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Peripheral and Central Contributions to Age-Related Proprioceptive Decline, Clinical Implications and Management

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ABSTRACT

Introduction: Proprioception is the body's ability to perceive its position and movement in space, crucial for maintaining balance and coordination, especially in older adults. As individuals age, both peripheral and central mechanisms of proprioception decline. Peripheral contributions include sensory mechanisms in muscle spindles and cutaneous mechanoreceptors, vital for joint position sense. This decline can lead to balance disturbances and increased fall risk. Central contributions involve neuroanatomical changes, neurochemical alterations, and cognitive factors such as decreased memory, obstructing effective proprioceptive integration.

Methods: The search utilised key databases such as PubMed, PubMed Central (PMC) BioMed Central (BMC) along with various grey literature sources, to gather a comprehensive range of information.

Clinical implications: Impaired proprioception can decrease postural control and balance, increasing fall risk and associated chronic pain conditions.

Interventions: Evidence highlights the effectiveness of technological advancements, personalised physical activity programmes, and proprioceptive training strategies. Collaborative efforts among healthcare professionals are vital for creating comprehensive care plans.

Conclusion: Age-related proprioceptive decline significantly impacts balance and functional independence in older adults. Effective interventions to preserve proprioceptive function and reduce fall risk are crucial. A multifaceted approach that includes targeted training and interdisciplinary collaboration can enhance outcomes and support a more active life for older individuals. Future research should address literature gaps through longitudinal studies and randomised controlled trials to evaluate intervention effectiveness and advancements in technologies like virtual reality. A holistic approach involving interdisciplinary collaboration among healthcare professionals is essential.

Keywords: Proprioception, ageing, balance, risk of falls, proprioception interventions

1. INTRODUCTION

Proprioception, referred to as the "sixth sense" by McCloskey (1978), is the body's ability to detect its position in space. Researchers differentiate between joint position sense (proprioception) and the conscious awareness of joint movement (kinaesthesia). [(1)] This sensory capability relies on proprioceptive receptors that perceive parameters such as effort, force, weight, joint position, and movement, located in the skin, joints, and muscles, including structures like muscle spindles and Golgi tendon organs. [(2)] Proprioceptors convert mechanical stimuli into electrical signals through mechanotransduction; when a stimulus like stretch or tension occurs, ion channels open, allowing sodium ions to enter cells, generating receptor potentials and

transmitting sensory information to the central nervous system. [3,4,5] These mechanisms are essential for maintaining balance and coordinated movements [6], with both peripheral and central components working together to provide body awareness but serving different roles. [7]

As individuals age, there is a notable decline in proprioception. [2] These age-related changes can significantly affect mobility and increase the risk of falls due to decreased sensitivity to body and limb positions. Falls are a major health concern, with over 30% resulting in serious injuries that require medical treatment. [3] Research indicates that elderly women fall more frequently than men, suggesting that gender should be considered when developing fall prevention strategies. [8]

Understanding the relationship between ageing and proprioception is crucial for developing interventions to mitigate age-related sensory declines. This review examines both central and peripheral contributions to proprioceptive decline, focusing on how ageing affects the central nervous system (CNS) and peripheral nervous system (PNS). Recent studies reveal that changes like the deterioration of mechanoreceptors and alterations in neural pathways reduce proprioceptive acuity. This knowledge is vital for designing tailored rehabilitation programs that enhance proprioceptive function, thereby reducing fall risk and improving mobility among older adults. Integrating proprioceptive training into therapeutic practices allows physiotherapists to better address age-related sensory decline and promote safer movement strategies for their patients.

2. OBJECTIVES

The aim of this narrative review was to investigate the peripheral and central mechanisms contributing to age-related declines in proprioceptive function in older adults, with the objectives of discussing the potential implications that declining proprioception may have on balance and overall functional mobility, and identifying holistic rehabilitation strategies aimed at mitigating these declines and improving overall balance and functional mobility.

3. METHODS

To effectively gather relevant literature for this narrative review, a comprehensive search strategy was employed. This strategy focused on identifying peer-reviewed articles, clinical studies, and relevant reviews that addressed the mechanisms of proprioceptive decline, its implications for balance and functional mobility, and effective management strategies. The search utilised key databases such as PubMed, PubMed Central (PMC) BioMed Central (BMC), along with various grey literature sources, to gather a comprehensive range of information. It encompassed essential search terms including “Proprioception”, “Older adults”, “Geriatrics”, “Ageing”, “Balance”, “Falls”, “Peripheral mechanisms”, “Central mechanisms”, “Mechanoreceptors”, “Neuroanatomical changes”, “Cognitive factors”, “Clinical implications”, “Effectiveness”, “Interventions”, “Proprioceptive neuromuscular facilitation”, “Footwear” “Proprioception training”, “Proprioception exercises, “Physical activity”, “Virtual reality”, “Social engagement”, “Community engagement”, and “Home modifications” . Using Boolean operators (AND, OR), queries were structured to ensure thorough coverage of the topic. For example, combinations like (Proprioception AND Ageing) or ((Peripheral mechanisms OR Central contributions) AND Proprioception) helped refine the search results. Google Scholar was utilised to access a variety of relevant grey literature for the study, and reference lists of identified articles were reviewed to capture additional relevant studies. Although this is a narrative review, quality assessment was conducted for select studies using the Cochrane Risk of Bias Tool (ROB II), Newcastle-Ottawa Scale (NOS) and ROBINS-I (Risk Of Bias In Non-randomized Studies - of Interventions) tools, specifically those deemed relevant (i.e. cohort studies,

cross-sectional studies, randomised control trials and systematic reviews). The articles were reviewed, and their content was summarised according to the following themes: peripheral and central contributions to proprioceptive decline, clinical implications, and interventions. **Figure 1** illustrates the peripheral and central contributions to proprioceptive decline in older adults, emphasising the roles of both systems in this process. **Table 1** offers detailed descriptions of studies that examine these peripheral and central factors, providing insights into how ageing impacts proprioception.

2. MECHANISMS OF PROPRIOCEPTIVE DECLINE:

1. Peripheral Changes

Proprioception is fundamentally constructed at the peripheral level through the integration of neural signals from various mechanoreceptors such as those found in the joints, muscles and skin. [(9)] With advancing age, several changes occur in the peripheral nervous system that can impact sensory and motor function. These changes include:

1. **Reduced Myelin in Sensory Nerves:** The reduction in myelin surrounding peripheral nerves due to ageing appears to affect sensory nerves first. This degeneration leads to slowed nerve conduction velocities (NVC), which can impair the transmission of proprioceptive signals to the central nervous system. [(10)]

2. **Altered Muscle Spindle Structure and Function:** With ageing, there is a notable decrease in the sensitivity of muscle spindles, which are crucial for our ability to sense body position and movement. Additionally, the composition of these muscle spindles undergoes significant changes, characterised by a preferential reduction in fast-twitch myosin heavy chain isoforms in favour of slow-twitch isoforms. This shift in the contractile proteins within muscle spindles is likely a contributing factor to the decline in proprioceptive acuity observed in older adults, impacting their overall balance and coordination. [(11)] Ageing has also been reported to be associated with increased capsular thickness of muscle spindles, a possible reduction in the number of intrafusal muscle fibres and a decrease in the diameter of the muscle spindles. [(12)]

3. **Reduced Cutaneous Receptors:** The number of receptors in the skin decreases with advancing age. These receptors, such as Meissner's corpuscles and Pacinian corpuscles detect touch, pressure and vibration. Their diminished density leads to impaired tactile sensitivity and reduced ability to detect light touch and vibration in the elderly. [(10)] Research indicates that the decline in tactile sensation associated with ageing is primarily due to modifications in cutaneous mechanoreceptors. A study demonstrated that the number of Meissner's corpuscles decreases progressively with age, resulting in smaller and less effective receptors located deeper within the dermis. Additionally, there is a notable reduction in the expression on Piezo2, a mechanoprotein crucial for maintaining these receptors' functionality. [(13)] Additionally, anatomical and physiological changes can reduce sensitivity in the soles of the feet, affecting proprioceptive performance in the ankle complex as these receptors are crucial for relaying information about weight-bearing activities. [(14)]

2. Central Changes

At the central level, proprioception is enhanced by internal feedback loops that facilitates communication among sensory and motor regions of the brain. [(9)] In this review, central changes have been categorised into neuroanatomical changes and cognitive changes as follows:

i. **Neuroanatomical Changes:** Neuroanatomical changes associated

with ageing encompass several significant alterations.

- **Dendritic Loss:** The ageing process affects the central somatosensory pathways, leading to a gradual decline in dendritic structures within the motor cortex. This decline results in a reduced population of both neurons and receptors, accompanied by neurochemical changes in the brain. [(15)] Dendritic spines - small specialised protrusions extending from the dendritic shaft - are essential for forming synaptic connections with other neurons. [(16)] Dendritic spines can be classified into four types - mushroom, thin, stubby, and filopodia - each with unique structures and functions related to synaptic strength, memory storage, and plasticity, varying across developmental stages and conditions. These spines vary in shape and size, often featuring a bulbous head and/or neck, which aids in compartmentalising biochemical signalling and supporting synaptic plasticity. [(17)] In various regions of the brain, typical ageing is associated with a reduction in dendritic structures and a loss of spines. Additionally, ageing appears to impact stubby, mushroom, and thin spines in distinct ways. The loss of spines and changes in these types of spines can significantly impact how excitatory signals are processed in our brain's neuronal circuits. [(18)]
- **Neurochemical Changes:** Age-related alterations in neurotransmitter levels have been observed, particularly a decrease in serotonin and dopamine. Dopamine levels decline by approximately 10% every decade from early adulthood, a trend linked to reductions in cognitive and motor performance. Serotonin is also vital for muscle contraction, wakefulness, and mood regulation, especially concerning depression. Research indicates that individuals experiencing depression often have lower concentrations of serotonin metabolites in their cerebrospinal fluid and brain tissue. [(19)] A decline in dopamine activity leads to slower processing speeds and reaction times, difficulties with fine motor skills, reduced walking speed, and balance issues. [(20)]
- **Subcortical Changes:** Subcortical changes associated with ageing have a significant impact on proprioceptive function, yet our understanding of how these alterations specifically influence cortical mechanisms remains limited. Research by Piitulainen et al. (2018) highlights that as individuals age, there is a pronounced decline in grey matter thickness, which is closely linked to decreased postural stability. Their findings suggest that denser grey matter correlates with improved balance, indicating that maintaining structural integrity in the brain is vital for stability. Furthermore, the study proposes that the loss of sensorimotor afferents due to ageing may lead to less efficient cortical processing of proprioceptive information. [(21)]

ii. Cognitive Factors

- **Decreased Attention and Memory:** The dorsolateral prefrontal cortex, which matures late, is vital for cognitive functions such as working memory and sensory attention, especially in processing proprioceptive feedback for limb position awareness. Age-related changes in brain structure, particularly in the frontal and prefrontal cortices, can impair cognitive functions like attention and memory, leading to reduced proprioceptive acuity in older adults. Diminished cognitive resources limit their ability to focus on sensory inputs crucial for posture and balance. Additionally, declines in cognitive processing can negatively affect proprioceptive function during complex tasks, potentially contributing to psychological issues such as depression, stress, and anxiety. [(22,14)]

Fig. 1: SUMMARY OF PERIPHERAL AND CENTRAL CONTRIBUTIONS TO PROPRIOCEPTIVE DECLINE IN OLDER ADULTS

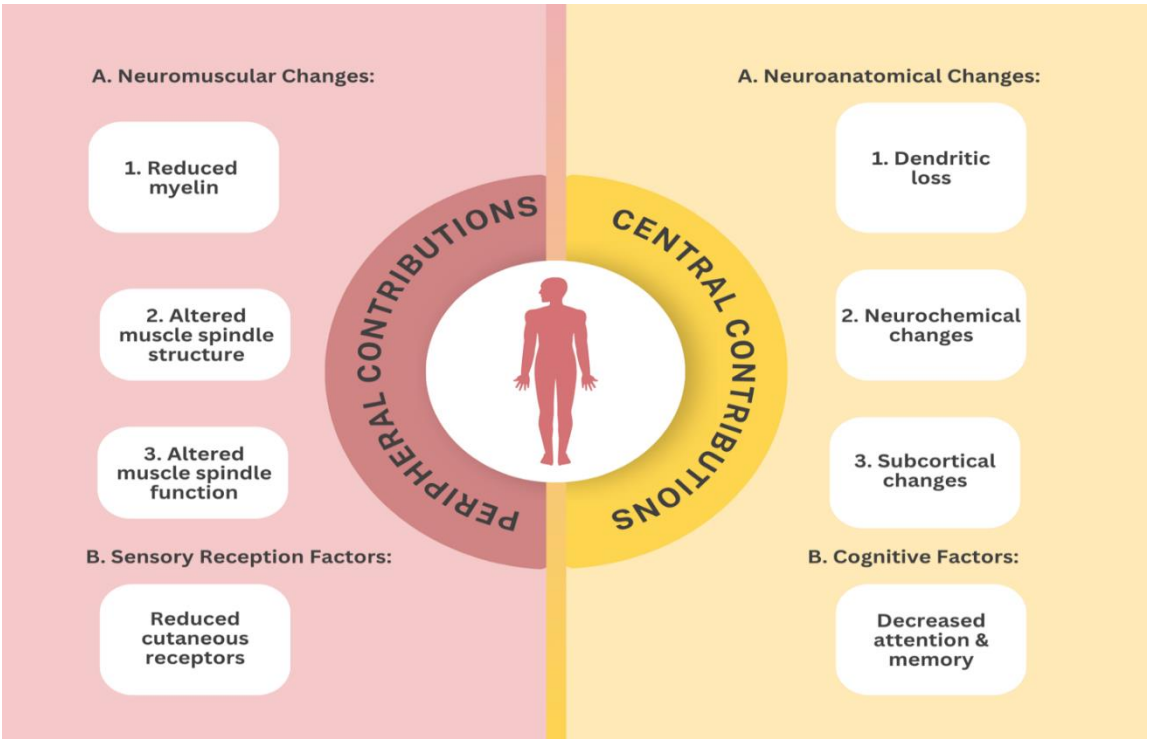

Fig. 1. summarises the peripheral changes (reduced myelin in sensory nerves, altered muscle spindle structure/function, and reduced cutaneous receptors) and the central contributions (neuroanatomical changes, including dendritic loss, neurochemical changes, subcortical changes, and cognitive factors such as decreased attention and memory) that collectively contribute to proprioceptive decline.

Table 1: DETAILS OF STUDIES DESCRIBING PERIPHERAL AND CENTRAL CONTRIBUTIONS TO PROPRIOCEPTIVE DECLINE IN OLDER ADULTS

No.	Author Name(s)	Title	Relevant Key Findings	Database	Quality Assessment Tool: Rating
1	Ribeiro & Oliveira (2007) [9]	Aging effects on joint proprioception: the role of physical activity in proprioception preservation	Discussed how ageing affects proprioception through central and peripheral mechanisms; Highlighted that age-related changes in muscle spindles and sensory processing contribute to proprioceptive decline.	BioMed Central (BMC)	N/A
2	Shaffer & Harrison (2007) [10]	Aging of the Somatosensory System: A Translational Perspective	Highlighted the nonuniform declines in the somatosensory system with ageing; age-related anatomical and physiological changes in the peripheral proprioceptive and cutaneous systems.	PubMed	N/A
3	Liu et al. (2005) [11]	Fiber content and myosin heavy chain composition of muscle spindles in aged human biceps brachii	Investigated age-related changes in biceps brachii muscle spindles, finding a significant decrease in intrafusal fibres, especially nuclear chain fibres, along with altered myosin heavy chain composition.	PubMed	N/A
4	Fan et al. (2021) [12]	Age-related alterations of hyaluronan and collagen in	Study aimed to investigate age-related physiological changes in the extracellular matrix surrounding muscle spindles and to determine if these changes contribute to	PubMed	N/A

		extracellular matrix of the muscle spindles	alterations in their surrounding environment; Referenced multiple studies highlighting morphological and physiological changes, such as thicker spindle capsules and a reduced number of intrafusal fibres; Results confirmed previous findings that older adults exhibit thicker muscle spindle capsules.		
5	García-Piqueras et al. (2019) [13]	Ageing of the somatosensory system at the periphery: Age-related changes in cutaneous mechanoreceptors	Analysed the effects of ageing on the structural and neurotrophic characteristics of cutaneous sensory corpuscles; Highlighted that ageing leads to a progressive reduction in the number of Meissner's corpuscles and Merkel cells, with Meissner's corpuscles becoming smaller and Merkel's cells reducing in number; Reported a reduction in the expression of Piezo2.	PubMed	N/A
6	Yang, Waddington, Adams, & Han (2019) [14]	Age-related changes in proprioception of the ankle complex across the lifespan	Established an inverted-U pattern of proprioceptive ability across ages; Indicated that the decline in ankle proprioceptive performance with age may be partly due to reduced tactile acuity in the plantar skin, with the lowest proprioceptive ability observed in individuals aged 75–90.	PubMed	NOS: 6 (Fair)
7	Lee, Kwon, Son, Nam, & Kim (2013) [15]	The effects of aging on visuomotor coordination and proprioceptive function in the upper limb	Examined the effects of ageing on visuomotor coordination and proprioceptive function in the upper limb; Found that older adults exhibited significant deficits in both visuomotor coordination and proprioceptive abilities compared to younger individuals; The discussion on ageing highlights that it induces a progressive loss of the dendritic system in the motor cortex, leading to a reduction in the number of neurons and receptors, as well as neurochemical changes in the brain.	PubMed	ROBINS I: Serious concerns
8	Yuste (2023) [16]	Dendritic spines	The book describes morphology and physiological functions of dendritic spines.	Google Scholar (Books)	N/A
9	Pchitskaya & Bezprozvanny (2020) [17]	Dendritic spines shape analysis-classification or clusterization?	Focused on the analysis of dendritic spine shapes in neurons.	PubMed	N/A
10	Dickstein, Weaver & Luebke (2013) [18]	Dendritic spine changes associated with normal aging	Explored how normal ageing affects dendritic spines in the brain and highlighted that ageing is linked to a decline in dendritic spine density and changes in spine morphology, which can impact synaptic function and neuronal communication.	PubMed Central	N/A
11	Nikhra (2017) [19]	The aging brain: Recent research and concepts	Highlighted the various changes that occur in the brain due to ageing; Found that neurotransmitters such as dopamine and serotonin experience significant declines with age, impacting various cognitive and behavioural functions.	Google Scholar	N/A

12	Taylor et al. (2022) [20]	Influences of dopaminergic system dysfunction on late-life depression	Highlighted the loss of dopaminergic neurons in the substantia nigra with increasing age, contributing to the characteristic symptoms of depression in older adults, such as anhedonia, cognitive decline, and emotional dysregulation; Highlighted the connection between depression and increased risk for motor problems such as slow gait speed and impaired balance; this relationship tends to be bidirectional.	PMC	N/A
13	Piitulainen et al. (2018) [21]	Cortical proprioceptive processing is altered by aging	Investigated how ageing impacts proprioceptive processing in the cortex; Found that ageing adversely affects cortical proprioceptive processing, with a significant reduction in grey matter thickness. It highlights that greater grey matter density is associated with better postural stability.	PubMed	ROBINS I: Moderate concerns
14	Laurence & Michel (2017) [22]	The fall in older adults: physical and cognitive problems	Highlighted that ageing significantly impacts cognitive functions, particularly attention and memory; As individuals age, there is a decline in the number of muscle spindles in the soleus muscles, which play a crucial role in proprioception and posture regulation. This reduction affects postural control, particularly under conditions of fatigue, making it more challenging for older adults to maintain stability. Consequently, they require greater concentration to stand quietly compared to their younger counterparts.	PubMed	N/A

Table 1 summarises studies investigating the peripheral and central factors contributing to proprioceptive decline in older adults, including author(s) and year, title, key findings related to proprioceptive mechanisms, database source, and quality assessment ratings where applicable

3. CLINICAL IMPLICATIONS

The decline in proprioception in older adults poses important clinical implications. A summary of these implications is shown in **Figure 2**, with detailed study descriptions in **Table 2**.

1) **Impaired Balance:**
   Proprioception plays a vital role in planning movement, estimating errors, and correcting them; however, the natural ageing process can negatively impact these abilities, resulting in impaired balance and coordination. [23] A decline in proprioceptive sensitivity disrupts the body's awareness of its position in space, making it difficult for older adults to maintain stability and respond to unexpected disturbances. Proprioception, along with tactile sensation and muscle strength, is crucial for regulating both dynamic and static balance and executing precise movements. For older individuals, motion perception is vital for maintaining balance; disturbances can lead to significant changes in lower limb angles, particularly at the ankle. [24] Consequently, the challenges in estimating and correcting errors increase the risk of falls, raising serious safety concerns for this demographic.
2) **Risk of Falls:**
   Impaired balance is regarded as one of the most critical risk factors for falls. [25] Adults over 60 are particularly at risk for fatal falls, with studies indicating that age-related declines in proprioceptive

mechanisms significantly contribute to this increased risk. [(26)] Falls are the second leading cause of accidental deaths globally [(27)] and often result in serious injuries for older adults, such as hip fractures, dislocations, lacerations, and bruises. In severe cases, falls can lead to traumatic brain injuries or death. Beyond physical injuries, falls can have psychological effects, including depression, low self-confidence, and diminished self-efficacy. [(28)] The fear of falling - whether or not it is linked to a previous incident - can profoundly affect older individuals. This apprehension is associated with negative outcomes, including reduced daily activity levels, a lower quality of life, and an increased likelihood of institutionalisation. [(29)] Other factors contributing to fall risk in older adults include low blood pressure (causing dizziness), certain medications, environmental hazards, poor vision, reduced muscle strength, and cognitive impairment. [(30)]

3) **Impaired Cervical Proprioception:**
Cervical proprioceptive signals are transmitted to the superior colliculus in the midbrain, which acts as a reflex centre for coordinating head and eye movements. These proprioceptors are closely connected to the vestibular nuclei and play a crucial role in regulating reflexes that control head and eye movement, as well as balance. They work alongside other reflexes that affect the neck and eye muscles linked to the vestibular and visual systems. Disruptions in cervical proprioception can lead to symptoms such as dizziness, visual disturbances, and impaired control and coordination of head and eye movements. [(31)]

4) **Disturbances in Functional Independence:**
Proprioceptive signals from the leg muscles are crucial for maintaining postural control due to their sensitivity in detecting body sway during stable upright standing, influenced by variations in leg muscle length from ankle joint rotations. However, ageing leads to changes in muscle spindles and their neural pathways, resulting in decreased sensitivity, acuity, and integration of proprioceptive signals, which can negatively impact postural control and threaten functional independence. [(32)]

5) **Pain and Proprioception:**
Research indicates that advancing age is a significant risk factor for chronic pain, particularly conditions such as chronic low back pain, neck pain, and hip and knee pain, which are especially prevalent among adults aged 65 and older. [(33)]
Lee and Chen (2024) highlight the role of proprioceptors in chronic musculoskeletal pain, noting that deficits in proprioception may be connected to functional abnormalities or compromised neural pathways. They suggest that tissue acidosis associated with chronic pain conditions activates proton-sensing ion channels in proprioceptors, potentially leading to non-nociceptive pain. They advocate for proprioception training as a therapeutic approach to alleviate chronic pain and call for further research into the interactions between proprioceptors and nociceptive pathways to develop innovative treatment strategies. [(34)]
Impaired body perception and proprioception at both central and peripheral levels leads to short-term issues like balance problems and sensorimotor dysfunctions. Over time, these disturbances can result in impaired motor output from the central nervous system, increasing the risk of injury and recurrence of pain disorders. Even after pain subsides, neuromuscular changes may persist, predisposing individuals to future episodes of pain. [(35,31)] The decline in proprioception is often linked to age-related changes in muscle function and neural pathways, reducing sensitivity and integration of proprioceptive signals. [(25)]

Fig. 2: SUMMARY OF CLINICAL IMPLICATIONS OF PROPRIOCEPTIVE DECLINE IN OLDER ADULTS

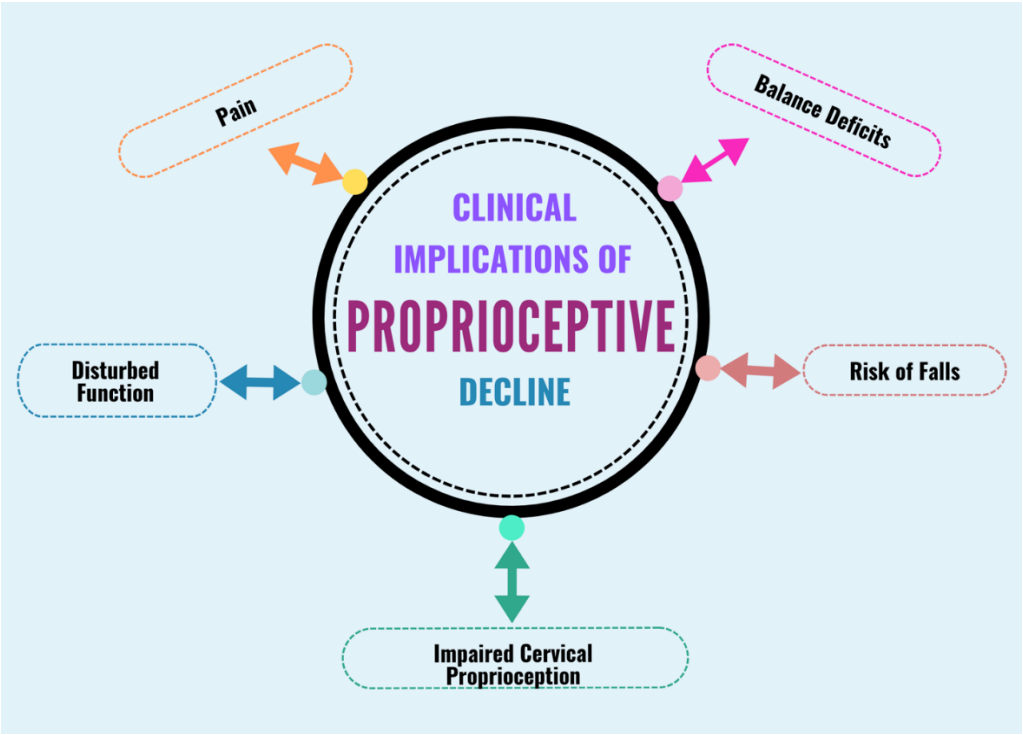

Fig. 2. summarises five key clinical implications of age-related proprioceptive decline, including impaired balance, increased fall risk, complications from impaired cervical proprioception, disturbances in functional independence and the relationship between proprioceptive disturbances and pain.

Table 2: DETAILS OF KEY STUDIES DESCRIBING CLINICAL IMPLICATIONS OF PROPRIOCEPTIVE DECLINE

No.	Author(s)/Year	Title	Relevant Key Findings	Database	Quality Assessment Tool: Rating
1	Tulimieri & Semrau (2023) [23]	Aging increases proprioceptive error for a broad range of movement speed and distance estimates in the upper limb	Indicated that ageing negatively impacts proprioceptive accuracy, with older adults showing increased proprioceptive errors influenced by movement speed and distance. These errors are generally higher across distances, and the response to changes in speed differs from that of younger individuals.	PubMed	ROBINS I: Serious concerns
2	Song et al. (2021) [24]	Relationship of proprioception, cutaneous sensitivity, and muscle strength with the balance control among older adults	Investigated how proprioception, cutaneous sensitivity, and muscle strength relate to both dynamic and static balance control in older adults; Results indicated that proprioception is linked to both dynamic and static balance control, aligning with the findings of most prior research.	PubMed Central (PMC)	NOS: 5 (Fair)

3	Wang & Fu (2022)[25]	Relationship between proprioception and balance control among Chinese senior older adults	Analysed balance control and its potential contributors - tactile sensation, proprioception, and muscle strength - while examining their relationships among older adults of varying ages; Authors emphasised that maintaining balance function is crucial for preventing falls in this population.	PubMed	N/A
4	Toosizadeh, Ehsani, Miramonte & Mohler (2018) [26]	Proprioceptive impairments in high fall risk older adults: the effect of mechanical calf vibration on postural balance	Investigated proprioceptive deficits in individuals at high risk of falling compared to healthy participants when their balance performance was challenged using low-frequency mechanical vibrations applied to the calves; Found that calf vibration led to an increase in both the overall amount and speed of body sway among participants, with the increase being minimal in those at high fall risk.	BioMed Central (BMC)	NOS: 5 (Fair)
5	World Health Organization (2021) [27]	Falls	Defined falls and acknowledged that falls are a major public health problem.	World Health Organization (WHO)	N/A
6	Terroso, Rosa, Torres Marques & Simoes (2014) [28]	Physical consequences of falls in the elderly: a literature review from 1995 to 2010	Highlighted that the risk of falling increases with age, with approximately one in three older adults experiencing a fall annually; Categorised various pathologies that contribute to fall risk, including neurological, musculoskeletal, and cardiovascular conditions. Other consequences of falling include loss of life.	BioMed Central (BMC)	N/A
7	Jung (2008) [29]	Fear of falling in older adults: comprehensive review	Aimed to clarify the definition of fear of falling, outline its measurement methods, and identify associated risk factors; Found that individuals with poorer perceived health were more likely to experience fear of falling, which was also linked to reduced physical function or mobility; Ultimately, fear of falling could lead to various physical and psychological problems.	PubMed	N/A
8	Stefanacci & Wilkinson (2023) [30]	Falls in older adults	Defined falls and described risk factors of falls among older adults.	MSD Manual	N/A

9	Röijezon, Clark, & Treleaven (2015) [31]	Proprioception in musculoskeletal rehabilitation. Part 1: Clinical assessment and intervention	Highlighted the essential role of cervical proprioception in head-eye coordination and movement control; Disruptions in proprioception, caused by pain, swelling, trauma, or fatigue, can adversely affect motor control and muscle stiffness regulation. These disturbances may lead to symptoms such as balance problems and clumsiness in individuals with musculoskeletal disorders.	PubMed	N/A
10	Henry & Baudry (2019) [32]	Age-related changes in leg proprioception: implications for postural control	Discussed how ageing affects proprioception in the legs and its consequences for postural stability; Highlighted that ageing leads to alterations in muscle spindles and their neural pathways, resulting in decreased sensitivity, acuity, and integration of proprioceptive signals. These changes adversely impact postural control, reducing its efficiency and potentially compromising an individual's functional independence.	PubMed	N/A
11	Domenichiello, & Ramsden (2019) [33]	The silent epidemic of chronic pain in older adults	Highlighted that age is a risk factor for high-impact chronic pain (HICP), which limits daily activities and participation. HICP is linked to a higher risk of depression, a significant concern for older adults that frequently occurs alongside chronic pain.	Google Scholar	N/A
12	Lee & Chen (2024) [34]	Role of proprioceptors in chronic musculoskeletal pain	Found that proprioceptors are acid-sensitive and express various proton-sensing ion channels and receptors, suggesting they may contribute to pain associated with tissue acidosis.	PubMed	N/A
13	Devecchi et al. (2021) [35]	Are neuromuscular adaptations present in people with recurrent spinal pain during a period of remission? a systematic review	The study reported that individuals with chronic pain exhibit varied changes in motor behaviour, primarily aimed at short-term protection of the body. However, these adaptations can lead to negative long-term effects, such as ongoing tissue strain and early fatigue, which may persist even after the pain has resolved. The authors emphasise the need for longitudinal research to	Google Scholar	N/A

			determine if changes in muscle activity can predict future episodes of pain.		

Table 2 outlines key studies that examine the clinical implications of proprioceptive decline in older adults, focusing on impaired balance, increased risk of falls, compromised cervical proprioception, disturbed function, and associated pain, detailing author(s) and year, title, significant findings, database source, and quality assessment ratings where applicable.

4. INTERVENTIONS

Although the fundamental principles of proprioception training remain consistent across age groups, methods must be tailored to meet the specific needs of each population. A study by Yang et al. (2019) assessed proprioceptive acuity in various age groups, from children to very old adults, revealing a significant improvement in proprioceptive acuity from childhood, peaking in young adulthood, followed by a decline starting in middle age. The lowest proprioceptive acuity was found in individuals aged 75 to 90 years, highlighting the need for targeted interventions for this older demographic to address their declining proprioceptive abilities. [(14)] A summary of interventions is provided in **Figure 3**.

1) Technological Advances:

Technological advancements, particularly in virtual reality (VR) and biofeedback systems, offer innovative approaches to engage older adults in proprioceptive training. As technology becomes increasingly integrated into daily life, physiotherapy has also evolved its rehabilitation techniques. [(36)] VR immerses users in a computer-generated environment that simulates real-world experiences, utilising headsets and motion-tracking systems. In physiotherapy, VR serves as a cutting-edge platform for delivering therapeutic interventions within a controlled and adaptable setting. [(37)] Fully immersive VR technology aims to create the sensation of being in a three-dimensional environment, tracking movement and weight distribution through sensors to provide immediate feedback on task performance and rehabilitation progress. Other forms of VR, such as augmented reality, mixed reality, and non-immersive VR, also contribute to this evolving landscape. [(38,39)]

In their pilot study, Shin and Hing (2024) explored the benefits of VR rehabilitation for older adults recovering from total knee replacement surgery. The experimental group that participated in fully immersive VR rehabilitation showed significant improvements in proprioception, gait velocity, cadence, and stride length compared to the control group, which experienced minimal improvements or declines in these metrics. These findings suggest that immersive VR rehabilitation is more effective for enhancing movement and balance. The authors recommend that future research focus on developing diverse content and structured VR programmes to address the limitations identified in their study. [(40)]

A study investigated a virtual reality rehabilitation system designed to help stroke patients improve upper-limb movement by focusing on proprioception. Researchers created virtual environments where visual feedback could be toggled on or off during training. Ten stroke patients participated, assessing their proprioceptive abilities before training, after one week, and after all training sessions. The results showed that training without visual feedback led to greater improvements in motor control compared to training with visual feedback. This suggests that incorporating proprioceptive feedback in VR can effectively enhance rehabilitation outcomes for stroke patients. [(41)]

Another study investigated the effects of conventional proprioceptive training compared to virtual reality training on functionality and fear of falling in elderly women. Conducted as a randomised clinical trial, the research found that participants in traditional proprioceptive training showed significant improvements in mobility, balance, and physical performance, along with a reduction in their fear of falling.

Conversely, the virtual reality training group improved in all measured outcomes except functional mobility. The control group did not show any improvements and experienced a statistically significant decline in mobility throughout the study period. [(42)]

2) Physical Activity as a Mitigating Factor

While the mechanisms through which exercise enhances proprioception are not fully understood, several hypotheses exist. Proprioception involves both central and peripheral components, with physical activity positively influencing both. At the peripheral level, improvements are linked to changes in muscle spindles, leading to structural adaptations rather than an increase in the number of mechanoreceptors. Centrally, physical activity may enhance proprioception by modulating mechanoreceptor gain and inducing plastic changes in the central nervous system. Regular physical activity is essential for older adults to maintain body position awareness, which typically declines with age, increasing fall risk. Engaging in exercises focusing on strength, balance, and coordination, such as Tai Chi and specific proprioceptive training, can help slow this decline and improve stability. Additionally, increased output from muscle spindles during exercise may enhance cortical projections related to proprioception, while repeated practice of motor skills strengthens synaptic connections and reorganises neuronal pathways in the brain. [(9)]

Ongoing exercise may also lead to desensitisation of Golgi tendon organs (GTOs), increasing muscle spindle sensitivity due to reduced inhibitory effects, which can improve proprioceptive and kinaesthetic awareness. [(43)] Additionally, Tai Chi, characterised by slow movements and continuous body position awareness, has been significantly associated with enhanced proprioceptive ability, improving joint position sense and the capacity to detect joint motion among older adults. [(44)]

3) Proprioceptive Training

Proprioceptive training aims to enhance the body's ability to perceive its position and movement through exercises such as balance and stability training. A systematic review found that effective proprioceptive training utilises somatosensory signals without relying on other senses like vision. The most effective methods combine passive and active movements with proprioceptive information, with or without visual feedback. Preliminary evidence suggests that this training may also facilitate cortical reorganisation, improving motor function. Various approaches, including balance training and somatosensory stimulation, can enhance balance, coordination, and overall motor skills. [(45)] Additionally, attention may enhance the benefits of proprioceptive input by initially increasing conscious awareness of proprioceptive cues, which could become automatic with practice. [(46)]

A controlled clinical trial investigated the effects of a structured proprioception training programme on various aspects of physical stability, including gait, balance, postural stability, and fall prevention in adults over the age of 65. The results revealed significant improvements in postural stability and balance among participants who underwent proprioception training compared to a control group that did not receive this intervention. [(47)] Another study focused on the impact of proprioceptive training on balance in older adults, aiming to determine whether such training could enhance both static and dynamic balance. Participants followed a structured regimen designed to improve sensory feedback and motor control, leading to notable improvements in both types of balance after training. This enhancement in stability and coordination was associated with a reduced risk of falls, indicating that proprioceptive training can be an effective intervention for elderly populations. [(48)] Additionally, Clarke et al. (2015) identified various clinical interventions aimed at enhancing proprioception in patients with musculoskeletal conditions. These interventions focus on alleviating pain,

swelling, and fatigue to facilitate effective strategies for improving proprioception. Key recommendations include enhancing somatosensory information through passive techniques such as manual therapy, soft tissue techniques, and the use of taping or bracing. [49]

The Proprioceptive Neuromuscular Facilitation (PNF) approach has its roots in the late 1930s and 1940s, pioneered by physician and neurologist Herman Kabat along with physiotherapist Margaret Knott. The term itself encompasses three key components: "proprioceptive", which relates to sensory receptors that provide information about body movement and position; "neuromuscular", which involves the interaction between nerves and muscles; and "facilitation", which refers to making movements easier. The primary aim of this intervention is to help patients achieve their maximum functional potential. PNF leverages the body's proprioceptive system to either facilitate or inhibit muscle contractions. The PNF approach has been a significant therapeutic technique for many years. Recently, the emphasis on functional activities has integrated PNF techniques into exercise programming, making them a vital component of rehabilitation practices. [50]

4) Role of Footwear

Prospective studies have shown that older adults are at a higher risk of falling when wearing shoes with slippery soles, high heels, or those with a reduced contact area on the sole. Shoes designed with high collars and firm soles have been found to enhance stability and decrease fall risk. [51] Foot orthoses (FOs) represent an effective intervention for improving postural stability, especially in older adults. They function by supporting and realigning the foot into a more mechanically stable and efficient position, which optimises lower limb function. This realignment increases the contact area between the foot and the ground, allowing the joint mechanoreceptors in the talocrural and subtalar joints to more effectively detect crucial sensory information. [52]

A study conducted by Jellema et al. (2019) systematically reviewed existing literature to identify the key characteristics of footwear that can improve stability and reduce fall risk among older adults. The review included original research examining how various aspects of footwear, such as fit, comfort, foot health, foot pain, balance, gait, fall risk, quality of life, and social functioning, affect men and women aged 65 and older who are independently mobile. The findings highlighted several essential features of optimal footwear for this demographic, including:

- **Sole firmness and elasticity**: The hardness of a shoe's sole is crucial for sensory awareness of foot position, which helps maintain stability and balance. A hard sole (Shore A-50) offers optimal stability, while softer soles can hinder balance. Shoes with hard insoles enhance balance, and materials that retain their thickness contribute to both stability and comfort.
- **Heel Height**: Low heels (1 cm to 3 cm) are recommended for better balance and fall prevention. Older adults, in particular women, should generally avoid high heels, as transitioning from them can pose stability challenges for those accustomed to wearing them.
- **Insoles:** Insoles improve foot joint alignment and enhance stability. Both flat and textured insoles boost balance, while rigid insoles offer better dynamic stability than softer ones. Medium-density insoles (10 mm thick) are particularly effective in improving postural stability and reducing fall risk. The use of arch supports has shown significant benefits in balance, mobility, pain reduction, and overall health in older individuals.
- **Tread:** Shoe soles must have adequate tread to provide friction in both forward-backward and side-to-side directions, as older adults are more prone to lateral slips.
- **Fit and Comfort:** Proper shoe fit significantly impacts quality of life

(QoL). Detailed fitting guidance and custom insoles have been linked to improvements in health-related QoL, especially among elderly women, addressing both mental and physical health aspects. [53]

Recognising the types of shoes typically worn in and around the home is vital for assessing whether the footwear used by older individuals increases their risk of falls. Seniors living independently in the community represent the most active segment of the elderly population and, consequently, are the most vulnerable to environmental risk factors. [54]

1) Interdisciplinary Collaboration

Interdisciplinary approaches to addressing proprioceptive decline in older adults can involve collaboration among geriatricians, podiatrists, physiotherapists (PTs), occupational therapists (OTs), geriatric dietitians, researchers and other healthcare professionals and stakeholders. Geriatricians are skilled at recognising asymptomatic and atypical clinical presentations in older adults. They provide comprehensive medication management, which includes identifying adverse drug reactions, minimising polypharmacy, and carefully de-prescribing medications that are no longer necessary. [55]

Physiotherapy is a healthcare discipline led by qualified physiotherapists who assess and treat patients with a range of conditions, including those related to orthopaedics, paediatrics, geriatrics, neurology, and respiratory issues. Through techniques such as cryotherapy, exercise therapy, and manual therapy, physiotherapy aims to relieve pain and improve physical function, ultimately promoting functional independence. [56]

Podiatrists play a crucial role in improving the mobility of older adults by diagnosing various lower limb conditions and implementing a range of treatment methods, including exercise, education, and recommendations for appropriate footwear. [57]

Occupational therapy was defined by Dr Pattison in 1922 as "*any activity, mental or physical, definitely prescribed and guided for the distinct purpose of contributing to, hastening and recovering from disease or injury*". Dr Hall's definition introduced two essential concepts in occupational therapy: the utilisation of work or occupation to facilitate recovery and the development of skills necessary for various tasks. Additionally, it emphasises assisting individuals in acquiring or reacquiring effective abilities when their emotional and psychological states are below normal levels. [58]

Researchers in geriatric studies are crucial for improving care for older adults through roles such as assessment, advocacy, collaboration, data analysis, education, and guideline development. A 2021 stakeholder meeting emphasised the importance of prioritising research across various specialties related to older adults rather than focusing solely on "ageing". [59]

Geriatric nutrition is a specialised discipline that focuses on the dietary needs of older adults, with the aim of optimising their health, preventing illness, and improving overall well-being. [60] Dietitians are the sole health professionals specifically trained to offer nutritional care aimed at preventing or alleviating age-related malnutrition and chronic diseases. By implementing targeted nutrition interventions, dietitians can significantly enhance the health and well-being of older adults. [61] Nutritional health is intricately linked to the ageing process, with older adults exhibiting diverse nutritional, health, and social needs. Barriers to adequate food intake in this demographic include low physical activity, functional decline, multiple chronic illnesses, polypharmacy, and changes in digestion. Addressing these challenges is crucial for creating tailored dietary strategies that support healthy ageing and enhance overall well-being among older adults. [62]

An interdisciplinary approach is essential for addressing the holistic health of older adults, encompassing their physical, cognitive, emotional, and social needs. By collaborating, healthcare teams can develop personalised interventions that enhance

patient engagement and adherence. This comprehensive care also includes preventive measures, such as fall risk assessments and lifestyle changes, to maintain independence and reduce hospitalisations, ultimately improving overall outcomes for ageing populations.

2) Social and Community Engagement

Social and community engagement is essential for older adults due to its significant impact on their physical, mental, and emotional well-being. According to the World Health Organization's estimates from 2015, the percentage of individuals aged 60 and above is projected to increase significantly, potentially reaching between 12% and 22% of the global population by 2050. This demographic shift underscores the importance of understanding social participation, which is defined as a structured process involving specific, collective, conscious, and voluntary actions by individuals. Such participation is crucial for self-actualisation and the attainment of personal goals. [(63)] Some research on social engagement has looked into social participation, which involves taking part in activities that have a social aspect. In contrast, other studies have focused on social networks, examining the number of connections individuals have with friends and family, as well as their involvement in different groups and organisations. [(64)]

Fig. 3: SUMMARY OF KEY INTERVENTIONS FOR MITIGATING AND MANAGING AGE-RELATED PROPRIOCEPTIVE DECLINE IN OLDER ADULTS

Fig. 3. illustrates six key interventions designed to address age-related proprioceptive decline in older adults, encompassing technological advancements, tailored physical activity programmes, proprioceptive training, optimal footwear, multidisciplinary collaboration, and social and community engagements, each aimed at enhancing overall sensory function and promoting greater independence in daily activities.

Physical activity (PA) is associated with a multitude of health benefits, which has led to global policy initiatives aimed at increasing participation levels among various demographics. Despite these efforts, the adherence to the recommended guidelines of

150 minutes of physical activity per week remains disappointingly low among older adults. [65] This discrepancy highlights the necessity for more effective strategies to motivate older individuals to engage in regular physical activity, which is crucial for their overall health and well-being. The drive for social interaction and the maintenance of personal identity are powerful motivators for community mobility, often surpassing barriers such as poor health, pain, limited functional ability, and hazardous conditions. To effectively promote community mobility, it is vital to address the social needs and lives of individuals. [66] Moreover, physical activity significantly enhances quality of life by improving muscle strength and balance - key components for daily living. For older adults, maintaining good physical function can mitigate the risk of injuries and alleviate the fear of falling. Regular participation in PA is essential for active ageing and leisure, showing a strong correlation with positive health outcomes, particularly regarding health-related quality of life (HRQOL). Consequently, productive engagement among older adults positively impacts their mental and physical well-being. [67] In addition to the importance of community engagement for mental health, there exists an urgent need to develop interventions tailored to gender-specific needs within communities. Such targeted initiatives can maximise the benefits of these programmes by effectively addressing the unique challenges faced by different groups within the older population. [68]

Home modification involves altering or adapting living spaces to simplify daily tasks, enhance comfort, minimise accidents, and promote independent living. Just as the health and functioning of older individuals can evolve, so too can their environments, particularly as homes age and maintenance becomes more challenging. In older properties or those not designed with accessibility in mind, home modifications can effectively address hazardous areas that may heighten the risk of falls. In environments that are thoughtfully designed or enhanced with home modifications to accommodate changes in physical abilities, older adults can optimise their functioning. This approach promotes physical health, fosters a sense of security, and encourages ongoing social interaction within the community. [69]

Table 3: DETAILS OF KEY STUDIES ON INTERVENTIONS TO MITIGATE/MANAGE PROPRIOCEPTIVE DECLINE

No.	Author name(s)/year	Title	Key Findings	Database	Quality Assessment Tool: Quality Rating
1	Shin & Hing (2024) [40]	A study on the effectiveness of VR rehabilitation training content for older individuals with total knee replacement: Pilot study	Explored the effectiveness of virtual reality (VR) rehabilitation training specifically designed for older individuals who have undergone total knee replacement; Highlighted that the use of fully immersive VR exercise program significantly improved proprioception and gait variables in these patients.	PubMed	ROB II: Some concerns
2	Kim, et al. (2013) [41]	Proprioception rehabilitation training system for stroke patients using virtual reality technology	Centred on training that adjusts visual feedback while also enabling exercises that depend exclusively on proprioceptive input; Revealed that focusing on proprioceptive feedback led to	PubMed	N/A

			notable improvements in motor control, as shown by decreased error distances in performance tasks compared to those using visual feedback.		
3	Mascarenhas et al. (2023) [42]	Effects of conventional proprioceptive training and virtual reality on functionality and fear of falling in elderly women: Randomized clinical trial	Aimed to compare the effects of conventional proprioceptive training and virtual reality (VR) on functionality and fear of falling in elderly women; Found that conventional proprioceptive training significantly improved mobility, balance, and physical performance in elderly women, while also reducing fear of falling. The virtual reality training group improved in most outcomes except functional mobility. Meanwhile, the control group showed no improvements and experienced a decline in mobility.	Google Scholar	N/A
4	Ribeiro & Oliveira (2007) [9]	Aging effects on joint proprioception: the role of physical activity in proprioception preservation	Reported that engaging in physical activity that enhances muscle strength can also lead to improvements in proprioception; On a central level, physical activity may influence proprioception by adjusting the gain of mechanoreceptors and inducing plastic changes within the central nervous system; At the peripheral level, enhancements in proprioception have been associated with changes in muscle spindles.	BMC	N/A
5	Swanik et al. (2002) [43]	The effects of shoulder plyometric training on proprioception and selected muscle performance characteristics	Assessed the impact of plyometric training on the shoulder internal rotators regarding proprioception, kinaesthesia, and specific muscle performance traits in female swimmers; Results showed that plyometric training led to notable enhancements in both proprioception and kinaesthesia.	PubMed	ROB II: Some concerns
6	Goble, Coxon, Wenderoth, Van Impe, & Swinnen (2009) [44]	Proprioceptive sensibility in the elderly: Degeneration, functional consequences and plastic-adaptive processes	Reported that physical activity acts as a significant stimulus for sensorimotor reorganisation, a concept that has recently been investigated in several studies examining the effectiveness of training interventions for preserving or improving proprioceptive function in the elderly; Among these activities, Tai Chi, a traditional Chinese exercise, has shown a	PubMed	N/A

			particularly strong association with proprioceptive ability.		
7	Aman, Elangovan, Yeh, & Konczak (2014) [45]	The effectiveness of proprioceptive training for improving motor function: A systematic review	Aimed to clarify the concept of training the proprioceptive system; Found that proprioceptive training can effectively enhance proprioceptive function; Training programs lasting six weeks or longer generally resulted in more significant improvements in proprioceptive and/or motor function; Proprioceptive training is relevant for a diverse array of clinical populations. Patients experiencing proprioceptive impairments may benefit from this training, regardless of whether the underlying cause is neurological or musculoskeletal.	PubMed	N/A
8	Ashton-Miller, Wojtys, Huston, & Fry-Welch (2001) [46]	Can proprioception really be improved by exercises?	Indicated that proprioceptive exercises might enhance the brain's attention to proprioceptive cues. Initially, this attention may be at a conscious level during early training, but with continued practice, it could shift to an autonomous level.	PubMed	N/A
9	Martínez-Amat, et al. (2013) [47]	Effects of 12-week proprioception training program on postural stability, gait, and balance in older adults: A controlled clinical trial	Evaluated the impact of a 12-week proprioceptive training program on postural stability, gait, balance, and fall prevention in adults over 65; Results demonstrated that the training effectively improved postural stability, static and dynamic balance, and gait, while also reducing the risk of falls in this age group; Findings support the use of proprioceptive training as a beneficial intervention for older adults.	PubMed	ROBINS I: Serious concerns
10	Esposito, et al. (2021) [48]	Proprioceptive training to improve static and dynamic balance in elderly	Evaluated the impact of a 12-week proprioceptive training program on static and dynamic balance in older adults who had previously experienced at least one fall; Findings indicated that the training significantly improved both static and dynamic balance, highlighting its potential benefits for enhancing stability and reducing fall risk in this population.	Google Scholar	ROB II: Some concerns
11	Clark, Röijezon, &	Proprioception in musculoskeletal rehabilitation. Part 2:	Focused on methods for clinically assessing and enhancing proprioception in the	PubMed	N/A

	Treleaven (2015) [49]	Clinical assessment and intervention	spine and extremities; Highlighted that manual therapy, taping, and bracing can provide immediate improvements in proprioception and should be used to prepare for exercise interventions. For long-term enhancement, the authors recommended various exercises, including active joint repositioning, force sense training, coordination exercises, muscle performance training, balance training on unstable surfaces, plyometric exercises, and vibration training.		
12	Guiu-Tula, et al. (2017) [50]	The Efficacy of the proprioceptive neuromuscular facilitation (PNF) approach in stroke rehabilitation to improve basic activities of daily living and quality of life: A systematic review and meta-analysis protocol.	Described PNF as a therapeutic approach that leverages the body's proprioceptive system to facilitate or inhibit muscle contractions.	PubMed	N/A
13	Menz, Auhl, & Munteanu (2017) [51]	Preliminary evaluation of prototype footwear and insoles to optimise balance and gait in older people	Assessed how prototype shoes affected balance ability and gait patterns among participants aged 65 to 83 years; Concluded that while the prototype footwear improved balance during specific tasks like tandem walking, further development is needed to enhance its aesthetic appeal and comfort for older women.	BMC	ROBINS I: Serious concerns
14	Aboutorabi, et al. (2016) [52]	A systematic review of the effect of foot orthoses and shoe characteristics on balance in healthy older subjects	Aimed to evaluate the effect of foot orthoses on balance control in older adults; Foot orthoses were shown to improve postural stability through somatosensory or biomechanical effects.	PubMed	N/A
15	Jellema, Huysmans, Hartholt, & Van Der Cammen (2019) [53]	Shoe design for older adults: Evidence from a systematic review on the elements of optimal footwear	Aimed to evaluate the effects of shoe design on the comfort and mobility of older adults, summarise evidence-based elements of safe and comfortable footwear, and compile design recommendations; Key findings identified critical features for optimal shoe design. Authors emphasised the need for specialised shoe designs tailored to the foot morphology and functional demands of older	PubMed	N/A

			adults to enhance comfort and reduce fall risk.		
16	Menant, et al. (2008) (54)	Optimizing footwear for older people at risk of falls	Reported that older adults should wear shoes with low heels and firm, slip-resistant soles both indoors and outdoors to reduce the risk of falls.	PubMed	N/A
17	Dehi & Mohammadi (2020) (63)	Social participation of older adults: A concept analysis	Sought to clarify the concept of social participation in older adults, defining it as involving community activities and interpersonal interactions focused on resource sharing, active engagement, and individual satisfaction; Identified various influencing factors, including individual, environmental, and social elements, as well as the consequences of social participation. This clarification is essential for enhancing the well-being of older adults and guiding healthcare strategies to promote their social engagement.	PubMed	N/A
18	Bath & Deeg, (2005) (64)	Social engagement and health outcomes among older people: Introduction to a special section	Introduced a special section on social engagement and health outcomes among older adults, emphasising the significant relationship between active social engagement and various health benefits.	PubMed Central (PMC)	N/A
19	Boulton, Horne, & Todd (2020) (65)	Involving older adults in developing physical activity interventions to promote engagement: A literature review	Aimed to identify the involvement of older adults in the design, delivery, implementation, and promotion of physical activity (PA) interventions and assess the benefits of this involvement; Found that older adults participated at various levels, including consultation, cooperation, co-learning, and collaboration, leading to improved intervention outcomes.	Google Scholar	N/A
20	Gardner (2014) (66)	The role of social engagement and identity in community mobility among older adults aging in place	Examined how neighbourhoods, as physical and social environments, affect community mobility among older adults ageing in place; Found that community mobility is a complex and dynamic process influenced by various individual and environmental factors that can change daily.	PubMed	N/A
21	Yen & Lin (2018) (67)	Quality of life in older adults: Benefits from the productive	Found that older adults maintained similar preferences for physical activities after	PubMed	N/A

		engagement in physical activity	relocating to long-term care facilities; Demonstrated that those with increasing productive engagement in physical activity reported better scores in the Mental Component Summary and social and emotional role functioning compared to those with decreasing engagement.		
22	Yeo, et al. (2022) [68]	Does gender matter to promote mental health through community engagement among older adults?	Explored the link between community engagement and mental health in older adults, finding that gender was the only demographic factor associated with psychological distress, with men reporting poorer mental health than women; Findings highlighted the importance of community engagement for mental well-being and recommended developing gender-specific interventions to maximise these benefits for older adults.	PubMed	N/A
23	Pynoos, Steinman, & Nguyen (2010) [69]	Environmental assessment and modification as fall-prevention strategies for older adults.	Focused on environmental assessment and modification as strategies for fall prevention among older adults; highlighted that the environments where older adults live often contain hazards and problem areas; Modifications involve removing hazards such as clutter, adding special features or assistive devices like grab bars, rearranging furnishings to create clear pathways, changing the locations of activities (e.g., sleeping on the first floor instead of the second), and renovating rooms to accommodate disabilities.	PubMed	N/A

Table 3 presents key studies focused on interventions to mitigate or manage proprioceptive decline in older adults, including findings related to technological advances such as virtual reality, physical activity, the role of footwear, interdisciplinary collaboration, and social and community engagement including home modifications, detailing author(s) and year, title, research findings on each intervention, database source, and quality assessment ratings where applicable.

6. DISCUSSION

This review emphasises the complex interactions between peripheral and central factors contributing to proprioceptive decline, highlighting the necessity for targeted interventions aimed at alleviating these effects.

Peripheral and Central Changes

Age-related proprioceptive declines are not uniform across all individuals; factors such as gender can influence the extent of proprioceptive impairment. For example, studies indicate that elderly women are at a higher risk of falls compared to their male counterparts, [70,71] suggesting that fall prevention strategies should be tailored to address these gender differences.

Peripheral changes, including alterations in muscle spindle function and sensory receptor integrity, contribute to proprioceptive

decline in older adults by decreasing sensitivity and accuracy in proprioceptive signalling, which ultimately impacts postural control and increases fall risk. [10-13] The central nervous system is crucial for proprioception, and age-related declines are influenced by neuroanatomical and cognitive changes. Dendritic loss in the motor cortex diminishes synaptic connections vital for proprioceptive processing, while reduced levels of neurotransmitters like dopamine and serotonin impair cognitive functions necessary for balance and limb awareness. Additionally, decreased grey matter thickness has been linked to reduced postural stability, highlighting the importance of brain structural integrity for effective proprioceptive function. [17,19,21] Cognitive factors also significantly affect proprioception; age-related declines in attention and memory can hinder an individual's ability to process proprioceptive feedback, making it more challenging to maintain balance during dynamic tasks. [14,22] This relationship underscores the importance of addressing cognitive health alongside physical rehabilitation when designing interventions for older adults.

Clinical Implications

The implications of impaired proprioception extend beyond an increased risk of falls; they also encompass a range of health concerns, including chronic pain conditions and a diminished quality of life. Falls are a leading cause of injury among older adults, often resulting in fractures and other serious injuries that require medical intervention. Furthermore, the fear of falling can lead to a decrease in physical activity, which exacerbates health issues associated with immobility. [26,29] This cycle highlights the importance of addressing proprioceptive decline through targeted interventions that not only enhance balance and stability but also promote overall well-being in older adults.

The relationship between pain and proprioception has yielded inconsistent findings across various studies. For example, a study showed that impaired shoulder proprioception is associated with heightened pain intensity and functional limitations in individuals with Subacromial Impingement Syndrome (SAIS). [72] While it is clear that shoulder pain can negatively impact kinaesthetic awareness and the perception of force, the overall effect on joint position sense (JPS) remains uncertain. [73] Additionally, although deficits in proprioception have been associated with low back pain, another study found no significant correlation between proprioceptive abilities and either pain or disability in individuals experiencing non-specific low back pain. [74]

Functional independence is a vital component of healthy ageing, enabling individuals to carry out daily activities without requiring assistance. Proprioceptive impairments in older adults, particularly concerning postural control, can hinder their ability to navigate uneven surfaces and respond effectively to sudden changes in their environment. [44] Furthermore, age-related cognitive changes, such as declines in working memory and executive function, are crucial for maintaining functional independence and facilitating effective communication with others. [75] Cognitive abilities are essential for older adults to manage daily tasks, and when cognitive decline occurs alongside proprioceptive impairments, it can lead to increased dependency and lower quality of life. Therefore, addressing both cognitive and proprioceptive health is vital for enhancing autonomy and well-being in older individuals.

Interventions for Addressing Age-Related Proprioceptive Decline

Technological advancements are transforming proprioceptive training, particularly through virtual reality and biofeedback systems. Studies have shown that VR rehabilitation can lead to significant improvements in proprioception and motor function. [40,41,42]

These technologies enable enjoyable, task-specific training that boosts motivation and

adherence. Virtual reality simulates real-life scenarios, allowing older adults to practice balance and mobility in a safe environment, which may lead to improved outcomes.

Regular physical activity is crucial for maintaining proprioceptive function in older adults. Exercise positively influences both central and peripheral components of proprioception. Research indicates that active elderly individuals exhibit better proprioceptive accuracy than their sedentary peers, suggesting that consistent physical activity enhances the sensitivity of mechanoreceptors and central processing pathways involved in proprioception. [(9)] Furthermore, the modulation of muscle spindle output during exercise can lead to enhanced proprioceptive awareness, ultimately contributing to better balance and coordination. [(43)] Engaging in activities such as Tai Chi has been associated with improved stability and reduced fall risk. [(44)]

Proprioceptive training focuses on exercises designed to enhance the body's ability to perceive its position and movement. This training can include balance exercises, stability training, and activities that challenge the sensory system. The primary goal is to improve or restore sensory and sensorimotor functions, which are crucial for maintaining balance and preventing falls, especially among older adults. A systematic review reveals that proprioceptive training enhances motor function by leveraging somatosensory signals instead of visual information, making it beneficial for those with visual impairments or in dynamic environments. Combining passive and active movements in training can significantly improve sensory and sensorimotor functions. [(45)]

Interventions such as balance exercises on unstable surfaces and stability balls enhance proprioception by engaging various muscle groups and improving neuromuscular control.

Footwear significantly impacts proprioception and stability among older adults. Properly designed shoes can enhance sensory feedback from the ground, thereby improving balance and reducing fall risk. [(53)]

An interdisciplinary approach is essential for addressing the multifaceted nature of proprioceptive deficits across various populations. Collaboration among healthcare professionals and stakeholders can lead to comprehensive assessments and tailored interventions that consider individual needs. Additionally, social and community factors also play a crucial role in supporting interventions aimed at enhancing proprioception among older adults. Access to safe environments for physical activity, community-based exercise programs, and social support networks greatly impact participation in activities that enhance proprioceptive function. Research shows that social support encourages physical activity and fosters important social connections that contribute to mental well-being. [(76)] Home modifications enhance safety and accessibility, improving quality of life and enabling ageing in place while decreasing healthcare costs from accidents.

7. CONCLUSION

The decline in proprioceptive function with age significantly impacts balance and functional mobility in older adults due to changes in sensory receptors and central nervous system mechanisms, increasing fall risk and leading to serious health issues. Future research should link these mechanisms to clinical implications by conducting longitudinal studies and randomised controlled trials (RCTs) with diverse populations, including individuals with orthopaedic and neurological conditions, to identify more targeted and effective interventions. Exploring innovative technologies like virtual reality and wearable sensors can improve proprioceptive training by offering real-time feedback, which boosts participation in exercise programs. Furthermore, collaboration among healthcare professionals is essential for creating comprehensive care plans that tackle the complex aspects of proprioceptive decline, ultimately enhancing functional

independence and health-related quality of life for older adults.

Declaration by Author

Ethical Approval: Not Applicable

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REFERENCES

1. Swanik CB, Lephart SM, Rubash HE. Proprioception, Kinesthesia, and Balance after Total Knee Arthroplasty with Cruciate-retaining and Posterior Stabilized Prostheses. JBJS. 2004; 86(2): 328-334.
2. Proske U, Gandevia SC. The Proprioceptive Senses: Their Roles in Signaling Body Shape, Body Position and Movement, and Muscle Force. Physiol. Rev. 2012; 92(4): 1651-1697.
3. Ferlinc A, Fabiani E, Velnar T, Gradisnik L. The Importance and Role of Proprioception in the Elderly: a Short Review. Materia socio-medica. 2019; 31(3): 219-221.
4. Kröger S. Experimental Physiology special issue: 'Mechanotransduction, muscle spindles and proprioception'. Exp. Physiol. 2024; 109(1): 1-5.
5. Iheanacho F VA. Physiology, Mechanoreceptors in StatPearls [Internet] Treasure Island, FL: StatPearls Publishing; 2023.
6. Marasco PD, de Nooij JC. A New Era Set in Motion by Emerging Genetic and Bionic Strategies? Annu. Rev. Physiol. 2023; 85: 1–24.
7. Büschges A, Mantziaris C. Proprioception: Blurring the Boundaries of Central and Peripheral Control. Curr. Biol. 2021; 31(9): 444-445.
8. Chang VC, Do MT. Risk Factors for Falls Among Seniors: Implications of Gender. Am J Epidemiol. 2015; 181(7): 521-531.
9. Ribeiro F, Oliveira J. Aging Effects on Joint Proprioception: The Role of Physical Activity in Proprioception Preservation. Eur Rev Aging Phys Act. 2007; 4: 71-76.
10. Shaffer SW, Harrison AL. Aging of the Somatosensory System: A Translational Perspective. Phys. Ther. 2007; 87(2): 193-207.
11. Liu JX, Eriksson PO, Thornell LE, Pedrosa-Domellöf F. Fiber Content and Myosin Heavy Chain Composition of Muscle Spindles in Aged Human Biceps Brachii. J. Histochem. Cytochem. 2005; 54(4): 445-454.
12. Fan C, Pirri C, Fede C, Guidolin D, Biz C, Petrelli L, et al. Age-related Alterations Of Hyaluronan and Collagen in Extracellular Matrix of the Muscle Spindles. J. Clin. Med. 2021 December 24; 11(1): 86.
13. García-Piqueras J, García-Mesa Y, Cárcaba L, Feito J, Torres-Parejo I, Martín-Biedma B, et al. Ageing of the Somatosensory System at the Periphery: Age-Related Changes in Cutaneous Mechanoreceptors. J. Anat. 2019; 234(6): 839-852.
14. Yang N, Waddington G, Adams R, Han J. Age-related Changes in Proprioception of the Ankle Complex Across the Lifespan. J. Sport Health Sci. 2019; 8: 548-554.
15. Lee NK, Kwon YH, Son SM, Nam SH, Kim JS. The Effects of Aging on Visuomotor Coordination and Proprioceptive Function in the Upper Limb. J. Phys. Ther. Sci. 2013; 25(5): 627-629.
16. Yuste R. Dendritic spines: MIT press; 2023.
17. Pchitskaya E, Bezprozvanny I. Dendritic Spines Shape Analysis-Classification or Clusterization? Perspective. Front. Synaptic NeuroSci. 2020; 12(31).
18. Dickstein DL, Weaver CM, Luebke JI, Hof PR. Dendritic Spine Changes Associated with Normal Aging. Neuroscience. 2013; 251: 21-32.
19. Nikhra V. The Aging Brain: Recent Research and Concepts. Gerontol Geriatr Stud. 2017; 1: 1-11.
20. Taylor WD, Zald DH, Felger JC, Christman S, Claassen DO, Horga G, et al. Influences of Dopaminergic System Dysfunction on Late-Life Depression. Mol Psychiatry. 2022; 27(1): 180-191.
21. Piitulainen H, Seipäjärvi S, Avela J, Parviainen T, Walker S. Cortical Proprioceptive Processing is Altered by Aging. front. aging neurosci. 2018; 10: 147.

22. Laurence BD, Michel L. The Fall in Older Adults: Physical and Cognitive Problems. Curr. Aging Sci. 2017; 10: 185-200.
23. Tulimieri DT, Semrau JA. Aging Increases Proprioceptive Error for a Broad Range of Movement Speed And Distance Estimates in the Upper Limb. Front. Hum. Neurosci. 2023; 17.
24. Song Q, Zhang X, Mao M, Sun W, Zhang C, Chen Y, et al. Relationship of Proprioception, Cutaneous Sensitivity, and Muscle Strength with the Balance Control Among Older Adults. J Sport Health Sci. 2021; 10(5): 585–593.
25. Wang Q, Fu H. Relationship Between Proprioception and Balance Control Among Chinese Senior Older Adults. Front physiol. 2022; 13(1078087).
26. Toosizadeh N, Ehsani H, Miramonte M, Mohler J. Proprioceptive Impairments In High Fall Risk Older Adults: The Effect of Mechanical Calf Vibration on Postural Balance. BioMed Eng OnLine. 2018; 17(51).
27. World Health Organization. World Health Organization. [Online].; 2021 [cited 2024 October. Available from: https://www.who.int/news-room/fact-sheets/detail/falls.
28. Terroso M, Rosa N, Torres Marques A, Simoes R. Physical Consequences of Falls in the Elderly: a Literature Review from 1995 to 2010. Eur Rev Aging Phys Act. 2014; 11: 51-59.
29. Jung D. Fear of Falling in Older Adults: Comprehensive Review. Asia. Nurs. Res. 2008; 2(4): 214-222.
30. Stefanacci RG, Wilkinson JR. MSD Manuals. [Online].; 2023 [cited 2024 October. Available from: https://www.msdmanuals.com/professional/geriatrics/falls-in-older-adults/falls-in-older-adults.
31. Röijezon U, Clark NC, Treleaven J. Proprioception in musculoskeletal rehabilitation. Part 1: Basic Science and Principles of Assessment and Clinical Interventions. Man. Ther. 2015; 20(3): 368-377.
32. Henry M, Baudry S. Age-related Changes in Leg Proprioception: Implications for Postural Control. J. Neurophysiol. 2019; 122(2): 525-538.
33. Domenichiello AF, Ramsden CE. The silent Epidemic of Chronic Pain in Older Adults. Prog. Neuro-Psychopharmacol. Biol. Psychiatry. 2019; 93: 284–290.
34. Lee CH, Chen CC. Role of Proprioceptors in Chronic Musculoskeletal Pain. Exp. Physiol. 2024; 109(1): 45-54.
35. Devecchi V, Rushton AB, Gallina A, Heneghan NR, Falla D. Are Neuromuscular Adaptations Present in People with Recurrent Spinal Pain During a Period of Remission? A Systematic Review. PloS one. 2021; 16(4): e0249220.
36. Brepohl PCA, Leite H. Virtual Reality Applied to Physiotherapy: A Review of Current Knowledge. Virtual Reality. 2023; 27: 71-95.
37. Dr. D. Y. Patil College of Physiotherapy. DPU. [Online].; 2024 [cited October 2024. Available from: https://physiotherapy.dpu.edu.in/blogs/virtual-reality-physiotherapy#:~:text=Understanding%20Virtual%20Reality%20in%20Physiotherapy&text=In%20physiotherapy%2C%20VR%20offers%20a,treatment%20protocols%20for%20optimal%20results.
38. Reilly CA, Greeley AB, Jevsevar DS, Gitajn IL. Virtual Reality-Based Physical Therapy for Patients with Lower Extremity Injuries: Feasibility and Acceptability. OTA Int. 2021; 4(2): e132.
39. Georgiev DD, Georgieva I, Gong Z, Nanjappan V, Georgiev GV. Virtual Reality for Neurorehabilitation and Cognitive Enhancement. Brain Sci. 2021; 11(2): 221.
40. Shin D, Hing S. A Study on the Effectiveness of VR Rehabilitation Training Content for Older Individuals with Total Knee Replacement: Pilot Study. Healthcare. 2024; 12: 1500.
41. Kim SI, Song IH, Cho S, Kim IY, Ku J, Kang YJ, et al. Proprioception Rehabilitation Training System for Stroke Patients Using Virtual Reality Technology. In Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Annual International Conference; 2013. p. 4621–4624.
42. Mascarenhas CHM, Silva IES, Carneiro JAO, Paula RP, Paula LSR, Araujo CM, et al. Effects of Conventional Proprioceptive Training and Virtual Reality on Functionality and Fear of Falling in Elderly Women: Randomized Clinical Trial. J Clin Med Surgery. 2023; 3(1): 1074.

43. Swanik KA, Lephart SM, Swanik CB, Lephart SP, Stone DA, Fu FH. The Effects of Shoulder Plyometric Training on Proprioception and Selected Muscle Performance Characteristics. J Shoulder Elbow Surg. 2002; 11(6): 579-586.
44. Goble DJ, Coxon JP, Wenderoth N, Van Impe A, Swinnen SP. Proprioceptive Sensibility in the Elderly: Degeneration, Functional Consequences and Plastic-Adaptive Processes. Neurosci. Biobehav. Rev. 2009; 33: 271-278.
45. Aman JE, Elangovan N, Yeh I, Konczak J. The Effectiveness of Proprioceptive Training for Improving Motor Function: A Systematic Review. Front Hum Neurosci. 2014; 8: 1075.
46. Ashton-Miller JA, Wojtys EM, Huston LJ, Fry-Welch D. Can Proprioception Really be Improved by Exercises? Knee Surg, Sports Traumatol, Arthrosc. 2001; 9: 128-136.
47. Martínez-Amat A, Hita-Contreras F, Lomas-Vega R, Caballero-Martínez I, Alvarez PJ, Martínez-López E. Effects of 12-week Proprioception Training Program on Postural Stability, Gait, and Balance in Older Adults: A Controlled Clinical Trial. J Strength Cond Res. 2013; 27(8): 2180-2188.
48. Esposito G, Altavilla G, Di Domenico F, Aliberti S, D'Isanto T, D'Elia F. Proprioceptive Training to Improve Static and Dynamic Balance in Elderly. Int. J. Stats. Med. Res. 2021; 10: 194-199.
49. Clark NC, Röijezon U, Treleaven J. Proprioception in Musculoskeletal Rehabilitation. Part 2: Clinical Assessment and Intervention. Man. Ther. 2015; 20(3): 378-387.
50. Guiu-Tula FX, Cabanas-Valdés R, Sitjà-Rabert M, Urrútia G, Gómara-Toldrà N. The Efficacy of the Proprioceptive Neuromuscular Facilitation (PNF) Approach in Stroke Rehabilitation to Improve Basic Activities of Daily Living and Quality of Life: A Systematic Review and Meta-Analysis Protocol. BMJ open. 2017; 7(12): e016739.
51. Menz HB, Auhl M, Munteanu SE. Preliminary Evaluation of Prototype Footwear and Insoles to Optimise Balance and Gait in Older People. BMC Geriatr. 2017; 17(212).
52. Aboutorabi A, Bahramizadeh M, Arazpour M, Fadayevatan R, Farahmand F, Curran S, et al. A Systematic Review of the Effect of Foot Orthoses and Shoe Characteristics on Balance in Healthy Older Subjects. Prosthet Orthot Int. 2016; 40(2): 170-181.
53. Jellema AH, Huysmans T, Hartholt K, Van Der Cammen TJ. Shoe Design for Older Adults: Evidence from a Systematic Review on the Elements of Optimal Footwear. Maturitas. 2019; 127: 64-81.
54. Menant JC, Steele JR, Menz HB, Munro BJ, Lord SR. Optimizing Footwear for Older People at Risk of Falls. J. Rehabil. Res. Dev. 2008; 45(8): 1167-1181.
55. Lester PE, Dharmarajan TS, Weinstein E. The Looming Geriatrician Shortage: Ramifications And Solutions. Journ. aging. health. 2020; 32(9): 1052-1062.
56. Kumar P, Raju P, Prasad V. Fundamental of Physiotherapy: Jaypee Brothers Publishers; 2005.
57. White J, Maier AB, Iacobaccio L, Iseli R. Foot Problems In Older Adults Presenting To A Falls And Balance Clinic. Gerontol. 2024: 1.
58. Reed KL, Sanderson SN. Concepts of occupational therapy: Lippincott Williams & Wilkins.; 1999.
59. Goodwin VA, Low MS, Quinn TJ, Cockcroft EJ, Shepherd V, Evans PH, et al. Including Older People in Health and Social Care Research: Best Practice Recommendations Based on the INCLUDE Framework. Age Ageing. 2023; 52(6): afad082.
60. Carriquiry A. Geriatric Nutrition System for Health and Well-Being. Nutr. clin. diet. hosp. 2023; 43(4).
61. Bartrim K, Moyle W, Rigby R, Ball L. Examining Dietitians' Knowledge, Skills and Attitudes Regarding Working with Older Adults in Residential Aged Care Facilities and Home Care Services: An Integrative Review. J Hum Nutr Diet BDA. 2023; 36(1): 86-96.
62. Bernstein M, Munoz N. Nutrition for the Older Adult: Jones & Bartlett Learning.; 2019.
63. Dehi AM, Mohammadi SF. Social Participation of Older Adults: A Concept Analysis. Int J Community Based Nurs Midwifery. 2020; 8(1): 55-72.
64. Bath PA, Deeg D. Social Engagement And Health Outcomes Among Older People: Introduction to a Special Section. Euro. Journ. Ageing. 2005; 2(1): 24-30.
65. Boulton ER, Horne M, Todd C. Involving Older Adults in Developing Physical Activity Interventions to Promote

Engagement: a Literature Review. Pop. Ageing. 2020; 13: 325-345.
66. Gardner P. The Role of Social Engagement and Identity in Community Mobility Among Older Adults Aging in Place. Dis. Rehab. 2014; 36(15): 1249–1257.
67. Yen HY, Lin LJ. Quality of Life in Older Adults: Benefits from the Productive Engagement in Physical Activity. Journ. Exe. Sci. Fit. 2018; 16(2): 49-54.
68. Yeo LHW, Mah FCY, Chong EY, Lim AHS, Ng ST, Yi H. Does Gender Matter to Promote Mental Health Through Community Engagement Among Older Adults? Aging. Ment. Health. 2022; 26(1): 186-195.
69. Pynoos J, Steinman BA, Nguyen AQ. Environmental Assessment and Modification as Fall-Prevention Strategies for Older Adults. Clin. Geriatric Med. 2010; 26(4): 633-644.
70. Riva D, Mamo C, Fani M, Saccavino P, Rocca F, Momenté M, et al. Single Stance Stability and Proprioceptive Control in Older Adults Living at Home: Gender and Age Differences. J Aging Res. 2013; 1: 561695.
71. Rossat A, Fantino B, Nitenberg C, Annweiler C, Poujol L, Herrmann FR, et al. Risk factors for Falling in Community-Dwelling Older Adults: Which of them are Associated with the Recurrence of Falls? J Nutr Health Aging. 2010; 14: 787-791.
72. Alfaya F, Reddy R, Alkhamis B, Kandakurti P, Mukherjee D. Shoulder Proprioception and Its Correlation with Pain Intensity and Functional Disability in Individuals with Subacromial Impingement Syndrome-A Cross-Sectional Study. Diagnostics. 2023; 13(12): 2099.
73. Ager A, Borms D, Deschepper L, Dhooghe R, Dijkhuis J, Roy J, et al. Proprioception: How is it Affected by Shoulder Pain? A systematic review. J Hand Ther. 2020; 33(4): 507-516.
74. Lin J, Halaki M, Rajan P, Leaver A. Relationship Between Proprioception and Pain and Disability in People with Non-Specific Low Back Pain: A Systematic Review with Meta-Analysis. SPINE. 2019; 44: E606–E617.
75. Murman D. The Impact of Age on Cognition. Semin. Hearing. 2015; 36: 111-121.
76. Berkman L, Glass T, Brissette I, Seeman TE. From Social Integration to Health: Durkheim in the New Millennium. Soc. Sci. Med. 2000; 15(51): 843-857.

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