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The effects of high intensity functional exercise and simultaneous dual-task training in older adults: a randomized controlled trial study protocol

Os efeitos do exercício funcional de alta intensidade e do treinamento simultâneo de dupla tarefa em idosos: protocolo de um estudo de ensaio clínico randomizado

Los efectos del ejercicio funcional de alta intensidad y del entrenamiento simultáneo de doble tarea en adultos mayores: protocolo de un estudio de ensayo clínico controlado aleatorizado

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Resumo

Objetivos: Este estudo tem como objetivo avaliar o impacto de um programa de exercícios funcionais de alta intensidade, com ou sem treinamento cognitivo simultâneo em dupla tarefa, sobre equilíbrio, capacidade funcional e desempenho cognitivo de pessoas idosas residentes na comunidade, com o desfecho primário de melhora na qualidade da marcha verificada pela redução do tempo de execução no teste de caminhada de três metros.
Métodos: Será realizado um ensaio clínico randomizado, duplo-cego, com pessoas idosas de 60 anos ou mais. Os participantes serão alocados aleatoriamente para um programa de exercícios funcionais de alta intensidade (grupo simples tarefa) ou para o mesmo programa combinado com desafios cognitivos simultâneos (grupo dupla tarefa) durante 12 semanas. Resultados físicos e cognitivos serão avaliados antes e após a intervenção por meio de variados testes cognitivos e físicos, incluindo o teste *Timed Up and Go, Mini-BESTest, Montreal Cognitive Assessment, Trail Making Test e Digit Span Test*, entre outros. A amostra foi estimada em 44 participantes (22 por grupo), considerando um poder estatístico de 95% e uma taxa de evasão de 20%, com base em estudos prévios de delineamento similar.
Resultados: Espera-se que o grupo de dupla tarefa apresente melhoras mais significativas no equilíbrio, função física e desempenho cognitivo em comparação ao grupo de simples tarefa, demonstrando a superioridade do treino motor-cognitivo de alta intensidade.
Conclusões: Caso as hipóteses sejam confirmadas, o treinamento em dupla tarefa poderá ser considerado uma intervenção eficaz e acessível para melhorar a saúde física e cognitiva das pessoas idosas, ajudando a reduzir o risco de quedas e os custos relacionados à saúde. Este estudo fornecerá evidências importantes para a inclusão de desafios cognitivos em programas de exercícios, visando maximizar os benefícios para essa população.
Registro do ensaio: O ensaio foi registrado prospectivamente no Registro Brasileiro de Ensaios Clínicos (RBR-107mtjc8).

Palavras-chave: Dupla tarefa; Pessoas idosas; Capacidade funcional; Cognição.

Abstract

Aims: This study aims to evaluate the impact of a high-intensity functional exercise program, with or without simultaneous cognitive training in a dual-task format, on the primary outcomes of balance, functional capacity, and cognitive performance in community-dwelling older adults, with the primary outcome of improved gait quality, measured by the reduction in execution time on the three-meter walk test.
Methods: A double-blind randomized controlled trial will be conducted with older adults aged 60 years or older. Participants will be randomly assigned to either a standalone high-intensity functional exercise program (single-task group) or the

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same program combined with simultaneous cognitive challenges (dual-task group) over 12 weeks. Physical and cognitive outcomes will be assessed before and after the intervention using validated measures, including the Timed Up and Go test, Mini-BESTest, Montreal Cognitive Assessment, Trail Making Test, and Digit Span Test, among others. The sample size was estimated at 44 participants (22 per group), considering a statistical power of 95% and a dropout rate of 20%, based on previous studies with a similar design.
Results: The dual-task group is expected to show more significant improvements in balance, physical function, and cognitive performance compared to the single-task group, demonstrating the superiority of high-intensity motor-cognitive training.
Conclusions: If confirmed, dual-task training may be considered an effective and accessible intervention to improve the physical and cognitive health of older adults, contributing to a reduced risk of falls and associated healthcare costs. This study will provide important evidence supporting the integration of cognitive challenges into exercise programs aimed at maximizing benefits for this population.
Trial registration: The trial has been prospectively registered in the Brazilian Registry of Clinical Trials (RBR-107mtjc8).
Keywords: Dual task; Older adults; Functional capacity; Cognition.

Resumen
Objetivos: Este estudio tiene como objetivo evaluar el impacto de un programa de ejercicios funcionales de alta intensidad, con o sin entrenamiento cognitivo simultáneo en tarea dual, sobre los desenlaces primarios de equilibrio, capacidad funcional y desempeño cognitivo de personas mayores que viven en la comunidad, con el desenlace primario de mejora en la calidad de la marcha, verificada por la reducción del tiempo de ejecución en la prueba de la caminata de tres metros.
Métodos: Se llevará a cabo un ensayo clínico aleatorizado, doble ciego, con personas mayores de 60 años o más. Los participantes serán asignados aleatoriamente a un programa de ejercicios funcionales de alta intensidad de forma aislada (grupo de tarea simple) o al mismo programa combinado con desafíos cognitivos simultáneos (grupo de tarea dual), durante 12 semanas. Los resultados físicos y cognitivos se evaluarán antes y después de la intervención mediante instrumentos validados, incluyendo la prueba Timed Up and Go, Mini-BESTest, Montreal Cognitive Assessment, Trail Making Test y Digit Span Test, entre otros. El tamaño de la muestra se estimó en 44 participantes (22 por grupo), considerando un poder estadístico del 95% y una tasa de abandono del 20%, con base en estudios previos de diseño similar.
Resultados: Se espera que el grupo de doble tarea muestre mejoras más significativas en el equilibrio, la función física y el desempeño cognitivo en comparación con el grupo de tarea única, demostrando la superioridad del entrenamiento motor-cognitivo de alta intensidad.
Conclusiones: Si se confirman los resultados, el entrenamiento en tarea dual podrá considerarse una intervención eficaz y accesible para mejorar la salud física y cognitiva de las personas mayores, ayudando a reducir el riesgo de caidas y los costos asociados a la salud. Este estudio proporcionará evidencia importante para la inclusión de desafíos cognitivos en programas de ejercicios, con el objetivo de maximizar los beneficios para esta población.
Registro del ensayo: El ensayo fue registrado prospectivamente en el Registro Brasileño de Ensayos Clínicos (RBR-107mtjc8).
Palabras clave: Tarea dual; Personas mayores; Capacidad funcional; Cognición.

Introduction

Aging is a natural and lifelong process that involves biological, psychological, and social changes in a person. These changes are particularly significant in the musculoskeletal system, affecting movement, strength, and stamina[1]. Consequently, several musculoskeletal disorders can arise from them, increasing the risk of falls, fractures and subsequent morbidity and mortality[2]. Falls are a global health concern, with alarmingly high rates of one or more falls per year[3-4].

One of the most effective and cost-efficient methods of preventing falls is the practice of exercise, which has been shown to reduce the fall rate by up to 23% among community-dwelling elderly individuals[5]. Particularly effective results have been obtained from multicomponent training programs, which target strength, aerobics, flexibility, and balance exercises[6]. The High Intensity Functional Exercise (HIFE) Program is an exercise protocol designed to increase the functionality and fitness of elderly individuals. It provides exercises in different weight-bearing positions, adaptable for distinct functional capacities and allowing for progression and adaptation. The protocol has been shown to have positive effects in balance, gait, and strength[7-8].

Furthermore, cognitive skills, such as memory, attention and executive functions are also shown to decrease with aging[9]. As a result, the execution of dual-task (DT) activities—where an individual must perform two distinct tasks simultaneously, a common practice in day-to-day life—is impaired[10]. Arising from this issue, dual-task training is a potential method to enhance not only cognitive functions but also physical abilities, improving balance, gait and executive functions, thus being an effective strategy in preventing falls in older adults[11-12].

However, evidence regarding the effects of both high-intensity functional exercise and dual-task training remains somewhat limited. Recent studies have shown that while dual-task training can improve both cognitive and physical functions in older adults, further research with higher methodological quality and larger sample sizes is needed to strengthen these findings[13]. Similarly, reviews on high-intensity exercise in older adults indicate that, despite generally positive physical outcomes, additional evidence is required to establish its consistent effects across different functional domains[14].

To date, few randomized controlled trials have directly examined the combined and isolated effects of high-intensity functional exercise and dual-task training on both cognitive and physical outcomes in older adults. Addressing this knowledge gap is essential to determine whether incorporating a cognitive component into a high-intensity functional training program provides additional benefits beyond those achieved by physical training alone.

Therefore, this randomized controlled trial aims to investigate the effects of a high-intensity functional training program, with and without a dual-task component, on balance, functional capacity, and cognitive performance in community-dwelling older adults. The primary outcome will be gait quality improvement, measured by a reduction in execution time on the three-meter walk test.

Method

Study design and ethics approval

This study is a double-blind randomized controlled trial, with a parallel two-arm design, for community-dwelling older adults. The study will be conducted as part of the PESCID program, a 10-year extension program of the university involved in collaboration with the city's Municipal Secretariat of Health. This study has been written in agreement with the principles of the Declaration of Helsinki and the guidelines of Good Clinical Practice, the Consolidated Standards of Reporting Trials (CONSORT) and the Standard Protocol Items (SPIRIT) statements. This trial was approved by the ethics committee of the involved institutions (CAAE: 78449824.4.0000.5345) and (CAAE: 78449824.4.3001.5338) and has been prospectively registered at the Brazilian Registry of Clinical Trials (RBR-107mtjc8). All patients will be asked to provide written informed consent prior to the study enrollment, using standard forms.

Study settings

The study data collection and training protocol will be carried out at the Public Physical Rehabilitation Unit of the IAPI's Health Center, Porto Alegre, Brazil.

Participants and recruitment

The recruitment strategy will follow referral from affiliated basic health units of the North Health Coordination of the Porto Alegre SMS or through posters displayed in the same units. All participants will be instructed to fill out an on-line registration form and will be contacted via phone call by a member of the research team. During this phone call, assessment of eligibility of participants with respect to inclusion and exclusion criteria will be performed. The established inclusion criteria are: (a) male or female community-dwelling older adults who are aged ≥60 years; (b) reside in Porto Alegre; (c) willingness and availability to participate in group activities on established days and times; and (d) be physically independent individuals (based on the Katz index). The established exclusion criteria are: (a) physical limitations that make it impossible to perform the proposed exercises; (b) uncontrolled chronic diseases or judged clinically unstable; (c) incapacitating pain; (d) inability to understand and execute simple instructions; and (e) refusal to give informed consent. No other inclusion or exclusion criteria will be applied. Eligible participants will be invited to participate in the study. During the first visit to the study site, participants will receive detailed study information (objectives, methods, benefits and risks of the research project) from the research team and will be asked to sign the informed consent form.

Sample size

The sample size was determined based on data from Teza et al., who reported a between-group difference of approximately 0.12 m/s in the 3-meter walk test (SD ≈ 0.39 m/s), corresponding to a small-to-moderate effect (d ≈ 0.34; f ≈ 0.17). To ensure a conservative estimation and adequate statistical power, an effect size of f = 0.25 was adopted for the a priori calculation. Power analysis performed in G*Power (α = 0.05; power = 0.80; ρ = 0.60) indicated that a total of 48 participants (24 per group) would be sufficient, accounting for an estimated 20% attrition rate.

Randomization

After signing the informed consent, participants will be randomly allocated to either a high-intensity and functional exercise program (single-task group) or to the same program with simultaneous cognitive training (dual-task group) for 12 weeks using a computer-generated random number for each participant. The participant's group will be kept confidential from assessors, participants, and the statistician of this study until the end of the study.

Blinding

All participants of this study will be blindly assigned to one of the intervention groups. Considering the nature of the intervention, participants in both groups will be unable to distinguish between the treatments applied. On the other hand, due to the particularity of the exercise protocol, instructors cannot be blinded to allocation. Thus, measurements pre- and post-intervention will be assessed by independent assessors, blinded to participant's conditions. Also, statistician staff will not be aware of the participants' allocation. Consequently, participants, assessors and the statistician will be blinded regarding the group allocation.

Intervention

Training sessions will be conducted at the Public Physical Rehabilitation Unit of the IAPI's Health Center, Porto Alegre, Brazil, in a group setting (15-20 participants) by pre-trained physical therapy students. Each session will last for 50 minutes, twice a week, for 12 weeks. All sessions will begin with a five to seven-minute warm-up period, followed by physical exercises based on the High-Intensity Functional Exercise program (HIFE) simultaneously or not with cognitive challenges.

Experimental group

The dual-task approach in this study defines dual-tasking as the "concurrent performance of two tasks with distinct and separate goals"[15]. Participants in the experimental group will be instructed to complete a warm-up period, followed by the exercises outlined in the HIFE program, while simultaneously performing cognitive challenges. The HIFE Protocol was developed at Umeå University in Sweden and is composed mostly of balance exercises in combination with standing, walking and lower-limb strength exercises[16]. The intensity of the exercises is tailored to each individual's pace, but participants are encouraged to gradually increase it as they progress. Exercise parameters are adjusted each session based on individual responses.

The cognitive tasks covered a variety of cognitive domains, each with a distinct goal separate from the primary HIFE exercise (e.g., performing serial-three subtraction while executing squats in a walking stance). Secondary cognitive tasks included: (a) mathematical operations (e.g., addition and subtraction); (b) counting backward by intervals (e.g., by 1, 3, 5, 7); (c) clapping when hearing a word from a specific category (e.g., objects, animals, colors, names); (d) naming words in a category (e.g., objects, animals, colors, names); (e) recite years, months, or days of week backwards; (f) memory tasks (e.g., recalling previously mentioned objects, animals, colors, names or stories); (g) auditory and visual discrimination (e.g., identifying differences in colors, shapes, or sounds, such as voices); (h) inhibitory control tasks (e.g., Simon Says, Stroop task), among others. Secondary tasks were simultaneously performed during the execution of primary motor tasks in 100% of the total of exercises. Examples and comparisons of these cognitive tasks across weeks 1, 6, and 12 of training are presented in Table 1. Additionally, examples of HIFE-based lower-limb motor tasks combined with cognitive tasks used in the dual-task intervention are summarized in Table 2, which illustrates the structure and logic of task pairing throughout the sessions.

The progression of exercises will be tailored using the dual-task taxonomy framework proposed by McIsaac et al.[15]. This framework enables instructors to classify the overall activity level as "easier", "moderate", or "harder" based on the task's characteristics and the participant's abilities, helping to identify the most suitable tasks for each individual. Instructors assess two task domains: novelty and complexity. Novelty refers to the participant's prior experience with a specific task, while complexity involves the number of components, and the attentional demands required. Examples of how novelty and complexity are systematically increased in both the motor and cognitive components of the dual-task intervention are presented in Table 3, illustrating the progression logic applied throughout the 12-week program. This approach ensures that each exercise progresses steadily and provides sufficient cognitive overload for effective stimulation.

Control group

Participants in the control group started with a five-to-seven-minute warm-up, followed by a series of HIFE program exercises. These exercises included lunges, sit-to-stands, heel raises, tandem walking, step-ups, and walking over obstacles, forming the core of the intervention and lasting about forty minutes per session. Each session ended with five to ten minutes of stretching and relaxation techniques, such as deep breathing and other mindfulness practices.

Evaluation

Participants will be assessed at the start of the program and after 12 weeks of intervention. At baseline, sociodemographic data (age, sex, education, and living situation), clinical history, fall history over the previous year, and current medication use will be collected, along with information on comorbidities and physical activity levels. Different instruments will be used to evaluate the efficacy of the intervention program on physical functioning and cognitive performance. Pre- and post-intervention measurements will be conducted by independent assessors who will be blind to the participants' conditions and group assignments.

Outcome measures

The primary and secondary outcome measures will focus on key domains: physical functioning and cognitive performance. Additionally, secondary outcomes will include satisfaction and psychological scales.

Physical functioning outcomes

The following physical functioning outcomes will be measured to evaluate the efficacy of the intervention program: (a) The Timed Up and Go (TUG) Test - measures the time required for a participant to rise from a chair, walk three meters, turn around, and return to the seated position. This assessment evaluates balance, mobility and the risk of falls during daily activities. Typically, healthy elderly individuals complete the task in ten seconds or less, with longer times indicating a higher fall risk[17]; (b) The Mini-Balance Evaluation Systems Test (Mini-BESTest) – assesses balance and postural control through 14 tasks, including anticipatory postural adjustments and dynamic gait[18]. The test has a maximum score of 28, with scores below 19 suggesting a higher risk of falls[19]; (c) The Short Physical Performance Battery (SPPB) - evaluates lower extremity function through three components: balance tests (standing in parallel, semi-tandem, and tandem stances), gait speed (walking four meters as quickly as possible), and a sit-to-stand test (performing the action five times as quickly as possible)[20]. Scores range from 0 to 12 and are useful for predicting mortality in older adults[21]; (d) The Functional Reach Test (FRT) – evaluates stability and balance by having participants reach forward as far as possible while keeping their feet stationary[22]. The distance reached is an important indicator of balance impairment in older adults[23]; and (e) The Sit-to-Stand Test (SST) - measures lower body strength by counting the number of sit-to-stand movements a participant can complete in one minute[24]. This test provides a reliable measure of lower limb strength and exercise capacity, useful for comparing pre- and post-intervention results[25]. Primary physical functioning outcomes include TUG, Mini-BESTest and SPPB. Secondary physical functioning outcomes include FRT and SST.

Cognitive performance outcomes

The following cognitive performance outcomes will be measured to evaluate the efficacy of the intervention program: (a) The Montreal Cognitive Assessment (MoCA) – it includes a variety of assessments covering attention, memory, executive functions, and language, with a maximum score of 30. The MoCA is widely used to identify cognitive impairments[26-27]; (b) The Trail Making Test (TMT) – assesses cognitive functions such as attention, processing speed, and executive function through two parts: Part A, where participants connect a sequence of numbers, and Part B, where they alternate between numbers and letters. This test measures completion speed and errors, serving as a strong indicator of cognitive performance[28]; (c) The Stroop Test (STROOP) – evaluates cognitive control, processing speed, and the ability to manage task interference[29]. Participants are presented with cards featuring color-word patterns and must read aloud only the color of the ink, ignoring the written words. This test provides insights into cognitive integrity and is useful for evaluating cognitive abilities[30]; (d) The Digit Span Test (DST) – consists of two parts: Forward and Backward. In Forward, participants repeat a sequence of numbers in the same order they were read aloud. In the Backward part, they repeat the sequence in the reverse order. This test primarily evaluates working memory and attention[31]; Primary cognitive performance outcomes include TMT-A, TMT-B, STROOP, and DST. Secondary cognitive performance outcomes include MoCA.

Psychological outcome

Psychological outcome will include the Geriatric Depression Scale-4 (GDS-4), a brief questionnaire with four yes/no questions used to screen for potential depression in older adults[32]. This scale is effective in identifying mental health issues within this population[33].

Satisfaction

After 12 weeks, the satisfaction of the participants with the exercise program will be examined by means of a questionnaire. The questionnaire consists of four questions related to the project's importance to their health, social integration, community and leisure. Satisfaction will be rated on a 1-5 Likert scale with response categories unimportant (1), slightly important (2), moderately important (3), important (4), and very important (5). An overall patient-perceived satisfaction score will be calculated by summing all question scores.

Adverse events and dropout

Adverse events will be self-reported by participants to the research team and are considered as any unfavorable or unintentional health-related incident developed or worsened during the study period. All participants who decide to leave or not complete the study protocol after randomization or during the intervention will be contacted.

Dissemination

Results of this study will be published in national or international journals. Also, the results will be presented at conferences as well as to the coordinator and staff members of the North Health Coordination of the Porto Alegre SMS.

Statistical considerations

The data will be analyzed using Linear Mixed Effects Models (LMEM) to evaluate the effects of the intervention on primary and secondary outcomes. The models will include covariates such as age, education, comorbidities, and medication use, and will test the group × time interaction (intervention vs. control; pre- vs. post-intervention). Analyses will follow the intention-to-treat principle, with missing data handled through maximum likelihood estimation. Results will be presented as estimated marginal means, standard deviations, effect sizes (Cohen's d or partial η^2), and 95% confidence intervals.

Discussion

The current study is a double-blind randomized controlled trial, with a parallel two-arm design, aiming to evaluate the impact of simultaneously incorporating cognitive challenges into a high-intensity functional exercise program and assess whether they can enhance outcomes on older adults physical functioning and cognitive performance.

The effects of physical exercise for preserving and even improving cognitive and physical performance in healthy older adults are well established[34-36]. Additionally, high intensity functional exercises have also demonstrated to counteract declines in functional capacity[37]. However, despite growing evidence supporting the integration of cognitive demands into exercise, findings across studies remain inconsistent. A similar study reported neutral or even negative outcomes of dual-task interventions, particularly when task complexity exceeds attentional capacity or when participants present frailty or cognitive impairment[38].

Therefore, rather than assuming superior effects of dual-task training, this protocol aims to rigorously test whether the concurrent performance of motor and cognitive tasks produces additive benefits beyond those of high-intensity exercise alone. The results may also clarify under which participant profiles, such as baseline cognition or functional level, these combined interventions are most effective.

Furthermore, recent studies have highlighted that the magnitude of dual-task training effects, particularly on cognitive outcomes, varies substantially between healthy and frail older adults, with the latter generally showing smaller improvement[39]. This difference may be explained by the strong interrelationship between frailty, cognitive decline, and dual-task performance[40]. Older adults with mild cognitive impairment tend to exhibit poorer performance under dual-task conditions, primarily due to reduced attentional resources and slower processing speed, which limit their ability to allocate cognitive effort efficiently across simultaneous tasks[41]. These findings reinforce the neurophysiological rationale that dual-task training benefits depend on the integrity of executive and attentional control networks and may be modulated by individual levels of cognitive reserve.

Our hypothesis is that the experimental program, with 100% of activities consisting of dual-task exercises, will demonstrate significantly better results compared to the sole high-intensity functional exercise program (single-task program), thereby validating motor-cognitive stimulation as an accessible and effective tool in older adults' physical training. Nevertheless, we acknowledge that dual-task training may not yield homogeneous effects across all participants, and that variability may arise from baseline cognitive status, education level, medication use, and other individual differences.

The protocol includes a comprehensive set of assessments, designed to capture the specific effects of both dual-task and high-intensity exercises on the physical, cognitive, and physiological aspects of participants. The use of blinding for participants, assessors, and the statistician, along with a progressive training program that increases difficulty and complexity, ensures that the protocol is carried out under optimal conditions.

However, the study may face certain limitations, particularly due to its twelve-week duration, with sessions held twice-weekly. This may impact participant adherence, as older adults often contend with health or family issues that could affect their ability to consistently attend or fully commit to the program. Furthermore, the instructors will not be blinded due to the nature of the intervention, which is inherent to exercise-based interventions. Other studies have also reported the same occurrence[42-43]. All other study personnel will remain blind, as previously described, and the instructors will follow identical session protocols, with predefined progression criteria for all participants.

Additional methodological challenges should also be acknowledged. Potential sources of bias include the Hawthorne effect, selective adherence among more motivated or healthier individuals, and the absence of stratification by baseline cognitive level. These limitations will be considered when interpreting the results.

Moreover, medication use, particularly psychotropic and neuroactive agents, may influence cognitive performance and responsiveness to training. While medication control will not be a formal exclusion criterion, these variables will be documented and adjusted for in the statistical analyses.

The findings from this study could provide valuable insights for healthcare professionals working with older adults, highlighting the potential benefits of integrating high-intensity exercises and simultaneous cognitive challenges to improve care outcomes and maximize results in aged populations. By explicitly addressing potential sources of bias and individual variability, the present protocol contributes to advancing methodological rigor and transparency in the field of motor-cognitive training. Additionally, the results could lead to a reduction in the risk of falls as well as the direct and indirect costs associated with fall episodes. Ultimately, this research could contribute to future guidelines on the relation of cognition and functional mobility in older adults.

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Conflict of interest

The authors report no conflicts of interest associated with this study.

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Table 1 – Structured examples illustrating cognitive task progression at weeks 1, 6, and 12 within the dual-task HIFE training program

Cognitive domain / task type	Week 1 – Initial familiarization (Easier)	Week 6 – Intermediate progression (Moderate)	Week 12 – Advanced complexity (Harder)
(a) Mathematical operations	Simple additions and subtractions (e.g., 2 + 3; 8 − 2). Counting by 2s forward.	Serial-three or serial-five subtractions (e.g., 50, 47, 44…). Alternating addition and subtraction (e.g., +3, −2).	Serial-seven subtraction (e.g., 100, 93, 86…). Performing mental arithmetic involving two-step calculations (e.g., ×2 then −3)
(b) Backward counting / sequencing	Count backward from 20 to 0 by 1. Recite months of the year in order.	Count backward from 50 by 2s or 3s. Recite days of the week backward.	Count backward from 100 by 5s or 7s. Alternate between counting numbers and letters (e.g., 1–A–2–B–3–C).
(c) Auditory response / selective attention	Clap when hearing a target word (e.g., an animal). Respond only to high-pitched sounds.	Respond to target words from two different categories (e.g., animals and colors). Ignore distractor sounds or words.	Respond differently to multiple stimuli (e.g., clap for "animal," say "yes" for "color," remain silent for "object"). Identify target words embedded in continuous speech.

Cognitive domain / task type	Week 1 – Initial familiarization (Easier)	Week 6 – Intermediate progression (Moderate)	Week 12 – Advanced complexity (Harder)
(d) Verbal fluency (semantic category)	Name common household objects or fruits. Generate words starting with the same letter.	Name items from a specific category (e.g., colors, countries) within 30 seconds. Alternate between two categories (e.g., fruit–animal–fruit–animal).	Name as many items as possible in one minute without repetition. Switch between phonemic and semantic categories (e.g., words starting with "F" and animals).
(e) Temporal sequencing / backward recall	Say days of the week in order. Recite months of the year forward.	Recite months of the year backward. List seasons in reverse order.	Recite alternating temporal units (e.g., Monday → January → Tuesday → February). Recall historical years or birthdays in chronological order.
(f) Memory recall (short-term / working memory)	Recall two previously mentioned words or objects. Immediate repetition of three numbers.	Recall four to five words after a short delay. Reorder a list alphabetically or numerically (e.g., 4–1–3–2 → 1–2–3–4).	Recall six to eight words or items after interference. Remember and manipulate information (e.g., repeat every second word from a sentence).
(g) Auditory–visual discrimination	Identify whether a tone is high or low. Point out differences between two pictures.	Distinguish between words that sound similar (e.g., "cap" vs "cat"). Recognize a target color or symbol among distractors.	Detect paired stimuli (e.g., green circle + high tone). Identify inconsistencies between auditory and visual cues (e.g., hearing "red" while seeing blue).
(h) Inhibitory control / attention shifting	"Simon Says": respond only when the cue includes "Simon says". Simple go/no-go task (respond to "A," ignore "B").	Simplified Stroop task: say the color of a printed word, not the word itself. Alternate between two response rules (e.g., "if number, say color; if letter, say shape").	Complex Stroop or flanker tasks with interference. Rapid rule-switching (e.g., change rule after every third trial).

Note: This table illustrates the cognitive dimension of the dual-task training. Each domain progresses in difficulty through increased cognitive load, multitasking demands, inhibition requirements, or working memory manipulation, providing structured and reproducible stimulation over 12 weeks.

Table 2 – Examples of motor tasks (HIFE-based) paired with cognitive tasks in a dual-task setting

Motor task (HIFE-based, lower-limb / balance)	Cognitive task example	Notes / remarks
Static standing balance, feet in parallel stance	Name as many animals as possible (semantic fluency)	Maintains upright posture while generating verbal responses.
Semi-squat in parallel stance	Perform simple addition/subtraction (e.g., 5 + 2, 9 − 3)	Combines lower-limb muscle activation with basic arithmetic.
Step-ups (stepping onto a small step and back)	Count backwards by 3s (e.g., 50, 47, 44…)	Requires sustained attention and rhythmic coordination with steps.
Walking forward (flat surface)	Recite months of the year backward	Engages sequencing and working memory during locomotion.
Walking with turns / changes in direction	Clap when hearing a target word (e.g., "animal") but not for distractors	Demands selective attention and inhibitory control while walking.
Walking over obstacles	Identify high vs. low tones played intermittently	Challenges auditory discrimination while maintaining gait stability.

Tandem walking (heel-to-toe)	Perform a Stroop-like task: say the color of printed words, not the word itself	Requires cognitive inhibition and dual attention while balancing.
Walking on a soft surface / foam	Recall six words from a list after interference (e.g., counting)	Engages short-term memory and balance control under unstable conditions.

Note: All motor tasks were adapted from the High-Intensity Functional Exercise (HIFE) program and emphasize lower-limb strength, balance, and dynamic stability. Cognitive tasks were performed concurrently according to McIsaac's dual-task taxonomy.

Table 3 – Example of progression of novelty and complexity for motor and cognitive tasks in the dual-task HIFE framework

Task type	Task examples	Task novelty	Task complexity	Progression logic
Single motor (HIFE-based)	Squat in parallel stance, step-up, walking with turns	Low: Familiar movement, stable surface, constant speed	Low: Simple movement sequence (e.g., parallel stance squats)	Start with familiar, controlled movements emphasizing posture and safety.
		High: New or less practiced movement (e.g., tandem walking, walking on foam)	High: Multi-component movement with instability or variable directions	Increase instability, range of motion, or direction changes to enhance challenge.
Single cognitive (same domain)	Serial subtraction, verbal fluency, auditory discrimination	Low: Simple or well-known task (e.g., count backward by 1s)	Low: One-step cognitive process, minimal switching	Begin with familiar operations with clear rules and slow pacing.
		High: New or unfamiliar mental operation (e.g., Stroop-like inhibition, alternating category naming)	High: Multiple rules or rapid alternation between categories	Progress to dual-rule or inhibition tasks requiring attention shifting.
Combined cognitive–motor (dual-task)	HIFE walking task + verbal fluency	Low novelty / low complexity: Familiar motor task (flat walking) + simple counting	Low–High: Increase either cognitive or motor demand, not both simultaneously	Introduce simultaneous performance after both tasks are mastered individually.
	HIFE step-up + serial subtraction	Moderate novelty: Slightly new task pairing (e.g., step-ups + subtraction)	Moderate complexity: Maintain rhythm and calculation simultaneously	Adjust one domain at a time to maintain feasibility and safety.
	HIFE walking with turns + Stroop-like task	High novelty: New combination of cognitive inhibition with balance-demanding task	High complexity: Rapid attentional switching + unstable motor control	Used in late sessions when participants can manage divided attention and instability safely.

Note: Task progression followed the dual-task taxonomy framework by McIsaac et al. (15), in which novelty refers to task familiarity and complexity to the number of components and attentional demands. Exercises advanced stepwise from low to high levels of difficulty, combining motor and cognitive challenges throughout the 12-week program.