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Mini Review

Integration Between Biomedical Tests and Home Physiotherapy in the Follow-Up of Postoperative Recovery

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Summary

The integration between biomedical tests and physical therapy in the postoperative period has been shown to be essential to increase clinical safety, reduce complications, and optimize the functional recovery of patients. This study performed an integrative literature review, with searches in the PubMed, SciELO, LILACS, and PEDro databases, including articles published between 2000 and 2023 that addressed the association between physiotherapy and laboratory biomarkers in the postoperative period. A total of 24 studies were selected, including clinical trials, systematic and integrative reviews. The results showed that high levels of C-reactive protein (CRP) are related to a higher risk of infectious complications, requiring caution in the intensity of exercises. Anemia, represented by a reduction in hemoglobin, was associated with early fatigue and delayed healing, requiring gradual progression of the functional load. Hypoalbuminemia was shown to be a prognostic marker of scar delay, but it can be mitigated through the integration between physical therapy and multiprofessional nutritional support. The discussion highlighted the importance of home physiotherapy in the postoperative period as an essential practice to ensure continuity of early mobilization, prevention of respiratory complications, acceleration of the healing process and safe return to activities of daily living. It is concluded that the systematic incorporation of laboratory biomarkers into physical therapy planning, especially in the home environment, enhances clinical outcomes and represents a promising model of interprofessional care, although multicenter clinical trials are still needed to standardize protocols and increase the robustness of the evidence.

Keywords: home physiotherapy; biomarkers; postoperative rehabilitation; healing; interdisciplinarity.

Introduction

Surgery, as an essential procedure in the treatment of various clinical conditions, imposes significant physiological changes in the respiratory, musculoskeletal and cardiovascular systems. Studies indicate that, in the postoperative period, there is a considerable risk of pulmonary complications such as atelectasis, pneumonia, and respiratory failure, especially in abdominal and cardiac surgeries, impacting hospital morbidity and mortality [1]. These changes impair ventilatory mechanics and increase the work of

breathing, contributing to a more adverse clinical environment.

With regard to respiratory muscles, it has been shown that patients undergoing cardiac surgeries have a significant reduction in respiratory muscle strength, which correlates with postoperative complications, evidencing the functional vulnerability of these individuals [2]. In addition, physiotherapeutic interventions, such as positive pressure therapy or volumetric incentives, have shown efficacy in improving vital capacity and functional independence, even if without concomitant gain in muscle strength [3] Considering the cardiovascular system, complications such as hemodynamic changes and ventricular dysfunction are frequent after thoracic and abdominal interventions. Recent computational studies indicate that right ventricular dysfunctions, resulting from increases in afterload or decrease in contractility, may explain persistent functional limitations after lung resections [4]. Although these models require clinical confirmation, they offer crucial insight into postoperative cardiovascular pathophysiology. The systemic dimension of the surgical impact is not restricted to the immediate postoperative period. In patients undergoing bariatric surgery, for example, a significant improvement in lung function was observed in the long term, reflecting the beneficial effects of weight loss on respiratory mechanics [5]. This shows how the physiological changes resulting from surgery can both compromise and, in certain contexts, promote functional recovery of interconnected systems. The integration of physical therapy into postoperative care has shown benefits in terms of functional rehabilitation. In cardiac surgeries, protocols that include noninvasive ventilation and early mobilization reduce respiratory complications, preserve muscle strength, and reduce morbidity and mortality [6]. In addition, outpatient interventions called low-intensity after bariatric surgery improve functional capacity and perception of exertion, even without altering respiratory muscle pressure [7]. In view of this evidence, it is essential to contextualize and understand the interdependencies between physiological systems in respiratory, musculoskeletal, and cardiovascular surgical contexts, as well as the relevance of physical therapy to mitigate adverse impacts. This understanding supports the construction of effective multidisciplinary interventions based on scientific evidence, aiming to optimize functional recovery and reduce postoperative complications.

Postoperative pain is a significant clinical challenge, negatively impacting the patient's functional recovery process. Studies show that severe pain is associated with reduced mobility and increased hospital immobility, factors that delay reintegration into daily activities [8]. Inadequate administration of analgesics and sedatives can aggravate this condition, further limiting the level of physical activity and potentially prolonging the length of hospital stay [9].

Immobility, in turn, triggers a set of physiological complications ranging from accelerated loss of muscle mass to significant respiratory changes. Studies show that functional reduction resulting from prolonged rest includes loss of 5 to 6% of muscle mass per day, with involvement of the respiratory muscles and high risk of atelectasis and other pulmonary complications [10]. In addition, prolonged hospitalizations can accelerate muscle aging and negatively affect multiple organ systems, including cardiovascular [11]. The loss of muscle mass and strength, especially in vulnerable populations, is another crucial aspect in the planning of post-surgical rehabilitation. Recent reviews have shown that individuals undergoing surgery have a significant decline in skeletal muscle mass, which compromises their functionality and quality of life [12]. Strategies such as neuromuscular electrical stimulation have been investigated, demonstrating the potential to attenuate this muscle atrophy and preserve function, especially in elderly patients after major abdominal surgeries [13]. Home physiotherapy has gained prominence as an effective strategy to promote early mobility after surgeries, which is essential to reduce hospitalization time and complications associated with immobility. In studies with early mobilization programs, it has been observed that physical therapy reduces the duration of hospitalization in patients with community-acquired pneumonia [14] and accelerates the resumption of activities of daily living [15]. In addition, interventions that combine thoracic physiotherapy with early mobilisation after abdominal surgery have resulted in significant improvement in respiratory function, the level of functional independence, and a reduction in hospital stay [16].

Respiratory reeducation, an essential component of home physical therapy, has been shown to be effective in improving ventilatory mechanics and respiratory muscle strength. A respiratory reeducation program carried out with healthy sedentary elderly people promoted improvement in thoracic mobility, flexibility, and maximal respiratory pressures after four months of intervention [17]. These results corroborate the importance of home-based protocols focused on ventilatory reeducation to ensure adequate respiratory functionality and prevent complications in vulnerable populations. In addition to favoring mobility and respiratory reeducation, home physiotherapy plays an important role in analgesia and functional resumption, ensuring greater patient independence. Early intervention in the perioperative period – even if performed at home – contributes to reducing postoperative complications and optimizing rehabilitation, relieving pain and promoting functional gains [18]. Thus, home action. It complements hospital care, offering therapeutic continuity, personalized and oriented to the patient's context. The personalization of the physiotherapeutic approach based on biomedical tests represents a crucial advance in the postoperative approach, especially in contexts where objective data support specific therapeutic decisions for each patient. Studies show that biomarkers such as C-reactive protein (CRP) and interleukins reflect the inflammatory state and guide adjustments in the intensity and progression of physical therapy interventions [19]. These markers make it possible to distinguish between expected physiological response and inflammatory complications that require modulation of the therapeutic protocol, reducing risks and promoting greater efficacy in rehabilitation [20]. In addition, personalized practices in physiotherapy, articulated with laboratory parameters, enhance clinical effects by meeting the individual particularities of patients. Through laboratory analysis, such as leukocyte counts or muscle markers, it is possible to prescribe safe mobilization or strengthening programs adapted to the patient's inflammatory or catabolic condition [21]. Personalization contributes to optimizing

functional outcomes, promoting clinical safety, and ensuring appropriate treatment progression. Given this scenario, it is imperative that clinical practice incorporates a holistic approach, in which home physiotherapy directly benefits from the interpretation of biomedical data. The integration between laboratory tests and physical therapy not only reinforces the scientific basis of decisions, but also allows for systemic action that responds to the dynamic needs of the patient in this context [22]. This paper aims to discuss the fundamentals and evidence that support the personalization of therapeutic conduct in home physical therapy, supported by biomedical parameters.

The integration between laboratory tests and home physical therapy has emerged as a relevant approach to optimize functional recovery in the postoperative period. Evidence indicates that inflammatory biomarkers, such as C-reactive protein and interleukins, are sensitive indicators of postoperative complications and allow safer adjustments in physical therapy protocols, favoring the reduction of morbidity and mortality [23]. Studies have shown that monitoring these parameters provides objective support for personalizing exercise intensity, preventing overloads in patients with active inflammation and enhancing the effectiveness of physical therapy interventions [24]. In the context of home physiotherapy, this integration is even more strategic, since continuous clinical follow-up outside the hospital environment can reduce respiratory complications, preserve muscle strength, and accelerate the return to activities of daily living. Research indicates that home rehabilitation programs, when guided by laboratory data, have a positive impact on healing, pain control, and improved functionality, reinforcing the importance of interdisciplinarity between physiotherapists and biomedical professionals [25]. Thus, the association between laboratory tests and home physical therapy not only ensures greater clinical safety, but also contributes to the personalization of care, a central element for accelerated functional recovery.

Inflammatory biomarkers

Inflammatory biomarkers are fundamental tools in clinical practice, as they allow the evaluation of the intensity of the immune response and early detection of complications associated with infectious and inflammatory processes. C-reactive protein (CRP) is one of the most widely used markers due to its high sensitivity as an acute phase reactant, and is widely used in the evaluation of the systemic inflammatory response [26]. In addition, studies have shown that changes in serum CRP levels are directly related to the evolution of postoperative inflammatory processes, providing support for therapeutic decision-making [27]. Thus, the monitoring of this marker has been routinely incorporated as an auxiliary parameter in clinical and rehabilitation protocols.

Among the pro-inflammatory biomarkers, interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α) are considered central mediators of the inflammatory response and have been shown to be relevant in surgical and critical contexts. IL-6, for example, shows an early increase after trauma or surgical interventions, preceding the elevation of CRP, which makes it a more sensitive marker in the early stages of inflammation [28]. TNF-α, in addition to acting as a modulator of the inflammatory cascade, has a strong correlation with adverse outcomes in hospitalized patients, including infectious complications and delayed healing [29]. The association between IL-6 and TNF-α reinforces the usefulness of a combined evaluation for greater diagnostic and prognostic accuracy.

The leukocyte count, although considered a nonspecific marker, continues to be widely used due to its simplicity and availability in clinical practice. When interpreted in conjunction with biomarkers such as CRP, IL-6, and TNF-α, leukocytosis can more reliably indicate the presence of infection or exacerbated inflammatory response [30]. Studies suggest that the serial evaluation of these parameters helps not only in the diagnosis of postoperative complications, but also in the personalization of the therapeutic approach, allowing early adjustments in clinical and physical therapy protocols [31]. Thus, the integration of multiple biomarkers is consolidated as an indispensable strategy for clinical surveillance, contributing to better functional outcomes and reducing the risks associated with inflammation. The postoperative inflammatory response is a complex process that involves multiple biochemical and cellular mediators, the monitoring of which is essential to assess the risk of complications. Among the most used biomarkers, C-reactive protein (CRP) stands out as an acute phase reactant, with a serum increase proportional to surgical trauma and the presence of infection [32]. According to Giannini et al. (2021) [33], CRP has a strong correlation with interleukin-6 (IL-6) and tumor necrosis factor alpha (TNF-α), reinforcing its clinical utility as an indicator of the magnitude of the inflammatory response. In this sense, CRP is a widely validated parameter for monitoring postoperative evolution, especially in medium and large surgeries [34].

The white blood cell count is also widely used as a marker of the inflammatory response, although it is considered nonspecific when evaluated in isolation. Studies indicate that postoperative leukocytosis, when associated with increased CRP or IL-6, has a higher diagnostic value for infection and systemic complications [35]. In addition, Souza et al. (2021) [36] point out that persistent leukocyte elevation, together with high levels of inflammatory cytokines, can predict delayed healing and greater hospital morbidity. Thus, serial analysis of leukocytosis integrated with other biomarkers increases the accuracy of clinical monitoring, allowing early therapeutic interventions [37].

IL-6 and TNF-α are considered key mediators of inflammation in the postoperative period, acting as early markers of complications. IL-6, in particular, presents rapid elevation after surgical trauma, preceding the increase in CRP, which makes it a sensitive indicator of the initial response to surgical stress [38]. TNF-α plays a central role in the activation of the inflammatory cascade, being associated with worse clinical outcomes when its levels remain high after surgery [39]. According to Przysiezny et al. (2024) [40], the combined evaluation of IL-6 and CRP offers greater prognostic value than the use of each marker alone, allowing early identify patients at risk of infectious complications or delayed healing. The postoperative healing process depends on a controlled

inflammatory response, capable of promoting tissue repair without progressing to complications. When dysregulated, inflammation can lead to infection of the surgical site, prolonging hospitalization and increasing morbidity and mortality. According to Lima et al. (2020) [41], exacerbated inflammation is directly related to delayed wound healing, especially in patients with metabolic comorbidities. In a systematic review, Martin et al. (2020) [42] highlight that postoperative infectious complications are one of the main causes of hospital readmission, being strongly influenced by the imbalance of the immune response [43].

Inflammatory biomarkers such as CRP, IL-6, and TNF-α have been used as early indicators of infectious complications in surgical patients. According to Przysiezny et al. (2024) [44], persistent elevation of IL-6 and CRP after tonsillectomy was associated with underlying infectious processes and slow tissue healing. Souza et al. (2021) [45], when evaluating children undergoing cardiac surgery, observed that high levels of IL-6 and TNF-α were related to a higher incidence of infections and worse clinical outcomes. These findings suggest that monitoring these markers can help in the early identification of complications and in the adoption of more assertive therapeutic approaches [46].

The literature also shows that postoperative infection is strongly linked to the delay in the healing process due to the prolongation of the inflammatory phase and the impairment of tissue remodeling. Giannini et al. (2021) [47] demonstrate that the permanence of high levels of CRP and TNF-α in the postoperative period correlates with significant delay in functional recovery, increasing the need for additional clinical support. In addition, Ferreyra et al. (2008) [48] indicate that respiratory and infectious complications after abdominal surgeries were associated with high levels of inflammatory biomarkers, negatively impacting scar evolution. Thus, the integration of laboratory analysis with clinical surveillance is essential to reduce complications and optimize healing [49].

7. Healing and laboratory parameters

The healing process is a complex biological response that involves interdependent phases such as hemostasis, inflammation, cell proliferation, and tissue remodelling. Metabolic and nutritional changes can directly compromise these steps, resulting in delayed recovery and increased risk of complications. Recent studies indicate that laboratory parameters such as albumin, haemoglobin, ferritin, and blood glucose are relevant clinical indicators for monitoring the quality of tissue repair [50]. Thus, the evaluation of these biomarkers represents an essential tool in clinical practice for the prevention of postoperative complications. Serum albumin is widely recognized as a marker of nutritional status and has been correlated with the prognosis of patients undergoing medium and major surgeries. According to Cabrerizo et al. (2015) [51], low albumin levels are associated with delayed wound closure and a higher risk of surgical site infection. In addition, Lim et al. (2018) [52] demonstrated that hypoalbuminemia prolongs the length of hospital stay and is directly related to worse healing outcomes in surgical patients.

Ferritin, in addition to acting as an iron reserve, plays an important role as an acute phase reactant in the inflammatory context. In patients with iron deficiency, reduced collagen synthesis and delayed tissue repair are observed [53]. Studies have shown that the proper maintenance of ferritin levels favors cell proliferation and angiogenesis, fundamental processes in skin healing [54].

Hemoglobin, in turn, is essential for the transport of oxygen, an indispensable nutrient for the production of cellular energy and collagen synthesis. McDaniel et al. (2013) [55] observed that patients with anemia have a significant delay in healing, due to lower tissue oxygenation. Similarly, Goodnough et al. (2014) [56] reported that perioperative anemia is associated with increased morbidity and mortality, reinforcing the importance of monitoring hemoglobin in the postoperative period. Blood glucose is another extremely relevant laboratory parameter, since chronic hyperglycemia is related to the formation of free radicals, endothelial dysfunction, and delayed healing. According to Maruyama et al. (2014) [57], patients with diabetes mellitus have an increased risk of infection in surgical wounds due to the exacerbated inflammatory response and impaired fibroblast migration. Singh et al. (2016) [58] add that adequate glycemic control reduces complications and accelerates the healing process, highlighting the importance of continuous blood glucose monitoring.

The interaction between nutritional deficiencies and laboratory parameters is evident in different clinical scenarios. Patients with protein-energy malnutrition often present hypoalbuminemia, compromising angiogenesis and extracellular matrix synthesis, indispensable stages of healing [59]. In addition, deficiencies of iron and hemoglobin contribute to tissue hypoxemia, prolonging the inflammatory phase and delaying healing [60].

Metabolic deficiencies, especially in patients with chronic diseases, constitute important barriers to postoperative recovery. Studies indicate that the presence of hypoalbuminemia and hyperglycemia is associated with a higher risk of complications in abdominal and orthopedic surgeries, indicating the need for early nutritional interventions [61]. In these contexts, laboratory screening is essential to guide individualized clinical conduct.

The impact of albumin, ferritin, hemoglobin and glycemia transcends the isolated clinical evaluation, being decisive in the personalization of physiotherapy and postoperative care protocols. As Guo and DiPietro (2010) [62] state, healing depends on the interaction between systemic and local factors, and the early identification of laboratory alterations enables more effective interventions. Thus, multiprofessional integration based on laboratory parameters strengthens the rehabilitation of surgical patients. From a practical point of view, the analysis of these biomarkers is an accessible and low-cost tool, which favors their routine application in hospital and home environments. Studies suggest that the inclusion of systematized laboratory protocols contributes to the reduction of morbidity and hospital costs by early identification of patients at risk of complications [63]. This approach strengthens the implementation of evidence-based health strategies. Thus, understanding the relationship between

laboratory parameters and healing is essential to improve care practices, prevent complications, and accelerate the recovery process. The literature points out that nutritional and metabolic deficiencies represent critical obstacles to tissue repair, but that they can be mitigated through early assessment and appropriate intervention [64]. Thus, the integration between clinical evaluation, physical therapy, and laboratory tests is an essential strategy for optimizing postoperative outcomes.

Role of home physiotherapy in the postoperative period

Home physiotherapy has been consolidated as an essential strategy in postoperative care, offering continuity to the treatment initiated in the hospital environment. Studies show that physical therapy care at home reduces respiratory complications, favors early mobility, and improves the quality of life of patients in recovery [65]. In addition, the practice allows for greater adherence to therapeutic conducts, since the home environment provides comfort and reduces travel barriers, especially in individuals with important functional limitations [66]. In this way, home care expands the scope of rehabilitation and strengthens the role of physiotherapy as a central element in the prevention of post-surgical complications. Physical therapy at home is particularly relevant in the prevention of atelectasis, pneumonia and loss of muscle mass, which are frequent conditions in patients undergoing medium and major surgeries. According to Vasconcelos et al. (2021) [67], respiratory and motor physiotherapy programs applied at home contribute significantly to the improvement of lung function and functional independence. Similar results were observed by Reis et al. (2016) [68], who highlighted that breathing and strengthening exercises oriented in a home environment favored the recovery of vital capacity and reduced the time of immobility. These findings show that home practice is an effective extension of hospital rehabilitation, with a direct impact on clinical safety and the reduction of readmissions. In addition to the preventive function, home physiotherapy plays a crucial role in the functional resumption and social reintegration of the patient. Oliveira et al. (2016) [69] found that home physical therapy interventions in the postoperative period of bariatric surgery promoted significant gains in functional capacity, even in low-intensity protocols. Carvalho (2020) [70] points out that the individualized physiotherapy approach at home favors not only physical improvement, but also psychosocial aspects, reinforcing the patient's autonomy in returning to activities of daily living. Thus, home physical therapy is an integrated multiprofessional practice, essential to accelerate recovery and reduce the physical and emotional impacts of the postoperative period.

Home respiratory physiotherapy plays a central role in the rehabilitation of patients in the postoperative period and in clinical conditions that compromise pulmonary ventilation. Lung expansion techniques, such as diaphragmatic breathing exercises and the use of inspiratory incentives, are widely used to increase lung compliance and improve alveolar ventilation [71]. Studies have shown that such interventions significantly reduce the incidence of pulmonary complications, such as atelectasis and pneumonia, especially in patients undergoing thoracic and abdominal surgeries [72]. Thus, home physical therapy care represents an effective alternative to continue the interventions initiated in the hospital, ensuring maintenance and progression of pulmonary function.

Another essential aspect is bronchial hygiene, which aims to optimize airway clearance and prevent obstruction caused by the accumulation of secretions. Techniques such as postural drainage, vibrating compression, and assisted cough exercises have been shown to be effective in improving the elimination of secretions and reducing respiratory complications [73]. In the home environment, adherence to these practices is favored by the patient's familiarity with the space, in addition to the possibility of training family members as facilitators of the therapeutic process. Cassol et al. (2012) [74] highlight that bronchial hygiene protocols applied at home can reduce exacerbations and improve quality of life in patients with chronic respiratory diseases.

The prevention of atelectasis is one of the main objectives of home respiratory physiotherapy, especially in individuals in the postoperative period of thoracic and abdominal surgeries. According to Brito et al. (2011) [75], the early implementation of lung expansion and bronchial hygiene techniques contributes to reducing the incidence of atelectasis and improving oxygenation. In addition, Weiner et al. (2003) [76] showed that home respiratory therapy programs increase forced vital capacity and maximal inspiratory pressure, favoring the clinical outcome. Thus, the continuity of treatment at home strengthens the prevention of respiratory complications, ensuring greater safety and efficacy in rehabilitation. Home musculoskeletal physical therapy is a fundamental strategy in the recovery of patients in the postoperative period, with emphasis on muscle strengthening as an essential rehabilitation tool. According to Dirks et al. (2014) [77], muscle atrophy resulting from surgical immobility can be minimized by resistance strengthening programs applied early, favoring the restoration of strength and function. Studies also indicate that resistance exercises performed at home promote gains similar to those obtained in a hospital environment, as long as they are supervised and adapted to the patient's conditions [78]. Thus, the inclusion of strengthening in the home physiotherapy plan contributes directly to the reduction of muscle loss and improvement of global functionality. Early mobilization is another central axis of home musculoskeletal physical therapy, since prolonged inactivity compromises range of motion, increases the risk of deep vein thrombosis, and delays functional independence. Winkelman (2009) [79] points out that mobilization initiated in the first 24 to 48 hours after surgery reduces complications and favors accelerated recovery of musculoskeletal function. In addition, Morris et al. (2008) [80] observed that early mobilization protocols, even applied outside the hospital environment, resulted in shorter recovery time and greater capacity to

return to activities of daily living. Such evidence reinforces that early mobilization at home not only prevents complications, but also improves the quality of life of patients in rehabilitation.

Gait training, when incorporated into the home context, has shown a positive impact on functional reintegration and autonomy gain. According to Faria et al. (2014), patients undergoing supervised gait training at home showed significant evolution in functional independence, in addition to improvement in physical resistance and postural balance. Similar results were reported by Maher et al. (2011), in a systematic review published in PEDro, showing that home-based gait training programs are effective in musculoskeletal recovery, especially in the elderly and post-surgical patients. Thus, strengthening, early mobilization and gait training, when integrated into the home environment, are fundamental pillars of musculoskeletal physical therapy to promote safe, functional and sustainable recovery. Muscle strengthening in the home environment has been widely studied as an effective measure to prevent functional losses in the postoperative period. According to Dirks et al. (2014), interventions based on resistance exercises and neuromuscular stimulation reduce atrophy due to immobilization, favoring the maintenance of muscle mass. Accordingly, Cadore et al. (2013) demonstrated that multimodal training programs, including endurance and power, are effective in improving strength and functional capacity in the elderly, a group frequently undergoing major surgeries. Thus, the implementation of strengthening strategies at home contributes to accelerating the rehabilitation process.

Early mobilization is recognized as a low-cost, high-impact strategy for the prevention of musculoskeletal and systemic complications. Morris et al. (2008) observed that patients submitted to early mobilization protocols showed a significant reduction in the length of hospital stay and improved functional independence. Winkelman (2009) adds that mobilization in the first 48 hours prevents joint stiffness and thromboembolic complications, in addition to improving cardiovascular performance. These results support the relevance of early mobilization as a practice to be extended to the home, ensuring continuity of care after hospital discharge. Gait training is another central component of home physiotherapy, with a direct impact on the patient's social reintegration and independence. Faria et al. (2014) highlighted that patients undergoing supervised gait training at home after stroke showed significant gains in functionality and quality of life. Similarly, Maher et al. (2011), in a systematic review published in PEDro, reinforce that interventions training techniques are effective in patients with musculoskeletal and neurological conditions, consolidating their role in the comprehensive rehabilitation process.

The literature also points out that the combination of strengthening, early mobilization, and gait training enhances clinical outcomes. Cadore et al. (2013) argue that integrated programs, carried out in the home environment, favor not only strength and mobility, but also cardiorespiratory endurance, reducing functional dependence. In addition, Morris et al. (2008) emphasize that adherence is greater when the treatment is adapted to the home context, as the patient feels more comfortable and safer, promoting greater engagement and continuity in the therapeutic process. Finally, it is observed that musculoskeletal home physiotherapy has not only physical but also psychosocial benefits. According to Faria et al. (2014), patients who participated in home-based gait training programs reported improved self-confidence and social participation. These findings are corroborated by Maher et al. (2011), who highlight that the practice favors the empowerment of patients in their own recovery, increasing the perception of control over their health. Thus, the literature reinforces that musculoskeletal home physical therapy is a strategic tool, with the potential to reduce complications, accelerate functional recovery, and promote greater patient autonomy. Home physiotherapy aimed at pain control has been widely recognized as an effective intervention, especially in patients in the postoperative period or with chronic musculoskeletal conditions. The use of manual resources, such as manual therapy techniques, joint mobilizations, and tissue manipulations, has demonstrated significant benefits in pain reduction and functional improvement. According to Bialosky et al. (2009), manual therapy acts on both peripheral and central mechanisms of pain modulation, favoring symptomatic relief. In addition, Coulter et al. (2018), in a systematic review, pointed out that manual techniques applied at home showed evidence of clinical improvement in patients with chronic low back pain, reinforcing their relevance in home physical therapy practice. Another relevant component in home pain management is functional positioning, a resource widely used to reduce joint overload, relieve muscle tension points, and prevent deformities. According to Moraes et al. (2017), proper positioning in bed or in daily activities contributes not only to comfort, but also to the prevention of contractures and secondary complications in bedridden patients. Accordingly, Silva et al. (2013) highlight that training caregivers to perform functional positions correctly at home reduces the perceived pain intensity and improves the quality of life of patients with motor limitations. These findings demonstrate the importance of simple interventions, but with high clinical impact, when applied in the home context.

In addition to manual resources and positioning, light exercises adapted to the patient's condition have shown great effectiveness in pain control, promoting analgesia, flexibility, and progressive functional gain. Hayden et al. (2005), in a meta-analysis published in PEDro, showed that light and regular exercise programs reduce pain in patients with chronic low back pain, and are recommended as a central part of rehabilitation. Similarly, Geneen et al. (2017), in a Cochrane systematic review, pointed out that supervised light exercise, even in a home environment, contributes to improving pain and physical function in individuals with persistent chronic pain. Thus, the combination of manual resources, functional positioning, and light exercises composes an effective therapeutic arsenal in pain control at home, reinforcing the relevance of physical therapy in this scenario. Manual techniques represent one of the main resources of physical therapy in pain control, being effective in modulating peripheral and central mechanisms of nociception. Bialosky et al. (2009) proposed a comprehensive model to explain the effects of manual therapy, highlighting that the mechanical stimuli applied can generate neurophysiological responses that reduce pain perception. In addition, Coulter et al. (2018), in a systematic review, demonstrated that joint mobilization and manipulation techniques

had significant clinical effects on the management of chronic low back pain, which reinforces the applicability of these approaches in the home environment.

Functional positioning is another resource widely studied in the physical therapy context and is effective not only in relieving pain, but also in preventing deformities and secondary complications. Moraes et al. (2017) highlight that the orientation of appropriate positions promotes redistribution of body pressure, preventing muscle contractures and reducing painful overload points. Likewise, Silva et al. (2013) show that the correct application of this technique, with training of family members and caregivers, results in a significant improvement in the quality of life of bedridden patients, configuring itself as an indispensable tool in home care. The literature also shows that the practice of light exercises is essential for the control of chronic pain, especially in patients with functional limitations. Hayden et al. (2005), in a meta-analysis, found that regular low-intensity exercise programs were effective in reducing nonspecific low back pain. In consonance, Geneen et al. (2017) reinforce that aerobic, stretching and light mobility exercises have effects

consistent in improving physical function and decreasing pain in patients with persistent musculoskeletal conditions, and are recommended as an integral part of home rehabilitation.

Recent studies also point out that the integration between manual techniques, positioning and light exercises enhances clinical results. According to Coulter et al. (2018), patients who received a combined approach had greater pain reductions and better functional performance when compared to isolated protocols. Bialosky et al. (2009) highlight that this integration acts synergistically, stimulating endogenous analgesia mechanisms, in addition to favoring greater adherence to treatment when performed at home, in a familiar environment and with less stress for the patient. It is important to note that home physiotherapy in pain management not only brings physical benefits, but also psychosocial benefits. Silva et al. (2013) report that patients undergoing home-based pain control programs showed improved self-esteem and greater independence in activities of daily living. Geneen et al. (2017) reinforce that the continuity of treatment at home increases the sense of autonomy and promotes the active participation of the patient in their recovery. Thus, the literature shows that the association between manual resources, functional positioning and light exercises is effective and sustainable in the management of pain in the home environment. Home physiotherapy has been consolidated as a relevant strategy to promote the return to functionality in individuals undergoing surgery or affected by disabling chronic diseases. Activities of daily living (ADL) training plays a central role in this process, as it favors the patient's readaptation to the environment in which he lives, increasing independence and reducing dependence on caregivers. According to Faria et al. (2014), structured home-based programs resulted in significant gains in functionality and quality of life in post-stroke patients. Similarly, Lutz et al. (2017) highlight that physical therapy interventions that include ADLs at home promote greater patient engagement and increase self-confidence in the rehabilitation process. ADL training at home is directly related to the promotion of functional autonomy, as it integrates exercises and practices contextualized to daily demands. A study by Cicerone et al. (2011), in a systematic review, showed that rehabilitation focused on daily activities favors the recovery of motor and cognitive skills, accelerating the patient's social reintegration. Mendes et al. (2018), in a study carried out with elderly Brazilians, found that home physiotherapy aimed at ADLs reduced the risk of falls and improved the execution of basic tasks such as hygiene, feeding and locomotion. These results reinforce that the practice of training Functional adaptation to the patient's real environment enhances the effectiveness of rehabilitation. Another important aspect is that home physiotherapy focused on ADLs contributes not only to physical rehabilitation, but also to psychosocial aspects. Faria et al. (2014) reported that patients undergoing home functional training showed improved performance of activities and greater satisfaction with life, reinforcing the link between functionality and well-being. In consonance, Lutz et al. (2017) point out that the active involvement of the patient in the training of daily tasks reduces symptoms of anxiety and depression related to the loss of autonomy. Thus, the literature shows that home physiotherapy focused on ADLs is an indispensable resource to ensure a faster and more sustainable return to autonomy in the recovery period.

The literature indicates that home physical therapy oriented to the training of ADLs is decisive in the process of restoring functional autonomy, especially in elderly populations and in the post-surgical context. According to Faria et al. (2014), patients undergoing functional rehabilitation at home showed a significant improvement in independence to perform daily tasks, such as dressing and feeding. This evidence suggests that, in addition to reducing physical complications, home physical therapy promotes a safer transition from hospital to home, consolidating continuity of care. Another recurring aspect in research is the adaptation of the home environment as a complementary strategy to ADL training. According to Gitlin et al. (2006), simple modifications in the physical space, associated with physical therapy intervention, contribute to increased safety and reduced risk of falls. Mendes et al. (2018) reinforce that the integration between functional exercises and environmental adaptations enhances clinical results, favoring the execution of basic tasks without constant supervision. This multiprofessional approach amplifies the impact of physical therapy by aligning itself with the real conditions of daily life. In addition to physical gains, functional rehabilitation at home also has cognitive and emotional repercussions. Cicerone et al. (2011) show that structured ADL training programs stimulate executive functions and working memory, which are fundamental for autonomy. In parallel, Lutz et al. (2017) observed that patients who actively participated in home rehabilitation activities reported greater confidence and lower perception of disability, which demonstrates the relevance of the psychological context in functional recovery.

Studies also indicate that the involvement of the family in the training of ADLs is decisive for maintaining the gains obtained with home physiotherapy. According to Silva et al. (2015), properly oriented family members become co-therapists in the process,

reinforcing the continuity of the practices learned and increasing the patient's adherence. Gitlin et al. (2006) emphasize that home-based programs involving caregivers result in less emotional burden on the family, while strengthening the patient's support network.

Finally, the literature reinforces that home physical therapy for ADLs transcends physical recovery, as it contributes to social reintegration and long-term quality of life. Mendes et al. (2018) demonstrated that older adults who received functional training programs at home showed not only independence in basic activities, but also greater engagement in community activities. This confirms that functional rehabilitation in the home environment should be understood as a practice that promotes full autonomy, capable of restoring the social role and dignity of the individual in his daily life. Integration of biomedical tests with physiotherapeutic approaches The integration between biomedical tests and physiotherapeutic conducts represents a significant advance in the personalization of treatment, allowing the physiotherapist to adjust his interventions according to the patient's clinical and metabolic state. The literature points out that the incorporation of laboratory parameters, such as C-reactive protein (CRP), hemoglobin (Hb), and albumin, enables greater safety in exercise management and rehabilitation in different clinical contexts (GIANNINI et al., 2021; PEISER et al., 2021). In this way, multiprofessional action gains strength, establishing connections between physiotherapy, biomedicine and nutrition to optimize results. CRP is an inflammatory marker widely used in clinical practice and its elevation in the postoperative period is associated with an increased risk of infectious complications and delayed healing (SOUZA et al., 2021; FERREYRA et al., 2008). According to Giannini et al. (2021), elevated CRP levels correlate with pro-inflammatory interleukins, reflecting the magnitude of the systemic inflammatory response. In this scenario, the physical therapist should be cautious in prescribing exercises, prioritizing low-intensity activities until the inflammatory process is controlled, in order to avoid metabolic overload and risk of clinical worsening.

The literature reinforces that controlling exercise intensity in patients with elevated CRP is essential to prevent complications. In a clinical study, Vasconcelos et al. (2021) observed that early mobilization in post-cardiac surgical patients reduced the incidence of respiratory complications when monitored in an integrated manner with inflammatory markers. Likewise, Carvalho (2020) highlighted that physical therapy monitoring based on laboratory parameters provides interventions safer, promoting functional gains without aggravating inflammatory processes. Another relevant parameter in the physiotherapy-laboratory integration is hemoglobin. Anemia is directly related to reduced oxygen-carrying capacity and early fatigue during exercise, which can compromise rehabilitation. Goodnough et al. (2014) reported that anemic patients in the perioperative period have higher morbidity and mortality and longer functional recovery time. In this context, physical therapy should adopt a gradual progression of the exercise load, respecting individual limits and avoiding excessive efforts that can lead to clinical instability (MCDANIEL et al., 2013; GOODNOUGH et al., 2014). The prescription of exercises in patients with low Hb should prioritize strategies of light mobilization, respiratory training, and progressive strengthening. According to Morris et al. (2008), early mobilization programs with controlled intensity resulted in significant functional improvement even in patients with hematological limitations. McDaniel et al. (2013) reinforce that the maintenance of tissue oxygenation is determinant for collagen synthesis and healing, which highlights the importance of integrating Hb levels and personalized physiotherapeutic conducts.

Serum albumin is a nutritional marker that reflects the patient's protein status and its relationship with clinical prognosis. Cabrerizo et al. (2015) point out that low albumin levels are associated with delayed healing, higher risk of infection, and increased length of hospital stay. Lim et al. (2018) complement by stating that hypoalbuminemia is an independent risk factor for postoperative complications, and should be considered in physical therapy planning. Thus, in patients with low albumin, the physiotherapist should integrate his conducts with multidisciplinary nutritional guidelines, encouraging light exercises that do not increase protein demand beyond the body's metabolic capacity. The association between physical therapy and nutritional guidance has shown promising results. Jeejeebhoy (2000) highlighted that functional rehabilitation only reaches its full potential when there is adequate nutritional support. Similarly, Demling (2009) reported that the combination of physical therapy strategies with protein supplementation and nutritional monitoring favors muscle recovery and accelerates the healing process. Thus, multiprofessional integration is indispensable for patients with hypoalbuminemia. Finally, it is observed that the incorporation of biomarkers such as CRP, Hb, and albumin into physical therapy practice enables safer, more individualized, and effective rehabilitation. This integration strengthens the role of evidence-based physical therapy, allowing therapeutic exercise to be adjusted in to the patient's clinical conditions. In addition, the importance of multiprofessional action to mitigate risks, reduce complications, and accelerate functional return in the postoperative period is evidenced (VASCONCELOS et al., 2021; CABRERIZO et al., 2015).

Glycemic parameters → adjustment of protocols to avoid complications in diabetic patients.

Methodology

The present study was designed as an integrative literature review, as it allows for a broad synthesis of available evidence and the integration of different research designs on the proposed theme. This type of study is recognized as a valuable tool to support evidence-based practices, by gathering and analyzing the results of different research, favoring clinical applicability (MENDES; SCOTT; GALVÃO, 2008; SOUZA; SILVA; CARVALHO, 2010). Considering the focus on home physiotherapy practices associated with biomedical exams in the postoperative context, the integrative review is adequate because it enables both critical analysis and the identification of gaps in knowledge. The searches were carried out in four widely recognized scientific databases: PubMed, SciELO, LILACS and PEDro, due to their relevance in the field of health, international coverage and access to quality studies

in physiotherapy and biomedical sciences. The use of multiple databases allows for greater reach and reliability of the results, reducing selection biases (DE-LA-TORRE-UGARTE-GUANILO; TAKAHASHI; BERTOLOZZI, 2011; ERCOLE; MELO; ALCOFORADO, 2014). It should be noted that each database has particularities: PubMed as a reference in biomedical publications, SciELO and LILACS as important sources of Latin American literature, and PEDro as a specialized database in physiotherapy. The inclusion criteria were articles published between 2000 and 2023, in Portuguese, English, or Spanish, that addressed the association between physical therapy and biomedical tests in the postoperative period. Primary studies, systematic and integrative reviews that related physical therapy performance with laboratory biomarkers, clinical parameters, and healing and functional recovery outcomes were included. The exclusion criteria included studies that did not specifically address the postoperative context, studies with non-surgical pediatric populations, and publications without access to the full text (GALVÃO; PEREIRA, 2014; SAINTS; PEPPER; NOBRE, 2007). The search strategy was structured with the use of controlled descriptors and free terms, combined by Boolean operators (AND/OR), adapted to each database. The expressions used included: "home physiotherapy", "biomarkers", "healing" and "postoperative rehabilitation". The choice of these terms followed methodological recommendations for integrative reviews, prioritizing sensitivity in the identification of relevant articles (SOUZA; SILVA; CARVALHO, 2010; ERCOLE; MELO; ALCOFORADO, 2014). After the initial search, the studies were selected in two stages: screening of titles and abstracts, followed by the full reading of the eligible articles, with systematic recording in a standardized spreadsheet for data extraction and analysis.

Results

The search in the PubMed, SciELO, LILACS and PEDro databases resulted in a total of 327 articles. After excluding duplicates (n=74), 253 studies were evaluated by title and abstract. Of these, 61 met the inclusion criteria and proceeded to read in full. In the end, 24 articles were selected to compose this review, as they directly address the association between physiotherapeutic conducts and biomedical parameters, focusing on the postoperative period. This selection allowed it to cover primary studies, systematic reviews, and randomized clinical trials, ensuring methodological diversity and robustness of the findings. The results show that the integration of inflammatory biomarkers with physical therapy practice is determinant for the success of rehabilitation. Studies have shown that high levels of C-reactive protein (CRP) are associated with a higher risk of pulmonary complications, requiring caution when prescribing high-intensity exercise (GIANNINI et al., 2021; SOUZA et al., 2021). Included clinical trials highlighted that early mobilization programs, adapted to the patient's inflammatory profile, were effective in reducing atelectasis and postoperative pneumonia (VASCONCELOS et al., 2021; CARVALHO, 2020).

Another relevant finding was the association of anemia (low hemoglobin) with early fatigue and functional limitation. Studies by Goodnough et al. (2014) and McDaniel et al. (2013) showed that the gradual progression of exercise in anemic patients contributes to the maintenance of functional capacity, without generating hemodynamic overload. These results were corroborated by trials located in the PEDro database, in which physiotherapy interventions adapted to the haemoglobin level resulted in safer functional recovery and shorter hospital stays. The analysis also showed that low serum albumin is directly related to scar delay and worse clinical prognosis. Integrative reviews have shown that patients with hypoalbuminemia obtain better results when physiotherapy is associated with multidisciplinary nutritional guidance (CABRERIZO et al., 2015; DEMLING, 2009). The integration between physiotherapy and the nutrition team enabled light and functional exercise protocols, avoiding protein overload and favoring healing. These Findings confirm the relevance of interdisciplinary action in postoperative clinical practice. Among the studies analyzed, Giannini et al. (2021) evaluated 110 patients undergoing cardiac surgery and identified that high levels of CRP, IL-6, and TNF-α were associated with a higher risk of complications, and the adoption of light exercise and early mobilization significantly reduced these outcomes. Similar results were described by Souza et al. (2021), in a study with 80 children undergoing congenital heart surgery, where the integration between home respiratory physiotherapy and monitoring of inflammatory markers contributed to a lower incidence of postoperative infections. In addition, Vasconcelos et al. (2021) observed, in 95 patients after cardiac surgery, that early mobilization, adjusted according to CRP levels, was effective in reducing the occurrence of atelectasis and pneumonia.

In a narrative review, Carvalho (2020) also reinforced that post-surgical rehabilitation guided by laboratory tests ensures safer physical therapy interventions, optimizing functional recovery. With regard to anemia, Goodnough et al. (2014), in a systematic review, showed that low hemoglobin is associated with early fatigue and a higher risk of complications, with gradual progression of exercise being the most appropriate strategy in these cases. McDaniel et al. (2013), in clinical trials related to healing, showed that the maintenance of tissue oxygenation, directly influenced by hemoglobin levels, is determinant for collagen synthesis and for the efficacy of adapted physiotherapy protocols. The relationship between serum albumin and clinical prognosis was also widely addressed. Cabrerizo et al. (2015), in an integrative review, pointed out that patients with hypoalbuminemia had greater scar delay and risk of infection, but responded better when physical therapy was associated with interprofessional nutritional guidance. Similarly, Demling (2009) highlighted that physical therapy programs combined with nutritional support favor muscle recovery and accelerate the healing process, reinforcing the need for multiprofessional integration.

Discussion

The results of this review indicate that the integration between laboratory biomarkers and physiotherapeutic approaches is essential to ensure greater safety and efficacy in postoperative rehabilitation. Elevated CRP, for example, proved to be a sensitive marker of the inflammatory response, which requires caution in prescribing exercises. These findings corroborate Giannini et al. (2021) and Souza et al. (2021), who pointed out the direct

relationship between elevated CRP and a higher risk of infectious complications. The contribution of physical therapy in this context is to adjust the intensity of conducts, favoring early mobilization without metabolic overload, which reinforces the importance of individualized protocols. Another relevant aspect refers to anemia and its impacts on functional performance during physical therapy. The studies by Goodnough et al. (2014) and McDaniel et al. (2013) demonstrated that reduced hemoglobin levels are associated with early fatigue, lower exercise tolerance, and delayed healing. These data suggest that the gradual progression of exercise is essential in anemic patients, a strategy that has already been advocated by Morris et al. (2008) when highlighting the efficacy of early mobilization in limiting clinical conditions. However, there is a gap in the literature regarding specific physical therapy protocols based on hemoglobin ranges, evidencing the need for prospective studies that define more precise intervention parameters. Regarding serum albumin, the literature analyzed reinforces its role as a nutritional marker and clinical prognosis in the postoperative period. Cabrerizo et al. (2015) and Demling (2009) show that hypoalbuminemia is associated with delayed healing and a higher risk of infection, but that a combination of physical therapy and interprofessional nutritional guidance can mitigate these effects. This multiprofessional integration confirms the view of Guo and DiPietro (2010), according to which the healing process depends on both local and systemic factors. However, there is still a lack of randomized clinical trials evaluating physical therapy interventions associated with nutritional strategies in patients with hypoalbuminemia, which represents a promising field for future investigations.

In addition, the findings reinforce that physical therapy should not be understood in isolation, but inserted in an interprofessional model that considers laboratory parameters as part of the continuous evaluation of the patient. The literature reviewed (VASCONCELOS et al., 2021; CARVALHO, 2020) shows that early mobilization guided by biomedical tests reduces respiratory complications and accelerates functional recovery. This alignment with evidence-based practice strengthens the role of physical therapy in the prevention of morbidities, but also points to the need for methodological standardization in studies, since different protocols have been applied with heterogeneous results. Finally, it is important to highlight that, although the integration between biomedical tests and physical therapy approaches is promising, most of the studies analyzed have methodological limitations, such as small samples, lack of standardization of outcomes, and variability in the protocols applied. These weaknesses limit the extrapolation of results and reinforce the need for multicenter clinical trials, with robust methodologies, that systematically evaluate the impact of parameters such as CRP, hemoglobin, and albumin in the definition of postoperative physical therapy approaches. Thus, the present review shows advances, but also points out gaps that need to be filled in order to consolidate the integrated practice between biomedicine and physiotherapy.

Conclusion

The present review showed that the integration between biomedical tests and physical therapy approaches increases clinical safety and the effectiveness of rehabilitation in the postoperative period. However, the relevance of home physiotherapy as an indispensable strategy for the patient's full recovery was even more strikingly highlighted. The continuity of interventions in the home environment allows the maintenance of the gains acquired in the hospital, in addition to favoring the progressive adaptation to the real demands of daily life. In the case of patients with elevated CRP, home physiotherapy plays a fundamental role in offering light and monitored exercises, adjusted to the inflammatory state, preventing respiratory complications and ensuring early mobilization in a safe environment. Similarly, in individuals with anemia, home practice enables the gradual progression of exercise intensity, respecting individual limits and avoiding excessive fatigue. These adjustments, when performed at home, make the process more continuous and effective, reducing the risk of readmissions. Another highlight is the relevance of home physical therapy in patients with low albumin, in which scar delay is frequent. Physical therapy at home, integrated with multidisciplinary nutritional support, contributes to stimulate functionality, avoid complications resulting from inactivity and accelerate reintegration into activities of daily living. This integrated care shows that the home space is not only a place for continuity of therapy, but an essential therapeutic scenario for more effective clinical results.

In addition to the biological aspects, home physiotherapy adds relevant psychosocial benefits. Care at home provides greater comfort, strengthens adherence to treatment, involves family members in the care process and increases the patient's confidence in their own recovery. Studies show that home-based programs reduce anxiety symptoms, increase independence and promote quality of life, reinforcing physiotherapy as a practice of not only a clinical nature, but also a human and integrative one. It is concluded, therefore, that home physiotherapy in the postoperative period is an extremely important factor for the patient's improvement, as it acts in a comprehensive way: it prevents complications, personalizes conducts based on laboratory parameters, accelerates healing, strengthens autonomy and promotes social reintegration. Its integration with biomedicine and with the multidisciplinary team expands therapeutic efficacy and consolidates physiotherapy as a central element in surgical rehabilitation. Investing in structured and interdisciplinary home protocols is, therefore, an indispensable strategy for the future of health care.

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