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Review Article

Immobility Syndrome – Consequences of Lower Limb Unloading. A Systematic Literature Review

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Abstract

Prolonged Immobility Syndrome (PIS) is characterized by a set of multisystemic alterations arising from the absence of mechanical load on the lower limbs. This article presents a systematic review of the literature published between 2013 and 2023, sourced from PubMed, Scopus, and Web of Science databases. The descriptors employed were: “immobility syndrome”, “sarcopenia”, “osteopenia”, “lower limbs”, and “mechanotransduction”, using the Boolean operators AND/OR. Studies written in English or Portuguese, with full-text availability and peer review, were included. The objective was to synthesize current knowledge regarding the pathophysiological consequences of immobility, with emphasis on the deprivation of load-bearing in the lower limbs and its impact on the musculoskeletal, nervous, and vascular systems. Findings suggest a strong interdependence between plantar support functions and systemic health, with direct implications for the rehabilitation of bedridden individuals. The evidence underscores the pivotal role of the foot as both a structural support element and a source of sensory afference, which contributes significantly to postural and functional homeostasis. The data reinforce the relevance of early interventions that simulate or restore plantar load, aiming to prevent complications and promote effective functional recovery.

Keywords: Immobility Syndrome; Lower Limb Disuse; Plantar Stimulation; Sarcopenia; Mechanotransduction

Introduction

Immobility syndrome is a prevalent condition among older adults, characterized by a progressive loss of mobility that significantly affects both health status and quality of life [1]. A scoping review is a valuable methodological approach to mapping key concepts, identifying gaps in the literature, and establishing future directions for research [2]. In accordance with the Joanna Briggs Institute (JBI) model, this study aims to explore existing evidence regarding immobility syndrome, its underlying causes, physiological consequences, and strategies for both prevention and intervention.

The relevance of this review lies in the pressing need to better understand the complexity of immobility in the elderly, particularly within the context of prolonged hospitalization, institutionalization, and environmental or social barriers [3]. Adopting the JBI model, this review seeks to synthesize the available knowledge and highlight effective strategies for mitigating the adverse impacts of immobility.

The human foot plays a fundamental role in bipedal locomotion, acting as both a base of support and a propulsive element during gait. Contemporary scientific literature continues to emphasize the foot's complex biomechanics, which are essential for maintaining posture, absorbing impact, and facilitating the forward progression of the body during walking [4].

Comparable to an engineering marvel, the foot's structural configuration allows its multiple joints, muscles, and ligaments to work in a coordinated manner, thereby ensuring dynamic stability and mechanical efficiency. This functional understanding echoes Leonardo da Vinci's classical description of the foot as "a masterpiece of engineering and a work of art"—a notion that remains valid in light of recent advances in biomechanics and neurophysiology [5].

From an architectural standpoint, the plantar arch system—comprising longitudinal and transverse arches—exhibits mobility in response to applied load and reverts to its natural configuration during rest. These arches act as resilient structures that distribute ground reaction forces, adapt to irregular surfaces, and promote efficient load transmission [5,6].

Beyond its structural role, the foot constitutes the initial functional link in the closed kinetic chain—a biomechanical concept describing the interaction between body segments when the distal point (the foot, in this case) is in fixed contact with a surface. Within this context, the foot not only receives but also initiates the ascending forces that affect the entire musculoskeletal system, thus playing a crucial role in proper load distribution and preventing overload in proximal joints [7].

During gait, particularly at the moment of initial heel contact, the foot is subjected to high-frequency impulsive forces. The adequate functioning of the foot's shock- absorbing mechanisms is vital to mitigate these forces, as failure to do so may lead to pathological overloads along the ascending kinetic chain [8].

In addition to its mechanical role, the foot is a rich source of sensory information. It is equipped with various proprioceptive receptors—such as Pacinian corpuscles, Ruffini endings, and Merkel discs—that predominantly respond to deep pressure. These receptors are stimulated under plantar loading conditions, generating afferent impulses essential for modulating postural tone and integrating spatial orientation [9].

Recent evidence affirms that somatosensory input—largely originating from the feet— remains a principal sensory source used by the central nervous system (CNS) for postural control, particularly in elderly populations and in contexts of postural instability [10].

The absence of plantar loading therefore raises pertinent questions about the systemic and functional implications: What are the consequences for the musculoskeletal system? What neurological and metabolic changes may ensue? What novel structural and functional pathologies may emerge as a result?

These concerns are especially relevant in the clinical context of bedridden patients, where weight-bearing is severely compromised. It is precisely with the intention of addressing these questions that the present systematic literature review was developed. Its purpose is to understand the real impact of mechanical unloading of the lower limbs thoroughly and critically.

Methodology

A systematic review of the literature was conducted in accordance with the Joanna Briggs Institute (JBI) methodology [11]. The search was carried out between March and June 2024 using the PubMed, Scopus, and Web of Science databases. The following descriptors and Boolean operators were used: ("immobility syndrome" OR "prolonged bed rest") AND ("sarcopenia" OR "osteopenia") AND ("lower limbs" OR "plantar stimulation") AND ("mechanotransduction" OR "mechanical loading").

Inclusion criteria: encompassed studies published between 2013 and 2024, with full- text availability, peer review, majority with a specific focus on bedridden adults or experimental models of immobility.

Exclusion criteria: included duplicate articles, opinion pieces, and non-systematic narrative reviews.

A total of 376 articles were initially identified. After applying selection criteria and screening titles and abstracts, 112 articles were selected for full-text reading. Of these, 54 articles were included in the final synthesis (Table 1).

Review Stages	Number of Studies
Studies identified in databases	376
Duplicates removed	56
Title and abstract screening	322
Full-text articles assessed	112
Articles included in final review	54

Table 1: Study Selection Flow (Adapted PRISMA / JBI Model).

Based on the themes intended for exploration, the literature review was structured and organized thematically. Within each theme, objectives and study populations were highlighted.

In the next part, the article transitions to the Analysis of Studies by Theme, starting with Muscular Effects and Sarcopenia.

Muscular Effects & Sarcopenia (14 studies)

Article (Year)	Type	Objective	Population
Addison & Lieberman (2015) [8]	Original research	To compare impact loading rate, vertical impulse and effective mass in walking vs. running with different footwear stiffness	Healthy adult walkers/ runners
Argilés et al. (2016) [12]	Review	To examine skeletal muscle's role in inter-organ metabolic crosstalk	General human physiology
Choi et al. (2022) [13]	Original research	To describe musculoskeletal complications in diabetes mellitus	Patients with diabetes mellitus
Collins et al. (2018) [14]	Review	To explore inflammatory pathways linking obesity, metabolic syndrome and muscle integrity	General human physiology
Damanti et al. (2024) [15]	Original research	To elucidate mechanisms and management of acute sarcopenia	Adults experiencing acute sarcopenia
Globus & Morey-Holton (2016) [16]	Review	To present hindlimb unloading as rodent analog for microgravity	Rodent models
Grima-Terrén et al. (2024) [17]	Review	To identify pathology, aetiology and therapeutic targets in muscle ageing and sarcopenia	Literature synthesis
Iida et al. (2017) [18]	Review	To discuss skeletal muscle dysfunction in critical illness	Critically ill patients
Jaryd & Te (2021) [19]	Original research	To test ultrasound-mediated gene delivery for skeletal muscle repair after denervation	Animal model
Juhl et al. (2021) [20]	Review	To update on microgravity's effects on the musculoskeletal system	Astronauts and analogue studies
Mariñansky & Jauregui (2021) [21]	Review	To define and characterize Immobility Syndrome	Literature synthesis

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Sartori et al. (2021) [22]	Review	To analyse molecular mechanisms of muscle atrophy and hypertrophy	Literature synthesis
Tesch et al. (2016) [23]	Original research	To evaluate physiological and "omic" responses to unilateral lower limb suspension	Healthy young adults
Thot (2023) [24]	Experimental study	To examine endomysium alterations in human soleus muscle after 60 days bed rest	Healthy adult volunteers

Osteopenia & Bone Mechanotransduction (10 studies)

Article (Year)	Type	Objective	Population
Avin et al. (2015) [25]	Review	To discuss biomechanical aspects of muscle–bone interaction	Literature synthesis
Hart et al. (2017) [26]	Original research	To explore mechanical foundations of bone strength	Animal and human data
Man et al. (2022) [27]	Review	To review microgravity's effects on bone structure and function	Astronauts and models
Moosavi et al. (2021) [28]	Scoping review	To survey exercise countermeasures against spaceflight bone loss	Humans and animals
Oladapo et al. (2023) [29]	Review	To assess piezoelectric effects on bone modelling	Literature synthesis
Tagliaferri et al. (2015) [30]	Review	To describe interconnections between muscle and bone tissues	Literature synthesis
Vanwanseele et al. (2002) [31]	Original research	To examine cartilage degeneration under immobilisation	Animal and human data
Wang et al. (2022) [32]	Review	To investigate mechanical regulation of bone remodelling	Literature synthesis
Yavropoulou & Yovos (2016) [33]	Review	To elucidate molecular basis of bone mechanotransduction	Literature synthesis
Zhang et al. (2021) [34]	Systematic review	To analyse ion channel-mediated mechanosensory/transductive processes in bone	Literature synthesis

Proprioceptive & Neurological Dysfunction (14 studies)

Article (Year)	Type	Objective	Population
Bernabei (2023) [35]	Original research	To correct postural deficits and promote lower-limb haemodynamics via plantar stimulation	Adults with postural instability
Biele (2022) [5]	Review	To explore human foot biomechanics in human–computer interaction	Literature synthesis
Bruijn & Van Dieën (2018) [9]	Original research	To control human gait stability through foot placement	Healthy adults
Deflorio et al. (2022) [36]	Review	To review simulation models of skin and mechanoreceptor contributions to tactile perception	Literature synthesis
Duysens et al. (2000) [37]	Review	To compare load-regulating mechanisms in gait and posture	Animals and humans

Forbes et al. (2015) [38]	Original research	To investigate frequency-dependent vestibular control of posture	Healthy adults
Hazari et al. (2021) [7]	Book chapter	To detail kinematics and kinetics of the ankle and foot complex	Literature synthesis
Clark (2022) [39]	Review	To examine spaceflight effects on the vestibular system	Literature synthesis
Reschke & Clément (2018) [40]	Review	To document vestibular and sensorimotor dysfunction during space flight	Literature synthesis
Ritzmann et al. (2017) [41]	Book chapter	To summarise posture and locomotion control mechanisms	Literature synthesis
Sarkodie-Gyan & Yu (2023) [42]	Review	To outline physiological and technological foundations of human locomotor system	Literature synthesis
Ten Donkelaar et al. (2020) [10]	Book chapter	To describe the somatosensory system's role in postural control	Literature synthesis
Mei et al. (2022) [4]	Narrative review	To improve understanding of foot biomechanics during running	Literature synthesis
Bukowska et al. (2021) [6]	Original research	To assess biomechanics of foot arch and balance in young footballers	Boys training football

Vascular & Cardiovascular Consequences (7 studies)

Article (Year)	Type	Objective	Population
Antonio González Fuenmayor et al. (2022) [43]	Original research	To identify DVT risk factors post-orthopaedic surgery	Orthopaedic surgical patients
D. Urden et al. (2022) [44]	Book chapter	To review postural diuresis and plasma volume changes in bed-ridden patients	Literature synthesis
Limper et al. (2021) [45]	Review	To discuss thrombotic risk of spaceflight	Literature synthesis
Pedrinolla et al. (2020) [46]	Review	To examine vascular side-effects of chronic bed rest	Literature synthesis
Mladen, Peter (2024) [47]	Review	To assess peripheral and central haemodynamics during leg exercise with blood-flow restriction	Literature synthesis
Rout et al. (2024) [48]	Original research	To study extended bed-rest effects on ICU patients' immobilisation	ICU patients
Taylor et al. (2023) [49]	Review	To provide a multisystem perspective on frailty modulation by physical activity	Older adults
Wright et al. (2022)	Original research	To evaluate ankle movement's effect on venous return via Doppler ultrasound	Immobilised patients

Therapeutic Interventions (8 studies)

Article (Year)	Type	Objective	Population
Abranches & Cavalleti (2020) [1]	Original research	To describe immobility syndrome in hospitalized older adults	Hospitalized older adults
Aries (2020) [50]	Original research	To test somatosensory stimulation for lower-limb recovery after stroke	Stroke patients

Canu et al. (2016) [51]	Original research	To trial a device combining plantar sole and Achilles' tendon mechanical stimulation	Immobilized patients
Kneafsey (2007) [52]	Review	To review nursing contributions to mobility rehabilitation	Literature synthesis
Monica Fan et al. (2023) [53]	Randomized trial	To assess bedside activity device's impact on functional status	Hospitalised older adults
Pacheco et al. (2020) [54]	Review	To review hospital-associated functional decline and physical activity interventions	Literature synthesis
Peters et al. (2020) [2]	Methodology guidance	To update JBI scoping review conduct guidelines	Literature synthesis
Souza et al. (2013) [3]	Original research	To compare functional mobility in institutionalized vs. non-institutionalized older adults	Older adults' community vs. institution

Data Extraction and Review Method

Data extraction was conducted using a standardized form, and the analysis was performed independently by two reviewers. Any discrepancies were resolved through consensus or, when necessary, by a third reviewer.

Review

Prolonged Immobility Syndrome

Prolonged maintenance of the supine position has been correlated with multisystem alterations that led to the conceptualization of Prolonged Immobility Syndrome (PIS) [55]. This refers to a set of organic dysfunctions arising from the sustained absence of weight-bearing through the lower limbs [21]. The condition is characterized by functional disturbances across several systems, namely the musculoskeletal, cardiovascular, nervous, and metabolic systems, and tends to worsen with advancing age and the presence of comorbidities [52].

Several studies highlight the significant consequences of immobilization, reporting that 25% to 35% of hospitalized older adults lost independence in at least three activities of daily living within just three days. More recent data reinforce the importance of preventive strategies in clinical settings to avoid this accelerated functional decline [53,54].

Somatosensory Deprivation

The lack of mechanical loading selectively affects antigravity muscles—particularly the extensors of the legs and trunk—due to reduced stimulation of plantar mechanoreceptors, especially the Pacinian and Ruffini corpuscles [42]. These receptors are activated by sustained pressure exerted on the plantar surface during upright stance and gait. In their absence, a deficit in afferent signalling to the central nervous system occurs, resulting in reduced muscle tone and subsequent atrophy.

Moreover, these mechanoreceptors directly influence the activation threshold of spinal motor neurons, interacting with vestibular and visual cues. Their continuous stimulation is crucial for postural control and the maintenance of segmental reflex activity [36]. The loss of plantar loading therefore initiates a cascade of neurophysiological changes that go beyond mere disuse, affecting motor coordination, postural stability, and even spatial perception [39-41].

Muscle Atrophy and Metabolic Alterations

Loss of muscle mass is among the most visible consequences of immobility. The literature demonstrates that even a mere reduction in muscular activity can trigger protein catabolism, and the absence of mechanical stimulation significantly exacerbates this process [16]. Experimental models involving lower limb suspension or immobilization have shown that muscle mass may decrease by up to 5% within just one week, with a proportional loss of function [23].

Furthermore, mechanical under-stimulation alters muscle metabolism by reducing protein synthesis and increasing local inflammatory processes. These changes are mediated by molecular pathways such as mTORC1 inhibition and ubiquitin– proteasome pathway activation, leading to accelerated proteolysis [22].

In fact, muscular integrity depends on the interaction between mechanical stimuli, proprioceptive input, motor innervation, and regular contractile activity. In bedridden patients, these stimuli are drastically reduced, resulting in rapid muscle atrophy, particularly in antigravity muscles such as the soleus [24].

During immobilization, muscle strength declines swiftly—by as much as 40% in the first week—due to increased levels of pro-inflammatory cytokines such as TNF-α and IL-6, which promote protein catabolism and heighten the risk of cardiovascular events [15].

Additionally, the absence of mechanical loading impairs osteomuscular stimulation, compromising bone mineral density and promoting neuromuscular dysregulation. The predominance of type I muscle fibres in postural muscles makes them particularly susceptible to disuse atrophy [19].

Effects on Bone and Cartilage

As with muscular tissue, bone is highly sensitive to mechanical stimuli. The skeletal system responds to external loading not only by altering its mass but also through modifications to its microstructural architecture.

Under conditions of mechanical unloading—such as prolonged bed rest or microgravity—a disequilibrium arises between osteoclastic resorption and osteoblastic formation, favouring bone loss, particularly in trabecular bone, which is metabolically more active. This process, commonly referred to as disuse osteopenia, compromises the structural integrity of the skeleton and increases the risk of fractures and overall morbidity and mortality [26].

Although bone degradation progresses more slowly than muscle loss, its clinical implications are substantial. Bone metabolism is tightly regulated by mechanotransduction—the process by which bone cells convert mechanical stimuli such as compression, tension, and shear into biochemical signals that activate or inhibit specific molecular pathways [33].

One of the core mechanisms of mechanotransduction is the piezoelectric effect of bone. As an anisotropic and semi-crystalline material, bone generates electrical charges when subjected to deformation forces such as bending. During this process, opposing electrical poles are generated: negative charges on the compressed side stimulate osteoblastic activity and bone formation, while positive charges on the tension side promote osteoclastic activity and bone resorption. This phenomenon enables adaptive bone remodelling in response to habitual mechanical loads [29, 34].

The compressive forces generated by upright posture and low-to-moderate impact physical activities are the primary anabolic stimulus for bone. Dynamic forces—which vary in both magnitude and direction—are more effective for osteogenesis than prolonged static loading, as they prevent cellular mechanoreceptor desensitisation. Moreover, even low-magnitude cyclic stimuli have been shown to offer osteoprotective effects, provided they are applied with appropriate frequency and duration [32].

Muscle–bone integrity is interdependent. Muscle contraction exerts tension upon bone, thereby activating osteogenic pathways via local mechanical deformation. Conversely, the quality of bone tissue influences the efficiency of muscular function [25]. Thus, sarcopenia and osteopenia frequently coexist and are mutually reinforcing, particularly in immobilized or elderly individuals [30].

Finally, it should be noted that bone structures with an antigravity function, such as the spine, pelvis and lower limbs, are also the most affected in non-load-bearing contexts [28]. In these regions, the loss of bone mass is more accelerated, which reinforces the need for therapeutic strategies that include regular mechanical stimuli - including in rehabilitation and long-term care contexts.

Hematopoietic effects

Sarcopenia doesn't just affect the locomotor system. Muscle mass is closely linked to glycaemia homeostasis, lipid metabolism, inflammatory response, and overall functional capacity. Muscle loss compromises lipid oxidation favors insulin resistance and predisposes to sarcopenic obesity - a condition with increased cardiovascular risk [12, 14]. This condition also represents a severe deterioration in body composition, where fat mass accumulates and the adipokines secreted aggravate systemic inflammation and insulin resistance, accentuating the loss of muscle function [14]. Sarcopenic obesity requires dual management strategies: reduction of adiposity and recovery of muscle mass.

In addition, the increase in connective tissue in atrophic muscle, coupled with the reduction in satellite cells and capillarization, establishes an ineffective regenerative environment, exacerbating atrophy.

In the feet in particular, sarcopenia associated with neuropathies and DM can generate structural deformities such as clubfoot and digital claw, making them more susceptible to trophic lesions due to the exposure of bony prominences as a result of plantar pad atrophy [13] Muscle atrophy due to immobilization follows a temporal pattern: in the first 7 to 10 days there is rapid protein degradation; between 2 and 3 months, recovery is still possible with reinnervation; after 7 months, there is stabilization of degeneration with scarce reversibility [18] Early intervention is therefore crucial.

This whole cascade of events associated with sarcopenia can be seen in the following organization chart (Figure 1):

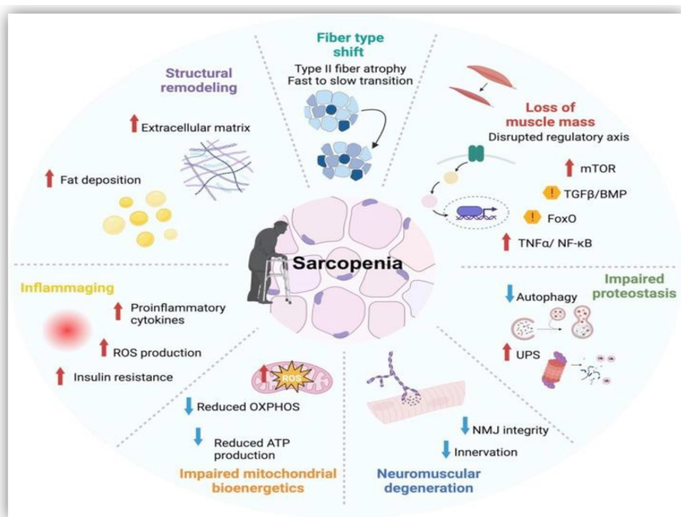

Figure 1: progression of sarcopenia and mechanism of aggravation: Adapted from Grima-Terrén et al., (2024) [17].

Implications for the Central Nervous System

In humans, as in other arthropods, the support of the lower limbs depends on load detection through exteroceptors and proprioceptors. Exteroceptors respond to muscle contractions and give rise to reflexes that can stiffen the limb or cause flexion or extension movements. Proprioceptors, on the other hand, are divided into two groups: one more related to position and movement detection (such as the chordotonal organs and muscle receptors), and the other more specialized in direct load detection. Both types of proprioceptors contribute to the regulation of limb support, adjusting force and position according to the load detected [37] Control of lower limb support also results from the integration of sensory signals, including those from the skin. These signals can trigger flexion or extension responses of the entire limb, helping to maintain balance and stability. Among the proprioceptors, the fusiforms are important for detecting movement and position, while the Golgi tendon organs, although they can inhibit muscle contraction, have a reduced role during walking, as their effect is often suppressed.

During the support (or stance) phase of gait, afferent signals from multiple load receptors activate the central circuits responsible for limb extension. This mechanism provides a 'reinforcing force feedback', which promotes the contraction of the extensor muscles and simultaneously suppresses the activity of the flexor muscles. This organization ensures that the limb remains firm while bearing weight, guaranteeing stability and preventing a premature transition to the swing phase. This type of feedback is only functionally relevant during locomotion. In the immobile animal, this mechanism does not manifest itself, which reinforces the idea that active support of the lower limbs during gait depends on the interaction between sensory feedback and the motor circuits involved in generating the locomotor pattern [37]. Additionally, the lack of load on the limbs leads to a decrease in the activity of the motor cortex and connectivity between areas related to postural and locomotor control. This can result in difficulties in returning to walking after long periods of immobility, even if muscle mass and joints are apparently preserved [18].

Vascular and cardiovascular effects

Reduced movement, especially walking, significantly compromises venous return from the lower limbs. Although decubitus eliminates the effect of gravity, the absence of skeletal muscle contraction represents an independent risk factor for venous stasis, hypercoagulability, and endothelial damage - the three components of Virchow's triad, which predispose to the development of deep vein thrombosis (DVT) and thromboembolism [43, 45]. The absence of continuous orthostatism reduces the efficiency of venous return, predisposing to stasis and the risk of venous thromboembolism. There is also deconditioning of the cardiovascular system, with a decrease in stroke volume and tolerance to exertion. Studies indicate that aerobic capacity can decline by up to 25 per cent after three weeks of bed rest [49] In bedridden patients, the absence of movement compromises the action of the leg muscle pump (LMP), which is fundamental for venous return. This pump, also known as the 'peripheral heart', is based on the compression of the triceps sural over the deep veins during muscle contraction, propelling blood towards the heart. Its inactivity contributes to stasis and increased blood viscosity (Peter & Mladen, n.d.) In addition, the postural diuresis induced by the lying position leads to a gradual loss of plasma volume, reaching up to 15 per cent after four weeks of rest. This increases haematocrit and blood viscosity, favoring the formation of [44] Over time, there is also a reduction in red blood cell mass and hemoglobin levels, worsening tissue oxygenation [46] Immobilization also affects lung function and gas exchange, resulting in tissue hypoxia. The skin, due to its terminal vascularization, is particularly vulnerable to ischemia - which increases the risk of pressure injuries and ulcers [48].

Simple movements such as active or passive plantar flexion have a beneficial effect on venous blood flow, as demonstrated by Doppler ultrasound studies. Regular exercise, even in decubitus, helps to activate the deep venous system and reduce the risk of VT.

On the other hand, suddenly resuming activity after long periods of rest can mobilize previously formed clots near the venous valves, increasing the risk of pulmonary embolism, ischemic stroke or myocardial infarction. For this reason, rehabilitation should be gradual and monitored, especially in individuals with additional risk factors [46].

Intervention Strategies

Understanding the systemic effects of the absence of mechanical load leads to an appreciation of therapeutic strategies that simulate or promote stimulation of the plantar receptors. Plantar tactile stimulation devices, partial unloading supports and closed kinetic chain exercises have been shown to be effective in maintaining muscle tone and proprioceptive function even in contexts of partial immobility.

In addition, the early use of assisted verticalization and dynamic orthoses that promote controlled weight unloading can help maintain the functional integrity of the foot as the first link in the kinetic chain, preparing the system for post-immobilization readaptation [50,51].

The therapeutic approach to sarcopenia must therefore be multifactorial: physical, nutritional, pharmacological, environmental and social, but this article aims to raise awareness among all health professionals that sarcopenia, rather than being treated, must be minimized, given the huge negative impact on the individual's overall health.

Conclusions

This systematic review, based on the analysis of 54 rigorously selected studies from an initial screening of 332 titles and abstracts, offers compelling evidence regarding the profound systemic consequences of mechanical unloading of the lower limbs. The literature consistently highlights that prolonged immobility—particularly in bedridden or hospitalised individuals—triggers a cascade of multisystem dysfunctions, with pronounced effects on the musculoskeletal, neurological, and vascular systems.

Across the majority of studies reviewed, a recurrent finding was the central role of mechanical loading through the lower limbs, particularly via plantar support, in maintaining postural tone, muscular strength, proprioceptive feedback, and bone density. The absence of such load results in accelerated muscle atrophy, predominantly affecting antigravity muscles, alongside osteopenia, due to the suppression of mechanotransductive stimuli essential for bone remodeling. Furthermore, deficits in plantar sensory input lead to neuromuscular dysfunction, postural instability, and impaired functional recovery.

Another key theme emerging from the evidence is the detrimental impact of somatosensory deprivation and its contribution to systemic inflammation, metabolic derangement, and heightened thrombotic risk. These pathophysiological consequences are often exacerbated by the under-recognition of immobility as a clinical condition, despite its highly preventable nature.

Given the weight of evidence, it is imperative that health professionals remain vigilant to the early signs of functional decline due to immobility. The clinical management of immobilized patients must move beyond passive care and incorporate active strategies that simulate or restore mechanical loading—even in contexts where full mobilization is not yet feasible. Interventions such as plantar stimulation devices, assisted verticalization, closed kinetic chain exercises, and sensory-motor rehabilitation protocols have demonstrated promise in preserving neuromuscular integrity and preventing long-term disability.

This review therefore underscores the urgent need for innovation in rehabilitation paradigms, emphasizing the restoration of mechanical loading as a therapeutic priority. Interdisciplinary approaches and targeted training for healthcare teams are essential to ensure that immobility does not remain a silent and underestimated contributor to functional decline in vulnerable populations.

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