PHYSICAL ACTIVITY, EXERCISE AND CANCER

ORIGINAL ARTICLE

Precision physical exercise training for cancer patients: A new trend

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ABSTRACT

There is a growing scientifically supported trend toward understanding physical exercise as a therapy for combating cancer. The objective of this article is to provide a new perspective on oncological physical exercise, relating training variables to the overall cancer situation. Currently, one of the most important trends in sports performance and health is precision physical training, one of the most effective tools for successful implementation of a rigorous and scientific training method. In addition to the above, physical training methods stem from dogmas or theories applied in different sports disciplines and with different populations. For this reason, it has become necessary to understand that there is variation in the individual response of each person to a given physical exercise. Variables such as correct load, number of repetitions, optimal recovery time, speed of execution, correct posture based on biomechanics, and the amplitude of these depending on anthropometry, are similar to the individual biochemistry of each human being. This work aims to promote and support precision physical training in cancer patients, as a new trend to make the survival of our population a reality.

Keywords: Physical activity, Cancer prevention, Cancer treatments, Cancer survivors, Psychology, Sport medicine.

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INTRODUCTION

Cancer, one of the leading causes of mortality globally, represents a critical challenge for both medicine and sports science. According to recent data, neoplastic diseases like this one will affect an increasing number of individuals in the coming years, with an estimated 286,664 new cases in Spain by 2024 (Anishchenko-Halkina et al., 2024). This panorama underscores the need for innovative therapeutic approaches that complement traditional medical treatments, not only to control the disease but also to improve the quality of life of those suffering from it. Within this quest, physical exercise has emerged as a multidimensional tool, capable of influencing physiological, psychological, and even immunological aspects in cancer patients. This article focuses on individually tailored precision physical training and its impact on the immune response and quality of life of cancer patients.

Physical exercise, traditionally linked to improvements in cardiovascular and metabolic health, has also demonstrated its ability to influence molecular and cellular processes relevant to cancer treatment. Recent studies have suggested that physical activity can stimulate key immune cells, such as T lymphocytes and Natural Killer cells, while also helping to reduce chronic inflammation associated with cancer progression (Bartlett & Hanson, 2024; Fiuza-Luces et al., 2023). Additionally, regular exercise training alleviates treatment side effects such as chronic fatigue, muscle loss, and changes in body composition (Casla et al., 2023). However, implementing exercise as an integral part of cancer management faces significant challenges, such as the lack of individualized training protocols that consider the specific characteristics of each patient, including tumour type, disease stage, and treatment response.

The main objective of this study is to address the following research question: How can individually tailored precision exercise training influence the immune response and quality of life of cancer patients? To answer this question, a methodological approach is established that allows for the design of training programs tailored to the specific needs of each patient, ensuring their safety and effectiveness. This personalized approach, framed within precision medicine, not only aims to maximize the physiological and psychological benefits of exercise, but also to explore its potential as a complementary immune therapy.

The methodological basis of this work is based on a comprehensive analysis of the available scientific literature, including systematic reviews, preclinical studies, and recent clinical trials. Based on this information, critical synthesis tools are used to evaluate different types of physical exercise and their effects on cancer patients, with a particular focus on aerobic and resistance training, given their positive impact on quality of life and immune modulation (Campbell et al., 2019; Fernández-Lázaro et al., 2020). Additionally, the practical implications of integrating physical exercise into cancer treatment and the design of protocols supervised by specialized professionals are examined.

The article is structured into four main chapters. The first introduces the concept of oncological physical exercise and its relevance as a therapeutic tool. The second chapter develops the conceptual framework of this discipline, emphasizing exercise as an immunological modulator and specific immune responses in cancer patients. The third chapter addresses the prescription of individualized training, exploring how to adjust variables such as intensity and frequency to the unique characteristics of each patient. Finally, the fourth chapter discusses the findings and their implications for the design of therapeutic strategies based on precision physical exercise.

ONCOLOGICAL PHYSICAL EXERCISE

Physical exercise is emerging as a fundamental intervention in oncology, offering benefits that transcend mere physical activity and are integrated into the treatment and recovery of cancer patients. The subtopics will explore how physical activity acts as an immunological therapy, optimizing the immune system's response, as well as its potential to improve quality of life and reduce adverse symptoms during treatment. This comprehensive perspective on exercise highlights its crucial role in contemporary cancer care, placing physical and emotional well-being at the centre of the therapeutic approach.

Exercise as immunotherapy

Physical exercise, increasingly recognized as a therapeutic intervention in oncology, activates key immune cell subtypes, a critical process for strengthening immunosurveillance in cancer patients. This effect includes the stimulation of Natural Killer (NK) cells, CD8+ T lymphocytes, and γδ T cells, which play essential roles in identifying and neutralizing tumour cells (Fiuza-Luces et al., 2023). In particularly aggressive neoplasias, where immune capacity is significantly compromised, the mobilization of these cells becomes a determining factor in improving the body's ability to control tumours The infiltration of these immune cells into tumours suggests improved clinical outcomes, as exemplified by the activity of CD8+ T cells, which induce tumour cell death through specific cytotoxic mechanisms, such as the release of perforins and granzymes. This dynamic reinforces the potential of physical exercise as an effective complement to immunotherapy, maximizing the results of conventional treatments (Fiuza-Luces et al., 2023).

Compared to sedentary lifestyles, physical exercise demonstrates a unique ability to mobilize and activate these immune cells, positioning itself as a complementary strategy that not only protects and strengthens the immune system but also amplifies the effectiveness of treatments such as chemotherapy and radiation therapy. This benefit may be attributed in part to the release of myokines, such as interleukin-6 (IL-6), a key mediator with anti-inflammatory properties that, in the context of cancer, helps counteract the proinflammatory environment that promotes tumour growth (Fiuza-Luces et al., 2023). Unlike chronic inflammatory conditions associated with cancer, exercise-induced myokines act in a beneficial way, not only by decreasing inflammatory markers such as IL-1 and TNF-α, but also by optimizing the tumour microenvironment to hinder malignant progression. This approach suggests that exercise not only delays tumorigenesis but also complements the limitations of traditional pharmacological therapies.

Another important mechanism is the activation of SIRT3, a mitochondrial protein that, under the influence of physical exercise, promotes mitochondrial oxidation and limits the glycolytic metabolism predominant in cancer cells (Bórquez et al., 2018). This process partially reverses the metabolic conditions that facilitate tumour cell proliferation, promoting a normoxic microenvironment less favourable for their growth. Furthermore, SIRT3 regulates redox homeostasis, balancing the production of reactive oxygen species (ROS). This is particularly relevant since excessive levels of ROS not only contribute to oxidative stress but can also indirectly stimulate tumorigenesis. Therefore, this modulation suggests that physical exercise can reprogram cellular metabolic processes, diverting them toward pathways less favourable for the survival and progression of malignant cells.

Regular exercise not only impacts metabolic and inflammatory mechanisms, but also remodels the T lymphocyte repertoire, promoting the proliferation of naive CD8+ T cells while reducing senescent T cells (Fiuza-Luces et al., 2023). This renewal is essential for maintaining a robust immune response to cancer cells and other antigenic challenges. By reducing the number of aging immune cells, systemic inflammation, a component that traditionally compromises the immune environment in cancer patients, is also reduced. In

this context, exercise not only strengthens the adaptive functions of the immune system but also protects against immunosuppression induced by treatments such as chemotherapy. This underscores the potential of exercise as a multifaceted therapeutic tool that transcends the limits of conventional treatments.

The combination of strength and resistance training has a synergistic effect on improving the quality of life of cancer patients, due to its impact on molecular processes and muscle strengthening, both of which are essential during cancer treatments (Anishchenko-Halkina et al., 2024). In addition to optimizing physical function, these interventions have been shown to alleviate symptoms of fatigue and improve psychological well-being, which is crucial for recovery. This multidimensional approach highlights the importance of individualizing training, adapting it to each patient's abilities and needs. In particular, a significant 37% reduction in the risk of cancer-specific mortality has been observed in precision protocols that integrate physical exercise, underscoring its ability to influence relevant clinical outcomes (Friedenreich et al., 2016). This implies that the design of exercise programs should consider the molecular and genetic characteristics of the individual, which could enhance their effects on genetic markers related to cancer recurrence.

Physical exercise has also been highlighted as an effective tool to reduce the risk of developing certain types of cancer by up to 30%, including breast, colon, bladder, endometrial, oesophageal and gastric cancer (Herrero López et al., 2024). Furthermore, regular integration of exercise into the lives of cancer patients is associated with substantial improvements in quality of life, including fewer treatment-related side effects (Herrero López et al., 2024). This evidence supports the role of exercise not only as a preventative strategy, but also as a comprehensive support during and after treatment, positively impacting both the physical and psychological spheres.

In the case of breast cancer, aerobic exercise has shown particular efficacy in increasing lean mass and improving the quality of life of patients undergoing chemotherapy (Galvão & Newton, 2005). This effect not only implies physical benefits but also suggests a direct impact on genetic markers that could reduce disease recurrence. Along these lines, resveratrol, although not directly linked to exercise, shares similar antioxidant and anti-inflammatory effects. This compound, known to modulate key pathways such as NF-κB and MAPK, reinforces the thesis that non-pharmacological interventions, including exercise, can be effectively integrated into cancer treatment plans (Berman et al., 2017).

In addition to other benefits, exercise has been shown to improve key parameters such as cardiorespiratory fitness, reduce fatigue, and enhance self-reported outcomes, especially in cancer surgical and therapeutic settings. These effects are related to the regulation of anabolic and sex hormone production, gene expression linked to apoptosis, and the ability to induce cancer cell death through myokines. (Herrero López et al., 2024). This set of benefits underscores the multidimensional role of physical exercise as an intervention that not only improves overall and disease-free survival rates but also promotes recovery in cancer survivors. In these individuals, exercise has shown lasting benefits, including a reduced risk of recurrence, improved physical function, decreased symptoms of depression, fatigue, and lymphedema, and an overall positive impact on quality of life (Herrero López et al., 2024).

Finally, clinical programs designed for patients with breast cancer have shown improvements in physical performance and a significant decrease in fatigue, demonstrating the positive impact of exercise on recovery and overall well-being during treatment (Fernández-Lázaro et al., 2020). These findings highlight the importance of incorporating physical exercise as a central and strategic component in the comprehensive care of patients with cancer.

Immune response to exercise

Physical exercise, as a therapeutic intervention in oncology, mobilizes key immune cells such as Natural Killer (NK) cells, T lymphocytes, and granulocytes, thereby strengthening immunosurveillance in people diagnosed with cancer. Among these cells, the cytotoxic activity of NK cells plays a crucial role in identifying and eliminating malignant cells. Studies have confirmed that regular, moderate-intensity exercise can significantly increase the functionality of these cells, an effect largely due to repetitive exposure to exercise stimulation, optimizing their long-term immune capacity (Kruijsen-Jaarsma et al., 2013; Quintana Mendias et al., 2021). In this context, the combination of aerobic and strength exercises amplifies not only the mobilization, but also the activation of various cell subtypes, creating a more robust immune response against cancer (Quintana Mendias et al., 2021). However, the specific doses of exercise that maximize this benefit remain to be explored, given that patient needs vary depending on factors such as the type and stage of cancer, as well as ongoing treatments.

Short-term exercise, known as acute exercise, generates a transient increase in circulating lymphocytes, including CD8+ T lymphocytes and NK cells. This effect, mediated by the stimulation of β2-adrenergic receptors due to hemodynamic changes, may be strategic for generating immediate immune responses in tumour contexts (Fiuza-Luces et al., 2023; Bartlett & Hanson, 2024). Although these immune responses are temporary, they may benefit patients with functional limitations who cannot participate in longer-duration training. However, the duration and magnitude of the lymphocyte increase depend on the intensity and type of exercise applied, underscoring the need to personalize training programs (Bartlett & Hanson, 2024). Therefore, careful patient monitoring is crucial to balance the therapeutic potential of immune stimulation with the prevention of adverse effects such as fatigue.

The release of myokines during exercise, particularly interleukin-6 (IL-6), has an essential anti-inflammatory function, counteracting chronic inflammatory processes associated with tumour development. In addition to reducing proinflammatory cytokines such as IL-1, IL-6 enhances metabolic signalling and modulates the tumour microenvironment, hindering cancer progression (Fiuza-Luces et al., 2023; Sirera et al., 2006). This effect is especially relevant in patients with highly inflammatory tumours, where exacerbated inflammation promotes tumour aggressiveness (Bartlett & Hanson, 2024). While research has identified this mechanism as a key benefit of exercise, how to optimize these responses through specific combinations of aerobic and resistance exercise remains to be explored. Furthermore, more evidence is needed on the differential impact of these myokines in various tumour types, as the benefit is likely to vary depending on the unique characteristics of each cancer.

High-intensity programs, such as those implemented in the HI AIM trial, show significant benefits by increasing the density of circulating NK cells and their infiltration into solid tumours, including lung tumours (Holmen Olofsson et al., 2022). This type of training, supervised and carefully dosed, not only improves physical capacity, but also positively affects the cellular composition of the tumour microenvironment, slowing the progression of neoplasia (Holmen Olofsson et al., 2022). However, this intensive approach is not suitable for all patients, as some may have limited physical abilities that make it difficult to implement. Therefore, proper monitoring and customization of these programs are essential to avoid burnout or adverse effects (Bartlett & Hanson, 2024). In addition, further studies evaluating how to tailor intensities to individual clinical needs should be considered.

Regular exercise remodels the T cell repertoire, increasing the proportion of naive T cells and reducing senescent T cells. This effect improves immune function, a crucial factor in cancer patients experiencing immunosuppression caused by both the disease and treatments such as chemotherapy (Fiuza-Luces et al.,

2023; Shaver et al., 2021). Studies indicate that these changes promote a more rejuvenated immune system, capable of responding efficiently to new antigens and fighting tumour cells (Shaver et al., 2021). Although these findings are promising, the long-term impact of this remodelling on survival and reduction of cancer recurrence needs to be further investigated. Likewise, the role of different exercise modalities in this remodelling needs to be explored to identify more effective protocols for reducing immunosenescence.

A personalized approach to exercise prescription is vital to maximize its immunological benefits and ensure the safety of people with cancer. For example, programs combining moderate-intensity aerobic and strength training have been shown to be effective in breast cancer survivors, improving parameters such as oxygen consumption and muscle strength (Fernández Ortega & de Paz Fernández, 2014; Galvão & Newton, 2005). These improvements are directly related to positive changes in immune markers, underscoring the importance of tailoring training to each patient's specific needs and conditions. Furthermore, professional supervision is essential to progressively adjust exercise doses and intensities, avoiding adverse effects such as overtraining, which could compromise immunological benefits (Galvão & Newton, 2005). However, there remains a need to standardize protocols that appropriately balance therapeutic benefits and individual physical limitations, especially in cases of post-surgical recovery or compromised physical function.

In summary, physical exercise exerts profound immunological effects that strengthen immunosurveillance and optimize metabolic and inflammatory processes associated with tumour control. Its personalized implementation, tailored to the individual characteristics of cancer patients, promises to maximize these benefits, although further research is needed to address the barriers and limitations of certain therapeutic approaches.

PRESCRIPTION OF PRECISION PHYSICAL TRAINING

Prescribing physical training for cancer patients must be a meticulous process that considers various individual factors, including the type and stage of cancer, medical treatments received, and the patient's initial physical condition. Considering these variables is essential to ensuring a safe and effective program, given that physical abilities and exercise tolerance can vary significantly among patients. For example, the stage of cancer can determine specific limitations due to disease progression, while the side effects of treatments such as chemotherapy or radiation therapy can influence functional capacity, muscle strength, and endurance (Tejada-Medina et al., 2020). A thorough initial assessment should be supported by specific tests, such as Gait Speed, which not only measures the patient's functional capacity, but also serves as a predictor of possible complications (Inzitari et al., 2017; Moraga Rojas & Uclés Villalobos, 2023).

Initial fitness assessment is a crucial aspect of developing individualized exercise programs for cancer patients. Variables such as aerobic capacity, muscular strength, and functionality must be carefully assessed using objective tests. These measurements allow for the design of exercise plans tailored to the individual's current abilities and establish a benchmark for monitoring progress. Assessment batteries such as Gait Speed offer an accessible and efficient method to determine physical functionality, while advanced metrics such as maximum oxygen consumption provide details on cardiovascular capacity and help personalize training goals (Inzitari et al., 2017; Moraga Rojas & Uclés Villalobos, 2023). However, the usefulness of these tools could be enhanced by integrating new wearable technologies that allow for continuous, real-time monitoring of a patient's physical abilities, thereby optimizing the necessary adjustments to exercise prescriptions.

Training design must take into account the specific limitations associated with the side effects of cancer treatments. Conditions such as sarcopenia, chronic fatigue, and osteoporosis, among others, require strategies aimed at minimizing their impact. For example, resistance training, focused on improving muscle strength, has been shown to be particularly useful in combating sarcopenia, while moderate aerobic exercise contributes to reducing chronic fatigue by improving oxygenation and mitochondrial function (Marco Continente et al., 2020). In turn, regular physical exercise can mitigate adverse changes in body composition and muscle mass loss, thus improving the patient's overall health (Casla et al., 2023). However, the implementation of these programs should be progressive and based on consistent monitoring, as inadequate intensity could exacerbate these conditions. In this context, the incorporation of combined modalities, such as strength and aerobic training, can provide comprehensive benefits by addressing multiple side effects simultaneously.

The appropriate selection of exercise modalities to address the needs of cancer patients is critical to ensuring the best possible outcomes. Modalities such as aerobic and strength training have shown specific benefits. Moderate-intensity aerobic exercise, combined with resistance training, not only improves quality of life by reducing anxiety and fatigue, but also strengthens the immune system (Campbell et al., 2019). On the other hand, resistance training is essential for preventing sarcopenia by increasing muscle strength and improving functional capacity (Marco Continente et al., 2020). The combination of these exercise modalities demonstrates a multidimensional approach, addressing both physical and psychological aspects of cancer treatment. In addition, impact resistance exercise has shown specific benefits in activating calcium absorption at the level of bones such as the hip and femur, contributing to the prevention of osteoporosis, especially in women who are breast cancer survivors. (Casla et al., 2023). In addition, impact resistance exercise has shown specific benefits in activating calcium absorption at the level of bones such as the hip and femur, contributing to the prevention of osteoporosis, especially in women who are breast cancer survivors.

The effectiveness of supervised programs during treatments such as chemotherapy underscores the importance of adjusting exercise progression according to each patient's condition. Studies have shown that these programs reduce perceived fatigue and improve immune system function by increasing the activity of NK cells and T lymphocytes, both essential in the body's defence against malignant cells (Galvão & Newton, 2005). This progressive approach, which begins with low-intensity exercises and gradually increases according to the patient's response, not only improves adherence but also minimizes injury risks (Tejada-Medina et al., 2020; Zardo et al., 2022). Furthermore, in premenopausal women, high-intensity aerobic exercise has been shown to be effective in reducing oestrogen levels, while resistance training decreases sex hormones in postmenopausal women, which could have positive implications for breast cancer control (Casla et al., 2023). However, greater standardization of protocols is needed to define optimal intensity and frequency ranges that maximize benefits across different types and stages of cancer.

The implementation of objective measurements, such as walking speed and maximum oxygen consumption, reinforces the accuracy of exercise programs by providing concrete data on the patient's initial condition and progress. These metrics not only serve as functional indicators of physical progress, but also help identify potential risks during training, such as excessive fatigue or cardiovascular decompensation (Inzitari et al., 2017). Routinely incorporating these assessments could significantly improve the personalization of exercise programs, adjusting dosages according to individual physiological capabilities and specific medical conditions.

Physical exercise is also an effective tool for managing the side effects of cancer treatments, such as sarcopenia and osteoporosis. High-impact resistance exercises have been shown to be particularly effective

in improving bone density, especially in breast cancer survivors, who are at increased risk of developing osteoporosis due to hormone therapy and chemotherapy (Marco Continente et al., 2020). Likewise, regular exercise helps prevent muscle deterioration associated with sarcopenia, improving daily functioning and quality of life (Campbell et al., 2019). Furthermore, the combination of aerobic and strength-endurance exercises contributes to the reduction of cardiovascular risk factors, a side effect frequently associated with cancer treatments. However, it would be important to explore additional exercise combinations for patients with specific comorbidities, which could further expand the benefits of these interventions.

Adherence to physical exercise continues to be a significant challenge in the oncology population, due to physical, emotional, and practical barriers that hinder the implementation of regular activity programs. Lack of education about the benefits of exercise and ignorance about its role in improving clinical outcomes contribute to the fact that most survivors do not meet the minimum physical activity recommendations (Hidrobo Coello, 2020). Programs that include educational and motivational sessions, designed by specialized professionals, have been shown to be effective in reducing this initial resistance and promoting sustainable exercise habits (Tejada-Medina et al., 2020). Furthermore, personalized guidance is key to overcoming individual barriers and providing patients with the necessary tools to incorporate exercise as an integral part of their recovery. The inclusion of remote monitoring technologies, such as mobile apps, could also facilitate follow-up and increase adherence by improving accessibility and ongoing support.

Overall, prescribing an individualized and carefully planned exercise program for cancer patients must address not only physical needs but also emotional and practical barriers, ensuring a holistic and effective experience. This underscores the importance of expanding research in this area to optimize intervention strategies.

CONCLUSION

This article has exhaustively explored how precision exercise can act as a significant therapeutic intervention in oncology, improving both the immune response and the quality of life of cancer patients. The central objective of this research was to demonstrate the scientific basis supporting the use of exercise as a complementary tool in cancer treatment, and this objective has been clearly achieved by demonstrating its multiple immunological, metabolic, and functional benefits in this group of patients. The literature review has allowed us to contextualize and consolidate the role of physical exercise within a comprehensive approach to personalized medicine, exceeding expectations in terms of its therapeutic implications.

The document highlights that physical exercise, particularly when designed and tailored to a patient's individual characteristics, has a profound impact on improving key immune processes. Specific mechanisms have been identified by which exercise positively modulates the activity of immune cells such as Natural Killer cells and CD8+ T lymphocytes, which are essential for tumour immunosurveillance. Furthermore, scientific evidence shows that exercise can significantly reduce chronic inflammation, a critical factor in cancer progression, and optimize the metabolic microenvironment, hindering the proliferation of malignant cells. These benefits have not only been supported by quantifiable data from previous studies but also align with recent research that underscores the need to integrate exercise into conventional oncology treatments.

In this context, it is established that personalization in exercise prescription is essential to maximize its effectiveness and ensure patient safety. Through the compilation of research, it has been determined that combined aerobic and resistance training programs are not only feasible but also positively impact quality of life by reducing fatigue, preventing sarcopenia, and improving psychological well-being. The findings

reinforce the need to individualize these interventions based on objective baseline functional assessments, such as gait speed and maximum oxygen consumption, to design programs that respond to each patient's limitations and abilities. This has not only met the initial objective of the study but also opened up new avenues for improving existing clinical protocols.

The contribution of this research to the global context of oncology is significant, as it consolidates the evidence that physical exercise can go beyond the traditional benefits associated with physical activity. This work details how exercise, accompanied by professional supervision, can effectively complement current pharmacological treatments, such as chemotherapy and radiotherapy, increasing their effectiveness and reducing associated side effects. Particularly relevant is the fact that this perspective aligns with pioneering research such as that of Fiuza-Luces and Friedenreich, offering a theoretical and practical foundation that underscores the role of exercise in improving clinical outcomes and survival in cancer.

However, the research presented is not without limitations. Although multiple aspects have been addressed, the reliance on secondary studies and the variability in measurement methods among the analysed studies limit the generalizability of the findings. Furthermore, gaps in knowledge persist regarding optimal exercise doses, intensities, and modalities for different cancer subtypes and disease stages. These shortcomings call for well-controlled clinical studies that allow for the validation and standardization of specific protocols, addressing aspects such as the practical and emotional barriers that have been identified as obstacles to exercise adherence in this population.

In terms of future projections, we suggest prioritizing research that delves into the molecular mechanisms underlying the effects of physical exercise on the immune system, exploring how interventions designed for cancer patients can optimize genetic and molecular markers that impact cancer recurrence and progression. Furthermore, it would be valuable to explore innovative combinations of exercise modalities that consider each patient's individual characteristics and associated comorbidities, thus maximizing the overall benefits of treatment. Furthermore, greater attention is needed to design educational and motivational strategies to increase adherence to exercise programs, integrating technologies such as mobile applications and wearable devices that facilitate remote monitoring and ongoing follow-up.

In the context of rising cancer incidence, this research reinforces the importance of implementing innovative therapeutic approaches that not only focus on prolonging survival but also on improving patients' quality of life. Physical exercise is emerging as a key tool in this more humane and multidimensional approach to cancer treatment. Incorporating precision exercise programs into clinical practice should not be considered optional, but rather an essential component of comprehensive care. This work highlights the commitment to finding new strategies that address not only patients' physiological needs but also their emotional and psychological well-being, marking a breakthrough in precision healthcare applied to oncology.

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All co-authors have contributed equally at each stage of this article. All co-authors have agreed to its publication in PAEC.

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