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The impact of nutritional support in treating decubitus ulcers (bedsores)

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ABSTRACT

Introduction: Pressure ulcers, commonly known as bedsores, are localized wounds affecting the skin and underlying tissues. They result from prolonged pressure, friction, or shear. There are different ways to treat pressure ulcers. One way is to give patients extra protein, vitamins like zinc and selenium, and special diets with a lot of eicosapentaenoic acid (EPA). This review looks at how vital nutritional support is in preventing and treating pressure ulcers and how it can be used with new technologies. Combining the findings of studies done between 2019 and 2024, this review finds out what works and still needs to be researched. *Results:* Special diets have been shown to improve wound healing in certain groups of people significantly. EPA-enriched enteral diets have been shown to reduce ulcer incidence by reducing inflammation and improving blood flow. *Conclusions*: It is clear that nutritional support plays a crucial but complicated role in treating pressure ulcers. Special diets with EPA or selenium can help with wounds in high-risk groups, but they must be part of a wider care plan that uses cutting-edge technology to get the best results.

Keywords: Pressure ulcers, nutritional support, protein supplementation, wound healing

1. INTRODUCTION

Pressure ulcers, also known as bedsores or pressure sores, are localized skin injuries and underlying tissue injuries caused by prolonged pressure, shear, or friction. These wounds occur mainly in bony areas of the body, such as the buttocks, heels, and hips. They are a significant concern in healthcare settings, especially for patients who cannot move (Langer et al, 2024). These ulcers are associated with significant morbidity, prolonged hospitalization, and increased healthcare costs, with severe cases contributing to mortality rates of up to 60% (Yap & Holloway, 2021). Although we have better ways to treat wounds and prevent pressure ulcers from worsening, many people still develop them. This indicates that we must examine all potential causes of pressure ulcers and take action to address them.

Poor nutritional status impairs wound healing by reducing collagen synthesis, angiogenesis, and immune function (Adıgüzel & Acar Tek, 2021). Patients with low serum albumin levels or protein-energy malnutrition exhibit delayed healing and are more susceptible to ulcer recurrence (Rahmadani & Chayati, 2023). Nutritional

interventions are now a key part of treating pressure ulcers. There is growing evidence that protein supplementation, micronutrients like zinc and selenium, and special diets can help repair tissue and reduce the number of ulcers (Ataollahi et al., 2025).

Technology-driven strategies have also been used in pressure ulcer care in recent years. It includes new mattresses, wearable sensors, and telemedicine platforms. These have made it easier to monitor high-risk patients and optimize preventative measures. These new approaches to care work well in conjunction with traditional methods, such as repositioning and pressure redistribution, but we must ensure they are accessible to patients and do not incur excessive costs. Furthermore, when used with other treatments, massage therapy has shown real promise in improving blood flow and reducing the risk of ulcers in patients who cannot move (Rahmadani & Chayati, 2023).

This review aims to thoroughly analyze how nutritional support can treat decubitus ulcers (pressure sores) and how it can be combined with new technologies and other treatments. Combining insights from recent studies published between 2021 and 2025, this review examines the most effective ways to enhance patient outcomes and identifies areas where further research is needed.

Pressure ulcers occur when pressure is applied to the skin for an extended period. That can stop blood from flowing correctly and damage tissue. It can cause the death of cells and tissue, which creates an environment where diseases and long-lasting inflammation can develop (Langer et al., 2024). Malnutrition can worsen this by reducing the body's ability to repair tissue. A lack of protein can prevent the body from producing collagen, which is essential for healing injuries. Also, insufficient vitamins and minerals stop blood vessels from growing and the immune system from fighting illnesses. Selenium is essential for wound healing, and an insufficient amount can prolong wound healing (Ataollahi et al., 2025).

Extrinsic factors such as shear forces, moisture from incontinence, and improper positioning contribute to ulcer formation by exacerbating mechanical stress on vulnerable areas. Immobilized patients, such as those recovering from stroke or spinal cord injuries, are particularly susceptible due to reduced sensory perception and the inability to redistribute pressure effectively (Rahmadani & Chayati, 2023).

Current methods to prevent these risks, like moving the patient often, often do not deal with bigger problems like malnutrition or other health problems the patient already has.

Protein is vital for wound healing because it helps the body make collagen, repair tissue, and boost the immune system. High-protein diets have been shown to reduce the incidence of pressure ulcers in at-risk populations while accelerating the healing of existing wounds (Yap & Holloway, 2021). A meta-analysis conducted by Yap and Holloway demonstrated that oral protein supplementation reduced ulcer incidence by 46% in hip fracture patients compared to standard care. Recommended protein intake for patients with pressure ulcers ranges from 1.2–1.5 g/kg/day for mild cases to 2.0 g/kg/day for severe ulcers (Langer et al., 2024).

Micronutrients play an essential role in modulating inflammatory responses and promoting tissue regeneration. Zinc is essential for making collagen and for the immune system to work well. Research has shown that taking zinc supplements can help patients with malnutrition who have ulcers heal more quickly (Yap and Holloway, 2021). Selenium-rich probiotics are a new way to boost antioxidant defenses in ulcerated tissues. Ataollahi demonstrated that Lactobacillus brevis LSe reduced healing time by 2.4 days compared to placebo ($p = 0.039$), highlighting selenium's potential in mitigating oxidative stress.

Arginine is an amino acid our body needs, but we do not make it. It has been studied extensively for its role in making nitric oxide and helping new blood vessels grow. Formulas containing high amounts of arginine have shown promise in improving wound healing; however, the results vary depending on the dosage and duration of treatment (Langer et al., 2024). While some studies suggest taking 9 grams daily for the best results, others warn against taking it without checking first because of possible side effects like high blood sugar.

Technology has made it much easier to prevent pressure ulcers by letting healthcare professionals monitor patients in real-time. Innovative mattresses with pressure sensors move weight around to reduce pressure on the parts of the body that are most at risk (Ghosh et al., 2024). Wearable devices such as sensor-embedded cushions provide continuous feedback on positioning while alerting caregivers to high-risk scenarios.

Telemedicine platforms have further enhanced access to wound care specialists by facilitating remote consultations and monitoring. Research showed how good AI systems predict ulcer risk. These systems make predictions about a patient's movement and nutrition. These technologies work well in conjunction with nutritional interventions, providing healthcare professionals with valuable information to support patient care. However, they must be tested in large trials to ensure they work.

Massage therapy has emerged as a cost-effective adjunctive measure for preventing pressure ulcers in patients who are immobilized. Rahmadani and Chayati demonstrated that effleurage massage combined with virgin coconut oil reduced ulcer incidence

by 18% compared to standard care alone. Variability in study designs—such as differences in nutrient dosages or intervention durations—further complicates consensus on best practices.

Emerging therapies like selenium-enriched probiotics require validation through multicenter trials before widespread adoption.

Nutritional support is crucial in treating ulcers, particularly when the cause is attributed to pressure. When given to each patient according to their specific needs, nutritional support has significantly impacted the healing process and prevented the sores from returning. The best ways to achieve this are to incorporate protein, utilize formulas rich in micronutrients, and supplement with probiotics containing selenium. However, it is essential to remember that these things should be part of a comprehensive plan for treating the patient, which should be developed by various medical professionals utilizing the best available technology, such as specialized mattresses and telemedicine.

Another effective treatment option is massage therapy, but it must be done regularly to get the best results. It is imperative that everyone, regardless of their background, can access the best treatments.

2. METHODOLOGY

Search strategy

A systematic literature search was performed in four electronic databases: PubMed, Cochrane Library, EMBASE, and Web of Science. The search covered publications from 2019 to 2024. The following keywords and their combinations were used: pressure ulcer, nutritional support, protein supplementation, arginine, omega-3 fatty acids, and enteral nutrition.

Inclusion Criteria

- Study types: Randomized controlled trials (RCTs), systematic reviews, and meta-analyses published between 2019 and 2024.
- Interventions: Studies evaluating oral or enteral nutritional supplements, protein intake, or micronutrient supplementation.
- Outcomes: Incidence of pressure ulcers, healing rates, and mortality.

Exclusion Criteria

- Non-English language studies
- Animal studies
- Non-peer-reviewed articles.

Screening and Selection Process

The initial search yielded 1,761 records. After removing duplicates, titles and abstracts were screened for relevance. Forty-one articles were selected for full-text review. Following detailed eligibility assessment based on the inclusion and exclusion criteria, 24 studies were included in the final synthesis. The main reasons for exclusion at the full-text stage were: an irrelevant population, the absence of a nutritional intervention, or failure to report relevant outcomes.

The selection process is summarized below:

- Records identified through database searching: 1,761
- Records after duplicates removed: [number after deduplication]
- Records screened by title and abstract: [number]
- Full-text articles assessed for eligibility: 41
- Studies included in the final synthesis: 24

The PRISMA flow diagram illustrates the study selection process (Figure 1). This diagram presents the number of records identified, screened, assessed for eligibility, and included in the final synthesis, ensuring transparency and reproducibility of the review process (Yap & Holloway, 2021).

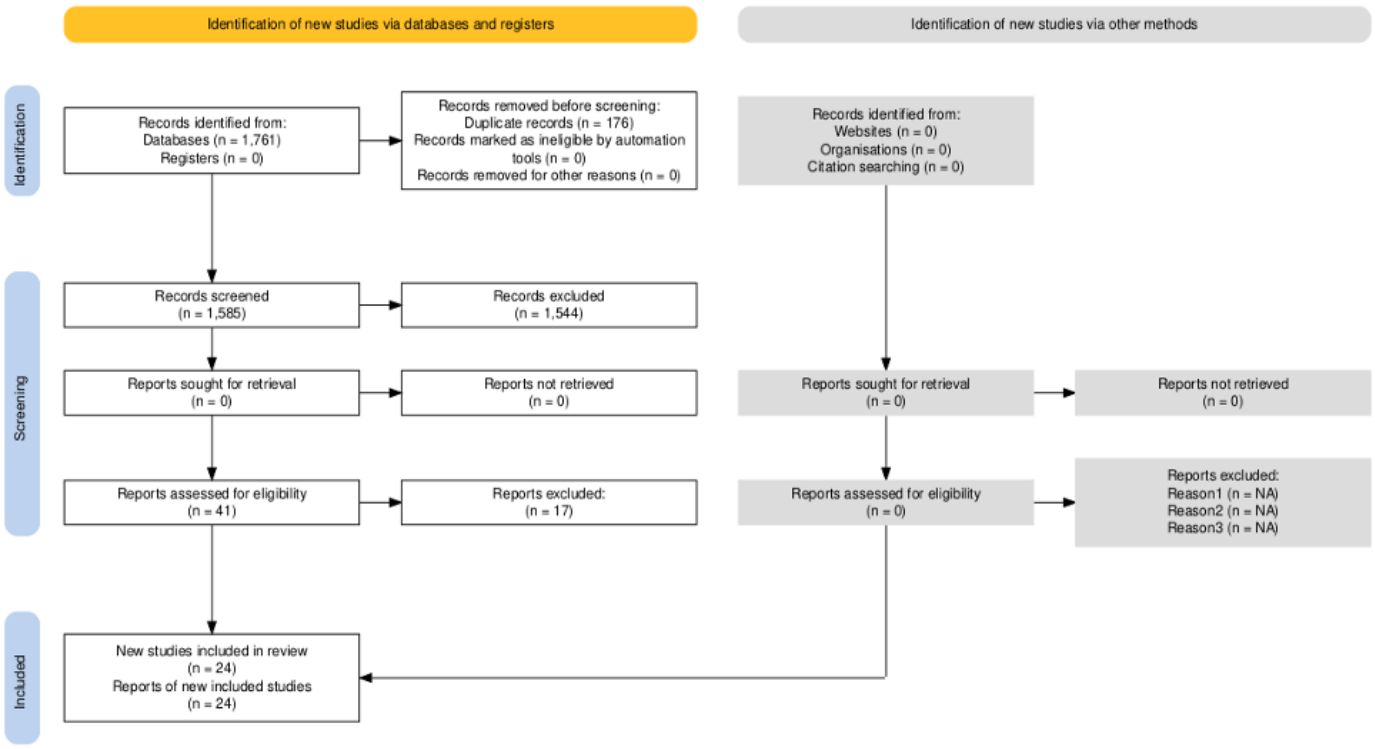

Figure 1. PRISMA flow diagram showing the study selection process.

3. RESULTS AND DISCUSSION

3.1. Individualized Nutritional Support and Mortality Reduction

Individualized nutritional interventions have demonstrated systemic benefits that indirectly mitigate pressure ulcer risk. Bargetzi et al., (2021) conducted a secondary analysis of a randomized trial involving hospitalized cancer patients, revealing that protocol-guided nutritional support reduced 30-day mortality by 5.8% (14.1% vs. 19.9%) and enhanced functional outcomes. Similarly, Hersberger et al., (2021) reported a 6.4% reduction in 30-day mortality (8.4% vs. 14.8%) and fewer cardiovascular events in chronic heart failure patients receiving tailored nutrition. While these studies underscore the role of nutrition in improving systemic health, critical for wound healing, their focus on mortality rather than ulcer-specific outcomes limits direct conclusions about pressure ulcer prevention.

Strengths: Both studies emphasize the importance of personalized care in high-risk populations, aligning with guidelines that recommend an energy intake of 30-35 kcal/kg/day and a protein intake of 1.2-1.5 g/kg/day.

Limitations: The absence of pressure ulcer incidence as a primary endpoint and potential confounders (e.g., comorbidities) make extrapolation to ulcer-specific contexts difficult.

3.2. Protein and Micronutrient Supplementation

Protein and some micronutrients are important for making collagen and repairing tissue. A study by Shimazu et al., (2021) found that providing stroke patients with the proper nutrients regularly and in the correct amounts can increase the levels of specific protein groups in their blood and reduce the issue of food not being swallowed, which can help maintain their skin health.

Ogawa (2021) tested eicosapentaenoic acid (EPA) - enriched enteral nutrition in neurosurgical patients and found fewer pressure ulcers in the intervention group (1 vs. 4 cases over 14 days). The anti-inflammatory properties of EPA, which inhibit pro-inflammatory eicosanoids, probably contributed to this result. These findings are consistent with the review by Yap and Holloway, which found that EPA/GLA supplements may improve tissue perfusion.

However, the Cochrane review by Langer et al., (2024) reported insufficient evidence for universal supplementation (RR 0.92, 95% CI: 0.71-1.19), citing methodological heterogeneity. The recommended dosage of arginine (3-9g/day) and the specific contexts in which it is analyzed (such as surgical patients or the elderly) have been challenging to standardize. In target populations, both EPA and high-protein diets have shown efficacy in postoperative stroke patients (Ogawa, 2021; Shimazu et al., 2021) and identified the heterogeneity

of the analysis population and the interpretation of dosage regimens as essential challenges to the validity of overarching determinations (Langer et al., 2024).

3.3. Serum Albumin as a Biomarker: Nuanced Interpretations

Patients with an albumin < 3.0 g/dL may be at risk for developing pressure ulcers. Much research has found a link between low albumin levels and the development of PUs, particularly in patients who are very ill or have limited mobility. Lower albumin levels in the blood (less than 3.0 g/dL) may indicate an increased risk of pressure ulcers (PUs). The existing body of research has established a connection between low albumin levels and the development of PUs, particularly in patients who are very ill or have limited mobility.

A study of 610 patients in intensive care found that 70% of people who developed pressure ulcers had low albumin levels when admitted. The worse the ulcers, the lower the albumin levels. In addition, older people with serum albumin levels of ≤3.1 g/dL were discovered to have a twofold improved risk of developing PUs. Highlighting its importance in predicting health outcomes (Elsorady & Nouh, 2023), albumin can also be a sign of inferior health, which might make it hard to tell how patients are doing nutritionally. In a study of 82 patients with PU, serum albumin exhibited a stronger correlation with C-reactive protein (CRP) and hemoglobin levels than with calorie intake. The conclusion is that serum albumin may reflect systemic inflammation and disease severity rather than just nutritional status alone. It is consistent with mechanistic evidence that albumin synthesis is suppressed during inflammatory states, separate from protein intake.

Interventional studies further illustrate the bidirectional relationship between albumin, inflammation, and healing. Personalized nutritional support in stroke patients improved albumin levels and enhanced functional recovery. Moreover, albumin normalization may result from reduced inflammation and improved metabolic health rather than direct nutritional correction (Shimazu et al., 2021). Conversely, administering 25 g/day of intravenous albumin to hypoalbuminemia ICU patients (serum albumin <3.3 g/dL) reduced PU incidence from 70% to 27% and mitigated ulcer severity, likely by restoring plasma oncotic pressure and microcirculatory integrity. Albumin is not a straightforward measure of nutrition, but its supplementation may address pathophysiological mechanisms contributing to tissue vulnerability.

Albumin serves as a valuable risk indicator but is insufficient to diagnose malnutrition. Hypoalbuminemia may signal liver dysfunction, chronic disease, or systemic inflammation rather than protein deficiency alone (Adıgüzel & Acar Tek, 2021). For example, anorexia nervosa patients often exhibit normal albumin levels despite severe malnutrition, whereas trauma patients with hypoalbuminemia may not be malnourished. Thus, albumin must be considered within a broader biomarker panel. A meta-analysis of 10,595 patients confirmed serum albumin's moderate predictive value for PU risk (AUC = 0.66), but combining it with CRP and clinical scales like the Braden or Waterlow score improved diagnostic accuracy (AUC = 0.74–0.79).

The C-reactive protein-to-albumin ratio (CAR) has emerged as a robust indicator, with a cut-off >1.27 predicting PU occurrence in geriatric patients with 78% sensitivity (Elsorady & Nouh, 2023). Prealbumin, with its shorter half-life (1.9 days), offers more granularity; in patients with fascial space infections, prealbumin levels inversely correlated with hospital stay duration, highlighting its sensitivity to acute nutritional and inflammatory changes.

Holistic monitoring strategies are essential. Patients with low albumin levels and high CRP should receive treatments to reduce inflammation and support their nutrition. However, low albumin levels alone may need more tests to check for liver or kidney problems. The European Pressure Ulcer Advisory Panel supports an integrative approach, which recommends combining albumin with CRP and prealbumin to distinguish malnutrition from inflammation-related protein loss. The implementation of such stratagems will refine risk stratification and guide targeted therapies.

3.4. Enteral Nutrition: Specialized vs. Standard Formulas

Enteral nutrition has been shown to play an essential role in the prevention and treatment of pressure ulcers (PUs), especially among high-risk groups such as immobilized or critically ill individuals. Special diets for people with PUs that are full of nutrients, such as eicosapentaenoic acid (EPA), are very good at reducing the number of PUs compared to regular energy-protein supplements. Research by Ogawa (2021) shows that EPA-enriched diets are very effective. In a randomized controlled trial of 20 neurosurgical patients, the group given the EPA-enriched diet had no new pressure ulcers over 14 days, while the control group given a conventional diet without EPA had three new ulcers. EPA has anti-inflammatory properties. These stop the body from producing substances like prostaglandin E2 and leukotriene B4. It means tissue damage caused by a lack of blood flow is significantly reduced. It also improves blood flow.

Other studies also demonstrate that EPA plays a crucial role in reducing tissue damage and enhancing blood flow. This makes it particularly good for patients who have difficulty moving around. However, the effectiveness of these supplements can vary from patient to patient. A Cochrane review conducted by Langer et al., (2024) which analyzed 33 randomized controlled trials involving 7,920 participants, found no significant benefit of generic energy-protein supplementation for PU prevention (RR 0.92, 95% CI: 0.71–1.19). The review highlighted substantial methodological variability, including differences in patient demographics (e.g., geriatric, surgical, and critically ill) and inconsistent nutrient dosages, which complicate the generalizability of findings. While standard formulas may meet baseline nutritional needs, they often lack targeted components, such as EPA or arginine, that address specific pathophysiological pathways, including inflammation and oxidative stress.

The effectiveness of specialized formulas is highly context-dependent. For patients at high risk of developing PUs due to being immobile for a long time or having inflammation in their body, diets rich in EPA have distinct advantages because they deal with both inflammation and circulatory problems. Ogawa's findings align with mechanistic studies that demonstrate EPA's ability to decline inflammation and improve blood vessel function, thereby reducing tissue exposure to pressure-induced ischemia. On the other hand, formal procedures might be enough for low-risk people, but they might not meet the metabolic needs of high-risk individuals.

New evidence suggests that combining eicosapentaenoic acid (EPA) with other compounds, such as gamma-linolenic acid (GLA), may improve outcomes. A study by Ogawa (2021) showed that adding EPA and GLA to the diets of patients who had undergone neurosurgery resulted in a significantly lower incidence of PU compared to those who did not receive these nutrients. The study found that there were a lot fewer new ulcers in the EPA-GLA group than in the control group. Only one person in the EPA-GLA group got a new ulcer in 14 days, but nine in the control group did. The study also demonstrated reduced inflammation and increased blood vessel growth, both of which are crucial for healing.

Despite these promising results, special formulas are not widely used in medical practice because they are expensive, and few people can afford them. This is especially true in places with limited financial resources, where standard formulas are still commonly used. The fact that PUs are expensive for patients and cost money to treat suggests that we need to find ways to help people that are affordable and effective. Specialist formulas, such as those enriched with EPA or GLA, are initially more expensive, but they can prevent PUs and reduce long-term care costs, making them a worthwhile investment to operate more widely.

3.5. Technology-driven integration: Synergy with nutrition

Decubitus ulcer management requires a dual strategy addressing intrinsic metabolic vulnerabilities and extrinsic mechanical stressors. Nutritional interventions, such as high-protein diets (1.2–1.5 g/kg/day) and anti-inflammatory nutrients like eicosapentaenoic acid (EPA), enhance collagen synthesis and reduce tissue-damaging inflammation (Ogawa, 2021; Yap & Holloway, 2021). However, these biochemical strategies alone cannot counteract the mechanical forces—prolonged pressure, shear, and friction—that impair tissue perfusion.

Advanced technologies are improving nutritional support by reducing mechanical stress on patients. AI-driven pressure mapping systems and innovative mattresses can redistribute pressure by up to 32%, lowering the risk of ischemia in vulnerable areas (Ghosh et al., 2024). Additionally, cushions with sensors help ensure patients are in the correct position. Telemedicine platforms can also help check that patients are eating enough. Combining nutrition and technology for patients who are unable to move is crucial. Studies have shown that diets high in EPA can reduce inflammation, as evidenced by lower CRP levels. Using devices that spread pressure can also help stop tissue from breaking down (Ogawa, 2021). However, there are still significant problems in places that lack resources, so we need to develop new ways to ensure people receive the nutrition they need. Technology, independently, cannot meet all metabolic needs, so a combined approach is needed. In the future, we should try to combine different methods, such as using wearable sensors to track changes in people's bodies, so we can provide them with the right food. It will be significant for dietitians, engineers, and clinicians to work together for good results.

3.6. Contradictions and Unmet Needs

Sensor-equipped cushions help ensure patients are correctly positioned, and telemedicine platforms help monitor what patients are eating. Combining nutrition with technology for patients who are unable to move is crucial. Studies have shown that diets high in EPA can reduce inflammation, as lower CRP levels show. Devices that redistribute pressure can also help prevent tissue breakdown (Ogawa, 2021). However, there are still significant problems in areas that lack sufficient resources. People must rely on nutritional strategies more. Technology alone cannot meet all metabolic needs, so we need a combined approach. Trials such as Bargetzi et al.

(2021) and Ogawa (2021) advocate for personalized nutrition, highlighting reduced mortality and ulcer incidence in cancer and neurosurgical patients through anti-inflammatory and metabolic mechanisms.

However, these positive outcomes contrast sharply with neutral or critical findings from broader analyses. The Cochrane review by Langer et al. (2024) concluded that standard energy-protein supplements showed no significant benefit in preventing pressure ulcers (RR 0.92, 95% CI: 0.71–1.19), attributing inconsistencies to methodological variability, including divergent nutrient dosages and short follow-up periods. For example, arginine supplementation regimens varied from 3–9 g/day across studies, while many trials lacked standardized endpoints, such as ulcer area reduction versus incidence (Yap & Holloway, 2021).

A key divergence lies in population specificity. Surgical or post-stroke patients benefit markedly from EPA or protein-enriched diets, often characterized by acute inflammation and immobilization (Ogawa, 2021; Bargetzi et al., 2021). Conversely, the findings from studies of geriatric or critically ill populations have yielded equivocal results, suggesting that chronic frailty and multifactorial metabolic dysfunction may compromise the effectiveness of generic nutritional strategies (Langer et al., 2024).

Furthermore, while biomarkers such as serum albumin have been shown to predict ulcer risk, they also reflect systemic inflammation to a comparable degree to nutritional status. This necessitates complementary assessments of C-reactive protein (CRP) and prealbumin to disentangle these contributions (Adıgüzel & Acar Tek, 2021). The problems of creating rules that apply equally to everyone and utilizing the latest technology persist. However, Ghosh et al., (2024) have shown that a mix of nutritional support and AI-driven pressure mapping systems could be a good way to deal with the causes of ulcers from the inside and outside. For example, using sensors has been shown to relieve pressure by 32%. At the same time, telemedicine platforms have been shown to improve people's adherence to their diets, creating a combined care model. Prospective research should focus on large-scale trials with similar patient groups, the same doses, and long-term follow-ups to verify that these strategies are effective. Cost-effectiveness studies are equally critical, particularly for specialized formulas in resource-limited settings where accessibility barriers persist (Table 1).

Table 1. Synthesis of findings

Aspect	Supporting Evidence	Contradictory Evidence
Protein Supplementation	Reduces ulcer incidence in hip fracture (Yap & Holloway, 2021).	No benefit in general populations (Langer et al., 2024).
EPA/GLA Formulas	Effective in neurosurgical patients (Ogawa, 2021).	Limited data for non-surgical cohorts.
Serum Albumin	Predicts ulcer risk (Adıgüzel & Acar Tek, 2021).	Reflects inflammation, not just nutrition.
Individualized Plans	Reduce mortality in cancer/HF (Bargetzi et al., 2021).	Resource-intensive; feasibility challenges in low-resource settings.

4. CONCLUSIONS

Advanced technologies can improve nutritional support by reducing stress on the body. Pressure mapping systems, the unknown mattresses, can reduce pressure, reducing the risk of tissue damage in sensitive areas. Sensor-enabled protectors help maintain proper patient positioning, while telehealth tools can observe nutritional intake. Integrating good nutrition and technology is crucial for patients who cannot move. Diets that are high in eicosapentaenoic acid have been shown to decrease inflammation, as indicated by reduced levels of C-reactive protein (CRP). Using pressure-relief devices can help prevent skin deterioration. However, challenges persist in resource-limited areas, making proper nutrition even more critical. Technology alone cannot meet all metabolic needs, so a collaborative approach among dietitians, engineers, and healthcare professionals is essential.

Advanced technologies can enhance nutritional support and reduce strain on the body. Systems that map pressure and new types of mattresses can reduce pressure by up to 32%, which helps lower the risk of tissue damage in sensitive areas.

Innovations such as AI pressure mapping systems, mattresses with sensors, and telemedicine platforms can complement nutritional interventions by addressing external mechanical stressors that can make the tissue more vulnerable. These technologies make high-

protein diets and anti-inflammatory nutrients like EPA more effective by ensuring patients are positioned correctly and by checking that they are sticking to their dietary plans. This combined approach, which looks at how the body's metabolism is supported and how pressure is redistributed, demonstrates the importance of improving tissue health and preventing ulcers. Despite these advances, significant challenges remain. For example, the way trials are conducted varies, and patients are not always followed for a sufficient period, making it challenging to create a single set of rules for all nutritional support. Additionally, there are insufficient resources to provide special formulas and new technologies to people in developing countries. That shows that we need to find cheap and effective ways to help. Tests like serum albumin, which help assess risk, must be combined with other tests, like C-reactive protein (CRP), to distinguish between poor nutrition and other diseases.

Future research should focus on conducting extensive randomized controlled trials with the same endpoints to evaluate the effectiveness of specialized nutritional formulations across different patient populations. We should explore ways to combine nutrition with technology to deal with the things that can cause ulcers. It will be essential for dietitians, clinicians, engineers, and researchers to collaborate to find the most effective ways to treat patients and ensure that everyone has access to the latest treatments.

Author's Contributions

Bartosz Zieliński - Conceptualization; writing - rough preparation; supervision
Karol Mateusz Wojnarowski - Writing - rough preparation
Justyna Gręda - Writing - rough preparation
Anna Klasa - Writing - rough preparation
Filip Maj - Writing - rough preparation

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Informed consent

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Ethical approval

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Conflict of interest

The authors declare that there is no conflict of interest.

Data and materials availability

All data sets collected during this study are available upon reasonable request from the corresponding author.

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