

Effects of action observation therapy for gait training in stroke: a scoping review

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ABSTRACT: Action observation therapy (AOT) is a rehabilitation approach integrating sensory perception of motor skills among stroke survivors. This review article aims to investigate the effectiveness of AOT for gait training among comparative studies in stroke rehabilitation. We searched through MEDLINE, Scopus, and Google Scholar using the following subsets of terms: 'stroke' AND 'gait' AND 'action observation.' Randomised controlled trials (RCTs) and non-RCT studies focusing on AOT for gait training in stroke patients were included. Eleven RCTs and one non-RCT study met the inclusion criteria and were included for analysis. Data were extracted on sample size, inclusion criteria, type of intervention, functional outcome measures, gait parameters, and intervention effectiveness. Overall, AOT demonstrated positive results as an adjunctive intervention for improving gait properties among stroke individuals. The review highlighted its neurophysiological mechanisms and benefits in stroke rehabilitation. AOT shows promise as a beneficial adjunctive intervention for improving gait properties among stroke individuals. Further research is warranted to explore its optimal implementation and long-term effects in stroke rehabilitation.

Keywords: Action observation therapy; Gait training; Stroke rehabilitation

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1.0 INTRODUCTION

Stroke is a leading cause of death globally, leaving up to 50% of its survivors chronically disabled, impacting motor function, speech, swallowing, vision, sensation, and cognition ([Donkor, 2018](#)). Among the challenges

faced by stroke survivors, physical disability poses a significant burden, often resulting in a diminished quality of life due to limitations in activities of daily living (ADL) ([Jaracz & Kozubski, 2003](#)). A key aspect of this disability is the impairment of walking ability, with gait

disturbance affecting 73% to 75% of stroke survivors and posing a significant obstacle to mobility, sometimes leading to hazardous fall events ([Alguren et al., 2010](#); [Hyndman et al., 2002](#); [Kim et al., 2014](#)).

Efforts to address these mobility issues have spurred the development of rehabilitation strategies aimed at improving gait performance, often targeting physical muscle activity, postural control, and task practice ([Bevaert et al., 2015](#)). Neuroplasticity is central to neurological recovery following a stroke. Neuroplasticity is the brain's ability to repair and reorganise after injury, influenced by therapy frequency, intensity, and task-specific training ([Livingston-Thomas et al., 2016](#)). Given the importance of motor function improvement in stroke rehabilitation, various interventions have been employed, including task-specific training, body weight-supported gait training, and neuromodulation therapies such as transcranial stimulation of electrical or magnetic activities ([Braun & Wittenberg, 2021](#)).

In recent years, action observation training has emerged as a promising approach, capitalising on activating specific brain regions during the observation and execution of motor actions to promote motor learning and recovery ([Rizzolatti & Sinigaglia, 2016](#)). This method taps into the principles of motor learning, facilitating the acquisition or reacquisition of motor behaviours, including gait, through practice and experience ([Nakano & Kodama, 2017](#)). Despite its potential, the effectiveness and clinical application of action observation therapy (AOT) in gait neurorehabilitation remain areas of ongoing investigation, with existing literature lacking clarity ([Plata-Bello, 2017](#)).

This review aims to update and investigate the role of AOT in improving gait among stroke populations. Specifically, it seeks to provide insights for constructing evidence-based clinical frameworks to enhance gait rehabilitation strategies for stroke survivors and guide rehabilitation professionals in optimising treatment approaches. Furthermore, the findings may inform interventions promoting functional recovery among stroke survivors, particularly in settings with limited technological resources, such as body weight-supported gait training or repetitive transcranial magnetic stimulation machines.

2.0 MATERIALS AND METHODS

2.1 Search methodology

The scoping review was conducted following the PRISMA-ScR checklist guidelines for transparent

reporting of scoping reviews ([Tricco et al., 2018](#)). Two reviewers conducted a comprehensive literature search in MEDLINE, Scopus, and Google Scholar using the following subsets of terms: 'stroke' AND 'gait' AND 'action observation.' The search was limited to articles published within ten years, from 2011 to 2020. In Google Scholar, additional terms were used to exclude and refine the search results. Terms such as 'spinal cord,' 'upper hand,' 'dissertation,' 'aphasia,' 'language,' 'Parkinson,' 'rats,' 'children,' and 'vertigo' were excluded to enhance the relevance of the search. The advanced search feature in Google Scholar was utilised with the exact phrase 'action observation'. Search results were then screened based on predetermined inclusion and exclusion criteria. Disagreements between reviewers were resolved through consultation with a third reviewer as necessary. This rigorous reviewer calibration process ensured consistency and reliability in the data acquisition phase of the scoping review.

2.2 Inclusion and exclusion criteria

The inclusion criteria encompassed articles published in English, focusing on clinical studies that explored gait outcomes through action observation as an intervention among adults (aged 18 years and above) diagnosed with the first stroke. Randomised controlled trials (RCTs) and non-RCT studies focusing on AOT for gait training in stroke patients were included. Studies conducted during both the subacute phase (from one week up to six months post-stroke onset) and the chronic phase (beyond six months post-stroke onset) were considered ([Bernhardt et al., 2017](#)). Review articles, technical/case reports, thesis dissertations, and publications consisting solely of abstracts were excluded from consideration.

2.3 Data extraction and recording

The following data were extracted and recorded: (1) Article details, including title, author, year of publication, study design, and sample size. (2) Aims, demographic, and clinical characteristics of the studied population, such as mean age and the onset of stroke. (3) Study interventions. (4) Outcome measures to measure gait function. (5) Corresponding results regarding the effectiveness of AOT. Subsequently, these findings are categorised into three main sub-chapters: (1) Interventions. (2) Outcome measures and gait analysis. (3) Effectiveness of AOT on gait.

3.0 RESULTS

The electronic search yielded 56 results. After removing duplicates and conducting a detailed screening of the abstracts based on the study selection criteria, we

included 12 articles. **Figure 1** illustrates the steps involved in the selection process, and **Table 1** summarises the basic demographics and characteristics of the selected articles. While our search strategy focused on electronic databases, it did not explicitly include searching reference lists of included articles or grey literature sources.

All twelve articles focused on studies involving individuals with stroke who had unilateral hemiparesis. Among these, there were 329 chronic stroke subjects included in eleven RCT studies ([Bang et al., 2013](#); [Kim & Sang-MiChung, 2016](#); [Kim & Lee, 2013](#); [Kim & Lee, 2018](#); [Kleynen et al., 2019](#); [Lee et al., 2017](#); [Moon & Bae, 2019](#); [Oh et al., 2019](#); [Park & Hwangbo, 2015](#); [Park et al., 2014](#); [Park et al., 2017](#)), and 16 subacute stroke individuals in one non-RCT study ([Hioka et al., 2020](#)). In nine of the RCT studies, participants were required to be capable of walking more than 10 meters, either with or without walking aids ([Bang et al., 2013](#); [Kim & Sang-MiChung, 2016](#); [Kim & Lee, 2013](#); [Kleynen et al., 2019](#); [Lee et al., 2017](#); [Park & Hwangbo, 2015](#); [Park et al., 2014](#); [Park et al., 2017](#)), while one RCT study required individuals to ambulate more than 30 meters with or without walking aids ([Kim & Lee, 2018](#)). The non-RCT study required individuals to exert voluntary muscle contraction in the paretic lower extremity ([Hioka et al., 2020](#)). In all twelve articles, the participants were first-time stroke individuals aged more than 18 years old, and they were free from major cognitive problems, auditory and visual deficits, or lower limb orthopaedic issues.

3.1 Interventions

Table 2 summarises the interventions employed in each of the selected articles. In most cases, the experimental (AOT) groups received a combination of AOT with conventional neurorehabilitation ([Kim & Lee, 2013](#); [Kim & Lee, 2018](#); [Moon & Bae, 2019](#); [Oh et al., 2019](#); [Park & Hwangbo, 2015](#)). All experimental groups had an intervention time that was equivalent to that of their control groups. AOT was consistently delivered through videos, with each session lasting at least 2 minutes and 30 seconds during the intervention. The intervention periods varied, ranging from 4 weeks ([Bang et al., 2013](#); [Kim & Sang-MiChung, 2016](#); [Kim & Lee, 2013](#); [Kleynen et al., 2019](#); [Moon & Bae, 2019](#); [Oh et al., 2019](#); [Park et al., 2014](#); [Park et al., 2017](#)), 6 weeks ([Kim & Lee, 2018](#); [Lee et al., 2017](#)), 8 weeks ([Park & Hwangbo, 2015](#)), to 3 months ([Hioka et al., 2020](#)).

For the control group, participants either watched the experimental video without practicing gait ([Lee et al., 2017](#)), engaged in different types of interventions

([Hioka et al., 2020](#); [Kim & Lee, 2013](#); [Kleynen et al., 2019](#); [Lee et al., 2017](#); [Oh et al., 2019](#)), or viewed videos without gait content ([Bang et al., 2013](#); [Kim & Lee, 2018](#); [Moon & Bae, 2019](#); [Park & Hwangbo, 2015](#); [Park et al., 2014](#); [Park et al., 2017](#)). In the study by Kim and Sang-MiChung, participants in the control group received one-on-one posture and gait training videos. In contrast, the experimental group used similar videos but underwent group training sessions ([Kim & Sang-MiChung, 2016](#)).

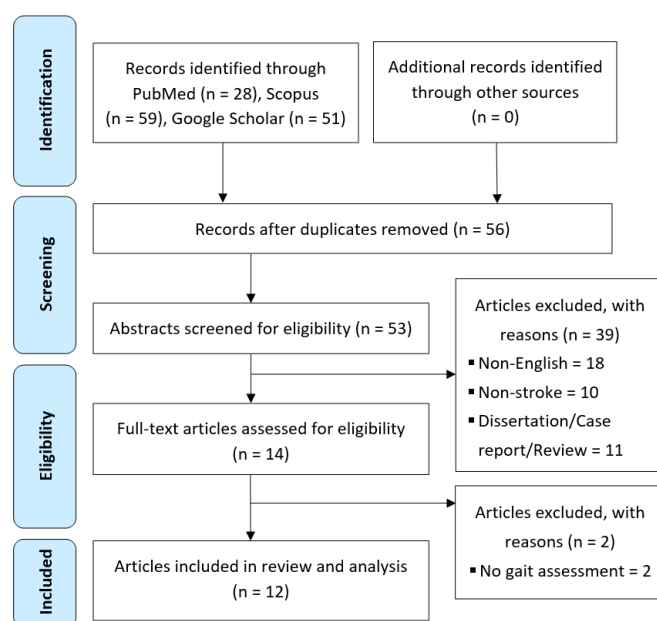


Figure 1. Flowchart of article selection for review

3.2 Outcome measures and gait analysis

Gait assessment and analysis in these studies were conducted manually by the researchers or digitally using various devices. The outcome measures in these studies encompassed three main categories: walking function, balance, and gait parameters. For walking function assessment, the following measures were employed: Time Up and Go test (TUG) ([Bang et al., 2013](#); [Kim & Lee, 2013](#); [Kim & Lee, 2018](#); [Moon & Bae, 2019](#); [Park & Hwangbo, 2015](#); [Park et al., 2014](#)), 10 Meter Walk Test (10MWT) ([Bang et al., 2013](#); [Hioka et al., 2020](#); [Moon & Bae, 2019](#); [Park & Hwangbo, 2015](#); [Park et al., 2014](#); [Park et al., 2017](#)), 6 Minute Walk Test (6MWT) ([Bang et al., 2013](#)), Figure of 8 Walk test (F8WT) ([Kim & Sang-MiChung, 2016](#); [Park et al., 2014](#)), Dynamic Gait Index (DGI) ([Kim & Sang-MiChung, 2016](#); [Kim & Lee, 2018](#); [Moon & Bae, 2019](#); [Park et al., 2014](#)), Functional Gait Assessment (FGA) ([Oh et al., 2019](#)), Modified Functional Ambulation Profile (mEFAP) ([Park et al., 2017](#)), Community Walk Test ([Park et al., 2017](#)), Walking Ability

Questionnaire ([Kim & Lee, 2013](#)), Rivermead Mobility Index (RMI) ([Moon & Bae, 2019](#)), and Functional Ambulation Category (FAC) ([Kim & Lee, 2013](#)).

In addition to walking function, some studies included assessments of balance function, recognising its significance as a prognostic factor for gait recovery in stroke. The measures used for balance assessment included the Activities Specific Balance Confidence Scale ([Park et al., 2017](#)), the Weight Distribution Index (WDI) ([Kim & Lee, 2018](#)), the Limit of Stability (LOS) ([Kim & Lee, 2018](#)), and Berg Balance Scale (BBS) ([Kim & Sang-MiChung, 2016](#); [Kleynen et al., 2019](#)). Various devices were used for the objective assessment of balance and gait parameters in these studies, such as GAITrite ([Kim & Lee, 2013](#); [Oh et al., 2019](#); [Park et al., 2017](#)), Dartfish motion analysis software ([Bang et al., 2013](#)), BioRescue ([Park & Hwangbo, 2015](#)), Biodex Balance System ([Lee et al., 2017](#)), Vicon motion analysis system ([Kleynen et al., 2019](#)), and BT4 Balance Measurement ([Kim & Sang-MiChung, 2016](#)).

3.3 Effectiveness of AOT on gait

All the articles suggested improvements in functional measures and gait parameters due to the AOT intervention (**Table 2**). The assessment of effectiveness was measured and compared through both intra- and inter-group changes. In all studies, significant improvements in functional measures related to walking and gait parameters were observed within the experimental groups when comparing pre- and post-intervention ([Bang et al., 2013](#); [Hioka et al., 2020](#); [Kim & Sang-MiChung, 2016](#); [Kim & Lee, 2013](#); [Kim & Lee, 2018](#); [Kleynen et al., 2019](#); [Moon & Bae, 2019](#); [Oh et al., 2019](#); [Park & Hwangbo, 2015](#); [Park et al., 2014](#); [Park et al., 2017](#)). However, in their study, Lee and colleagues did not find significant differences in walking function between the experimental and control groups ([Lee et al., 2017](#)).

It's worth noting that their study placed a stronger emphasis on balance rather than walking function. In a study by Oh and colleagues, a comparison was made between the effectiveness of action observation training for practising walking on a treadmill and practising gait stability. The former was significantly more effective in improving gait parameters ([Oh et al., 2019](#)). Gait speed assessed directly using devices ([Kim & Lee, 2018](#); [Kleynen et al., 2019](#); [Moon & Bae, 2019](#); [Oh et al., 2019](#); [Park et al., 2017](#)) and through various outcome measures ([Bang et al., 2013](#); [Hioka et al., 2020](#); [Kim & Sang-MiChung, 2016](#); [Kleynen et al., 2019](#); [Moon & Bae, 2019](#); [Oh et al., 2019](#); [Park & Hwangbo, 2015](#);

[Park et al., 2014](#); [Park et al., 2017](#)) showed substantial improvements over time within the groups and between groups.

Similarly, balance function also showed significant improvements between groups ([Bang et al., 2013](#); [Hioka et al., 2020](#); [Kim & Sang-MiChung, 2016](#); [Kim & Lee, 2013](#); [Kim & Lee, 2018](#); [Kleynen et al., 2019](#); [Moon & Bae, 2019](#); [Oh et al., 2019](#); [Park & Hwangbo, 2015](#); [Park et al., 2017](#)), except in the study by Lee and colleagues ([Lee et al., 2017](#)). Despite the lack of significant differences between groups in Lee and colleagues' study, there were improvements in balance within each group. Furthermore, a study by Kim and Sang-MiChung found that implementing action observation training on a one-on-one basis was not superior to implementing in a group format ([Kim & Sang-MiChung, 2016](#)).

4.0 DISCUSSION

This literature review offers insights into the current state of knowledge regarding applying AOT for gait improvement in stroke patients. The majority of the studies included in this review emphasise the effectiveness of AOT when used in conjunction with other rehabilitation approaches to improve gait function in chronic stroke patients, particularly for short-distance walking. Our findings align with those established by Peng and colleagues ([Peng et al., 2019](#)).

However, it's worth noting that articles involving patients in the earlier phases of stroke recovery are limited, with only one study focusing on subacute-stage patients. Early intervention in stroke rehabilitation is crucial, as the optimal recovery window for survivors is typically during the first few months after stroke onset ([Bae et al., 2020](#)). Delayed recovery may lead to compensatory strategies involving the unaffected lower limb rather than restoring muscle coordination patterns in the affected area during walking ([Jorgensen et al., 1995](#)). The presence of compensatory strategies during action observation training in studies involving chronic stroke patients needs to be further explored in the context of gait function.

Measuring and training gait properties alone may not yield the desired gait rehabilitation outcomes. Walking abilities should be linked to mechanisms that restore support function and equilibrium reactions in the paretic leg ([Buurke et al., 2008](#)). Kollen and colleagues have suggested that improving balance control is more critical for gait improvement than enhancing leg strength or walking patterns ([Kollen et al., 2005](#)).

Table 1. Demographics and characteristics of selected studies.

Author (Year)	Study design Aims	Stroke onset, Total sample size (n)	Inclusion criteria	Mean age of each group (years) Male : female ratio
Kim and Lee (2013)	RCT To compare the effects of AOT and motor imagery training on recovery from chronic stroke.	> 6 months N = 27	1. First-time stroke (ischemic/haemorrhagic) 2. Walk independently > 10 meter 3. > 24 points on the MMSE 4. Lesser than 36 points on the Vividness Motor Imagery Questionnaire-2	AOT : 55.3 ± 12.1 MI : 54.8 ± 8.8 NDT : 59.8 ± 8.9 AOT = 7 : 2 MI = 6 : 3 NDT = 7 : 2
Bang et al. (2013)	RCT To investigate the effect AOT on walking ability with chronic stroke patients.	> 6 months N = 30	1. Hemiparesis 2. First-time stroke (haemorrhage/ infarction) 3. Gait speed > 0.5 m/s, (suffice to exercise on treadmill) 4. No other interventions related to gait (from other institutions) 5. Independent gait > 10m 6. Sufficient cognition to participate in training.	EG : 64.1 CG : 58.9 EG = 9 : 6 CG = 8 : 7
Park et al. (2014)	RCT To identify the effects of AOT on the walking ability of subjects with post-stroke hemiparesis.	> 12 months N = 21	1. Independent walking >10 m (with/without walking aids) 2. No orthopaedic impairment of trunk and lower limbs 3. No visual and auditory deficits 4. No cognitive alterations (>24 points on MMSE)	EG : 55.91 ± 9.10 CG : 54.80 ± 12.22 EG = 8 : 3 CG = 7 : 3
Park and Hwangbo (2015)	RCT To investigate the effects of AOT on the static balance and walking ability of patients who had suffered a stroke.	> 12 months N = 40	1. No visual field defects 2. No abnormality in vestibular organs 3. No orthopaedic disease (unrestricted ROM) 4. Understand and perform exercise as instructed by researcher) 5. MMSE (Korean) ≥ 24	EG : 51.15 ± 14.81 CG : 48.65 ± 12.81 EG = 10 : 10 CG = 11 : 9
Kim and Sang-MiChung (2016)	RCT To evaluate the effects of Group AOT on chronic stroke patient's balance and gait.	> 6 months N = 16	1. Walk ≥ 10 m independently 2. MMSE (Korean) ≥21	EG : 52.88 ± 9.58 CG : 55.75 ± 12.06 EG = 6 : 2 CG = 2 : 6
Lee et al. (2017)	RCT To evaluate the effects of AOT and mirror therapy on improving balance and gait function in stroke.	> 6 months N = 35	1. Walk ≥ 10 m independently (without aid) 2. MMSE ≥23 3. No visual perception deficits	EG : 62.8 ± 7.4 MTA : 57.27 ± 5.7 CG : 59.8 ± 6.7 The study did not specify male : female ratio

Park et al. (2017)	RCT To investigate the effects of AOT involving community-based ambulation for improving walking ability after stroke.	≥ 6 months N = 25	1. Hemiparesis 2. First stroke 3. Walk > 10 m independently (with/without aid/orthosis) 4. No orthopaedic or cardiovascular disease 5. MMSE >24 6. No auditory or visual impairment (including hemineglect)	EG : 57.33 ± 6.89 CG : 55.08 ± 8.12 EG = 9 : 3 CG = 7 : 6
Kim and Lee (2018)	Crossover RCT to investigate the effects of an AOT on balance and sit-to-walk in chronic stroke.	> 6 months N = 21	1. No cognitive impairment 2. No abnormalities in visual, auditory, or proprioceptive senses, 3. No orthopaedic disease in the lower limbs 4. Independent sit down and stand up 5. Walk > 30m with/ without assistive device	EG : 57.08 ± 7.29 CG : 52.92 ± 8.21 EG = 10 : 1 CG = 9 : 1
Moon and Bae (2019)	RCT To evaluate the feasibility of backward walking observational training on the gait ability of chronic stroke patients.	≥ 12 months N = 14	1. Independent gait >10 m 2. Walking aids not used 3. MMSE >24 4. No visual or auditory deficits.	EG : 59.1 ± 10.0 CG : 55.8 ± 6.2 EG = 6 : 1 CG = 3 : 4
Oh et al. (2019)	RCT To investigate the effects of functional AOT on gait ability in patients with post-stroke hemiparesis.	> 6 months N = 35	1. Stroke diagnosed through CT or MRI 2. MMSE (Korean) >21 3. No visual deficits 4. Independent standing (60 sec) 5. Gait >10m	EG : 58.85 ± 7.60 CG : 59.35 ± 9.39 EG = 11 : 6 CG = 12 : 6
Kleynen et al. (2019)	RCT To investigate immediate changes in walking performance associated with three implicit motor learning strategies and to explore patient experiences of each strategy.	> 3 months N = 56	1. Walk independently (with/without a walking aid) >10 m (with a self-selected gait speed <1.2 m/s) 2. Hemiparesis (score of <100 on the lower extremity part of the Motricity Index) (score <34 on the lower extremity part of the Brunnstrom Fugl-Meyer assessment) 3. Able to visit one of the two motion capture laboratories 4. Have a sufficient understanding of the Dutch language	AI : 67.0 ± 11.9 EC : 61.1 ± 11.9 EG : 63.9 ± 12.5 AI = 10 : 9 EC = 11 : 6 AOT = 11 : 9

Hioka et al. (2020)	Non-RCT To investigate the effects of AOT on gait ability in patients with subacute to convalescent stroke.	> 21 days N = 16	1. Cerebral haemorrhage/ infarction within 21 days from onset 2. Aged between 18 and 75 years old 3. Patients who could exert voluntary muscle contraction of the paretic lower extremity	EG : 60.9 ± 5.8 CG : 54.1 ± 9.6 EG = 3 : 5 CG = 7 : 1
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AI: Analogy instruction; **AOT:** Action observation therapy; **CG:** Control group; **EC:** Environmental constraint; **EG:** Experimental group; **MI:** Motor imagery; **MMSE:** Mini-mental state examination; **MTA:** Mirror therapy with activity; **NDT:** Neurodevelopmental therapy; **RCT:** Randomised control trial.

Table 2. Details of interventions, intervention periods, outcome measures and results of selected studies.

Author (Year)	Intervention (No. of patients in each group)	Length of Intervention	Outcome Measure	Results
Kim and Lee (2013)	AOT: Watch task video for 20mins, then physical training for 10 mins (9) vs MI: Listen to the motor imagery program for 20 mins, then physical training for 10 mins (9) vs PT: Physical therapy training (9)	30mins/day, 5 days/week, for 4 weeks All subjects received NDT for 30 minutes, 2x/day, 5x/week for 4 weeks.	1. TUG 2. FAC 3. Gait Speed (GAITrite Gold)	<ul style="list-style-type: none"> Significant improvement in TUG between pre- & post-test in all 3 groups ($p < 0.05$). Significant improvement in gait speed between AOT and PT group ($p < 0.05$).
Bang et al. (2013)	EG: Treadmill training after watching a person on a treadmill video (15) vs CG: Treadmill training after watching nature video (15)	40mins/day, 5x/week, for 4 weeks	1. TUG 2. 10MWT 3. 6MWT 4. Max flexed knee angle in the swing phase during walking	<ul style="list-style-type: none"> TUG showed a significant difference between groups ($p = 0.018$). 10MWT showed a significant difference between groups ($p = 0.001$). 6MWT showed a significant difference between groups ($p = 0.001$). Max flexed knee angle was significantly different between groups ($p = 0.03$).
Park et al. (2014)	EG: Watch the walking video for 10 mins, then execute the task in the same environment for 20 mins (11) vs CG: Watch nature video (not relevant to walking for 10mins, then perform the walking task for 20 mins (10)	30mins/day, 3x/week, for 4-weeks	1. 10MWT 2. F8WT 3. DGI 4. Gait symmetry scores: swing phase, stance phase, stride length	<ul style="list-style-type: none"> 10MWT, F8WT, and DGI showed significant differences between the groups ($p < 0.05$). EG: 10MWT, F8WT, DGI, and gait symmetry score in the stance phase showed significant differences between pre- and post-test ($p < 0.05$). CG: no significant differences were found for all variables between pre- and post-test ($p > 0.05$).

<p>Park and Hwangbo (2015)</p>	<p>EG: watch a video of a man walking on different surfaces and practice for 20 mins (20) vs CG: Watch a video showing nature & practice walking for 20 mins (20)</p>	<p>30mins/day, 5x/week, for 8 weeks</p> <p>All participants in both groups received 30 mins of general physical therapy before the session.</p>	<ol style="list-style-type: none"> 1. TUG 2. 10MWT 3. Static Balance (BioRescue, France) 	<ul style="list-style-type: none"> ▪ Both groups showed significant improvements in TUG and 10MWT after intervention between pre- and post-test ($p<0.05$). ▪ TUG and 10MWT showed significant differences between 2 groups ($p<0.05$). ▪ Both groups significantly decreased sway area, sway speed and stability limit after the intervention ($p<0.05$). ▪ Significant differences in sway speed and total length of the limit of stability between the two groups after the experiment ($p<0.05$). ▪ No significant differences in the sway area between the two groups after the experiment ($p>0.05$)
<p>Kim and Sang-MiChung (2016)</p>	<p>EG: watch a video on posture and gait in daily life and trained in group (8) vs CG: watch video on posture and gait in daily life and trained on a one-on-one basis (8)</p>	<p>30mins/day, 5x/week, for 4 weeks</p> <p>All session consists of observation for 15 mins and physical training for 15 mins.</p>	<ol style="list-style-type: none"> 1. BT4 Balance Measurement 2. BBS 3. 10MWT 4. F8WT 5. DGI 	<ul style="list-style-type: none"> ▪ Significant increase of EG posterior stability limit ($p<0.05$). ▪ No significant variation improvement (before and after intervention) between groups ($p>0.05$). ▪ Both groups showed significant improvement in BBS scores between pre- and post-intervention ($p<0.05$) but no significant differences between groups. ▪ Significance improvement within groups for DGI, time and number of steps of 10MWT and F8WT. No significance differences between groups.
<p>Park et al. (2017)</p>	<p>EG: watched video clips demonstrating 4 staged ambulation training for 30 mins (12) vs CG: observe 4 clips of the static landscape for 30 mins (13)</p>	<p>30 mins/week, for 4 weeks (to complete 12 sessions)</p> <p>All subjects received neurodevelopment treatment for 30 minutes, 5x per week for 4 weeks.</p>	<ol style="list-style-type: none"> 1. 10MWT 2. Community walk test 3. Activities-specific balance confidence scale 4. Spatio-temporal gait measures (GAITRite) 	<ul style="list-style-type: none"> ▪ All outcome measures showed significant differences between EG and CG for pre- and post-intervention ($p<0.05$). ▪ 10MWT: $0.17\pm 0.19\text{m/s}$ vs $0.05\pm 0.08\text{m/s}$ ▪ Community walk test: $151.42\pm 123.82\text{secs}$ vs $67.08\pm 176.77\text{secs}$ ▪ Activities-specific balance confidence: 6.25 ± 5.61 scores vs. 0.72 ± 2.24 scores ▪ Spatio-temporal parameters: <ul style="list-style-type: none"> ○ stride length: 19.00 ± 11.34 cm vs. 3.16 ± 11.20 cm ○ single support: $5.87 \pm 5.13\%$ vs. $0.25 \pm 5.95\%$ ○ velocity: $15.66 \pm 12.34\text{cm/s}$ vs. $2.96 \pm 10.54\text{cm/s}$

<p>Lee et al. (2017)</p>	<p>EG: Watch the modified mirror therapy video for 15 mins, then physical training for 15 mins (AOTA) (12) vs MTA: Mirror therapy for 15 mins, then physical training without a mirror for 15 mins (11) vs CG: Watch the modified mirror therapy video for 35 mins without physical training (AOT) (12)</p>	<p>30mins/day, 3x/week, for 6 weeks</p>	<ol style="list-style-type: none"> 1. Modified Functional Ambulation Profile (mEFAP) 2. Balance index: Overall Balance Index (OBI), Anteroposterior Balance Index (ABI), Mediolateral Balance Index (MBI), Fall Risk (using the Biodex Balance System) 	<ul style="list-style-type: none"> ▪ The mEFAP significantly decreased in the AOTA and MTA groups ($p<0.05$) ▪ Balance index ▪ OBI: significantly decreased in the AOTA group ($p<0.05$), not significantly decreased in MTA group ($p>0.05$), increased in the AOT group but did not reach significance level, no significant difference between the groups ($p>0.05$) ▪ ABI: significantly decreased in the AOTA group ($p<0.05$), and increased in MTA and AOT groups but did not reach a significance level, with no significant difference between the groups ($p>0.05$). ▪ MBI: decreased in the AOTA, MTA, and AOT groups but did not reach a significance level, with no significant difference between the groups ($p>0.05$) ▪ Fall risk: decreased in the AOTA group and MTA group but did not reach significance level, increased in the AOT group but did not reach significance level, no significant difference between the groups ($p>0.05$)
<p>Kim and Lee (2018)</p>	<p>EG: Watch observation video for 2 mins 30s, then physical training (based on functional status & level) for 12mins 30s (11) vs CG: Watch nature video for 2 mins 30s, then physical training (based on functional status) for 12 mins 30s (10)</p>	<p>30mins/session, 2x/day, 3x/week, for 6 weeks</p>	<ol style="list-style-type: none"> 1. TUG 2. DGI 3. WDI 4. LOS 	<ul style="list-style-type: none"> ▪ Both groups showed statistically significant differences in TUG, DGI, WDI, and LOS over time. ▪ LOS showed a significant difference between 2 groups ($p<0.05$). ▪ No significant difference was observed in terms of TUG, DGI and WDI.
<p>Moon and Bae (2019)</p>	<p>EG: backward walking (BW) observation video for 10mins, then performed BW training for 20 mins (7) vs CG: watched a landscape picture video for 10mins, then performed BW training for 20 mins (7)</p>	<p>30mins/day, 5x/week, for 4 weeks</p>	<ol style="list-style-type: none"> 1. DGI 2. 10MWT 3. TUG 	<ul style="list-style-type: none"> ▪ Both groups significantly increased DGI, 10MWT & TUG time between pre- and post-test. ▪ DGI ($p=0.04$), 10MWT ($p=0.04$), and TUG ($p=0.03$) significantly increased in the EG than CG.

Oh et al. (2019)	<p>EG: (Functional AOT) Watch a video of walking during daily activities for 15 minutes then walking training on a treadmill for 15 mins vs CG: (General AOT) Watch a video on increasing gait stability for 15 mins, then perform an exercise program to increase gait ability with a therapist for 15 minutes</p>	<p>30mins/day, 5x/week, for 4 weeks</p>	<ol style="list-style-type: none"> 1. Spatio-temporal gait measures (GAITRite) 2. FGA 	<ul style="list-style-type: none"> ▪ Step length, stride length, cadence, velocity, and FGA score in EG improve significantly in the CG ($p<0.05$).
Kleynen et al. (2019)	<p>AI: Analogy Instructions presented to participants pictorially with brief instruction (19) vs EC: Environmental Constraints (17) vs EG: Action Observation using demonstration and video observation (20)</p>	<p>A single-session trial. In all 3 groups, each condition was repeated 3x and a minimum of nine complete strides per condition was included in the analysis.</p>	<ol style="list-style-type: none"> 1. Motricity Index 2. BBS 3. RMI 4. FMA of lower limb 5. Spatio-temporal parameters: speed, step length, step width and step height (using the Vicon motion analysis system) 	<ul style="list-style-type: none"> ▪ AI: Three of the 4 applied analogies led to small but significant changes in walking speed, step height (on the affected side) and step width ▪ EG: Walking speed generally decreased but did not reach a significant level. ▪ EC: only the 'narrow beam component' showed a significant increase in step width.
Hioka et al. (2020)	<p>EG: Watch gait action video for 20mins, then train for 10mins (8) vs CG: Watch gait action video for 10 mins & non-gait video for 10 mins, then conducted non-gait training (8)</p>	<p>30 mins/day, 5x/week, for 3 months</p>	<ol style="list-style-type: none"> 1. FAC 2. 10MWT 3. NIHSS 4. BRS 	<ul style="list-style-type: none"> ▪ 10MWT showed significant improvement in the sub-assessment period for EG, but not for CG.

ABI: Anteroposterior balance index; **AI:** Analogy instruction; **AOT:** Action observation therapy; **AOTA:** Action observation therapy with activity; **BBS:** Berg balance scale; **BRS:** Brunnstrom recovery stage; **CG:** Control group; **DGI:** Dynamic gait index; **EC:** Environmental constraint; **EG:** Experimental group; **FAC:** Functional ambulation classification; **FGA:** Functional gait assessment; **FMA:** Fugl-Meyer assessment; **F8WT:** Figure of 8 walk test; **LOS:** Limit of stability; **MBI:** Mediolateral balance index; **mEFAP:** Modified functional ambulation profile; **MI:** Motor imagery; **MTA:** Mirror therapy with activity; **NDT:** Neurodevelopmental therapy; **NIHSS:** National institutes of health stroke scale; **OBI:** Overall balance index; **PT:** Physical training; **RMI:** Rivermead mobility index; **TS:** Tardieu scale; **TUG:** Time up and go; **WBLT:** Weight distribution index; **WDI:** Weight distribution index; **6MWT:** 6 minute walk test; **10MWT:** 10 meter walk test.

Despite Kollen and colleagues' findings, a study by Oh and colleagues has demonstrated that AOT's effectiveness in treadmill walking improved gait parameters more significantly than its effects on gait stability (Oh et al., 2019). This suggests that AOT when solely focused on gait, may not be sufficient to achieve the desired outcomes. In gait rehabilitation, it is important to include balance training to improve postural control and maintain the centre of pressure above the non-affected lower limb.

Additionally, the duration and intensity of AOT interventions varied across studies, highlighting the need for standardised protocols and further investigation into optimal training regimens. Past studies have suggested that improved functional capability in stroke patients is associated with increased intensity in rehabilitation training (Kollen et al., 2005). High-intensity practice is expected to promote the networking of motor neuron cells, which is the principle behind AOT (De Sousa et al., 2019). However, current evidence on brain neuroplasticity through AOT application remains somewhat uncertain, and further studies with similar duration intervals are needed for meaningful comparisons.

An investigation by Lee and colleagues revealed that a control group that observed videos without engaging in physical gait training showed no significant improvement in balance and ambulatory profiles compared to the experimental group (Lee et al., 2017). This finding suggests that practising observed gait might not be necessary for AOT gait intervention. However, this outcome contradicts the application of AOT for post-stroke upper limb intervention, where the combination of AOT and action training was found to be more effective than AOT alone (Lee et al., 2013). Differences in neuroanatomy, biomechanics, and physiological properties between upper and lower limbs may play a role in the effectiveness of AOT intervention.

Moreover, a notable finding by Kim and Sang-MiChung showed that implementing AOT as an individual treatment is not superior to group-based therapy for delivering AOT on gait outcomes after training (Kim & Sang-MiChung, 2016). This suggests that AOT can be effectively applied in a group format, allowing for broader access to stroke patients for treatment while optimising resources, particularly in facilities with a high volume of clients but limited therapists.

It is important to acknowledge that the studies included in this review excluded participants with major cognitive

problems, which limits the generalisation of the findings to the broader stroke population. The prevalence of cognitive dysfunction among stroke survivors varies widely, ranging from 20% to 80% (Sun et al., 2014). The effectiveness of AOT for participants with Parkinson's disease and mild cognitive issues has shown positive outcomes in gait (Rojasavastera et al., 2020). Perception and cognition are interrelated but distinct entities. Applying AOT, which activates the motor neuron system based on an individual's perception to execute physical movement, may be an effective tool in the early stages of motor learning. Future therapies involving AOT application should consider assessing an individual's perception and cognition.

Furthermore, while high-tech devices for explicit gait performance analysis are more common in clinical studies, their accessibility in a general clinical setting is limited, primarily due to cost considerations. Traditional outcome measures for gait assessment are more relevant in clinical settings as they are more accessible and practical. These traditional measures may be sufficient for assessing and predicting gait rehabilitation outcomes for post-stroke patients using AOT (Selves et al., 2020).

5.0 CONCLUSION

Incorporating AOT as an adjunct to standard physical approaches has yielded positive results, demonstrating its neurophysiological mechanisms and benefits in improving gait properties among stroke individuals. Several important considerations emerge for future studies on AOT in gait training for stroke survivors. First, it may be beneficial to explore more extended intervention periods to understand better the long-term effects and sustainability of AOT in gait rehabilitation. Second, the inclusion of balance and postural training as integral components of AOT interventions should be considered, as these aspects play a vital role in achieving comprehensive gait improvements. Lastly, the utilisation of perceptual evaluations as part of the assessment process should be explored. Such evaluations can provide valuable insights into patient selection, enabling identifying individuals who are more likely to experience significant improvements in gait functions and parameters through AOT. These future research directions will contribute to a deeper understanding of the potential of AOT in enhancing gait recovery for stroke survivors and further inform its integration into clinical practice.

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