Efficacy of dual-task training in improving balance, mobility, and cognitive-motor function in the geriatric population

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Abstract:

Ageing is accompanied by progressive alterations in neuromuscular, sensory, cognitive, and executive functions that collectively affect postural control, gait, mobility, and the ability to safely perform complex activities of daily living. Older adults frequently encounter situations in which walking or maintaining balance must be performed simultaneously with another cognitive or motor activity, such as talking while walking, carrying an object while navigating obstacles, counting while walking, or responding to environmental stimuli. The ability to successfully manage these simultaneous demands is commonly referred to as dual-task performance. Age-related reductions in attentional capacity, executive functioning, processing speed, sensory integration, muscle strength, and automaticity of gait can increase dual-task interference and consequently contribute to instability, mobility limitation, and falls. Dual-task training (DTT), particularly cognitive-motor dual-task training, has therefore emerged as an important rehabilitation strategy designed to simultaneously challenge motor and cognitive systems under functionally relevant conditions. Evidence accumulated over the last decade suggests that DTT can improve dynamic balance, functional mobility, gait performance, executive functioning, divided attention, and dual-task ability in many older adults. Recent systematic reviews and meta-analyses indicate that DTT produces clinically relevant benefits for balance and mobility, although the magnitude of benefit varies according to intervention design, task complexity, training dose, participant characteristics, adherence, and the type of comparator used. A 2024 systematic review and meta-analysis involving 14 studies and 691 participants reported significant improvements in balance following DTT, while a 2025 systematic review incorporating 44 studies and 2,782 older adults found significant improvements in dynamic balance and functional mobility and reductions in fall frequency. Evidence also indicates that cognitive-motor DTT may improve executive function and working memory, although cognitive outcomes are less consistently reported than physical outcomes. Emerging approaches include variable-priority training, exergaming, virtual reality, rhythm-based interventions, home-based programs, and technology-assisted telerehabilitation. The present article reviews the physiological and cognitive basis of dual-task interference, mechanisms of DTT, intervention modalities, evidence for balance and mobility improvement, effects on cognitive-motor function, clinical assessment, dosage considerations, safety, limitations, and future directions. Overall, DTT represents a promising multidimensional intervention for maintaining independence and reducing functional decline among older adults, although standardized protocols and larger long-term trials are required to establish optimal training parameters and durability of benefits.

Keywords:

Ageing, Older Adults, Geriatric Rehabilitation, Dual-Task Training, Cognitive-Motor Training, Balance, Gait, Mobility, Executive Function, fall, Physiotherapy.

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1. Introduction:

Population ageing has become one of the most important demographic and public-health developments of the twenty-first century. Increasing life expectancy has resulted in a growing proportion of adults living into advanced age, thereby increasing the importance of maintaining physical independence, cognitive capacity, mobility, and participation in daily activities. Ageing, however, is accompanied by gradual changes in multiple physiological systems. Reductions in muscle strength and power, slower reaction time, altered sensory integration, reduced visual and vestibular function, changes in proprioception, and declining executive control can collectively impair the ability to maintain balance and perform complex mobility tasks. These changes become particularly important when an older person must simultaneously manage more than one activity. Everyday mobility rarely occurs in isolation, walking may occur while conversing, carrying groceries, monitoring traffic, remembering instructions, using a mobile telephone, or negotiating environmental obstacles. Consequently, the ability to divide attention between cognitive and motor demands is fundamental to safe community mobility. Dual-tasking describes the performance of two tasks concurrently, generally involving a primary motor task and a secondary cognitive or motor task. MacPherson (2018) described dual-tasking as a situation in which two activities compete for processing resources, whereas contemporary motor-cognitive rehabilitation approaches deliberately use this competition to challenge attentional allocation and improve functional performance. In older adults, simultaneous task performance can expose deficits that remain less obvious during isolated single-task testing. A person may demonstrate adequate walking speed under uncomplicated conditions but slow considerably when required to count backward, converse, carry an object, or respond to visual cues. Such deterioration is commonly referred to as dual-task interference or dual-task cost. The significance of this phenomenon is particularly evident in falls prevention. Falls among older adults are frequently multifactorial, involving combinations of impaired balance, muscle weakness, sensory deficits, environmental hazards, medication effects, reduced reaction time, and cognitive limitations. When an individual allocates excessive attention to a secondary task, fewer cognitive resources may remain available for postural control. The result may be slower gait, shorter steps, increased variability, reduced foot clearance, inappropriate turning strategies, or delayed corrective responses. A systematic review of dual-task paradigms has indicated that dual-task assessments may provide additional information regarding fall-related vulnerability, although their predictive superiority over single-task assessments is not uniform across populations and protocols (Beck Jepsen et al., 2022).

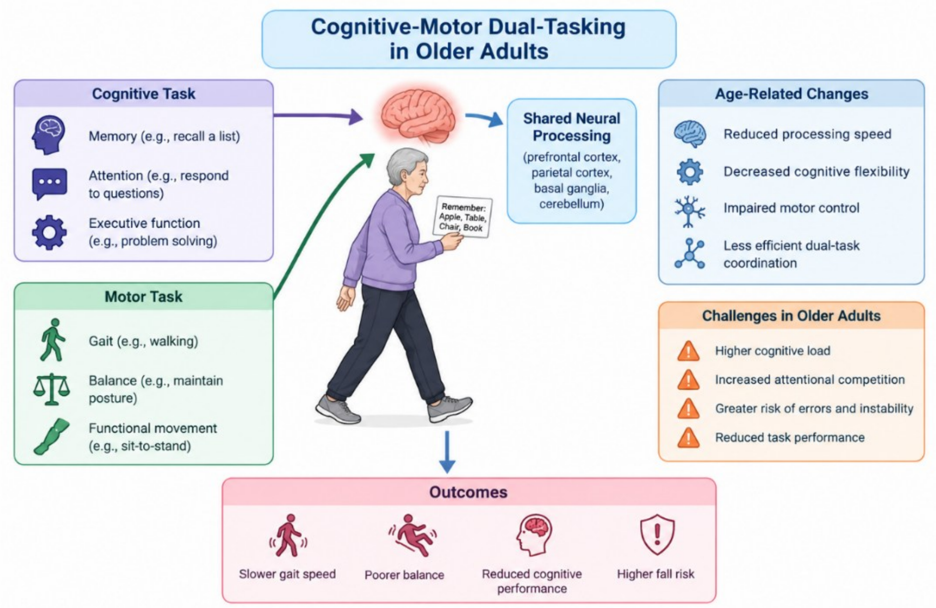

Figure 1. Conceptual representation of cognitive-motor dual-tasking in older adults

The figure 1 illustrates common real-world situations in which a motor task such as walking, standing, turning, or stair negotiation is performed simultaneously with a cognitive task such as counting, conversation, memory recall, decision-making, or visual attention. The interaction between these systems provides the functional rationale for dual-task training. The growing evidence base suggests that dual-task training may be particularly valuable because it resembles the demands of real-world mobility more closely than conventional isolated exercise. A 2022 systematic review and meta-analysis of randomized controlled trials involving 91 studies and

3,745 participants reported that motor-cognitive interventions improved single-task gait speed, Timed Up and Go performance, and Berg Balance Scale performance, although the benefit for dual-task walking speed was less consistent and was influenced by the comparator group (Teraz et al., 2022). More recently, a 2024 systematic review and meta-analysis of 14 studies involving 691 older adults found a significant benefit of DTT on balance compared with non-intervention and a smaller but significant advantage over alternative interventions. The therapeutic importance of DTT extends beyond balance. Cognitive-motor training may influence executive function, working memory, divided attention, processing speed, motor planning, and the ability to allocate attention between competing activities. Norouzi et al. (2019), for example, reported improvements in both balance and working memory following dual-task training combined with resistance training. Similarly, Wang et al. (2021) demonstrated benefits of exergame-based DTT on executive function and dual-task performance in community-dwelling older adults. Figure 2 illustrates Age-related interaction between cognitive and motor systems, Ageing can reduce executive control, processing speed, sensory integration, muscle strength, and gait automaticity. Consequently, walking and balance become increasingly dependent on cognitive resources. Dual-task training aims to improve the ability of the ageing nervous system to coordinate these overlapping demands. The purpose of this article is to provide an integrated review of the efficacy of DTT for improving balance, mobility, gait, and cognitive-motor function in the geriatric population. Particular attention is given to contemporary evidence from randomized controlled trials, systematic reviews, and meta-analyses published during the last decade.

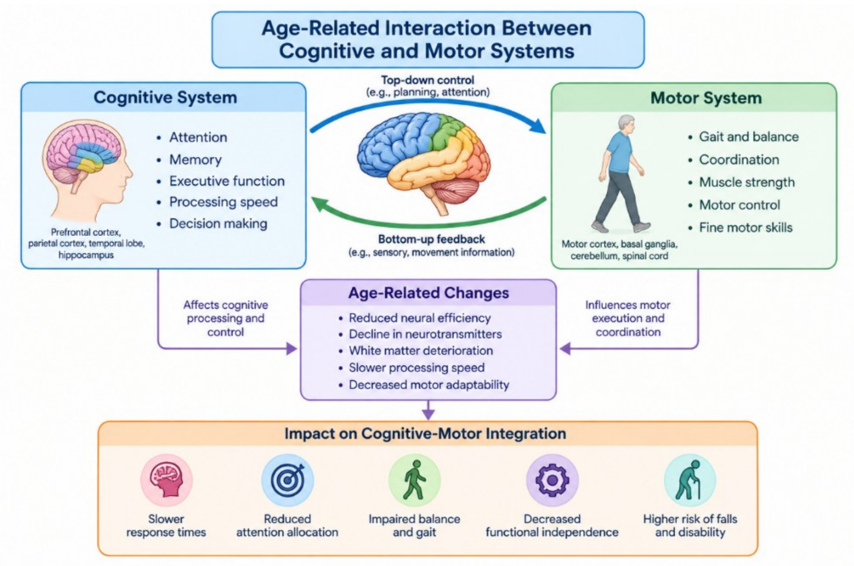

Figure 2. Age-related interaction between cognitive and motor systems

2. Age-Related Changes Relevant to Dual-Task Performance:

Ageing affects mobility through a complex interaction of neurological, musculoskeletal, sensory, and cognitive changes. Muscle mass and strength progressively decline, particularly in the lower limbs, while power and rapid force production may decline even more substantially. These changes reduce the ability to recover from perturbations, negotiate obstacles, initiate gait rapidly, and perform transfers. Physical activity and exercise can attenuate these age-related changes, and systematic reviews have demonstrated that exercise interventions can improve balance and physical function in older adults (Levin et al., 2017, Lee et al., 2018). The nervous system also undergoes substantial changes. Older adults may demonstrate reduced processing speed, impaired divided attention, slower response inhibition, and reduced working memory. Executive functions are particularly important because they enable individuals to select relevant information, suppress distractions, switch between tasks, and adapt behaviour according to environmental demands. When walking is highly automated, relatively few attentional resources are required. However, ageing may reduce gait automaticity, causing walking to depend more heavily on higher-level cognitive processes. This relationship between cognition and movement explains why a secondary cognitive task can disproportionately affect older adults. During dual-task walking, an older individual may slow down or modify gait to preserve postural stability. This strategy may be adaptive in some situations because walking more slowly provides additional time for environmental processing and postural correction. However, excessive slowing or increased gait variability may compromise community mobility. Figure 3 illustrates Age-related progression from single-task to dual-task mobility difficulty. The conceptual sequence illustrates how an older adult may perform adequately during

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isolated standing or walking but demonstrate increased gait variability, reduced speed, impaired turning, and greater postural instability when a concurrent cognitive or motor demand is introduced. A systematic review by Smith et al. (2017) demonstrated that cognitive dual-tasking can modify gait parameters in healthy older adults, highlighting the sensitivity of gait to concurrent cognitive demand. Similarly, a later systematic review demonstrated that dual-task conditions can significantly alter walking speed in healthy older adults (Smith et al., 2017, Bridenbaugh et al., 2023). The clinical implication is that evaluating mobility only under single-task conditions may underestimate functional limitations.

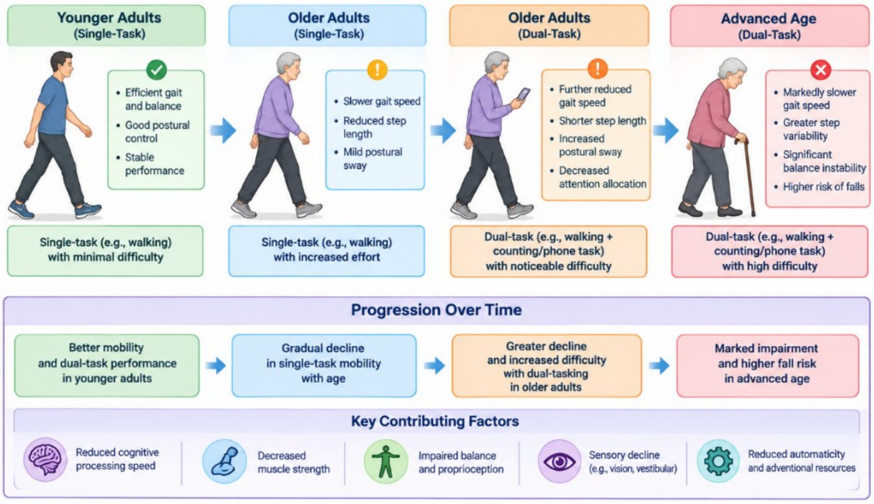

Figure 3. Age-related progression from single-task to dual-task mobility difficulty

3. Concept and Classification of Dual-Task Training:

Dual-task training can be broadly divided into motor-cognitive, motor-motor, and cognitive-cognitive paradigms. Motor-cognitive training is the most commonly investigated approach in geriatric rehabilitation. In this approach, an individual performs a physical activity while simultaneously completing a cognitive task. Examples include walking while counting backward, standing while naming words, stepping while responding to auditory stimuli, walking while remembering sequences, or navigating an obstacle course while solving simple arithmetic problems. Motor-motor DTT involves two physical tasks performed simultaneously. Examples include walking while carrying a tray, walking while manipulating a ball, or stepping while performing upper-limb movements. Brustio et al. (2018) demonstrated that 16 weeks of motor dual-task training involving balance and walking with additional object-manipulation tasks improved functional mobility. Their results support the ecological relevance of motor-motor DTT because carrying and manipulating objects are common daily activities. Cognitive-motor DTT can also be classified according to whether tasks are performed simultaneously or sequentially. Sequential training exposes individuals to motor and cognitive activities separately, whereas simultaneous training requires concurrent performance. Herold et al. (2018) emphasized that the distinction is clinically important because simultaneous motor-cognitive training places greater demands on task integration and attentional allocation. Table 1 summarizes the major DTT modalities and demonstrates that the intervention is not a single standardized exercise but rather a broad therapeutic framework. The secondary task can be manipulated according to cognitive domain, motor complexity, sensory demand, environmental challenge, and individual functional capacity.

Table 1. Major types of dual-task training and representative clinical applications

Dual-task modality	Motor component	Secondary task	Examples	Main therapeutic target
Motor-cognitive	Walking/standing/stepping	Arithmetic	Walking while counting backward	Divided attention, gait stability
Motor-cognitive	Balance	Verbal fluency	Standing while naming animals	Executive function and balance
Motor-cognitive	Walking	Memory	Walking while recalling sequences	Working memory and mobility

Motor-motor	Walking	Object manipulation	Carrying tray or ball	Functional mobility
Motor-motor	Stepping	Upper-limb movement	Step-and-reach tasks	Coordination and balance
Technology-assisted	Interactive movement	Visual/auditory game	Exergames/VR	Balance, reaction and cognition
Rhythm-motor	Walking/tapping	Rhythm production	Walking with rhythmic cues	Gait control and attention

4. Mechanisms Underlying the Efficacy of Dual-Task Training:

The therapeutic effect of DTT is likely mediated by several interacting mechanisms rather than a single physiological pathway. One important mechanism is improved attentional allocation. During dual-task performance, individuals must decide how cognitive resources are distributed between the primary and secondary tasks. Repeated practice may improve the efficiency of this allocation and reduce the amount of attention required for routine motor tasks. A systematic review by Khan et al. (2022) examining theories underlying DTT found that attention theory was the most frequently identified explanation for improvements in balance and fall-related outcomes. The review included 30 studies and found that most used motor-cognitive DTT. Twenty-six studies reported improved balance, while five reported reductions in fall incidence. A second mechanism is improved automaticity of movement. Repeated practice under cognitively demanding conditions may allow walking and postural adjustments to become more efficient. This could free attentional resources for environmental monitoring. DTT therefore does not simply train the ability to perform two tasks simultaneously, it may also improve the neural efficiency of motor control. A third mechanism is enhanced executive function. Executive processes such as inhibition, shifting, working memory, and planning are continuously involved when an individual must adjust walking according to changing environmental circumstances. Wang et al. (2021) found that exergame-based DTT improved executive function and dual-task performance, while Norouzi et al. (2019) reported improvements in working memory and balance. A fourth mechanism involves sensory integration. Maintaining upright posture requires integration of visual, vestibular, and somatosensory information. DTT may increase the capacity to process multiple sensory inputs while simultaneously controlling movement. This is particularly relevant in environments where visual distractions, uneven surfaces, pedestrians, or obstacles are present. A fifth mechanism is increased adaptability. Traditional exercise may improve strength or balance under predictable conditions, whereas DTT introduces variability and uncertainty. Such variability can improve the ability to select appropriate movement strategies under changing circumstances. Recent work on variable-priority cognitive-motor training suggests that shifting attentional priority may enhance functional balance and mobility, although evidence remains insufficient to demonstrate a consistent advantage over fixed-priority training (Yu et al., 2026).

5. Effect of Dual-Task Training on Balance:

Balance is one of the most extensively investigated outcomes of DTT. Balance requires continuous integration of sensory information with anticipatory and reactive motor control. Older adults may have adequate static balance during simple conditions but experience substantial instability when required to perform another task. Evidence accumulated over the last decade generally supports DTT as an effective strategy for improving balance. In a 2024 systematic review and meta-analysis, Yildiz et al. analyzed 14 studies involving 691 participants and found that DTT significantly improved balance compared with non-intervention, with a standardized mean difference of approximately −0.69. DTT also demonstrated a smaller but statistically significant advantage over other interventions. The findings of Teraz et al. (2022) are consistent with this conclusion. Their meta-analysis of 91 randomized controlled trials involving 3,745 participants found a positive effect on Berg Balance Scale performance and Timed Up and Go performance. The authors concluded that motor-cognitive interventions were particularly relevant to multicomponent mobility tasks involving transfers, walking, stopping, turning, and balance. Kao et al. (2018) reported that interactive cognitive-motor training improved gait and balance among older adults, further supporting the use of cognitively enriched movement practice. Similarly, Laatar et al. (2018) found that combined physical-cognitive training enhanced postural performance during daily-life tasks. Figure 4 illustrates the Progression of balance challenge during dual-task training. A graded intervention may progress from stable standing with a simple cognitive task to weight shifting, stepping, turning, obstacle negotiation, and complex community mobility while simultaneously performing cognitive tasks. The challenge should be increased only when safe performance is established. Balance improvements are clinically important because postural instability contributes directly to

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falls. However, it is important to distinguish between laboratory balance measures and real-world balance. Improvements in a Berg Balance Scale score do not automatically guarantee reduced falls in every individual. Training should therefore incorporate functional conditions that resemble the patient's daily environment.

Figure 4. Progression of balance challenge during dual-task training

6. Effect of Dual-Task Training on Gait and Mobility:

Mobility is a multidimensional construct encompassing walking speed, transfers, turning, obstacle negotiation, stair performance, and community ambulation. Among the most commonly used clinical mobility measures are the Timed Up and Go test, 10-Meter Walk Test, Four Square Step Test, and dual-task gait assessments. Brustio et al. (2018) demonstrated that 16 weeks of dual-task training improved mobility performance in older adults. Participants who performed balance and walking exercises with additional motor tasks demonstrated significant improvements in TUG and Four Square Step Test performance compared with control and single-task training groups. Jehu et al. (2017) similarly reported improvements in TUG, TUG-cognitive, and TUG-manual performance following balance and mobility training with or without concurrent cognitive training. These findings suggest that even conventional balance and mobility training can have benefits under multiple-task conditions, but cognitively enriched practice may provide additional functional relevance. Conradsson and Halvarsson (2019) examined dual-task balance training in older women with osteoporosis and reported changes in gait characteristics following training. Their findings illustrate that DTT may be relevant not only to healthy older adults but also to populations with musculoskeletal vulnerability. A 2025 systematic review and meta-regression involving 44 studies and 2,782 older adults provided particularly important evidence. Khan et al. reported significant improvements in dynamic balance and functional mobility and reductions in fall frequency following DTT. The authors also investigated dosage and found that dynamic balance was improved with approximately 30-minute sessions performed three times weekly for four weeks when adherence was high, while functional mobility showed benefit with longer approximately 50-minute sessions over 13 weeks. These findings suggest that training dose matters. A short intervention may be sufficient to produce early improvements in balance, while more prolonged exposure may be necessary to generate meaningful changes in complex functional mobility. Table 2 highlights the importance of multidimensional assessment. Because DTT affects interacting cognitive and motor domains, relying on a single physical test may fail to capture clinically meaningful changes.

Table 2. Common outcome measures for evaluating dual-task training in older adults

Domain	Outcome measure	Primary construct	Typical interpretation
Dynamic balance	Berg Balance Scale	Functional balance	Higher score indicates better balance
Functional mobility	Timed Up and Go	Transfer, walking and turning	Lower time indicates better performance

Gait	10-Meter Walk Test	Walking speed	Higher speed generally indicates better mobility
Complex mobility	Four Square Step Test	Multidirectional stepping	Lower time indicates better performance
Cognitive-motor mobility	TUG-cognitive	Mobility under cognitive load	Lower time indicates better dual-task ability
Executive function	Trail Making Test-B	Set shifting and executive control	Lower completion time indicates better function
Verbal executive function	Verbal Fluency	Retrieval and cognitive flexibility	Greater output generally indicates better performance
Falls	Fall diary/history	Real-world fall incidence	Fewer falls indicate improved safety
Confidence	Falls Efficacy Scale	Fear/confidence related to falling	Lower fear generally indicates better confidence

7. Dual-Task Cost and Its Clinical Importance:

Dual-task cost is an important concept in evaluating DTT. It represents the deterioration in performance that occurs when a second task is introduced compared with performance of the primary task alone. It can be calculated for gait speed, step length, reaction time, cognitive accuracy, or other variables. For example, if an older adult walks at 1.0 m/s during single-task walking but only 0.75 m/s while simultaneously counting backward, the reduction represents a substantial dual-task cost. Successful DTT should ideally reduce this deterioration, although an increase in absolute performance may occur without complete elimination of dual-task interference. A recent systematic review of walking in healthy older adults confirms that dual-task conditions substantially affect gait speed and other walking characteristics. The clinical relevance lies not simply in whether walking becomes slower but in how an individual prioritizes motor safety and cognitive accuracy. Some individuals maintain cognitive performance at the expense of gait speed, while others preserve walking speed but make more cognitive errors. This concept is closely related to the idea of postural prioritization. Older adults at high fall risk may appropriately prioritize gait stability when faced with a secondary task. DTT can gradually teach individuals to manage competing demands without compromising essential postural control.

8. Effects on Cognitive-Motor Function:

The cognitive component of DTT is particularly important because executive dysfunction may compromise mobility even when muscle strength is relatively preserved. Executive functions include inhibitory control, cognitive flexibility, working memory, planning, monitoring, and attentional switching. These functions are required for navigating crowded environments, responding to unexpected obstacles, remembering instructions while moving, and adapting movement strategies. A systematic review by Ye et al. (2024) involving 20 randomized controlled trials and 1,477 older adults with cognitive impairment found that DTT improved global cognition, executive function, working memory, gait, physical activity, and depressive symptoms, although the strength of evidence varied by outcome. Earlier evidence also supports cognitive benefits. Norouzi et al. (2019) found improvements in working memory following motor-cognitive dual-task training, while Wang et al. (2021) demonstrated improvements in executive function following exergame-based DTT. Jardim et al. (2021) also investigated dual-task exercise for cognition and functional capacity in healthy older adults. Rhythm-based interventions represent another interesting approach. Kim and Yoo (2020) examined a rhythm-motor dual-task program involving walking or bimanual tapping combined with rhythmic activities. After eight weeks, improvements were observed in executive control measured by Trail Making Test-B and in gait control under dual-task conditions. Exergames, interactive visual environments, virtual reality, wearable sensors, and computer-assisted tasks can simultaneously stimulate movement and cognitive processing. Such technologies may increase motivation and provide objective feedback regarding speed, accuracy, reaction time, and task completion. The cognitive effects of DTT should nevertheless be interpreted carefully. Not every study reports cognitive outcomes, and cognitive measures differ substantially between studies. Recent systematic reviews emphasize that physical outcomes are generally more consistently demonstrated than cognitive outcomes. A 2026 review of variable-priority DTT found potential improvements in balance and mobility but concluded that evidence for cognitive benefits remained limited because cognitive outcomes were reported in relatively few trials.

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9. Dual-Task Training and Fall Prevention:

Falls represent one of the most important clinical outcomes associated with geriatric mobility impairment. A fall can result in fracture, hospitalization, fear of falling, reduced physical activity, social withdrawal, and loss of independence. Fear of falling may itself initiate a cycle of reduced activity, muscle deconditioning, further balance deterioration, and increased fall risk. DTT may reduce falls by improving both physical and cognitive components of mobility. Unlike isolated strengthening, DTT exposes individuals to the cognitive distractions that often occur immediately before real-world falls. For example, an older adult may fall not while walking carefully through a physiotherapy clinic but while turning to speak to someone, carrying an object, looking at traffic, or responding to an unexpected stimulus. Khan et al. (2022) identified balance improvement as the dominant outcome in the DTT literature and reported fall reductions in a subset of studies. The 2025 meta-analysis by Khan et al. strengthened the evidence by incorporating 44 studies and finding that DTT improved dynamic balance and functional mobility while reducing fall frequency. Gao and Liu (2025) specifically examined cognitive-motor DTT for fall prevention in community-dwelling older adults. Their systematic review concluded that cognitive-motor DTT could improve gait, static and dynamic balance, and executive function and could reduce fall risk, although effects on lower-limb strength and fear of falling remained less consistent. The clinical implication is that DTT should not replace conventional fall-prevention strategies but should complement strength, balance, gait, environmental modification, medication review, vision assessment, and education.

10. Training Dosage and Progression:

There is no universally accepted DTT protocol. Interventions vary from approximately four to 24 weeks, with sessions ranging from 20 to 60 minutes and frequencies of one to five sessions per week. The 2025 meta-regression provides useful preliminary information regarding dose, suggesting that high adherence and moderate training intensity may be particularly important for balance and mobility outcomes. A clinically appropriate progression should begin with tasks that the individual can perform safely. The motor task may initially involve seated or supported activities, progressing to standing, weight shifting, stepping, walking, turning, obstacle negotiation, and community mobility. The cognitive task can similarly progress from simple counting to memory, verbal fluency, response inhibition, decision-making, and more complex problem-solving. Task difficulty should be modified using several dimensions. These include motor complexity, cognitive complexity, environmental complexity, speed requirements, sensory conditions, and attentional priority. The therapist may increase only one variable at a time to avoid excessive challenge. Figure 5 illustrates proposed progression model for dual-task training. The intervention can progress from simple supported cognitive-motor activities to standing tasks, multidirectional stepping, walking with cognitive interference, obstacle negotiation, and object carrying, turning, and community-based mobility. Progression should be individualized according to safety and performance. A practical program may involve three sessions per week, with approximately 30–50 minutes of active training per session. However, the exact prescription should be individualized according to age, frailty, baseline balance, cognitive status, musculoskeletal limitations, cardiovascular tolerance, and fall history.

Figure 5. Proposed progression model for dual-task training

11. Variable-Priority Dual-Task Training:

Variable-priority training is a more advanced DTT strategy in which participants are deliberately instructed to alternate attention between the motor and cognitive tasks. For example, during one trial the participant may prioritize walking stability, while during another trial cognitive accuracy may receive greater emphasis. The theoretical advantage is that individuals learn flexible attentional allocation rather than simply learning one fixed strategy. Varela-Vásquez et al. (2020) identified variability in DTT designs and suggested that variable-priority approaches may have particular value for improving balance and walking speed. More recent evidence, however, remains cautious. The 2026 systematic review by Yu et al. found that variable-priority DTT was generally associated with improvements in balance and mobility, but it did not consistently outperform fixed-priority DTT. This indicates that variable-priority training may be useful as an advanced component rather than being considered inherently superior. The priority instruction should also reflect clinical safety. When a patient has significant instability, motor safety should generally take precedence over cognitive accuracy.

12. Technology-Assisted Dual-Task Training:

Technology has expanded the possibilities for DTT. Exergames and virtual reality systems allow older adults to interact with visual and auditory environments while performing physical movements. These systems may provide immediate feedback and automatically adjust difficulty. Howes et al. (2017) reviewed active computer gaming in older adults and reported potential benefits for physical and cognitive outcomes. Pacheco et al. (2020) also found that exergames can improve mobility and balance. Chen et al. (2021) compared exergame interventions with traditional physical training and found evidence supporting exergames for balance and fall prevention. The advantages of technology-assisted DTT include increased motivation, task variability, objective performance monitoring, and the ability to simulate complex environments. However, technological complexity may create barriers for individuals unfamiliar with digital devices. Equipment cost, cybersickness, visual impairment, cognitive impairment, and fear of technology must also be considered. The recent expansion of home-based and telerehabilitation DTT is particularly relevant. A 2026 systematic review of nonclinic-based DTT involving 23 randomized controlled trials and 1,674 participants with cognitive decline reported significant improvements in functional mobility and global cognition compared with active controls, as well as improvements in gait speed and cognition compared with passive controls. Mean adherence was approximately 80.8%, suggesting that appropriately designed home-based approaches may be feasible.

13. Role of Exergaming and Virtual Reality:

Exergaming integrates movement with interactive game-based cognitive challenges. During an exergame, participants may have to step toward a target, avoid virtual obstacles, remember sequences, respond to visual stimuli, or shift weight according to changing instructions. Such activities create simultaneous demands on attention, balance, reaction time, and executive control. Wang et al. (2021) demonstrated that exergame-based DTT could improve executive function and dual-task performance. Phirom et al. (2020) similarly reported beneficial effects of interactive physical-cognitive game-based training on fall risk and cognitive performance in older adults. Virtual reality may provide an additional advantage because it can recreate community environments. For example, a virtual supermarket can require an older person to walk, turn, identify objects, remember shopping instructions, and avoid virtual obstacles. Such environments may offer a bridge between clinic-based exercise and real-world mobility. Nevertheless, virtual environments should be used carefully in frail or high-risk patients. Initial sessions should be supervised, and the therapist should ensure adequate physical support and environmental safety.

14. Cognitive-Motor Training in Older Adults with Cognitive Impairment:

The benefits of DTT may be particularly important in individuals with mild cognitive impairment or dementia because cognitive and mobility deficits frequently coexist. Older adults with cognitive impairment may demonstrate slower gait, increased gait variability, impaired attention, and reduced ability to respond to environmental challenges. A systematic review and meta-analysis by Ye et al. (2024) involving 20 studies and 1,477 participants found that DTT improved global cognition, executive function, working memory, gait, and physical activity. A separate 2022 systematic review involving 21 studies and 2,221 participants with cognitive impairment reported positive effects on global cognition, memory, executive function, gait speed, dual-task cost, and balance. The 2026 evidence is particularly relevant to contemporary geriatric practice. Rattanatreyanupab et al. evaluated nonclinic-based DTT in older adults with cognitive decline and found improvements in functional mobility and global cognition compared with active controls. However, DTT in cognitively impaired patients requires additional precautions. Instructions must be simple and repetitive, the environment must be uncluttered, and the cognitive task should be adjusted to avoid frustration. Caregiver involvement can improve adherence, especially for home-based programs.

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15. Safety Considerations:

Safety is central to DTT because the intervention intentionally introduces competing demands. The therapist should first determine whether the individual can perform the primary motor task independently. Cognitive distraction should not be introduced at a level that produces unsafe instability. A graded safety approach is recommended. Early training may involve seated or supported tasks. Standing exercises should be performed near stable support, and walking tasks should initially be conducted in a controlled environment. Harness systems, parallel bars, gait belts, or close therapist supervision may be appropriate for high-risk individuals. The cognitive task should also be adjusted according to fatigue. Excessive cognitive demand can result in compensatory slowing, loss of balance, frustration, or reduced adherence. DTT should therefore be challenging but achievable. Table 3 provides a clinically oriented framework for progressive DTT. Progression should depend on safety and quality rather than simply completion of a predetermined number of sessions.

Table 3. Suggested clinical framework for prescribing dual-task training

Stage	Motor task	Cognitive task	Environment	Progression criterion
1	Seated/standing	Simple counting	Stable	Safe task completion
2	Weight shifting	Word generation	Supported standing	Minimal instability
3	Stepping	Simple arithmetic	Open clinic area	Accurate movement
4	Walking	Counting backward	Supervised corridor	Stable gait
5	Walking/turning	Memory/fluency	Obstacles	Controlled turning
6	Carrying objects	Cognitive decision-making	Functional circuit	Safe multitasking
7	Community mobility	Complex attention	Simulated community	Independent strategy
8	Real-world task	Self-selected cognitive load	Home/community	Transfer to daily life

16. Clinical Assessment Before and After Training:

A comprehensive baseline assessment should include physical, cognitive, functional, and environmental components. The Berg Balance Scale can provide information regarding functional balance, while the Timed Up and Go provides a practical measure of transfers, walking, and turning. The 10-Meter Walk Test assesses gait speed, while the Four Square Step Test evaluates multidirectional stepping. Dual-task versions of conventional tests may provide additional information. The TUG can be performed while counting backward, naming words, carrying an object, or responding to auditory stimuli. Similarly, gait speed can be assessed under single- and dual-task conditions. Cognitive assessment may include Trail Making Test-B, verbal fluency, digit span, reaction-time tasks, or standardized cognitive screening instruments when appropriate. The purpose is not to diagnose cognitive disease within physiotherapy but to characterize the cognitive demands influencing mobility. Fall history and fear of falling should also be documented. Beck Jepsen et al. (2022) emphasized that no single gait or balance test can predict falls with high certainty. Therefore, DTT assessment should form part of a broader multidimensional clinical evaluation.

17. Proposed Clinical Model of Dual-Task Training:

The available evidence supports a multidimensional model in which DTT simultaneously targets physical capacity, cognitive control, attentional allocation, and environmental adaptability. DTT simultaneously challenges balance, gait, strength, executive function, attention, reaction time, and task adaptability. Improvements in these domains may reduce dual-task interference and support safer community mobility and greater independence. The model begins with assessment of baseline motor and cognitive capacity. Intervention is then individualized according to the person's main limitations. Motor difficulty and cognitive difficulty are gradually increased. Feedback is provided during training, and outcomes are reassessed using both single-task and dual-task measures. The final goal is not merely improvement in a laboratory score but transfer of training benefits to activities of daily living.

18. Evidence From Recent Systematic Reviews and Meta-Analyses:

The evidence base has expanded substantially. Yildiz et al. (2024) demonstrated a significant balance benefit from DTT, while Teraz et al. (2022) showed positive effects on TUG and BBS outcomes across a large number of randomized controlled trials. The 2025 meta-analysis by Khan et al. provides particularly strong contemporary evidence because it included 44 studies and 2,782 participants and incorporated meta-regression to explore dose. It found significant improvements in dynamic balance and functional mobility and reductions in falls. The 2025 systematic review by Gao and Liu also supports cognitive-motor DTT for improving gait, balance, executive function, and fall-related outcomes in community-dwelling older adults. Evidence from 2026 further expands the field toward home-based and variable-priority interventions. Rattanatreyanupab et al. reported significant gains in functional mobility and global cognition in older adults with cognitive decline, whereas Yu et al. reported generally favorable effects of variable-priority DTT on physical function but highlighted the need for stronger evidence regarding cognitive and psychosocial outcomes. These findings collectively indicate that DTT is not simply a balance intervention. Rather, it is a multidomain rehabilitation strategy that may improve the interaction between cognition and movement.

19. Potential Neurophysiological Basis:

The neurophysiological basis of DTT involves interaction among cortical, subcortical, cerebellar, and sensory-motor networks. Walking requires coordination between spinal locomotor circuits and higher-level motor planning. When cognitive demands increase, frontal and parietal networks contribute more strongly to movement regulation. Ageing may result in compensatory recruitment of prefrontal regions during walking. Exergame and balance training have been associated with changes in prefrontal activity and executive performance, suggesting that training may alter the neural efficiency required for complex mobility. Cognitive-motor DTT may also strengthen communication between executive and motor networks. Repeatedly switching attention between movement and cognition could improve the ability to allocate resources efficiently. This may partly explain why DTT can influence both cognitive and physical outcomes. The principle of neuroplasticity is relevant. Repeated, challenging, task-specific practice can facilitate adaptation. Because DTT provides simultaneous cognitive and motor stimulation, it may promote broader neural adaptation than repetitive single-task exercise. However, direct evidence of specific neural mechanisms remains less developed than behavioural evidence.

20. Transfer to Activities of Daily Living:

One of the strongest theoretical advantages of DTT is ecological validity. Real-world mobility requires simultaneous management of multiple demands. An older person may walk while talking to a family member, remember a shopping list, carry groceries, watch traffic, avoid pedestrians, or respond to a telephone. Conventional exercises such as isolated knee extension or simple standing balance may improve specific physical capacities but do not necessarily reproduce these combined demands. DTT intentionally bridges the gap between impairment-level training and functional activity. The 2022 meta-analysis by Teraz et al. emphasized that motor-cognitive interventions may be particularly useful for multicomponent tasks resembling the TUG, including sit-to-stand transfers, walking, stopping, and turning. However, transfer should be explicitly trained rather than assumed. Wongcharoen et al. (2017) found that home-based intervention improved trained dual-task balance performance but did not necessarily generalize equally to novel dual-task conditions. This finding emphasizes the importance of variability and task generalization. Figure 6 illustrates Transfer of dual-task training from clinic to community mobility. Effective rehabilitation should progress from controlled clinic-based tasks toward simulated and real-world activities such as walking while conversing, carrying objects, and navigating obstacles, turning, responding to environmental cues, and negotiating community environments.

Figure 6. Transfer of dual-task training from clinic to community mobility

21. Limitations of Current Evidence:

Despite promising findings, several limitations should be considered. First, DTT protocols vary substantially in duration, frequency, task selection, cognitive difficulty, motor difficulty, and progression. This heterogeneity makes direct comparison between studies difficult. Second, control conditions differ considerably. A DTT intervention may appear highly effective when compared with no intervention but demonstrate a smaller advantage when compared with high-quality balance or strength training. Teraz et al. (2022) observed that the effect of motor-cognitive interventions was moderated by the type of comparator. Third, cognitive outcomes are inconsistently measured. Some studies use executive-function tests, others use global cognition, and others focus only on dual-task gait performance. Standardization would improve interpretation. Fourth, long-term retention is insufficiently investigated. Many studies measure outcomes immediately after intervention, while fewer assess whether improvements persist for six months or longer. Fifth, fall outcomes require large sample sizes because falls are relatively infrequent events. Short interventions with small sample sizes may detect changes in balance but lack statistical power to demonstrate reductions in actual fall incidence. Finally, technology-based interventions may not be equally accessible to all older adults. Digital literacy, socioeconomic status, sensory impairment, and caregiver support can influence feasibility.

22. Future Directions:

Future research should focus on establishing standardized DTT prescriptions. Studies should clearly report frequency, duration, intensity, cognitive task complexity, motor task complexity, progression criteria, adherence, and adverse events. Dose-response studies are particularly important. Current evidence suggests that moderate-intensity training performed approximately three times weekly may improve balance and mobility, but the optimal duration and intensity for different geriatric subgroups remain unclear. Future trials should also distinguish between healthy older adults, frail individuals, individuals with a history of falls, and those with mild cognitive impairment or dementia. These populations may respond differently to the same intervention. Technology offers significant potential. Wearable sensors can quantify gait variability and dual-task cost in real time. Artificial intelligence may eventually personalize cognitive task difficulty according to performance. Virtual reality can simulate increasingly complex community environments while maintaining clinical safety. Home-based DTT and telerehabilitation may also increase access, particularly for individuals who have difficulty attending frequent outpatient appointments. The encouraging findings of recent nonclinic-based DTT research suggest that this approach deserves further investigation. Future studies should also evaluate cost-effectiveness, adherence, caregiver burden, quality of life, activities of daily living, and participation. These outcomes may be more meaningful to patients than improvements in isolated laboratory measures.

23. Discussion:

The evidence reviewed in this article supports the view that DTT is an effective and clinically relevant intervention for improving several dimensions of geriatric function. Its strongest evidence appears to involve dynamic balance and functional mobility. The effect on cognitive outcomes is also promising, particularly for executive function and working memory, but requires further standardization. The central advantage of DTT is ecological validity. Older adults do not normally walk in environments where only one task is performed at a time. Instead, mobility occurs within cognitively and environmentally complex situations. Therefore, rehabilitation that reproduces these challenges may provide greater functional relevance than isolated exercises. The evidence also indicates that DTT should not be regarded as a replacement for conventional exercise. Strength, endurance, balance, flexibility, and gait training remain important. Instead, DTT should be considered a higher-level intervention that integrates physical and cognitive components. An appropriate clinical sequence may therefore begin with conventional strengthening and balance training, followed by progressive cognitive-motor challenges. Once basic mobility is safe, the therapist can introduce dual-task conditions. As performance improves, task complexity, environmental variability, and cognitive load can be increased. The concept of progressive overload applies to DTT, but overload is multidimensional. The therapist can increase the physical challenge, cognitive challenge, speed, environmental complexity, or attentional competition. This flexibility allows DTT to be individualized. Importantly, the goal should not be to eliminate all dual-task interference. Some degree of interference is normal, especially in older adults. The therapeutic objective is to reduce excessive interference and improve the ability to maintain safe motor performance while managing cognitive demands. The 2025 evidence suggesting that high adherence and moderate training intensity are associated with better dynamic balance and mobility outcomes provides useful practical guidance. Nevertheless, the optimal dose likely differs according to frailty, cognitive status, baseline fitness, and fall risk. The recent expansion of home-based DTT is also encouraging. The finding that nonclinic-based interventions can improve functional mobility and cognition suggests that DTT may eventually become a scalable component of community geriatric rehabilitation.

24. Conclusion:

Dual-task training represents a promising and increasingly evidence-based approach for addressing the interconnected physical and cognitive challenges associated with ageing. The available literature demonstrates that cognitive-motor and motor-motor DTT can improve balance, functional mobility, gait-related performance, executive function, working memory, and dual-task ability in many older adults. Recent systematic reviews and meta-analyses provide particularly strong evidence for improvements in dynamic balance and functional mobility and suggest a potential reduction in falls. The effectiveness of DTT is likely related to its ability to challenge attentional allocation, executive control, sensory integration, motor automaticity, and adaptability under functionally meaningful conditions. Unlike conventional single-task exercise, DTT closely reproduces the complex situations encountered during everyday mobility. Nevertheless, important uncertainties remain regarding optimal dosage, long-term retention, cognitive outcomes, fall reduction, task specificity, and transfer to novel real-world situations. Future research should use larger randomized controlled trials, standardized outcome measures, clearly defined training protocols, longer follow-up periods, and subgroup-specific interventions. From a clinical perspective, DTT should be progressively incorporated into geriatric physiotherapy once basic movement safety has been established. Beginning with simple cognitive-motor activities and progressing toward complex walking, turning, obstacle negotiation, object carrying, and community-based tasks may help older adults develop greater confidence and functional independence.

25. References:

(1) Akin, H., Senel, A., Taskiran, H., & Kaya Mutlu, E. (2021). Do motor-cognitive and motor-motor dual task training effect differently balance performance in older adults? *European Geriatric Medicine, 12*, 371–378.

(2) Beck Jepsen, D., Robinson, K., Ogliari, G., Montero-Odasso, M., Kamkar, N., Ryg, J., & Freiberger, E. (2022). Predicting falls in older adults: An umbrella review of instruments assessing gait, balance, and functional mobility. *BMC Geriatrics, 22*, 780.

(3) Bischoff, L. L., Cordes, T., Meixner, C., Schoene, D., Voelcker-Rehage, C., & Wollesen, B. (2021). Can cognitive-motor training improve physical functioning and psychosocial wellbeing in nursing home residents? A randomized controlled feasibility study as part of the PROCARE project. *Aging Clinical and Experimental Research, 33*, 943–956.

(4) Brustio, P. R., Rabaglietti, E., Formica, S., & Liubicich, M. E. (2018). Dual-task training in older adults: The effect of additional motor tasks on mobility performance. *Archives of Gerontology and Geriatrics, 75*, 119–124.

(5) Chen, Y., Zhang, Y., Guo, Z., Bao, D., & Zhou, J. (2021). Comparison between the effects of exergame intervention and traditional physical training on improving balance and fall prevention in healthy older

adults: A systematic review and meta-analysis. *Journal of NeuroEngineering and Rehabilitation, 18*, 164.

(6) Conradsson, D., & Halvarsson, A. (2019). The effects of dual-task balance training on gait in older women with osteoporosis: A randomized controlled trial. *Gait & Posture, 68*, 562–568.

(7) Desjardins-Crépeau, L., Berryman, N., Fraser, S., Vu, T. T. M., Kergoat, M. J., Li, K. Z. H., & Bherer, L. (2016). Effects of combined physical and cognitive training on fitness and neuropsychological outcomes in healthy older adults. *Clinical Interventions in Aging, 11*, 1287–1299.

(8) Eggenberger, P., Wolf, M., Schumann, M., & de Bruin, E. D. (2016). Exergame and balance training modulate prefrontal brain activity during walking and enhance executive function in older adults. *Frontiers in Aging Neuroscience, 8*, 66.

(9) Falbo, S., Condello, G., Capranica, L., Forte, R., & Pesce, C. (2016). Effects of physical-cognitive dual task training on executive function and gait performance in older adults: A randomized controlled trial. *BioMed Research International, 2016*, 5812092.

(10) Fraser, S. A., Li, K. Z. H., Berryman, N., Desjardins-Crépeau, L., Lussier, M., Vadaga, K., & Bherer, L. (2017). Does combined physical and cognitive training improve dual-task balance and gait outcomes in sedentary older adults? *Frontiers in Human Neuroscience, 10*, 688.

(11) Gallardo-Meza, C., Simon, K., Bustamante-Ara, N., Ramirez-Campillo, R., García-Pinillos, F., & Keogh, J. W. L. (2022). Effects of 4 weeks of active exergames training on muscular fitness in elderly women. *Journal of Strength and Conditioning Research, 36*, 427–432.

(12) Gallou-Guyot, M., Mandigout, S., Bherer, L., & Perrochon, A. (2020). Effects of exergames and cognitive-motor dual-task training on cognitive, physical and dual-task functions in cognitively healthy older adults: An overview. *Ageing Research Reviews, 63*, 101135.

(13) Gao, Y., & Liu, N. (2025). Effectiveness of cognitive-motor dual task training in preventing falls in community older adults: A meta-analysis and systematic review. *Geriatric Nursing, 64*, 103366.

(14) Gavelin, H. M., Dong, C., Minkov, R., Bahar-Fuchs, A., Ellis, K. A., Lautenschlager, N. T., & others. (2021). Combined physical and cognitive training for older adults with and without cognitive impairment: A systematic review and network meta-analysis of randomized controlled trials. *Ageing Research Reviews, 66*, 101232.

(15) Gregory, M. A., Gill, D. P., Zou, G., Liu-Ambrose, T., Shigematsu, R., Fitzgerald, C., & others. (2016). Group-based exercise combined with dual-task training improves gait but not vascular health in active older adults without dementia. *Archives of Gerontology and Geriatrics, 63*, 18–27.

(16) Herold, F., Hamacher, D., Schega, L., & Müller, N. G. (2018). Thinking while moving or moving while thinking—Concepts of motor-cognitive training for cognitive performance enhancement. *Frontiers in Aging Neuroscience, 10*, 228.

(17) Howes, S. C., Charles, D. K., Marley, J., Pedlow, K., & McDonough, S. M. (2017). Gaming for health: Systematic review and meta-analysis of the physical and cognitive effects of active computer gaming in older adults. *Physical Therapy, 97*, 1122–1137.

(18) Jardim, N. Y. V., Bento-Torres, N. V. O., Costa, V. O., Carvalho, J. P. R., Pontes, H. T. S., Tomás, A. M., & others. (2021). Dual-task exercise to improve cognition and functional capacity of healthy older adults. *Frontiers in Aging Neuroscience, 13*, 589299.

(19) Jehu, D. A., Paquet, N., & Lajoie, Y. (2017). Balance and mobility training with or without concurrent cognitive training improves the Timed Up and Go, TUG cognitive, and TUG manual in healthy older adults: An exploratory study. *Aging Clinical and Experimental Research, 29*, 711–720.

(20) Kahya, M., Moon, S., & Ranchet, M. (2019). Brain activity during dual task gait and balance in aging and age-related neurodegenerative conditions: A systematic review. *Experimental Gerontology, 128*, 110756.

(21) Kao, C. C., Chiu, H. L., Liu, D., Chan, P. T., Tseng, I. J., Chen, R., & others. (2018). Effect of interactive cognitive motor training on gait and balance among older adults: A randomized controlled trial. *International Journal of Nursing Studies, 82*, 121–128.

(22) Khan, M. J., Fong, K. N. K., Wong, T. W. L., Tsang, W. W. N., Chen, C., Chan, W. C., & others. (2025). Effectiveness of dual-task exercise in improving balance and preventing falls among older adults: Systematic review with meta-analysis and meta-regression. *European Geriatric Medicine, 16*, 2047–2083.

(23) Khan, M. J., Kannan, P., Wong, T. W. L., Fong, K. N. K., & Winser, S. J. (2022). A systematic review exploring the theories underlying the improvement of balance and reduction in falls following dual-task training among older adults. *International Journal of Environmental Research and Public Health, 19*, 16890.

(24) Kim, S. J., & Yoo, G. E. (2020). Rhythm-motor dual task intervention for fall prevention in healthy older adults. *Frontiers in Psychology, 10*, 3027.

(25) Laatar, R., Kachouri, H., Borji, R., Rebai, H., & Sahli, S. (2018). Combined physical-cognitive training enhances postural performances during daily life tasks in older adults. *Experimental Gerontology, 107*, 91–97.

(26) Lee, S. Y., Tung, H. H., Liu, C. Y., & Chen, L. K. (2018). Physical activity and sarcopenia in the geriatric population: A systematic review. *Journal of the American Medical Directors Association, 19*, 378–383.

(27) Levin, O., Netz, Y., & Ziv, G. (2017). The beneficial effects of different types of exercise interventions on motor and cognitive functions in older age: A systematic review. *European Review of Aging and Physical Activity, 14*, 20.

(28) MacPherson, S. E. (2018). Definition: Dual-tasking and multitasking. *Cortex, 106*, 313–314.

(29) Marusic, U., & Grosprêtre, S. (2018). Non-physical approaches to counteract age-related functional deterioration: Applications for rehabilitation and neural mechanisms. *European Journal of Sport Science, 18*, 639–649.

(30) Marusic, U., Verghese, J., & Mahoney, J. R. (2018). Cognitive-based interventions to improve mobility: A systematic review and meta-analysis. *Journal of the American Medical Directors Association, 19*, 484–491.e3.

(31) Medeiros, L. B., Ansai, J. H., Buto, M. S., Barroso, V. D. V., Farche, A. C. S., & others. (2018). Impact of a dual task intervention on physical performance of older adults who practice physical exercise. *Brazilian Journal of Kinanthropometry and Human Performance, 20*, 10–19.

(32) Morat, M., Bakker, J., Hammes, V., Morat, T., Giannouli, E., Zijlstra, W., & others. (2019). Effects of stepping exergames under stable versus unstable conditions on balance and strength in healthy community-dwelling older adults: A three-armed randomized controlled trial. *Experimental Gerontology, 127*, 110719.

(33) Norouzi, E., Vaezmosavi, M., Gerber, M., Pühse, U., & Brand, S. (2019). Dual-task training on cognition and resistance training improved both balance and working memory in older people. *The Physician and Sportsmedicine, 47*, 471–478.

(34) Pacheco, T. B. F., de Medeiros, C. S. P., de Oliveira, V. H. B., Vieira, E. R., & de Cavalcanti, F. A. C. (2020). Effectiveness of exergames for improving mobility and balance in older adults: A systematic review and meta-analysis. *Systematic Reviews, 9*, 163.

(35) Park, J. H. (2022). Is dual-task training clinically beneficial to improve balance and executive function in community-dwelling older adults with a history of falls? *International Journal of Environmental Research and Public Health, 19*, 10198.

(36) Phirom, K., Kamnardsiri, T., & Sungkarat, S. (2020). Beneficial effects of interactive physical-cognitive game-based training on fall risk and cognitive performance of older adults. *International Journal of Environmental Research and Public Health, 17*, 6079.

(37) Pothier, K., Gagnon, C., Fraser, S. A., Lussier, M., Desjardins-Crépeau, L., Berryman, N., & others. (2018). A comparison of the impact of physical exercise, cognitive training and combined intervention on spontaneous walking speed in older adults. *Aging Clinical and Experimental Research, 30*, 921–925.

(38) Raichlen, D. A., Bharadwaj, P. K., Nguyen, L. A., Franchetti, M. K., & others. (2020). Effects of simultaneous cognitive and aerobic exercise training on dual-task walking performance in healthy older adults: Results from a pilot randomized controlled trial. *BMC Geriatrics, 20*, 83.

(39) Rattanatreyanupab, J., Hnin, H. H., Witthiwej, T., Hiengkaew, V., Piriyaprasarth, P., Nikaido, Y., Thakkinstian, A., Thadanipon, K., Liampeng, S., & Bovonsunthonchai, S. (2026). Effectiveness of nonclinic-based dual-task training on physical and cognitive functions and activities of daily living in older adults with cognitive decline: A systematic review and meta-analysis. *PLOS Digital Health, 5*, e0001571.

(40) Rezola-Pardo, C., Arrieta, H., Gil, S. M., Zarrazquin, I., Yanguas, J. J., López, M. A., & others. (2019). Comparison between multicomponent and simultaneous dual-task exercise interventions in long-term nursing home residents: The Ageing-ONDUAL-TASK randomized controlled study. *Age and Ageing, 48*, 817–823.

(41) Sadeghi, H., Jehu, D. A., Daneshjoo, A., Shakoor, E., Razeghi, M., Amani, A., & others. (2021). Effects of 8 weeks of balance training, virtual reality training, and combined exercise on lower limb muscle strength, balance, and functional mobility among older men: A randomized controlled trial. *Sports Health, 13*, 606–612.

(42) Sápi, M., Domjan, A., Kiss, A. F., & Pinter, S. (2019). Is Kinect training superior to conventional balance training for healthy older adults to improve postural control? *Games for Health Journal, 8*, 41–48.

(43) Schättin, A., Arner, R., Gennro, F., & de Bruin, E. D. (2016). Adaptations of prefrontal brain activity, executive functions, and gait in healthy elderly following exergame and balance training: A randomized-controlled study. *Frontiers in Aging Neuroscience, 8*, 278.

(44) Sipilä, S., Tirkkonen, A., Savikangas, T., Hänninen, T., Laukkanen, P., Alén, M., & others. (2021). Effects of physical and cognitive training on gait speed and cognition in older adults: A randomized controlled trial. *Scandinavian Journal of Medicine & Science in Sports, 31*, 1518–1533.

(45) Smith, E., Cusack, T., Cunningham, C., & Blake, C. (2017). The influence of a cognitive dual task on the gait parameters of healthy older adults: A systematic review and meta-analysis. *Journal of Aging and Physical Activity, 25*, 671–686.

(46) Teraz, K., Šlosar, L., Paravlić, A. H., de Bruin, E. D., & Marusic, U. (2022). Impact of motor-cognitive interventions on selected gait and balance outcomes in older adults: A systematic review and meta-analysis of randomized controlled trials. *Frontiers in Psychology, 13*, 837710.

(47) Varela-Vásquez, L. A., Minobes-Molina, E., & Jerez-Roig, J. (2020). Dual-task exercises in older adults: A structured review of current literature. *Journal of Frailty, Sarcopenia and Falls, 5*, 31–37.

(48) Wang, R. Y., Huang, Y. C., Zhou, J. H., Cheng, S. J., & Yang, Y. R. (2021). Effects of exergame-based dual-task training on executive function and dual-task performance in community-dwelling older people: A randomized-controlled trial. *Games for Health Journal, 10*, 347–354.

(49) Wongcharoen, S., Sungkarat, S., Munkhetvit, P., Lugade, V., & Silsupadol, P. (2017). Home-based interventions improve trained, but not novel, dual-task balance performance in older adults: A randomized controlled trial. *Gait & Posture, 52*, 147–152.

(50) Ye, J. Y., Chen, R., Chu, H., Lin, H. C., Liu, D., Jen, H. J., Banda, K. J., Kustanti, C. Y., & Chou, K. R. (2024). Dual-task training in older adults with cognitive impairment: A meta-analysis and trial sequential analysis of randomized controlled trials. *International Journal of Nursing Studies, 155*, 104776.

(51) Yildiz, S. E., Fidan, Ö., Gulsen, Ç., Colak, E., & Genc, G. A. (2024). Effect of dual-task training on balance in older adults: A systematic review and meta-analysis. *Archives of Gerontology and Geriatrics, 121*, 105368.

(52) Yu, X., Dev Omar Dev, R., & Harun, M. M. (2026). Effect of variable priority cognitive-motor dual-task training on cognitive and physical function in older adults: A systematic review. *Brain Sciences, 16*, 308.