



Effects of Dual-Task Versus Single-Task Gait Training on Walking Performance After Stroke: A Systematic Review and Meta-Analysis

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ABSTRACT

Stroke frequently causes persistent gait impairments that limit independence and safe participation in community activities, particularly when walking requires the simultaneous performance of cognitive or motor tasks. This study aimed to compare the effects of dual-task gait training and single-task gait training on walking performance in adults after stroke. A systematic review and meta-analysis were conducted in accordance with the PRISMA guidelines. PubMed, the Cochrane Library, and ScienceDirect were searched for randomized controlled trials involving adults with ischemic or hemorrhagic stroke. Four studies were included in the qualitative synthesis, while three studies involving 87 participants provided comparable absolute gait-speed data for quantitative analysis. Mean differences and 95% confidence intervals (CIs) were calculated using a fixed-effect model, and statistical heterogeneity was assessed using the I^2 statistic. The pooled analysis showed no statistically significant difference in postintervention gait speed between dual-task and single-task gait training (mean difference = 0.05; 95% CI: -0.08 to 0.18; I^2 = 0%). Nevertheless, the qualitative findings indicated that dual-task gait training was feasible and may provide context-specific benefits for walking capacity, gait adaptability, and performance under divided-attention conditions. In conclusion, dual-task gait training was not superior to single-task gait training for improving absolute gait speed after stroke, although its functional benefits may be better captured by outcome measures that reflect complex, real-world walking demands and everyday mobility.

INTRODUCTION

Stroke remains a leading cause of long-term disability worldwide and continues to impose a substantial burden on individuals, healthcare systems, and societies (GBD 2019 Stroke Collaborators, 2021). Advances in acute stroke management have improved survival; however, a large proportion of stroke survivors experience persistent functional limitations, particularly in walking ability. Impaired gait is one of the most disabling consequences of stroke because it directly affects independence, social participation, and reintegration into community life (Lord et al., 2004; Nayak et al., 2023). Among various gait parameters, reduced gait speed is especially prominent and has been widely recognized as a robust indicator of functional mobility, overall health status, and long-term prognosis in individuals after stroke (Tasseel-Ponche et al., 2022).

Conventional poststroke gait rehabilitation has historically focused on single-task walking practice, emphasizing repetitive stepping, balance control, and lower-extremity strengthening under relatively stable and predictable conditions (Langhorne et al., 2011). These interventions can improve basic locomotor capacity and walking endurance in controlled environments. Nevertheless, improvements achieved during rehabilitation do not always translate into optimal walking performance in daily life (Brown et al., 2022; Lang et al., 2022; Moore et al., 2022; Wade, 2024). Many stroke survivors continue to experience difficulty ambulating in complex environments, where walking rarely occurs in isolation and often requires the simultaneous management of additional cognitive or motor demands.

Walking in real-world settings commonly requires divided attention, such as conversing while walking, monitoring traffic, navigating obstacles, or carrying objects. The ability to manage these concurrent tasks is frequently impaired after stroke, leading to deterioration in gait performance, reduced stability, and an increased risk of falls (Al-Yahya et al., 2011). This phenomenon, known as cognitive–motor interference, reflects limitations in attentional resources and impaired integration between motor and cognitive processes. Experimental studies have consistently demonstrated that individuals after stroke exhibit greater reductions in gait speed, cadence, and stride length under dual-task conditions than healthy individuals, underscoring the clinical relevance of dual-task walking deficits (Al-Yahya et al., 2011).

Dual-task gait training has therefore emerged as a rehabilitation strategy aimed at addressing the mismatch between conventional therapy and real-world walking demands (Aderinto et al., 2025; Bartloff et al., 2025; Kwon, 2026; Zainol Abidin et al., 2026; Zhao et al., 2026). By intentionally incorporating a secondary cognitive or motor task during walking practice, dual-task gait training is designed to challenge attentional capacity and promote more automatic and adaptable gait control. The theoretical basis of this approach is grounded in motor learning principles and attentional resource theories, which suggest that practice under conditions of increased task complexity may enhance neural efficiency and facilitate the transfer of learned skills to everyday activities (Chow et al., 2018). From this perspective, dual-task gait training may encourage a shift from conscious, attention-demanding gait control toward more automatic locomotor patterns.

Despite its strong theoretical rationale, the clinical effectiveness of dual-task gait training compared with conventional single-task gait training remains uncertain. Randomized controlled trials evaluating dual-task interventions in stroke populations have reported heterogeneous findings. Some studies have demonstrated greater improvements in gait speed following dual-task gait training, suggesting a potential advantage of training under divided-attention conditions (Zhang et al., 2022). In contrast, other trials have reported similar improvements in walking performance between dual-task and single-task gait training, indicating that structured walking practice itself may be a major driver of improvement, regardless of whether a secondary task is incorporated (Liu et al., 2017; Plummer et al., 2014). These inconsistencies may be influenced by differences in training protocols, including the type of secondary task, training intensity and duration, and participant characteristics.

Another challenge in interpreting the existing literature is the diversity of outcome measures used to assess walking performance. Studies have employed a wide range of measures, including gait speed, walking distance, balance scales, and indices of dual-task interference (Al-Yahya et al., 2011; Plummer & Eskes, 2015). Although this diversity reflects

the multidimensional nature of walking, it complicates quantitative synthesis and limits the ability to draw definitive conclusions regarding the superiority of one intervention over another. Absolute gait speed, however, remains one of the most consistently reported and clinically meaningful outcomes across trials, providing a pragmatic basis for comparative analysis.

Although previous reviews have examined dual-task training and cognitive–motor interference in neurological populations, focused systematic reviews and meta-analyses directly comparing dual-task gait training with single-task gait training in stroke survivors, while restricting quantitative synthesis to outcomes consistently reported across studies, remain limited. Clarifying whether dual-task gait training provides additional benefits over conventional gait training is essential for informing evidence-based clinical decision-making and optimizing rehabilitation strategies.

Therefore, this systematic review and meta-analysis aimed to compare the effects of dual-task gait training and single-task gait training on walking performance in adults after stroke. By synthesizing evidence from randomized controlled trials and focusing on walking outcomes consistently reported across studies, this review sought to provide a clearer and more clinically relevant understanding of the role of dual-task gait training in poststroke gait rehabilitation (Meester et al., 2019).

METHOD

Study Design and Reporting Framework

This systematic review and meta-analysis evaluated the effects of dual-task gait training compared with single-task gait training on walking performance after stroke. The review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A predefined protocol guided the literature search, study selection, data extraction, and data synthesis.

Literature Search Strategy

A comprehensive literature search was performed using three electronic databases: PubMed, the Cochrane Library, and ScienceDirect. The search strategy combined keywords related to stroke, dual-task training, gait, walking, and rehabilitation. Boolean operators were used to broaden the search and capture relevant studies across different terminologies. The final search strategy was designed to be sufficiently sensitive to identify all potentially eligible studies without restricting outcomes or study design at the search stage. All records retrieved from the databases were exported and screened for eligibility. The search yielded a total of 738 records, which formed the basis for subsequent screening and selection.

Eligibility Criteria

Studies were considered eligible if they met the following criteria. The population consisted of adult patients with ischemic or hemorrhagic stroke. The intervention of interest was dual-task gait training, defined as walking practice performed concurrently with an additional cognitive or motor task. Comparator interventions included single-task gait training or conventional gait rehabilitation without a concurrent secondary task. Eligible studies were required to report walking performance outcomes. Randomized controlled trials were included, while observational studies, case reports, conference abstracts, and study protocols without outcome data were excluded. Only full-text articles published in English were considered.

Study Selection

Following removal of duplicates, titles and abstracts were screened independently to exclude clearly irrelevant studies. Full-text articles were subsequently assessed for eligibility based on the predefined inclusion and exclusion criteria. Studies were excluded at the full-text stage if the intervention regimen did not align with the dual-task versus single-task gait training comparison or if outcome data were not suitable for synthesis. Disagreements during the screening and selection process were resolved through discussion. The study selection process and reasons for exclusion were documented using a PRISMA flow diagram.

Data Extraction

Data were extracted from included studies using a standardized extraction form. Extracted information included study characteristics, participant demographics, stroke phase, intervention and comparator details, training duration and frequency, and reported outcomes. For quantitative synthesis, post-intervention values of absolute gait speed were extracted, including means, standard deviations, and sample sizes for both intervention and comparator groups. When studies reported multiple walking conditions, only outcomes relevant to absolute gait speed under comparable conditions were retained for meta-analysis. Outcomes that were not consistently reported across studies were reserved for qualitative synthesis.

Risk of Bias Assessment

The methodological quality of included randomized controlled trials was assessed using a domain-based risk of bias approach. Key domains evaluated included random sequence generation, allocation concealment, blinding of outcome assessment, completeness of outcome data, and selective reporting. Each study was categorized as having low risk of bias, some concerns, or high risk of bias. Given the nature of rehabilitation interventions, blinding of participants and therapists was generally not feasible and was considered when interpreting overall study quality.

Data Synthesis and Statistical Analysis

A qualitative synthesis was conducted for all included studies to summarize intervention characteristics and reported outcomes. Quantitative synthesis was performed only for outcomes that were consistently reported across studies. Absolute gait speed was identified as the only outcome suitable for meta-analysis and was therefore selected as the primary outcome for quantitative synthesis.

Meta-analysis was conducted using the inverse variance method with a fixed-effects model. Mean differences and 95% confidence intervals were calculated to estimate the pooled effect of dual-task gait training compared with single-task gait training. Statistical heterogeneity was assessed using the chi-square test and quantified with the I^2 statistic. An I^2 value of less than 25% was interpreted as low heterogeneity. Statistical significance was set at a two-sided p value of less than 0.05.

Qualitative Synthesis Approach

Studies reporting walking outcomes that were not directly comparable with absolute gait speed were synthesized qualitatively. These outcomes included measures of walking capacity and other functional walking-related parameters. Findings from qualitative synthesis were integrated with quantitative results to provide a comprehensive interpretation of the effects of dual-task gait training after stroke.

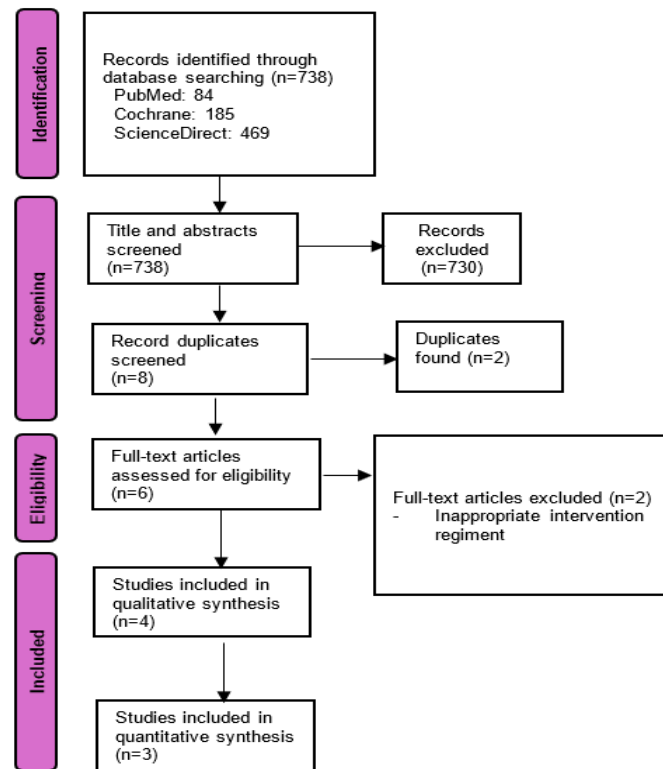


Figure 1. Diagram flow of literature search strategy for this meta-analysis

Table 1. Characteristics and Summary of Findings of Included Studies

First Author (Year)	Country	Study Design	Stroke Phase	Sample Size (DT / ST)	Mean Age (years)	Type of Dual Task	Intervention Description (DT)	Comparator (ST)	Session Duration & Frequency	Total Training Duration	Outcome Included for Meta-analysis	Summary of Findings	Risk of Bias
Khavan (2023)	Pakistan	Randomized controlled trial	Chronic	16 / 16	~58	Motor dual-task	Dual-task gait training incorporating gait rehabilitation motor tasks during walking	Conventional single-task rehabilitation	30 min/session, 4x/week	4 weeks	Absolute gait speed	Dual-task gait training resulted in greater post-intervention improvements in gait speed compared with single-task gait training	Some concerns

Meester (2019)	United Kingdom	Randomized controlled trial	Chronic	26 / 24	~61	Cognitive—motor	Treadmill-based dual-task gait training combined with concurrent cognitive tasks	Single-task treadmill gait training	30 min/session, 2×/week	10 weeks	— (qualitative synthesis only)	Dual-task gait training improved walking capacity measured by walking distance, although outcomes were not directly comparable with gait speed.	Some concerns
Plummer (2021)	United States	Singled-blind randomized controlled trial	≤3 years post-stroke	17 / 19	~57	Cognitive—motor	Cognitive dual-task gait training using a variable-priority strategy during walking	Ideational gait training without concurrent cognitive task	30 min/session, 3×/week	4 weeks	Absolute gait speed	Both dual-task and single-task gait training improved gait speed, with no significant between-group difference.	Some concerns
Liu (2017)	Taiwan	Singled-blind randomized controlled trial (3-	Chronic	CDT: 9 / CPT: 10M DTT: 9 / CPT: 10	~50	Cognitive—motor (CDT)Motor—motor (MDTT)	Cognitive or motor dual-task gait training performed concurrently	Conventional physical therapy (single-task gait, bala	30 min/session, 3×/week	4 weeks	Absolute gait speed	Dual-task gait training produced modest improvements in single-task gait speed	Some concerns

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RESULT AND DISSCUSSION

Study Selection

The literature search identified a total of 738 records from three electronic databases, consisting of 84 records from PubMed, 185 from the Cochrane Library, and 469 from ScienceDirect. After title and abstract screening, 730 records were excluded due to irrelevance to the study objectives. Eight records proceeded to duplicate screening, of which two were identified as duplicates and removed. Six full-text articles were subsequently assessed for eligibility. Two studies were excluded at the full-text stage because the intervention regimen did not align with the predefined dual-task versus single-task gait training comparison. Ultimately, four randomized controlled trials met the inclusion criteria and were included in the qualitative synthesis, while three studies reporting comparable gait speed outcomes were included in the quantitative synthesis.

Qualitative Synthesis

The qualitative synthesis incorporated four randomized controlled trials that examined the effects of dual-task gait training compared with single-task gait training or conventional gait rehabilitation in individuals after stroke. Across studies, dual-task interventions varied in their composition, incorporating either cognitive–motor or motor–motor task combinations performed concurrently with walking. Despite this variability, all studies consistently reported improvements in walking-related outcomes following intervention, underscoring the general effectiveness of structured gait rehabilitation in the post-stroke population.

Khan et al. (2023) demonstrated a clear advantage of motor dual-task gait training over conventional single-task gait training, with participants in the dual-task group showing greater post-intervention improvements in absolute gait speed. This finding suggests that integrating concurrent motor demands during walking practice may enhance motor learning and adaptability, potentially by increasing task complexity and promoting more automatic gait control. The study's results support the concept that dual-task training may better approximate real-world walking conditions, where individuals are frequently required to manage multiple motor demands simultaneously.

In contrast, Plummer et al. (2022) reported improvements in gait speed in both the dual-task and single-task groups, with no statistically significant difference between interventions. This finding highlights the possibility that the intensity, structure, and repetition of gait practice itself may play a dominant role in driving improvements in walking performance, regardless of whether an additional cognitive task is incorporated. The absence of a between-group difference may also reflect a ceiling effect in participants with relatively preserved walking ability, limiting the detectable incremental benefit of dual-task training when assessed using single-task gait speed.

Liu et al. (2017), using a three-arm randomized design, provided further insight into the nuanced effects of dual-task gait training. Both cognitive dual-task and motor dual-task

interventions resulted in modest improvements in single-task gait speed that were comparable to those achieved with conventional physical therapy. These findings suggest that while dual-task gait training can improve walking performance, its effects on absolute gait speed may not be substantially different from those of traditional gait-focused rehabilitation when evaluated under single-task conditions. Importantly, the study highlighted training-specific adaptations, indicating that dual-task interventions may preferentially influence performance under conditions that closely match the trained task demands.

Meester et al. (2019) reported improvements in walking capacity, assessed using walking distance rather than gait speed, following dual-task treadmill training. Although this outcome could not be quantitatively pooled with other studies, the findings add complementary evidence suggesting that dual-task gait training may positively influence endurance-related aspects of walking. The inclusion of this study in the qualitative synthesis strengthens the overall narrative by illustrating that the benefits of dual-task gait training may extend beyond speed alone and may be more apparent when broader dimensions of walking performance are considered.

Taken together, the qualitative evidence indicates that dual-task gait training is a feasible and potentially beneficial intervention for improving walking performance after stroke. However, the magnitude and nature of its benefits appear to depend on the specific outcome assessed, participant characteristics, and the degree to which the evaluation context reflects the trained task conditions.

Quantitative Synthesis

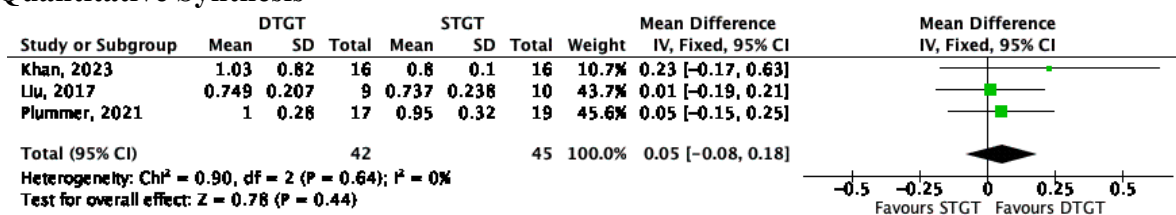


Figure 2. Forest Plot of Absolute Gait Speed

Three randomized controlled trials reporting absolute gait speed were included in the quantitative synthesis, comprising a total of 87 participants. Absolute gait speed was selected for meta-analysis because it was the only outcome consistently reported across studies using comparable measurement approaches, allowing for a robust pooled analysis. A fixed-effects model was applied due to the low level of observed heterogeneity.

The pooled analysis demonstrated no statistically significant difference in post-intervention gait speed between dual-task gait training and single-task gait training. The overall mean difference was 0.05, with a 95% confidence interval ranging from -0.08 to 0.18 . The confidence interval crossed the line of no effect, indicating that the observed difference was not statistically meaningful. Moreover, statistical heterogeneity was minimal, with an I^2 value of 0% , suggesting that the direction and magnitude of effects were consistent across the included studies.

The absence of heterogeneity indicates that, despite differences in intervention content and study design, the effect of dual-task gait training on absolute gait speed was relatively uniform. This consistency strengthens the reliability of the pooled estimate and suggests that the lack of a significant between-group difference is unlikely to be driven by methodological

inconsistencies or outlier effects. Instead, it reflects a genuine similarity in the impact of dual-task and single-task gait training on this specific outcome.

Clinically, these findings imply that dual-task gait training does not confer a clear advantage over single-task gait training in improving absolute gait speed when assessed under single-task walking conditions. It is important to note, however, that gait speed represents only one dimension of walking performance. Improvements in adaptability, attentional control, or performance under complex walking scenarios may not be fully captured by this outcome measure. As such, the neutral pooled effect should not be interpreted as evidence against the utility of dual-task gait training, but rather as an indication that its benefits may not be adequately reflected by absolute gait speed alone.

Overall, the quantitative synthesis provides a stable and reproducible estimate of the effect of dual-task gait training on gait speed after stroke, while the qualitative findings suggest that dual-task interventions may offer additional, context-specific benefits that warrant further investigation using outcome measures tailored to real-world walking demands.

This systematic review and meta-analysis synthesized evidence from randomized controlled trials comparing dual-task gait training with single-task gait training in individuals after stroke. The primary finding of this study is that dual-task gait training did not demonstrate a statistically significant advantage over single-task gait training in improving absolute gait speed. This finding was robust across included studies, as indicated by the absence of statistical heterogeneity, suggesting that the pooled estimate reflects a stable and reproducible effect rather than variability driven by methodological inconsistency.

The lack of superiority of dual-task gait training in terms of gait speed improvement may be explained by the fundamental role of task-specific repetition in gait recovery after stroke. Repetitive walking practice remains a cornerstone of post-stroke rehabilitation and has consistently been shown to improve locomotor capacity, regardless of whether additional cognitive or motor tasks are incorporated. From a motor learning perspective, the sheer volume and intensity of walking practice may exert a stronger influence on gait speed recovery than the complexity of the training task itself, particularly when the outcome is assessed under single-task walking conditions.

Findings from the qualitative synthesis provide important nuance to the quantitative results. While some studies reported greater improvements in gait speed following dual-task gait training (Zhang et al., 2022), others observed comparable gains between dual-task and single-task interventions (Liu et al., 2017; Plummer et al., 2014). These discrepancies likely reflect differences in intervention design, including the nature of the secondary task, task prioritization strategies, and training progression. For example, motor–motor dual-task paradigms may impose different biomechanical and attentional demands compared with cognitive–motor tasks, potentially leading to distinct adaptations that are not uniformly captured by gait speed alone.

Another important consideration is the baseline functional status of participants. Individuals with relatively preserved walking ability may experience ceiling effects in gait speed outcomes, limiting the observable benefit of dual-task training when speed is used as the primary endpoint. In such cases, improvements in other domains, such as gait adaptability, balance during complex tasks, or attentional allocation, may be more clinically meaningful but remain underrepresented in pooled analyses. This interpretation is supported by studies

demonstrating that dual-task deficits persist even in higher-functioning stroke survivors and may not be adequately reflected by single-task gait assessments.

The theoretical framework of cognitive–motor interference provides further insight into the observed findings. After stroke, walking often requires increased conscious control due to impaired automaticity of movement. Dual-task gait training is designed to challenge this reliance on attentional resources by exposing individuals to concurrent task demands, thereby encouraging the development of more automatic gait control. However, improvements arising from such training may preferentially manifest during dual-task walking rather than during isolated single-task assessments. As a result, evaluating the effectiveness of dual-task interventions solely through single-task gait speed may underestimate their true functional impact.

From a clinical perspective, the findings of this meta-analysis suggest that dual-task gait training should not be universally expected to produce greater improvements in gait speed compared with conventional single-task gait training. Nevertheless, this does not diminish its potential clinical value. Dual-task gait training may be particularly relevant for patients who report difficulties walking in cognitively or motorically demanding environments, such as crowded public spaces or uneven terrain. In such contexts, improving the ability to maintain stable gait under divided-attention conditions may be more relevant than increasing maximal walking speed.

Several methodological limitations should be considered when interpreting these findings. First, the number of included studies and overall sample size were relatively small, which may limit the precision of the pooled estimate. Second, intervention protocols varied considerably across studies in terms of task type, training frequency, and duration, potentially influencing training effects. Third, outcome heterogeneity restricted quantitative synthesis to absolute gait speed, precluding pooled analysis of other clinically relevant domains such as walking endurance, balance, and dual-task interference. The inclusion of Meester et al. in the qualitative synthesis highlights this issue, as improvements in walking capacity were observed using walking distance measures that could not be directly pooled with gait speed outcomes.

Additionally, most included studies recruited participants in the chronic phase after stroke, limiting the generalizability of findings to acute or subacute populations. Neural plasticity and responsiveness to training may differ substantially across recovery phases, and it remains unclear whether dual-task gait training may yield greater benefits if implemented earlier after stroke. Furthermore, long-term retention of training effects and transfer to daily life activities were not consistently assessed, representing another important gap in the current literature.

Future research should aim to address these limitations by adopting standardized outcome measures that capture both single-task and dual-task walking performance. Incorporating measures that reflect real-world walking demands, such as dual-task gait speed, obstacle negotiation, or community ambulation, may provide a more comprehensive evaluation of dual-task gait training effects. Larger, well-designed randomized controlled trials with sufficient power are also needed to identify patient subgroups who may derive greater benefit from dual-task interventions and to determine optimal training parameters.

In summary, this meta-analysis indicates that dual-task gait training does not provide a clear advantage over single-task gait training in improving absolute gait speed after stroke.

However, qualitative findings and theoretical considerations suggest that dual-task gait training may offer context-specific benefits that are not fully captured by single-task gait speed outcomes. These findings underscore the importance of aligning rehabilitation strategies and outcome selection with the functional demands faced by stroke survivors in everyday life.

CONCLUSION

This systematic review and meta-analysis concluded that dual-task gait training did not provide a statistically significant advantage over single-task gait training in improving absolute gait speed among individuals after stroke. The pooled analysis of three randomized controlled trials involving 87 participants yielded a mean difference of 0.05 (95% CI: -0.08 to 0.18), with no observed statistical heterogeneity ($I^2 = 0\%$). Nevertheless, the qualitative synthesis of four trials indicated that dual-task gait training was feasible and may provide context-specific benefits related to walking capacity, gait adaptability, and performance under concurrent cognitive or motor demands. Therefore, its clinical benefits may not be fully captured by absolute gait speed measured under single-task conditions.

Future research should include adequately powered randomized controlled trials involving participants across the acute, subacute, and chronic phases of stroke recovery. Intervention protocols should be more consistently reported and, where appropriate, standardized with respect to secondary-task type, intensity, frequency, duration, task-prioritization strategy, and progression. Researchers should assess both single-task and dual-task outcomes, including dual-task gait speed, dual-task cost, balance, walking endurance, obstacle negotiation, community ambulation, falls, and functional independence. Longer follow-up periods are also needed to determine the retention and real-world transfer of training effects and to identify patient subgroups that may benefit most from dual-task gait training.

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