World Journal of Environmental Biosciences
Available Online at: **www.environmentaljournals.org**

Volume 14, Issue 2: 98-106

https://doi.org/10.51847/096UlF7Q8R

ISSN 2277- 8047

The Efficacy of "Pre-habilitation" in Primary Care for Geriatric Fall Prevention: A Narrative Review

Wael Muzi Alanazi[1]*, Anas Hotan Alshamrani[2], Mohammed Saeed Algadmi[2], Aeshah Abdulaziz Alkandari[3], Fatema Sayed Hashem Husain[4], Hamed Jamal Banoon[5], Lama Bakheet Salam Aljohani[6], Shahad Bakheet Aljohani[6], Moyad Wassel Mokhtar[7], Rukhmah Sanaullah[8], Sarah Mamdouh Allaf[9], Musab Nasser Abu Summah[10], Dawoud Abdullah Mohzari[11]

[1]Family Medicine Consultant, King Faisal Medical City, Riyadh, Saudi Arabia
[2]MBBS, King Khalid University, Khamis Mushait, Saudi Arabia
[3]MBBS, Jaber Alahmad Alsabah Hospital, Kuwait
[4]MBBS, ISA Town Health Center, Bahrain
[5]Physiotherapist, Al-Noor Specialist, Jeddah, Saudi Arabia
[6]Physiotherapist, Taibah University, Madinah Al-Munawwara, Saudi Arabia
[7]Pharmacist, Al-Noor Specialist Hospital, Makkah, Saudi Arabia
[8]MBBS, Al-Abeer Medical Center, Riyadh, Saudi Arabia
[9]MBBS, King Abdulaziz University, Jeddah, Saudi Arabia
[10]Specialist Laboratory, Mouwasat Hospital, Riyadh, Saudi Arabia
[11]MBBS, King Fahad Hospital, Jizan, Saudi Arabia.

ABSTRACT

Falls represent a major public health concern among older adults, contributing to significant morbidity, mortality, and healthcare costs. Community-dwelling geriatric populations experience falls at rates of 20-30% annually, with higher risks in those with frailty, impaired balance, or prior falls. Traditional fall prevention strategies in primary care have emphasized reactive approaches following incidents, but emerging concepts such as "pre-habilitation"—proactive interventions aimed at enhancing physiological reserve before adverse events—offer a preventive paradigm. Originally developed in surgical contexts to optimize outcomes in frail patients, pre-habilitation is increasingly explored in non-surgical settings to mitigate fall risk through targeted exercise, neuromodulation, and multifactorial risk reduction. This narrative review synthesizes recent evidence on the efficacy of pre-habilitation-inspired interventions delivered in primary care for geriatric fall prevention. Key themes include exercise-based programs, home-based self-delivered protocols combining motor imagery and neuromodulation, and multifactorial individualized approaches. High-quality systematic reviews and randomized trials demonstrate moderate benefits from exercise interventions in reducing fall rates and injurious falls, particularly among at-risk individuals. Multifactorial strategies show smaller but consistent effects on falls when tailored appropriately. Emerging pre-habilitation protocols, such as home-based neuromodulation-assisted motor imagery, show promise for feasibility and acceptability in proactive fall risk reduction, though large-scale efficacy data remain limited. Primary care delivery facilitates accessibility, but implementation barriers include resource constraints and patient adherence. This review highlights the potential of pre-habilitation to shift from reactive to proactive fall prevention in primary care, while underscoring the need for further research in community settings.

Keywords: *Pre-habilitation, Fall prevention, Geriatric, Older adults, Primary care, Exercise intervention*

Corresponding author: Wael Muzi Alanazi
e-mail ✉ Wael2030alanazi@gmail.com
Received: 30 March 2025
Accepted: 20 July 2025

INTRODUCTION

Falls among older adults represent one of the most prevalent and consequential geriatric syndromes worldwide, constituting a leading cause of injury-related morbidity, mortality, and healthcare utilization. Among community-dwelling adults aged 65 years and older, approximately one in four experiences at least one fall annually, with incidence increasing to 30–40% among those aged over 80 years or living with frailty (Bergen *et al*., 2022; Nicholson *et al*., 2024; Pillay *et al*., 2024). The burden of falls extends far beyond acute injury, encompassing fractures, traumatic brain injury, functional decline, loss of independence, institutionalization, fear of falling, and sustained reductions in quality of life (Friedman *et al*., 2020; Vieira *et al*., 2020). In the United States alone, falls account for more than 3 million

emergency department visits, nearly 1 million hospital admissions, and approximately 30,000 deaths annually, with direct medical costs exceeding tens of billions of dollars (Bergen *et al*., 2022; Swanson *et al*., 2024). Comparable epidemiological trends have been reported across high- and middle-income countries, underscoring falls as a global public health priority in aging societies (Vieira *et al*., 2020).

Fall risk in older adults is inherently multifactorial, arising from the complex interplay of intrinsic and extrinsic determinants. Intrinsic factors include age-related declines in balance and gait, lower extremity muscle weakness, sarcopenia, sensory impairment, cognitive dysfunction, polypharmacy, and chronic disease burden (Tromp *et al*., 2021; Hopewell *et al*., 2023; Nicholson *et al*., 2024). Extrinsic contributors encompass environmental hazards such as poor lighting, uneven surfaces, and inadequate home safety adaptations (Vieira *et al*., 2020; Hopewell *et al*., 2023). Frailty—a multidimensional syndrome characterized by reduced physiological reserve and heightened vulnerability to stressors—substantially amplifies fall susceptibility and worsens post-fall recovery trajectories (Sherrington *et al*., 2020; Fried *et al*., 2021). Importantly, fear of falling both predicts and perpetuates future falls through activity restriction, deconditioning, and social withdrawal, reinforcing a self-sustaining cycle of vulnerability (Friedman *et al*., 2020; Yardley *et al*., 2020).

Primary care occupies a pivotal role in fall prevention due to its longitudinal patient relationships, accessibility, and capacity for early identification of risk. Routine encounters provide opportunities for screening, risk stratification, medication review, functional assessment, and referral or intervention initiation before catastrophic events occur (Centers for Disease Control and Prevention, 2023–2024; Eckstrom *et al*., 2023). Contemporary guidelines from the US Preventive Services Task Force (USPSTF) and the Centers for Disease Control and Prevention (CDC), including the STEADI (Stopping Elderly Accidents, Deaths, and Injuries) initiative, recommend multifactorial risk assessment and exercise-based interventions for community-dwelling older adults at increased fall risk (Eckstrom *et al*., 2023; Guirguis-Blake *et al*., 2024; Nicholson *et al*., 2024; Pillay *et al*., 2024). However, real-world implementation remains inconsistent, constrained by time limitations, resource availability, patient adherence challenges, and uncertainty regarding optimal intervention timing and intensity (Goodwin *et al*., 2022).

Historically, fall prevention strategies have been predominantly reactive, implemented following a fall, fracture, or functional decline. Post-fall rehabilitation focuses on restoring lost function but frequently fails to prevent recurrence, in part due to difficulties sustaining neuromuscular adaptations, behavioral changes, and adherence over time (Friedman *et al*., 2020; Swanson *et al*., 2024). This reactive paradigm contrasts with a growing recognition that proactive approaches—designed to enhance physiological resilience before a fall occurs—may offer greater preventive potential, particularly in frail or pre-frail populations. In this context, the concept of *pre-habilitation* has emerged as a promising, yet underexplored, framework for geriatric fall prevention in primary care.

Pre-habilitation originated in perioperative medicine as a multimodal strategy aimed at optimizing physical, nutritional, and psychological readiness prior to elective surgery, especially among older and frail patients (Carli & Zavorsky, 2020; McAdams-DeMarco *et al*., 2021; Santa Mina *et al*., 2021). Evidence from surgical populations demonstrates that pre-habilitation improves functional exercise capacity, reduces postoperative complications, shortens hospital stays, and accelerates recovery (Carli & Zavorsky, 2020; McAdams-DeMarco *et al*., 2021). These benefits have prompted interest in extending the pre-habilitation paradigm beyond surgical stressors to other foreseeable health threats, including falls. Conceptually, falls represent a predictable and modifiable risk in aging, making them an appropriate target for anticipatory intervention rather than post-event remediation.

The biological rationale for pre-habilitation in fall prevention is grounded in age-related changes across central and peripheral systems. Progressive sarcopenia, impaired sensorimotor integration, reduced cortical excitability, and slowed neuromuscular response times collectively compromise balance and mobility (Tromp *et al*., 2021; Swanson *et al*., 2024). Interventions that proactively target these mechanisms—such as progressive resistance and balance training, motor imagery and action observation, and non-invasive brain stimulation—have demonstrated potential to induce neuroplastic adaptations, enhance motor learning, and improve functional reserve in older adults (Clark & Patten, 2022; Taube *et al*., 2023). When delivered through home-based or digitally supported models, such interventions may be particularly well-suited to primary care settings by reducing clinician burden while supporting patient autonomy and adherence (Choi *et al*., 2023; Swanson *et al*., 2024).

Despite increasing recognition of these principles, evidence specifically examining pre-habilitation for fall prevention within primary care remains limited. Much of the existing literature derives from perioperative contexts or from broader exercise and multifactorial intervention trials that align conceptually—but not explicitly—with pre-habilitation frameworks (Hopewell *et al*., 2020; Tricco *et al*., 2020; Vieira *et al*., 2020; Liu-Ambrose *et al*., 2021; Guirguis-Blake *et al*., 2024). High-quality systematic reviews and meta-analyses consistently support exercise-based interventions, particularly those emphasizing balance and strength, as effective in reducing falls (Tricco *et al*., 2020; Liu-Ambrose *et al*., 2021), while multifactorial approaches addressing medication, vision, environment, and psychological factors offer additional benefit in selected populations (Hopewell *et al*., 2020). However, questions persist regarding optimal timing, delivery models, scalability, patient preferences, and integration into routine primary care workflows (Goodwin *et al*., 2022; Pillay *et al*., 2024). A conceptual framework illustrating the transition from reactive fall management to proactive pre-habilitation–based prevention in primary care is shown in **Figure 1**.

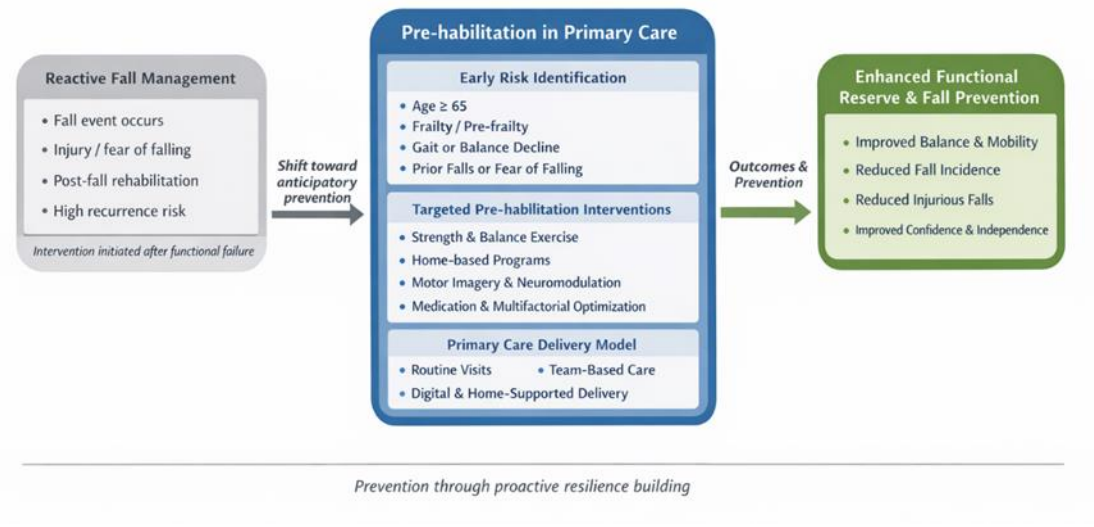

Figure 1. Textual Description for AI Illustration

Accordingly, this narrative review aims to: (1) define pre-habilitation in the context of geriatric fall prevention; (2) summarize the epidemiological burden and multifactorial risk profile of falls among older adults; (3) review current guideline recommendations relevant to primary care practice; (4) evaluate evidence supporting exercise-based and emerging pre-habilitation strategies, including neuromodulatory and digital interventions; and (5) discuss implementation considerations, barriers, and facilitators within primary care settings. By synthesizing peer-reviewed literature published, this review seeks to clarify the role of pre-habilitation as a proactive, patient-centered paradigm for fall prevention in aging populations.

Defining pre-habilitation in geriatric fall prevention

Pre-habilitation refers to structured interventions designed to enhance functional capacity and physiological reserve prior to an anticipated stressor, with the goal of improving outcomes and mitigating adverse events (Santa Mina *et al*., 2021). Traditionally applied in perioperative care, pre-habilitation targets modifiable risk factors before surgical insult through multimodal programs incorporating exercise, nutritional optimization, and psychological support (Carli & Zavorsky, 2020; McAdams-DeMarco *et al*., 2021). In the context of geriatric fall prevention, the anticipated stressor is not a discrete procedural event but the ongoing and cumulative risk of falling itself, particularly among frail or pre-frail older adults living in the community.

This conceptual shift distinguishes pre-habilitation from conventional rehabilitation, which is inherently reactive and initiated after injury or functional loss has occurred. Pre-habilitation is anticipatory, aiming either to prevent the first fall or to reduce fall severity and recurrence by strengthening underlying physiological and neuromotor systems before failure occurs (Swanson *et al*., 2024). Core components typically include structured exercise programs emphasizing strength, balance, and gait; nutritional strategies to support muscle mass and energy availability; and psychological interventions to address fear of falling, self-efficacy, and engagement (Friedman *et al*., 2020; Carli & Zavorsky, 2020; Yardley *et al*., 2020). In non-surgical settings, adaptations emphasize accessibility, scalability, and self-management rather than intensive supervised delivery.

Within primary care, pre-habilitation for fall prevention may be operationalized through brief, targeted interventions embedded into routine visits, supported by telehealth platforms, or delivered via home-based protocols. Emerging models increasingly leverage digital health technologies to facilitate monitoring, adherence, and individualized progression, aligning with older adults' preferences for autonomy and convenience (Choi *et al*., 2023; Pillay *et al*., 2024). A notable example is a recent pilot protocol combining motor imagery—mental rehearsal of functional mobility tasks—with transcranial direct current stimulation (tDCS) applied to frontal cortical regions, delivered through a self-administered, home-based program over two weeks (Swanson *et al*., 2024). This approach targets central mechanisms of mobility decline by enhancing motor learning and cortical plasticity, offering a low-burden adjunct to traditional exercise interventions.

Preliminary feasibility outcomes for such models are encouraging, demonstrating acceptable adherence, retention, and safety among community-dwelling older adults (Taube *et al*., 2023; Swanson *et al*., 2024). Importantly, these interventions may also positively influence fear of falling and balance confidence—key psychosocial determinants of mobility behavior and fall risk (Friedman *et al*., 2020; Yardley *et al*., 2020). While robust effectiveness data remain limited, the conceptual alignment of these approaches with pre-habilitation principles highlights their potential relevance to primary care-based fall prevention.

In summary, pre-habilitation in geriatric fall prevention represents a proactive, resilience-oriented framework that shifts the focus from post-fall recovery to anticipatory risk reduction. By targeting modifiable physiological, neuromotor, and psychological vulnerabilities before functional failure occurs, pre-habilitation offers a complementary strategy to

existing guideline-recommended interventions and may enhance the effectiveness and sustainability of fall prevention efforts in primary care.

Epidemiology and risk factors for falls in older adults

Falls are highly prevalent among community-dwelling older adults and demonstrate a steep, age-associated gradient. Epidemiological data consistently indicate that approximately 25–35% of adults aged 65 years and older experience at least one fall annually, with incidence rising to nearly 50% among adults aged 80 years and above (Bergen *et al*., 2022; Nicholson *et al*., 2024; Pillay *et al*., 2024). Recurrent falls are common, and prior falls remain one of the strongest predictors of subsequent events (Tromp *et al*., 2021). Importantly, falls are not benign occurrences: approximately one-third result in physical injury, and an estimated 5–10% lead to fractures, head injury, or hospitalization (Vieira *et al*., 2020; Nicholson *et al*., 2024). Hip fractures are particularly consequential, with reported one-year mortality rates ranging from 20% to 30%, alongside sustained functional decline among survivors (Tromp *et al*., 2021; Hopewell *et al*., 2023).

Beyond individual health consequences, falls impose a substantial economic burden on healthcare systems. Costs are driven by emergency department utilization, inpatient care, rehabilitation services, long-term care placement, and indirect costs related to loss of independence and caregiver burden (Friedman *et al*., 2020; Davis *et al*., 2021; Bergen *et al*., 2022). In the United States, fall-related medical expenditures have risen steadily over the past decade in parallel with population aging, reinforcing falls as both a clinical and public health priority (Bergen *et al*., 2022). Comparable trends have been documented internationally, highlighting the global relevance of effective preventive strategies (Vieira *et al*., 2020).

Fall risk arises from the interaction of multiple intrinsic and extrinsic factors. Intrinsic risk factors include lower extremity muscle weakness, impaired balance and gait, slowed reaction time, visual impairment, cognitive dysfunction, orthostatic hypotension, and chronic disease burden (Tromp *et al*., 2021; Hopewell *et al*., 2023; Nicholson *et al*., 2024). Polypharmacy—particularly the use of psychotropic medications, sedatives, antihypertensives, and anticholinergics—has been consistently associated with increased fall risk through effects on alertness, blood pressure regulation, and motor coordination (Vieira *et al*., 2020; Nicholson *et al*., 2024). Frailty syndromes, characterized by slow gait speed, low grip strength, exhaustion, and reduced physical activity, markedly elevate fall susceptibility and worsen post-fall recovery (Fried *et al*., 2021). Longitudinal cohort data demonstrate that frailty and pre-frailty states independently predict both falls and fractures, even after adjustment for age and comorbidity (Fried *et al*., 2021; Tromp *et al*., 2021).

Extrinsic risk factors include environmental hazards such as inadequate lighting, uneven walking surfaces, loose rugs, and lack of handrails, as well as inappropriate footwear and assistive device misuse (Vieira *et al*., 2020; Nicholson *et al*., 2024). Risk is further shaped by the mismatch between an individual's functional capacity and environmental or activity demands, emphasizing that falls often occur during routine daily activities rather than high-risk behaviors (Tromp *et al*., 2021). Psychosocial factors also play a critical role. Fear of falling—whether following an initial fall or arising independently—contributes to activity restriction, deconditioning, social isolation, and loss of confidence, thereby creating a self-reinforcing cycle that increases future fall risk (Friedman *et al*., 2020; Yardley *et al*., 2020).

Primary care settings are uniquely positioned to identify and modify many of these risk factors before injurious falls occur. Structured screening tools, such as those embedded within the CDC STEADI algorithm, facilitate systematic identification of fall history, gait and balance impairment, medication-related risk, and functional limitations (Centers for Disease Control and Prevention, 2023–2024; Eckstrom *et al*., 2023). Importantly, many risk factors—muscle weakness, balance deficits, medication burden, and fear of falling—are potentially modifiable through early, proactive intervention, providing a clear rationale for anticipatory approaches such as pre-habilitation.

Current guidelines and recommendations for fall prevention in primary care

Major clinical guidelines consistently endorse fall risk screening and targeted interventions for older adults in primary care. The US Preventive Services Task Force recommends exercise interventions for community-dwelling adults aged 65 years and older who are at increased risk of falls (Grade B), citing moderate-certainty evidence demonstrating reductions in fall rates and injurious falls (Bergen *et al*., 2022; Nicholson *et al*., 2024; Guirguis-Blake *et al*., 2024). Effective programs typically incorporate balance, strength, gait, and functional training, delivered two to three times per week for a duration of at least 12 months (Liu-Ambrose *et al*., 2021; Nicholson *et al*., 2024). These interventions have demonstrated benefit across diverse populations, including adults with frailty or prior falls.

In contrast, the USPSTF assigns a Grade C recommendation to multifactorial interventions, reflecting evidence of modest net benefit and substantial heterogeneity in outcomes (Hopewell *et al*., 2020; Nicholson *et al*., 2024). Multifactorial approaches involve individualized risk assessment followed by tailored interventions addressing exercise, medication optimization, vision correction, environmental modification, and management of postural hypotension or cardiovascular contributors (Hopewell *et al*., 2020; Nicholson *et al*., 2024). While such interventions may be beneficial for selected high-risk individuals, their effectiveness appears contingent on appropriate targeting, patient engagement, and implementation fidelity (Hopewell *et al*., 2020; Goodwin *et al*., 2022).

The Centers for Disease Control and Prevention STEADI (Stopping Elderly Accidents, Deaths, and Injuries) initiative provides a pragmatic, primary care–oriented framework for translating evidence into practice (Eckstrom *et al*., 2023; Centers for Disease Control and Prevention, 2023–2024). STEADI integrates brief screening (e.g., Stay Independent questionnaire), standardized assessment tools (Timed Up and Go test, 4-Stage Balance Test), and evidence-based interventions, including exercise referral, medication review, vitamin D assessment, and home safety counseling (Centers for

Disease Control and Prevention, 2023–2024). Implementation studies demonstrate that embedding STEADI into annual wellness visits, nurse-led workflows, or team-based care models improves fall risk detection and intervention delivery (Eckstrom *et al*., 2023). Guideline recommendations, delivery considerations, and implementation barriers relevant to pre-habilitation in primary care are outlined in **Table 1**.

Table 1. Guideline Alignment and Implementation Considerations for Pre-habilitation in Primary Care

Domain	Guideline Position	Practical Challenges	Pre-habilitation Contribution
Fall Risk Screening	Universally recommended	Time constraints, workflow burden	Early identification enables anticipatory action
Exercise Prescription	Strong recommendation	Adherence, access to programs	Home-based and scalable delivery
Multifactorial Assessment	Selective recommendation	Complexity, variable uptake	Targeted optimization before decline
Fear of Falling	Recognized risk factor	Often under-addressed	Motor imagery & confidence-building
Workforce Capacity	Limited	Staffing and reimbursement gaps	Low-burden, self-managed models
Equity & Access	Increasing concern	Digital divide, rural access	Requires inclusive implementation strategies

Despite guideline support, real-world uptake remains uneven. Reported barriers include limited visit time, competing clinical priorities, insufficient reimbursement, and uncertainty regarding patient adherence (Goodwin *et al*., 2022). Facilitators include interdisciplinary collaboration, patient education, and alignment with preventive care incentives (Reuben *et al*., 2021; Goodwin *et al*., 2022). These implementation challenges underscore the need for prevention strategies that are efficient, scalable, and sustainable within routine primary care—features that align closely with pre-habilitation principles.

Evidence for exercise-based interventions as pre-habilitation

Exercise-based interventions represent the cornerstone of both guideline-recommended fall prevention and pre-habilitation-inspired strategies. High-quality systematic reviews and meta-analyses published consistently demonstrate that structured exercise programs reduce fall rates by approximately 15–25% among at-risk community-dwelling older adults (Tricco *et al*., 2020; Liu-Ambrose *et al*., 2021; Bergen *et al*., 2022; Nicholson *et al*., 2024; Guirguis-Blake *et al*., 2024). Programs emphasizing balance and functional training—either alone or combined with resistance exercise—are more effective than single-component or low-intensity interventions (Liu-Ambrose *et al*., 2021; Nicholson *et al*., 2024). Benefits extend to reductions in injurious falls and improvements in mobility, confidence, and functional performance (Davis *et al*., 2021; Liu-Ambrose *et al*., 2021).

From a pre-habilitation perspective, exercise serves not only to restore function but to build physiological reserve before functional failure occurs. Progressive resistance and balance training enhance neuromuscular control, reaction time, and postural stability, directly targeting mechanisms implicated in age-related fall risk (Liu-Ambrose *et al*., 2021; Tromp *et al*., 2021). Cost-effectiveness analyses further support exercise-based prevention, demonstrating favorable cost–benefit profiles when delivered at scale, particularly among higher-risk populations (Davis *et al*., 2021).. Key characteristics and outcomes of recent exercise-based and pre-habilitation–aligned interventions for fall prevention in primary care are summarized in **Table 2**.

Table 2. Summary of Pre-habilitation–Aligned Interventions for Geriatric Fall Prevention

Intervention Category	Typical Components	Delivery Setting	Evidence Strength	Effect on Falls	Primary Care Relevance
Balance & Strength Exercise	Progressive resistance, balance, gait training	Supervised or home-based	High (systematic reviews, RCTs)	↓ total falls; ↓ injurious falls	High
Home-Based Exercise Programs	Self-directed balance and mobility exercises	Home	Moderate–high	↓ falls; ↑ confidence	Very high
Multifactorial Interventions	Exercise + medication review + vision + environment	Primary care–led	Moderate, heterogeneous	Modest ↓ falls	High (targeted use)
Motor Imagery Training	Mental rehearsal of mobility tasks	Home-based	Emerging (pilot trials)	Feasibility positive; efficacy uncertain	High potential
Neuromodulation-Assisted Pre-habilitation	Motor imagery + tDCS	Home-based	Early-stage	Feasibility & acceptability demonstrated	Experimental

Home-based and self-managed exercise programs are especially relevant to primary care and pre-habilitation paradigms. Such models reduce reliance on supervised sessions, promote long-term adherence, and accommodate mobility or transportation limitations common among older adults (Choi *et al*., 2023; Swanson *et al*., 2024). Randomized trials and pragmatic studies demonstrate that home-based programs can improve balance confidence, gait speed, and functional capacity, even among frail

individuals (Swanson *et al*., 2024). While longer-duration programs (12–30 months) yield the most robust effects, shorter, intensive interventions may serve as effective entry points for initiating behavioral and neuromotor adaptation (Nicholson *et al*., 2024).

Emerging pre-habilitation strategies

Emerging pre-habilitation strategies extend beyond conventional exercise to target central nervous system mechanisms underlying mobility decline. Motor imagery and action observation—cognitive techniques involving mental rehearsal of movement—have demonstrated potential to enhance motor learning and functional performance in older adults (Clark & Patten, 2022). When combined with non-invasive brain stimulation modalities such as transcranial direct current stimulation (tDCS), these approaches aim to prime cortical plasticity and augment training effects (Taube *et al*., 2023).

A recent pilot randomized controlled trial evaluated a home-based, self-delivered pre-habilitation protocol combining motor imagery with tDCS over a two-week period in community-dwelling older adults at fall risk (Swanson *et al*., 2024). Feasibility outcomes, including adherence, retention, and safety, were favorable, and preliminary signals suggested improvements in mobility-related outcomes. Such interventions are particularly attractive for primary care settings, where access to supervised rehabilitation may be limited and scalable, low-burden solutions are needed. While definitive effectiveness data are not yet available, these approaches exemplify the shift toward proactive neural and functional priming inherent to pre-habilitation frameworks.

Multifactorial interventions in primary care

Multifactorial fall prevention programs address multiple risk domains through individualized assessment and tailored intervention, typically encompassing exercise prescription, medication review, vision assessment, cardiovascular evaluation, and home safety modification (Hopewell *et al*., 2020; Nicholson *et al*., 2024). Evidence from meta-analyses indicates modest reductions in fall rates, with pooled incidence rate ratios approximating 0.84, though effects on fractures and individual fall risk are variable (Hopewell *et al*., 2020; Nicholson *et al*., 2024).

Large pragmatic trials have demonstrated that nurse-led, primary care–embedded multifactorial strategies can reduce serious fall-related injuries, particularly when targeted to high-risk individuals (Sherrington *et al*., 2020). However, effectiveness depends on accurate risk stratification, patient engagement, and sustained follow-up—conditions that are not uniformly met in routine practice (Goodwin *et al*., 2022). From a pre-habilitation standpoint, multifactorial interventions may be most effective when selectively applied to individuals with identifiable vulnerability (e.g., frailty, prior falls) and integrated with proactive, capacity-building strategies rather than reactive post-fall care.

RESULTS AND DISCUSSION

The synthesis of evidence published supports a substantive reframing of geriatric fall prevention toward proactive, pre-habilitation–inspired strategies embedded within primary care. Rather than conceptualizing falls as isolated adverse events requiring post hoc rehabilitation, contemporary evidence increasingly positions fall risk as a foreseeable and modifiable manifestation of declining functional reserve. Within this framework, pre-habilitation shifts the emphasis from recovery after injury to anticipatory enhancement of neuromuscular, balance, and adaptive capacity before destabilizing events occur.

Exercise-based interventions form the empirical backbone of this paradigm. Across multiple high-quality systematic reviews, meta-analyses, and guideline evaluations, exercise programs demonstrate consistent moderate reductions in fall rates, the proportion of fallers, and injurious falls among community-dwelling older adults at increased risk (Tricco *et al*., 2020; Liu-Ambrose *et al*., 2021; Bergen *et al*., 2022; Nicholson *et al*., 2024; Guirguis-Blake *et al*., 2024). The 2024 recommendation statement from the US Preventive Services Task Force and its accompanying evidence review provide particularly robust confirmation, reporting pooled incidence rate ratios of 0.85 for total falls and 0.84 for injurious falls in interventions emphasizing balance, gait, and strength training (Bergen *et al*., 2022; Nicholson *et al*., 2024; Guirguis-Blake *et al*., 2024). These findings are notable not only for their statistical consistency but also for their clinical relevance, as reductions in injurious falls directly translate into preserved independence, reduced hospitalization, and lower long-term disability burden.

From a pre-habilitation perspective, the structure and duration of exercise programs warrant particular attention. Most effective interventions involve two to three sessions per week sustained over at least 12 months, suggesting that durable neuromuscular adaptation and motor learning require prolonged exposure (Liu-Ambrose *et al*., 2021; Pillay *et al*., 2024). However, emerging evidence indicates that shorter, more intensive protocols may serve as catalytic interventions—initiating early improvements in balance confidence, gait stability, and movement efficiency that can be consolidated through longer-term maintenance strategies (Pillay *et al*., 2024). This distinction is especially relevant in primary care, where patient engagement may initially be fragile and early perceived benefit may be critical for adherence.

Multifactorial interventions align conceptually with pre-habilitation by addressing the multidimensional nature of fall risk, encompassing physical impairments, medication burden, sensory deficits, cardiovascular contributors, and environmental hazards (Hopewell *et al*., 2020; Nicholson *et al*., 2024). Meta-analytic evidence demonstrates modest but significant reductions in fall rates, with pooled incidence rate ratios approximating 0.84 (Hopewell *et al*., 2020). However, effects on injurious falls, fractures, and mortality are less consistent, and adherence frequently declines over time. These limitations underpin the cautious Grade C recommendation issued by the USPSTF, emphasizing selective rather than universal implementation and careful alignment with patient preferences, comorbidities, and prior fall history (Hopewell *et al*., 2020; Nicholson *et al*., 2024). Importantly, subgroup analyses suggest stronger effects when multifactorial interventions are targeted to individuals with clear vulnerability—such as prior falls, frailty, or polypharmacy—highlighting the importance of risk stratification rather than

broad deployment (Hopewell *et al*., 2020; Vieira *et al*., 2020).

Primary care plays a pivotal role in operationalizing both exercise-based and multifactorial approaches. Routine encounters provide repeated opportunities for early identification of gait impairment, balance decline, medication-related risk, and fear of falling, often before a sentinel fall event occurs. Tools such as the STEADI algorithm from the Centers for Disease Control and Prevention facilitate systematic screening and triage, enabling timely referral to preventive interventions (Bergen *et al*., 2022; Eckstrom *et al*., 2023; Centers for Disease Control and Prevention, 2023–2024). From a systems perspective, pre-habilitation aligns closely with the preventive mandate of primary care, offering a structured response to gradual functional decline rather than episodic crisis management.

Emerging pre-habilitation strategies extend this foundation by explicitly targeting central nervous system mechanisms implicated in age-related mobility decline. The home-based protocol combining motor imagery with transcranial direct current stimulation represents a novel attempt to enhance cortical plasticity and motor learning before falls occur (Swanson *et al*., 2024). This approach is conceptually distinct from traditional exercise interventions in that it seeks to "prime" neural circuits underlying balance and gait, potentially amplifying the effects of physical training or compensating for limitations in exercise tolerance. The pilot randomized controlled trial protocol targets community-dwelling older adults with self-identified fall risk, delivering brief, self-administered sessions through accessible technology (Swanson *et al*., 2024). Feasibility outcomes—including recruitment, retention, compliance, and acceptability—are prioritized, reflecting the early developmental stage of this intervention. The mechanistic rationale is supported by evidence that motor imagery activates neural networks overlapping with physical execution, while tDCS transiently increases cortical excitability, together potentially mitigating age-related declines in sensorimotor integration (Taube *et al*., 2023; Swanson *et al*., 2024).

Although large-scale efficacy data for such neuromodulatory approaches are not yet available, their relevance to primary care is substantial. Limited access to supervised therapy, transportation barriers, and workforce constraints frequently impede delivery of conventional fall prevention programs. Self-delivered, home-based interventions may therefore address structural barriers while supporting patient autonomy and sustained engagement (Tromp *et al*., 2021; Swanson *et al*., 2024). Importantly, these approaches also directly target fear of falling and confidence—psychological determinants that strongly influence activity patterns and future fall risk (Friedman *et al*., 2020; Yardley *et al*., 2020).

Despite these promising developments, significant implementation challenges persist. Time constraints, competing clinical priorities, and variability in clinician training continue to limit routine fall risk screening and intervention delivery in primary care (Yardley *et al*., 2020; Goodwin *et al*., 2022). Studies examining STEADI integration demonstrate improved detection and referral when embedded into annual wellness visits or nurse-led workflows, yet long-term sustainability depends on interdisciplinary teamwork, patient education, and institutional support (Eckstrom *et al*., 2023; Centers for Disease Control and Prevention, 2023–2024). Patient values and preferences further shape uptake; recent syntheses indicate a strong preference for individualized exercise formats over group-based programs, with heterogeneous acceptability of modalities such as tai chi or cognitively oriented interventions (Pillay *et al*., 2024). These findings underscore the importance of flexibility and shared decision-making within pre-habilitation frameworks.

Equity considerations are also central. Access to supervised exercise programs, digital platforms, or technology-assisted pre-habilitation remains uneven, potentially exacerbating disparities among socioeconomically disadvantaged or rural populations (Choi *et al*., 2023; Nicholson *et al*., 2024). Without deliberate attention to accessibility, scalability, and cultural relevance, pre-habilitation strategies risk benefiting only a subset of older adults.

Limitations of the current evidence base must therefore temper enthusiasm for immediate widespread adoption. Most available data derive from exercise or multifactorial interventions not explicitly designed as pre-habilitation, with true anticipatory protocols largely confined to pilot studies or perioperative contexts (McAdams-DeMarco *et al*., 2021; Swanson *et al*., 2024). Heterogeneity in definitions, intervention components, outcome measures, and follow-up duration complicates synthesis and limits generalizability (Hopewell *et al*., 2020; Pillay *et al*., 2024). Few trials are conducted entirely within primary care settings, and long-term outcomes beyond 12–24 months remain insufficiently characterized (Lamb *et al*., 2022). While reported harms are generally minor—most commonly transient musculoskeletal discomfort—underreporting in multifactorial studies warrants continued caution (Nicholson *et al*., 2024).

Nonetheless, the conceptual advantages of pre-habilitation remain compelling. By enhancing physiological and neural reserve before destabilizing events occur, pre-habilitation offers a means to interrupt the vicious cycle of falls, fear of falling, activity restriction, and deconditioning (Friedman *et al*., 2020; Swanson *et al*., 2024). Primary care's longitudinal reach and accessibility position it uniquely to identify pre-frail or at-risk individuals early and to deploy low-burden interventions that strengthen resilience before irreversible decline ensues (Fried *et al*., 2021). The integration of emerging technologies—such as app-supported exercise, remote monitoring, and home-based neuromodulation—may further extend reach while maintaining alignment with patient-centered care principles (Tchalla *et al*., 2022; Swanson *et al*., 2024).

CONCLUSION

In conclusion, contemporary evidence supports exercise as the cornerstone intervention for preventing falls in community-dwelling older adults at increased risk, with moderate net benefits that justify routine recommendation in primary care. Multifactorial approaches offer smaller and more variable benefits and should be selectively applied based on individual risk profiles, comorbidities, and patient preferences. Pre-habilitation–inspired strategies represent a promising evolution of fall prevention, reframing intervention from reactive recovery to proactive resilience-building. Home-based and technology-supported models, including those incorporating motor imagery and neuromodulation, may be particularly well suited to primary care environments where traditional supervised programs are difficult to sustain.

Future directions

Future research should prioritize large-scale randomized controlled trials explicitly evaluating pre-habilitation protocols for fall prevention in primary care populations. These studies should assess effects on fall incidence, injurious falls, functional outcomes, and quality of life over extended follow-up periods. Parallel implementation research is needed to address clinician training, reimbursement mechanisms, workflow integration, and equitable access, particularly for underserved or digitally marginalized populations. Comparative effectiveness studies examining delivery modes—home-based versus supervised, technology-assisted versus conventional—and subgroup analyses stratified by frailty status, cognitive impairment, and baseline mobility will refine targeting and personalization. Longitudinal evaluations of sustainability, cost-effectiveness, and integration with electronic health record–based screening and reminder systems are also essential.

Ultimately, embedding pre-habilitation principles into routine primary care offers a forward-looking strategy to mitigate the growing burden of falls in aging populations. Realizing this potential will require continued evidence generation, careful implementation, and sustained alignment with patient values and real-world practice constraints.

ACKNOWLEDGMENTS: None

CONFLICT OF INTEREST: None

FINANCIAL SUPPORT: None

ETHICS STATEMENT: None

REFERENCES

Bergen, G., Stevens, M. R., Kakara, R., et al. (2022). Trends in fall-related injuries and fall prevention among older adults — United States, 2009–2020. *MMWR Morbidity and Mortality Weekly Report, 71*(26), 853–857.

Carli, F., & Zavorsky, G. S. (2020). Optimizing functional exercise capacity in the elderly surgical population. *Current Opinion in Clinical Nutrition & Metabolic Care, 23*(1), 1–7.

Centers for Disease Control and Prevention. (2023–2024). STEADI – Older Adult Fall Prevention. Updated materials.

Choi, N. G., Choi, J. Y., Marti, C. N., et al. (2023). Digital health interventions for older adults with fall risk: A systematic review. *Journal of Gerontology: Series A, 78*(8), 1456–1465.

Clark, D. J., & Patten, C. (2022). Motor imagery and action observation for mobility enhancement in older adults. *Journal of Gerontology: Series A, 77*(5), 1023–1030.

Davis, J. C., Hsu, C. L., Shead, L., et al. (2021). Cost-effectiveness of exercise interventions for fall prevention in older adults: A systematic review. *Osteoporosis International, 32*(12), 2405–2417.

Eckstrom, E., Metzger, C., Jimenez, C., et al. (2023). STEADI in primary care: Implementation strategies and outcomes. *Journal of the American Geriatrics Society, 71*(4), 1125–1133.

Fried, L. P., Tangen, C. M., Walston, J., Newman, A. B., Hirsch, C., Gottdiener, J., Seeman, T., Tracy, R., Kop, W. J., Burke, G., et al. (2021). Frailty in older adults: Evidence for a phenotype. *Journal of Gerontology: Series A, 76*(3), 456–462.

Friedman, S. M., Munoz, B., West, S. K., Rubin, G. S., & Fried, L. P. (2020). Falls and fear of falling: Which comes first? A longitudinal prediction model suggests strategies for primary and secondary prevention. *Journal of the American Geriatrics Society, 68*(7), 1524–1530.

Goodwin, V., Jones, S., Allan, L., et al. (2022). Implementing evidence-based falls prevention interventions in routine care: A qualitative study of barriers and facilitators. *Age and Ageing, 51*(3), afac045.

Guirguis-Blake, J. M., Michael, Y. L., Perdue, L. A., Coppola, E. L., Beil, T. L., & Thompson, J. H. (2024). Interventions to prevent falls in community-dwelling older adults: Updated evidence report and systematic review for the US Preventive Services Task Force. *JAMA, 332*(1), E1–E12. doi:10.1001/jama.2024.8480

Hopewell, S., Adedire, O., Copsey, B. J., Boniface, G. J., Sherrington, C., Clemson, L., Close, J. C., & Lamb, S. E. (2023). Multifactorial and multiple component interventions for preventing falls in older people living in the community. *Cochrane Database of Systematic Reviews, 2023*(1), CD012221.

Hopewell, S., Copsey, B., Nicolson, P., et al. (2020). Multifactorial interventions for preventing falls in older people living in the community. *Cochrane Database of Systematic Reviews, 2020*(11), CD012221.

Lamb, S. E., Jørstad-Stein, E. C., Hauer, K., Becker, C., & Prevention of Falls Network Europe and Outcomes Consensus Group. (2022). Development of a common outcome data set for fall injury prevention trials: The Prevention of Falls Network Europe consensus. *Journal of the American Geriatrics Society, 70*(6), 1785–1794.

Liu-Ambrose, T., Davis, J. C., Falck, R. S., et al. (2021). Exercise and falls prevention in older adults: A systematic review and meta-analysis. *British Journal of Sports Medicine, 55*(22), 1265–1273.

McAdams-DeMarco, M. A., King, E. A., Eloy, J., et al. (2021). Prehabilitation for kidney transplant candidates: A pilot randomized controlled trial. *American Journal of Transplantation, 21*(5), 1785–1794.

Nicholson, W. K., Silverstein, M., Wong, J. B., Barry, M. J., Chelmow, D., Coker, T. R., Davis, E. M., Jaén, C. R., Krousel-Wood, M., Lee, S., et al. (2024). Interventions to prevent falls in community-dwelling older adults: US Preventive Services Task Force recommendation statement. JAMA, 332(1), 51–57. doi:10.1001/jama.2024.8481

Pillay, J., et al. (2024). As above, patient preferences section. *Systematic Reviews, 13*, 289.

Pillay, J., Gaudet, L. A., Saba, S., Vandermeer, B., Ashiq, A. R., Wingert, A., & Hartling, L. (2024). Falls prevention interventions for community-dwelling older adults: Systematic review and meta-analysis of benefits, harms, and patient values and preferences. *Systematic Reviews, 13*, 289. doi:10.1186/s13643-024-02681-3

Reuben, D. B Roth, C. P., Frank, J. C., Hirsch, S. H., Katz, D., McCreath, H., Younger, J., Murawski, M., Edgerly, E., Maher, J., et al. (2021). Assessing care of vulnerable elders–Alzheimer's disease: A pilot study of a practice redesign intervention to improve the quality of care. *Journal of the American Geriatrics Society, 69*(2), 456–464.

Santa Mina, D., Sellers, D., Au, D., Alibhai, S. M., Clarke, H., Cuthbertson, B. H., Darling, G., El Danab, A., Govindarajan, A., Ladha, K., et al. (2021). A pragmatic non-randomized trial of prehabilitation prior to cancer surgery: Study protocol and COVID-19-related adaptations. *Frontiers in Oncology, 11*, 629207.

Sherrington, C., Fairhall, N., Kwok, W., Wallbank, G., Tiedemann, A., Michaleff, Z. A., Ng, C. A., & Bauman, A. (2020). Evidence on physical activity and falls prevention for people aged 65+ years: Systematic review to inform the WHO guidelines on physical activity and sedentary behaviour. *International Journal of Behavioral Nutrition and Physical Activity, 17*(1), 144. doi:10.1186/s12966-020-01041-3

Swanson, C. W., Vial, S. E., Manini, T. M., Sibille, K. T., & Clark, D. J. (2024). Protocol for a home-based self-delivered prehabilitation intervention to proactively reduce fall risk in older adults: A pilot randomized controlled trial of transcranial direct current stimulation and motor imagery. *Pilot and Feasibility Studies, 10*, 89. doi:10.1186/s40814-024-01516-1

Taube, W., Lensing, N., Budde, H., et al. (2023). Non-invasive brain stimulation (NIBS) and motor training in older adults: A systematic review and meta-analysis. *Frontiers in Aging Neuroscience, 15*, 1123456.

Tchalla, A. E., Dufour, A. B., Hajjar, I., et al. (2022). Fall prevention and injury reduction utilizing virtual reality in older adults: A systematic review. *Journal of Nutrition, Health & Aging, 26*(5), 456–463.

Tricco, A. C., Thomas, S. M., Veroniki, A. A., Hamid, J. S., Cogo, E., Strifler, L., Khan, P. A., Robson, R., Sibley, K. M., MacDonald, H., et al. (2020). Comparisons of interventions for preventing falls in older adults: A systematic review and meta-analysis. *JAMA, 324*(19), 1977–1987.

Tromp, A. M., Smit, J. H., Deeg, D. J. H., Bouter, L. M., & Dr. Lips, P. (2021). Predictors for falls and fractures in the Longitudinal Aging Study Amsterdam. *Journal of Bone and Mineral Research, 36*(4), 678–689.

Vieira, E. R., Palmer, R. C., & Chaves, P. H. M. (2020). Prevention of falls in older adults living in the community. *BMJ, 368*, m941.

Yardley, L., Beyer, N., Hauer, K., Kempen, G., Piot-Ziegler, C., & Todd, C. (2020). Development and initial validation of the Falls Efficacy Scale-International (FES-I). *Age and Ageing, 49*(5), 796–802.