved cognitive function and mood regulation. Exercise is also associated with increased levels of brain-derived neurotrophic factor (BDNF)[62], which is a neurotrophic factor critical for mood regulation and neuroplasticity[63]. BDNF levels have been positively correlated with both exercise intensity and duration, suggesting that regular aerobic exercise may be particularly effective in enhancing BDNF levels.

In cancer therapy, neuroendocrine transformation (NEPC) is a significant mechanism of treatment resistance[64]. Exercise may influence by affecting neuroendocrine pathways related to NEPC. For instance, exercise may impact the process of neuroendocrine conversion by regulating the expression of transcription factors associated with NEPC, such as ASCL1[65].

Biological clock rhythms

Biological clock rhythms play a crucial role in regulating the HPA axis and neuroendocrine functions[66]. Exercise can influence the expression of biological clock genes, which may regulate stress-related biological rhythms[67]. This modulatory effect may be important in improving sleep quality, mood, and cognitive function in cancer patients.

Gut-Brain Axis

Emerging research suggests that the gut-brain axis plays a significant role in mood regulation[68]. Exercise can positively influence the composition of gut microbiota, which, in turn, affects the production of neurotransmitters and other metabolites that impact mood[69]. A healthy gut microbiome has been associated with improved mental health outcomes, and exercise appears to promote beneficial changes in gut microbiota diversity and function. This connection underscores the importance of physical activity not only for physical health but also for psychological well-being[70].

Immune Mechanisms of Stress Relief

Cancer and its treatment can impair immune function, increasing vulnerability to infections and reducing the efficacy of treatment [71]. Recent studies suggest that exercise not only affects the neuroendocrine system but may also influence cancer progression by modulating the tumor immune microenvironment (TIME)[72]. The interaction between the neuroendocrine system and TIME may occur through the infiltration of nerve fibers, the migration of cancer cells toward nerve fibers, and the action of neurotransmitters[73]. Exercise may have an impact on cancer progression by affecting these pathways to modulate TIME.

Exercise has been shown to enhance immune function by modulating

cytokine production and natural killer cell activity, which may contribute to improved disease outcomes[74]. It influences immune function in cancer patients through various mechanisms, including the modulation of immune cell dynamics, regulation of immune cell metabolism, and enhancement of immune memory. Collectively, these mechanisms position exercise as a promising adjuvant therapy for cancer. By improving the immune function and enhancing the body's resistance, exercise can also help reduce stress in cancer patients.

Exercise can significantly influence the dynamics of immune cells. Following an acute exercise session, an increase in the number of leukocytes in the peripheral blood is often observed, primarily due to the exercise-induced stress response, which triggers the rapid mobilization of lymphocyte subpopulations into circulation[75]. This lymphocyte redeployment (lymphocyte redeployment) may represent an evolutionarily conserved immune mechanism that enhances immune surveillance and regulates peripheral tissues, thereby improving the body's ability to combat infections.

Cancer cells exhibit a distinct metabolism compared to normal cells, and exercise can influence tumor growth by regulating cancer metabolism. Engaging in physical activity enhances glucose and lipid metabolism, increases energy supply, and alleviates the burden on the body[76], [77]. For instance, exercise elevates PGC-1 α levels in muscle tissue, which modulates kynurenine metabolism and contributes to resilience against stress-induced depression[78].

In recent years, the phenomenon of (TI) within the realm of innate immunity has garnered significant attention[79]. Trained immunity refers to the capacity of innate immune cells to mount a more robust immune response to subsequent infections or stimuli following an initial exposure[80]. Exercise is believed to enhance the body's resistance to infection by inducing trained immunity. Moreover, the process of developing immune tolerance is primarily driven by metabolic reprogramming, and exercise has been demonstrated to influence metabolic reprogramming across various cell types, including immune cells.

Exercise may also enhance the body's immune defenses by influencing immune memory. Research has demonstrated that physical activity improves the immune memory characteristics of immune cells. Specifically, after exposure to an exercise stimulus, these cells can the stimulus and exhibit a more robust immune response when they encounter the same or a different stimulus in the future[81,82].

Inflammation

Chronic inflammation is a hallmark of cancer and is associated with increased stress[83]. Exercise is known to reduce systemic inflammation, potentially alleviating stress-related inflammation in cancer patients. Additionally, exercise can enhance the activity of antioxidant enzymes, effectively scavenging free radicals and reducing oxidative stress-induced cellular damage and gene mutations, thereby lowering the risk of cancer [84].

Psychosocial mechanisms

Beyond biochemical changes, psychological factors also play a significant role in mood enhancement through exercise. Engaging in physical activity fosters a sense of accomplishment and mastery, which can improve self-esteem and self-efficacy. Group exercise settings offer essential social support, which is crucial for emotional resilience. The camaraderie and shared experiences in group workouts can alleviate feelings of isolation and enhance overall mood. Exercise enhances self-efficacy and perceived control while diminishing feelings of helplessness, all of which are crucial psychological resources for managing stress. Furthermore, exercise can serve as an effective coping strategy, enabling individuals to respond positively to stressful events in their lives.

Exercise can enhance cognitive function by increasing brain plasticity[85]. For cancer patients, physical activity can facilitate cognitive remodeling, altering negative perceptions of the disease and improving their ability to cope with stress. For instance, regular aerobic exercise has been shown to improve patients' executive function and attention, enabling them to better manage stressful situations in their lives[86].

Exercise serves as an effective mood-regulating tool that can help cancer patients alleviate symptoms of depression and anxiety. It enhances mood by increasing levels of dopamine and serotonin (5-hydroxytryptamine) in the brain. Additionally, exercise offers a platform for social interaction, which enhances patients' social support and further alleviates emotional stress[87]. At the same time, exercise can serve as an effective coping strategy, helping patients manage stressful events in their lives. It allows them to redirect their attention toward their disease and treatment, thereby diminishing excessive focus on their condition. This shift can reduce psychological stress and function as a buffer against it[88].

Exercise activities typically occur in a group setting, offering cancer patients the opportunity to interact with others and strengthen their social support networks. Social support is widely recognized as a crucial factor in alleviating stress and enhancing quality of life. The mutual support and encouragement found in exercise groups can significantly boost patients' self-esteem and sense of belonging, thereby mitigating psychological stress. Group exercises serve as a source of social support, which is a well-known stress-buffering factor[89,90]. Cancer patients who engage in group exercises may experience a greater sense of belonging, reduced feelings of isolation, and improved communication skills, all of which can contribute to stress reduction. The main stress-relieving effects of exercise and their proposed mechanisms are summarized in **Table 2**.

Table 2. Exercise relieves stress in cancer patients

Aspects of stress relief	Specific mechanisms of action	Impact on cancer patients
Improve Mood [34]	The release of endorphins and other neurotransmitters, such as serotonin and dopamine, contributes to a reduction in inflammation and oxidative stress.	Alleviates symptoms of depression and anxiety; improves overall emotional and mental well-being; enhances mental resilience to cope with illness.
Relieving Physical Stress [37]	Improved cardiorespiratory fitness and endurance; increased muscle strength and stamina; reduced treatment-related fatigue and side effects.	Enhance patients' ability to manage their daily self-care; alleviate fatigue resulting from chemotherapy and radiation therapy; improve digestion and appetite.
Psychological stress relief [38]	Enhances self-efficacy and a sense of control; increases mental toughness; provides social support.	Reduces anxiety related to the uncertainty of illness; alleviates low self-esteem stemming from changes in body image; diminishes feelings of loneliness and social isolation.
Improvement of sleep quality [50]	Regulates sleep cycles and alleviates symptoms of anxiety and depression-related insomnia.	Enhance sleep quality; alleviate psychological stress associated with sleep issues; improve overall quality of life.
Enhancing quality of life [53]	Engages physical functioning, improves mental, social, and emotional well-being, and accelerates the healing process.	Enhance patients' ability to engage in daily activities; improve treatment adherence; increase overall life satisfaction.
Regulation of stress hormone levels [51]	Reduces cortisol and adrenaline levels while modulating the HPA axis.	Reduces the adverse effects of chronic stress on the body while enhancing immune function; and cognitive performance.
Enhancement of immune function [35]	Regulates cytokine production; enhances natural killer cell activity; improves immune cell metabolism and memory.	Reduces the risk of infection; enhances the body's resistance to tumors; alleviates psychological stress caused by immunosuppression.
Reducing the inflammatory response [84]	Reduces systemic inflammation, enhances the activity of antioxidant enzymes, and decreases oxidative stress damage.	Relieves psychological stress associated with chronic inflammation; reduces the risk of disease progression.

6. Integrating exercise into cancer care

Type and intensity of exercise

Choosing the appropriate type and intensity of exercise is essential for exercise interventions in cancer patients. Currently, common forms of exercise include aerobic exercise, resistance training, and flexibility and balance training[91]. Aerobic activities, such as brisk walking, jogging, swimming, and cycling, enhance cardiorespiratory fitness, increase oxygen intake, and are particularly effective in improving cardiovascular health and reducing fatigue. Resistance training, which encompasses weight lifting, the use of elastic bands, and bodyweight exercises, helps maintain and increase muscle strength while preventing muscle atrophy. Flexibility and balance training, including practices like yoga and Tai Chi, can enhance joint range of motion and decrease the risk of falls.

Regarding exercise intensity, it is widely acknowledged that cancer patients should begin with low to moderate intensity and gradually progress. The American College of Sports Medicine recommends that cancer survivors participate in moderate-intensity aerobic exercise (e.g., brisk walking) for a minimum of 150 minutes per week or high-intensity aerobic exercise for at least 75 minutes per week[92,93]. However, the selection of exercise intensity should consider the patient's specific medical condition, stage of treatment, level of physical fitness, and personal preferences.

Frequency and duration of exercise

Exercise frequency and duration are critical factors in determining the effectiveness of exercise interventions. It is generally recommended that cancer patients engage in physical activity approximately five times per week, with each session lasting between 30 to 60 minutes[93]. For patients who are unable to exercise continuously for extended periods, physical activity can be performed in segments, such as 10 to 15 minutes at a time, cumulatively reaching the total recommended duration[94]. Studies have demonstrated that even short bouts of exercise, when performed with adequate frequency, can yield significant psychological and physiological benefits[95].

Individualized exercise prescription development

The development of an individualized exercise prescription is essential due to the significant variation in disease progression, treatment responses, and fitness levels among patients with cancer[94]. Individualized exercise prescriptions should be grounded in a comprehensive assessment of the patient, which includes medical history, physical fitness evaluations, psychological status, and lifestyle habits. The prescription must specify the type, intensity, frequency, duration, and any potential contraindications to exercise. Furthermore, exercise prescriptions should be tailored to align with the patient's personal goals and preferences to enhance adherence. Stage-specific exercise recommendations, including exercise type, frequency, duration, intensity, and key precautions, are summarized in **Table 3**.

Table 3. Integrating Exercise into Cancer Care: Stage-Specific Exercise Guidelines

Point	Purpose	Type of exercise	Frequency	Span	Intensity	Caveat
Pre-operative phase [92]	Enhances physical function; improves surgical tolerance; reduces postoperative complications.	Aerobic exercise (brisk walking, jogging, and cycling); resistance training (dumbbells and elastic bands); flexibility training (yoga and stretching)	3-4 times per week	20-30 minutes/times	medium strength	Communicate with your surgeon to establish a safe exercise program and avoid overexertion.
Postoperative Hospitalization Phase [92,93]	Promote wound healing; restore basic mobility; prevent thrombosis	Bed activities (ankle pump exercises, deep breathing, coughing exercises); early activities (bedside standing, short distance walking)	Ankle pump exercise, short-distance walking	5-10 minutes/time	Light Activity	Please follow your healthcare provider's instructions and monitor the condition of your wound closely.
Post-Operative Rehabilitation Stage [94]	Gradually restore the ability to perform activities of daily living while enhancing muscle strength and cardiorespiratory function.	Aerobic exercise; resistance training; and flexibility training	3-4 times per week	20-30 minutes	Moderate Intensity	Follow your doctor's advice and avoid overexertion.
Complementary Stages of Treatment [95]	Relief of treatment-related fatigue; reduction of psychological stress; maintenance of physical functioning	Aerobic exercise; resistance training; flexibility training	3-5 times per week	15-30 minutes/session	Low to moderate intensity	Avoid high-intensity exercise on the day of chemotherapy or radiation therapy; reduce exercise when severely fatigued or nauseated.
Rehabilitation Stage [95]	Full restoration of body functions; improvement of quality of life and prevention of relapse.	Aerobic exercise; resistance training; flexibility training	4-5 times per week	30-60 minutes each time	Moderate intensity	Regular medical checkups; consult your doctor if you experience unusual symptoms.
Long-term maintenance phase [93]	Maintain a healthy lifestyle to prevent cancer recurrence; improve long-term survival rates	Aerobic exercise; resistance training; flexibility training	4-5 times per week	30-60 minutes per session	Moderate intensity	Keep exercise varied and interesting; communicate regularly with your healthcare team.

7. Future research directions

Despite the numerous benefits of exercise interventions for cancer patients, they encounter several challenges in practical implementation. First, cancer patients may struggle to adhere to exercise regimens due to treatment side effects, fatigue, or a lack of motivation. Potential solutions include offering professional exercise guidance, creating a supportive exercise environment, and providing incentives for participation. Second, insufficient awareness of exercise interventions among both physicians and patients can result in a lack of exercise recommendations. Consequently, there is a pressing need to educate healthcare professionals and emphasize the significance of exercise interventions in clinical practice.

Additionally, the absence of standardized guidelines for exercise among cancer patients presents a significant challenge. Exercise should be regarded as an essential component of cancer care. Oncology centers can incorporate exercise programs, led by specialized professionals, to offer personalized exercise prescriptions. These programs should be customized to align with the patient's disease stage, treatment phase, and individual preferences.

While the benefits of exercise for cancer patients are well-documented, several research gaps remain. Longitudinal studies are necessary to assess the long-term effects of exercise on stress reduction and disease outcomes. Furthermore, additional research is needed to identify the optimal dosage, type,

and timing of exercise to achieve maximum psychological benefits.

Given the substantial impact of exercise on mood, it is essential to integrate physical activity into cancer care protocols. Regular exercise can act as a complementary intervention alongside traditional therapies, enhancing not only the psychological well-being of cancer patients but also their overall quality of life. Future research should further investigate the optimal types, intensities, and durations of exercise that maximize mood enhancement in this population.

8. Conclusion

Exercise serves as a powerful stress buffer for cancer patients, offering substantial psychological and physiological benefits. By regulating stress hormones, enhancing immune function, and decreasing inflammation, exercise promotes improved mood, cognitive function, and overall well-being. As the body of evidence expands, exercise should be more systematically incorporated into standard cancer care. Future research should concentrate on optimizing exercise interventions and clarifying the mechanisms that underlie their effects.

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