FINAL CRITICALLY APPRAISED TOPIC:

Utilizing High Intensity Training for Improving Ambulatory Function after Stroke

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FOCUSED CLINICAL QUESTION

In patients recovering from a stroke (P), is high intensity training (I) more effective compared to low/moderate intensity training and no training (C) for improving ambulatory function (O)?

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CLINICAL SCENARIO

This question was inspired during my outpatient neuro rotation, where the therapists on the team began to implement intensity training more intentionally in the clinic. We began to investigate ways to measure the intensity of exercise/training and how to safely implement high intensity training into our practice as a consistent intervention. The caseload consisted of a varied population of age with the main diagnosis treated being subacute stroke.

Stroke is one of the largest causes of disability in adults worldwide and one of the leading causes of death in the United States.[1] For stroke survivors, walking - and doing so safely, independently, and efficiently - is a top priority for improved quality of life and health outcomes.[2] Higher intensities have been found to positively affect the induction of neural plasticity after a brain injury, with the research emphatically depicting that "Intensity Matters".[3] I am interested in investigating the effects of high-intensity training as it relates to functional outcomes during stroke rehabilitation. It is my hopes that reviewing this evidence will help expand my clinical toolbox to be able to accurately and appropriately prescribe and implement high-intensity exercise as an effective intervention for stroke patients.

SUMMARY OF SEARCH

Eight studies including three systematic reviews, two RCTs, one randomized clinical trial, and two secondary analyses of a RCT met criteria to be used in this search.

- High intensity training/exercise was shown to improve lower extremity functional task performance, gait speed, and gait kinematics in acute and subacute stroke patients when compared to interventions of lower intensities.[4-7]
- HIT and HIIT (high intensity interval training) was well-tolerated in stroke survivors with minimal to no adverse effects found in all studies investigated.[4-8]
- The full long-term effects of HIT on functional outcomes for stroke patients appears to be positive, but are difficult to fully gather. Further research with larger clinical populations, standardized outcome measures, and long-term follow up is recommended.

CLINICAL BOTTOM LINE

The available evidence suggests that high intensity training/exercise is more effective than exercise at lower intensities, normal physical therapy, and usual physical activities for improving ambulatory function. It has been shown to be feasible and safe to implement for patients in the acute, subacute, and chronic stages post-stroke.[4-7]

This critically appraised topic has been individually prepared as part of a course requirement and has been peer-reviewed by one other independent course instructor

SEARCH STRATEGY

Terms used to guide the search strategy			
Patient/Client Group	**I**ntervention (or Assessment)	**C**omparison	**O**utcome(s)
Stroke, CVA	High intensity training, high intensity interval training, HIT, HIIT, gait training	Low intensity training, moderate intensity training, no training	Gait, walk, walking, ambulate, ambulation, ambulatory function, balance, function, functional mobility

Final search strategy:

(stroke OR CVA) AND (low intensity training OR moderate intensity training OR high intensity training OR high intensity interval training OR HIT OR HIIT) AND (gait OR step* OR ambulat* OR walk* OR mobility)

(stroke OR CVA) AND (high-intensity OR high intensity interval training OR HIT OR HIIT) AND (gait OR step* OR ambulat* OR walk* OR mobility)

Filters applied (PubMed): Free full text, Meta-Analysis, Randomized Controlled Trial, Systematic Review.

Databases and Sites Searched	**Number of results**	**Limits applied, revised number of results (if applicable)**
PubMed	**272**	Filters applied (PubMed): Free full text, Meta-Analysis, Randomized Controlled Trial, Systematic Review. **29 results**
PEDro	**77**	Sub-discipline: neurology
Cochrane	**236**	0 Cochrane Reviews matching criteria, 236 trials found

RESULTS OF SEARCH

Summary of articles retrieved that met inclusion and exclusion criteria

Author (Year)	Risk of bias (quality score)*	Level of Evidence**	Relevance	Study design
Munari D (2018)	PEDro 8/10	Level 2; RCT	High	Randomized, controlled pilot study
Gjellesvik TI (2021)	PEDro 7/10	Level 2; RCT	Low; VO2 max was main outcome	Single-blind, multicenter, parallel group, randomized controlled trial.
Lamberti N (2017)	PEDro 7/10	Level 2; RCT	Moderate	Two-arm, parallel group, pilot randomized controlled clinical trial.
Mah SM (2022)	All studies in SR PEDro 5/10 or above, 4/7 included studies with some concerns on RoB 2 scale.	Level 1; SR of RCTs	High	Systematic Review
Ardestani (2020)	PEDro 4/10	Level 3 due to study design	High	Secondary analysis of a RCT
Hornby TG (2022)	PEDro 5/10	Level 3 due to study design	High	Secondary analysis of a RCT
Anjos (2022)	Mean methodological quality score of 7.2/10 on PEDro scale (range from 6-8/10)	Level 1; SR of RCTs	Moderate	Systematic Review
Luo L (2019)	Cochrane Risk of Bias Tool (RoB 2)l 6.22 studies with high risk of bias in 1 domain or more.	Level 1; SR of RCTs	High	Systematic Review

BEST EVIDENCE

The following 2 studies were identified as the 'best' evidence and selected for critical appraisal. The rationale for selecting these studies was:

- Mah SM, Goodwill AM, Seow HC, Teo WP. Evidence of High-Intensity Exercise on Lower Limb Functional Outcomes and Safety in Acute and Subacute Stroke Population: A Systematic Review. Int J Environ Res Public Health. 2022;20(1):153. Published 2022 Dec 22. doi:10.3390/ijerph20010153
- Luo L, Zhu S, Shi L, Wang P, Li M, Yuan S. High Intensity Exercise for Walking Competency in Individuals with Stroke: A Systematic Review and Meta-Analysis. J Stroke Cerebrovasc Dis. 2019;28(12):104414. doi:10.1016/j.jstrokecerebrovasdis.2019.104414

I selected these two articles for critical appraisal after review. Both articles are level 1 evidence. They are both systematic reviews of randomized controlled trials and directly investigated my clinical question with interventions of high-intensity exercise. I thought these systematic reviews included more substance and analysis than the RCTs did alone. Both articles investigated outcomes relevant to walking/ambulatory function such as gait speed and the 6MWT. I am pleased with the evidence found in these 2 articles and excited to move on to critically appraising them.

SUMMARY OF BEST EVIDENCE

(1) Description and appraisal of "Evidence of High-Intensity Exercise on Lower Limb Functional Outcomes and Safety in Acute and Subacute Stroke Population: A Systematic Review" by Mah SM, Goodwill AM, Seow HC, and Teo WP; 2022.

Aim/Objective of the Study/Systematic Review:

The authors' aim of this study was to investigate the effects of high-intensity exercise (HIE) on lower limb (LL) function in acute and subacute stroke patients.

They addressed 2 main questions:

- (1) Is HIE effective for improving LL functional outcomes in the acute and subacute stroke population (0–6 months post-stroke)?
- (2) Is the implementation of HIE safe in acute and subacute stroke settings?

Study Design

Study Design: Systematic Review. This study consisted of randomized controlled trials comparing an intervention group of high intensity exercise to a control group of lower intensity exercise or no intervention.

Search Strategy: The authors performed a systematic search in the databases PubMed, Web of Science, and CINAHL (EBSCOhost) up until 30 June 2022. They utilized the 5 main keywords of "stroke", "intensity training", "high intensity training", "acute" or "subacute", and "functional outcomes" with Boolean Operators (AND, OR) to include related terms and all 5 keywords in the final search.

Selection Criteria:

Inclusion Criteria: Articles that were included fulfilled the following 5 criteria:

(1) Randomized controlled trials (RCTs) which fulfilled the following criteria: Active or passive control group as comparator; Adults aged 18 years and above; Any form of stroke; Stage of stroke: Acute (0–3 months) and subacute (3–6 months). (2) Articles had to include a detailed description of the exercise intervention; (3) The intervention group had to meet the target of HIE; (4) The control group had to have a lower intensity training, or no exercise intervention; (5) All studies had to include a LL functional outcome measure.

Exclusion Criteria: Unpublished and ongoing trials, as well as articles that were not published in English were excluded.

Methods: This systematic review followed the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Titles and abstracts of the references retrieved from the search to identify studies that satisfy the inclusion criteria were screened by two researchers (SMM and HCS) independently. Studies that did not fulfill the inclusion criteria were excluded and full text articles of potentially relevant content were retrieved. Any conflicts in study inclusion/exclusion during the title, abstract and full-text article screening were first resolved by discussion between the two researchers, and if no resolution was achieved, the recommendation of a third researcher (WPT) would be solicited.

Setting

This systematic review was conducted by 4 researchers in Singapore, supported by The Department of Physiotherapy of Sengkang and Singapore General Hospitals.

Included studies were conducted in the following settings: inpatient units, inpatient stroke units, inpatient/outpatient clinics, inpatient rehabilitation wards, and home-based.

Participants

N: 944 participants across 7 studies were included in this review.

Diagnosis: Acute or subacute stroke (from 0 months up until 6 months post-stroke)

Key Demographics: Mean age across 7 studies ranging from 50 to 79.2; number, age, and duration since stroke (days) all comparable at baseline.

Drop-out rate: 3.6-15.6% for follow up assessments across 7 studies.

Intervention Investigated

Control

4/7 included studies had control groups who did conventional physiotherapy at lower intensities including functional training, balance, strengthening, stretching, and seated group and walking exercises with a physical therapist.

Duration of sessions ranged from 11-60 minutes, at a frequency of 2-6 times per week for 4-12 weeks.

The remaining 3 groups used a passive control group that provided education and advice on post-stroke symptoms, medication, lifestyle changes, and exercise.

Experimental

All 7 studies used functional training or movements and high intensity walking/stepping within the exercise regime in the intervention group. Modalities such as treadmill training, cycling, and ergometer cycling were used. Intensity of exercise was measured using heart rate reserve (HRR), peak heart rate (HR)., and/or the Borg rating of perceived exertion (RPE) scale.

Duration of sessions ranged from 11-60 minutes, at a frequency of 2-6 times per week for 4-12 weeks.

Outcome Measures

Main outcomes measured lower limb function and activities of daily living that reflect the level of impairments post-stroke. Primary outcome measures included: the 6 minute walk test (6MWT), gait speed, steps per day, Berg Balance Scale (BBS), and the Barthel index (BI). Secondary outcomes included reports of adverse events because of the intervention.

Outcomes were administered at baseline, post-intervention, and at follow-up (if conducted). A total of four studies investigated 6MWT, three looked at BBS, three at maximal gait speed, and one at self-selected gait speed, one used physical activity as measured by total steps/day, and two studies investigated BI.

Main Findings

6MWT: Three of four studies found significant improvement in 6MWT walking distance in the intervention group (IG) compared to the control group (CG).

- Significant difference for 6MWT in favor of IG $p = 0.001$; Significant difference for 6MWT in favour of IG $p = 0.011$; Significant difference in favor of IG (HIE): 124.3 ± 78.13m compared to CG: 62.8 ± 66.25m
- In one RCT, the group differences were not statistically significant for 6MWT $p = 0.12$;

Gait Speed: Three studies measured gait speed, with all RCTs finding significant improvements in the group performing HIE/HIT compared to the control groups.

- One study measured both maximal and self-selected gait speed finding significant differences in favor of IG for both ($p = 0.002$ and $p = 0.006$, respectively).
- Significant improvements in peak speed favoring IG over CG, 0.48 ± 0.31 versus 0.13 ± 0.17 m/s respectively, $p < 0.01$.
- Significant difference for maximal gait speed in favor of IG, $p = 0.003$

Berg Balance Scale: Only one study of three found a meaningful difference on the Berg Balance Scale in the high intensity exercise group compared to passive and active control groups. (IG 2: 6.8 ± 6.28; IG 1: 4.6 ± 6.29; CG: 2.8 ± 4.51)

Barthel Index: One study noted improvements in the high-intensity group compared to an active control group post-intervention (IG: 27.2 ± 8.92; CG: 10.3 ± 7.94) Another study only found significant difference in favor of IG for the BI at 6 months follow up, p = 0.05.

Steps Per Day: Only one study measured steps-per-day, finding no statistical difference between groups in total steps/day (p = 0.8).

Adverse Events: No major adverse events were reported during intervention.

- Five RCTs reported no adverse events during the study period.
- One study reported minor adverse events including joint and back pain, bruises, and scrapes.
- One study did not report any adverse events during intervention, but reported falls outside of the training sessions during the study period. There was no significant difference in fall related injuries between groups.

Original Authors' Conclusions

The original authors found that high intensity exercise can be effective at improving motor function in acute and subacute stroke patients, and concluded that supervised HIE is able to be safely implemented with good adherence and minor adverse events. They indicated that caution should still be used when interpreting these findings due to the limitations in studies that they were able to include. Finally, they concluded that more work should be done looking into proper recommendations for exercise prescription in the different stages of stroke recovery to optimize neurorehabilitation.

Critical Appraisal

Validity

AMSTAR score: 8/11: priori design provided: yes; duplicate study selection and data extraction: yes; comprehensive literature search performed: yes; status of publication used as an inclusion criteria: yes; list of studies provided: yes; characteristics of included studies provided: yes; scientific quality of included studies assessed: yes; scientific quality used appropriately in forming conclusions: no; methods used to combine findings appropriate: n/a; likelihood of publication bias assessed: no; conflict of interest included: yes

AMSTAR 2 Results: Moderate quality review.

All studies included in SR were scored 5/10 or above on the PEDro scale, indicating that the methodological quality of the RCTs was medium-high. Four of the seven included studies had "some concerns" on the RoB 2 scale.

Key Strengths:

- All trials were randomized
- All trials had blinded assessors who measured at least one of the key outcomes
- All studies presented the results of between-group characteristics and statistical comparisons, and baseline outcomes in the comparison groups were similar.
- No studies included had a high risk of bias on the RoB 2 tool.

Key Weaknesses:

- None of the included trials had blinded therapists or blinded participants.
- Limited follow-up time in conducted studies to measure long-term results and effect sizes, with some studies having no follow-up.
- Small sample size and amount of included trials (seven) for a systematic review.
- High heterogeneity of various interventions, implementation strategies, and outcome measures used, resulting in limited ability to generalize results.

Interpretation of Results

This systematic review presents moderate quality evidence for the use of high intensity exercise/training for acute/subacute stroke patients to improve functional mobility. The review is admittedly limited by the small sample size and amount of high quality studies available for inclusion. The authors made consistent efforts to reduce bias, acknowledge limitations, and discuss relevant evidence. Their methods for searching for and selecting studies was detailed and easy to follow. I think that the AMSTAR and AMSTAR 2 results are an accurate representation of the quality of this review.

The results of this review are promising, as the majority of the results indicate that HIE had a significant effect on many of the primary outcome measures compared to control groups of lower intensities. Five out of the seven studies showed significant gains in functional outcomes related to walking after a period of high intensity training. The two measures directly measuring aspects of walking ability (the 6MWT and max gait speed) demonstrated significant differences compared to the control groups. There is moderate quality evidence that

high intensity exercise is more effective than training at lower intensities for lower limb functional outcomes post-stroke. It is also a safe intervention as there were no significant adverse effects noted throughout the study period of all trials. Caution is still advised until a study with larger populations, standardized outcome measures, and long-term followup can be done.

Applicability of Study Results

This review is very applicable to my clinical question and scenario. The studies included in the review consisted of key demographics that would commonly be seen in our specific clinic, and the interventions used were similar to the interventions that we were seeking to implement.

I would have preferred to have more homogeneity in the outcomes used and intervention/control groups across studies. There was a large amount of variation between studies in training parameters, with specific implementations of high intensity exercise ranging from stepping exercises to cycling. There is not one specific protocol or prescription to follow, and no single recommendation of what to do. One could argue, however, that this adds to the versatility as an intervention and allows a skilled clinician to creatively individualize the implementation of various methods to each patient at a heightened intensity.

High intensity training is a feasible and practical intervention, and may be immediately implemented in the clinic. It has been shown to be safe when performed with supervision. Due to the supporting evidence in this review, high intensity exercise is an applicable intervention for improving ambulatory function in acute/sub acute stroke patients.

(2) Description and appraisal of "High Intensity Exercise for Walking Competency in Individuals with Stroke: A Systematic Review and Meta-Analysis" by Luo L, Zhu S, Shi L, Wang P, Li M, and Yuan S; 2019.

Aim/Objective of the Study/Systematic Review:

To assess the effects of high intensity exercise on walking competency in individuals with stroke.

Study Design

Study Design: Systematic Review and Meta-Analysis of randomized controlled trials investigating the effects of high intensity exercise on walking in stroke survivors.

Search Strategy: The databases PubMed, EMBASE, Web of Science, Cochrane Central Register of Controlled Trials (CENTRAL), CINAHL (EBSCOhost), and SPORTSDiscus (EBSCOhost) were searched up to June 25, 2019. The authors utilized the keywords of "stroke", "intensity training", and "high intensity training" with Boolean Operators (AND, OR) to include related terms and all keywords in the final search.

Selection Criteria: The authors used the following criteria for selection.

(1) Study design: all randomized controlled trials or clinical controlled trials; (2) Patients: individuals (≥18 years of age) at acute, subacute, or chronic stages of stroke recovery; (3) Intervention: A detailed description of the high intensity exercise intervention, including intensity, duration, and frequency; (4) Control: low to moderate intensity exercise (<60% HRR/VO2peak, <70% HRmax, or <14 RPE), usual physical activities or no any exercise interventions; (5) Outcomes: 6MWT, gait analysis (cadence, stride length and the gait symmetry), Cw, BBS, TUG, comfortable gait speed (only speeds identified as comfortable, habitual, or self-selected were included; fast gait speed was excluded). The secondary outcome measures included adverse events (eg, falls, pain, and injuries). And the study statistic could be transformed into an effect size (eg, means/standard deviation [SD], 95% CI and/or P values); (6) The included studies were further limited to be published in English. Conference abstract, case reports, observational studies, and studies without available data were excluded.

Methods: The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) Statement Guidelines were followed for this review and analysis. Data extraction was performed based on the Cochrane Handbook for Systematic Reviews.

Setting

This review was conducted in China by members of the Department of Rehabilitation Medicine of Fudan University (Shanghai, China), Ningxia Medical University (Ningxia, China), and Taihe Hospital (Shiyan, China).

Participants

N: 952 participants from 22 total trials (21 randomized controlled trials and 1 controlled trial).

Key Demographics: Mean ages ranged from 45-71.3 years. Mean duration since stroke range from 4.9 days to 5.2 years. 600 (63%) of the participants were male, and 352 (37%) were female.

Diagnosis: Stroke/Cerebral Vascular Accident (CVA)

Intervention Investigated

Control

The control group performed 28-45 minutes aerobic exercise (ie, underground walking, stretching exercise, usual physical therapy) at planned intensities below 50% HRR/VO2peak.

Experimental

All intervention groups utilized high intensity training in various modes. The intensity of exercise (range 60%-85% HRR/VO2peak) and total time (range 25-50 minutes, with most training lasting 30 to 40 minutes [n = 18]) as well as weekly frequency (range 2-5 times, with most training 3 times per week [n = 11]) and duration (range 4-24 weeks, with 11 studies being between 8 and 12 weeks in length) varied widely between the 22 studies.

Various modes of high intensity exercise included treadmill training (13 studies) and cycle ergometer (9 studies).

Outcome Measures

Primary outcomes used were assessments measuring either gait kinematics or functional balance and mobility. These measures included: The 6 minute walk test (6MWT), comfortable gait speed, cost of walking, stride length, cadence, gait symmetry, Berg Balance Scale (BBS), Timed Up and Go (TUG). Secondary measures included falls, pain, and injuries.

Outcomes were measured at baseline, post-intervention, and the first follow-up if available.

Walking distance was measured in 17 studies among 777 participants, comfortable gait speed in 11 studies (n = 345), cost of walking in 5 studies (n = 146), stride length and cadence in 4 studies (n = 117), gait symmetry in 4 studies (n = 128), BBS in 7 studies (n = 363), and the TUG in 4 studies (n = 120).

Main Findings

After sensitivity analysis, the results showed significant improvements in walking distance, comfortable gait speed, stride length, and TUG in favor of high intensity exercise groups compared to control groups of lower intensities. Standardized mean difference (SMD), weighted mean difference (WMD), and odds ratio (OR) were used to compute effect size.

- Walking distance (SMD = .32, 95% CI, .17-.46, P < .01, I2 = 39%; WMD = 21.76 m)
- Comfortable gait speed (SMD = .28, 95% CI, .06-.49, P = .01, I2 = 47%; WMD = .04 m/s)
- Stride length (SMD = .51, 95% CI, .13-.88, P < .01, I2 = 0%; WMD = .12 m)
- TUG (SMD = -.36, 95% CI, -.72 to .01, P = .05, I2 = 9%; WMD = -1.89 s)

No significant differences in adverse events were found between the high intensity exercise and control group.

- Falls (OR = 1.40, 95% CI, .69-2.85, P = .35, I2 = 11%)
- Pain (OR = 3.34, 95% CI, .82-13.51, P = .09, I2 = 0%)
- Skin injuries (OR = 1.08, 95% CI, .30-3.90, P = .90, I2 = 0%)

Original Authors' Conclusions

The authors concluded that evidence suggests that high intensity has the potential to be a safe and more powerful stimulus in improving walking abilities in stroke patients. They concluded that high intensity exercise has the capacity to improve walking distance, comfortable gait speed, stride length, and dynamic balance compared to exercise of lower intensities or usual physical activities. They also showed that a high intensity exercise program with parameters of 70%-85% HRR/VO2peak, 3-5 times lasting 30-40 minutes per week for 8-12 weeks as beneficial for improving walking in subacute/chronic stroke patients.

Critical Appraisal

Validity

AMSTAR Score: 10/11: priori design provided: yes; duplicate study selection and data extraction: yes; comprehensive literature search performed: yes; status of publication used as an inclusion criteria: no; list of studies provided: yes; characteristics of included studies provided: yes; scientific quality of included studies assessed: yes; scientific quality used appropriately in forming conclusions: yes; methods used to combine findings appropriate: yes; likelihood of publication bias assessed: yes; conflict of interest included: yes

AMSTAR 2 Results: High quality review

Methodological quality was assessed by two authors using the Cochrane risk of bias tool. Quality of evidence was assessed using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) system and ranged from low-moderate.

- Moderate Level GRADE outcomes: walking distance, comfortable gait speed, stride length, TUG, pain
- Low Level GRADE outcomes: cost of walking, cadence, gait symmetry, BBS, falls, injuries
- Tang et al were assessed to be at high risk of bias in random sequence generation due to the prospective matched control design of the study.

Key Strengths:

- High scores/results on AMSTAR and AMSTAR 2.
- Thorough meta-analysis conducted with sub-group analysis and discussion and explanation of results.
- Standard mean differences, weighted mean differences, odds ratios, and p values readily available for determining effect sizes of results.
- Investigation of publication bias and admission of potential areas of bias/limitations of study.

Key Weaknesses:

- Drop-outs were not listed or accounted for in the study characteristics. An intention to treat analysis was not conducted in most included studies.
- One included study was not randomized. Another included study demonstrated high risk of bias on the Cochrane risk of bias tool.
- The settings of studies was not included in the study characteristics or in the article.
- Heterogeneity across studies (highly variable interventions/controls/frequency/duration, etc.) limits the generalizability of results and reliability of the review.
- Low number of studies for various outcomes and for subgroup analysis.

Interpretation of Results

This is a high quality review, with moderate level evidence supporting the use of high intensity exercise as an intervention for improving walking in stroke patients. Overall, I think this systematic review and meta-analysis has important findings with large effect sizes supporting this intervention with use in stroke patients. Important outcomes related to walking such as comfortable gait speed, stride length, and improved walking distance were found to be significantly better with high intensity exercise compared to lower intensity training and usual activities. Furthermore, poststroke high intensity exercise training was found to be safe, with no differences compared to control groups in regards to falls, pain, skin injuries, and other adverse events. Interestingly, outcomes of cost of walking, cadence, and BBS were not significantly different between groups but were discussed appropriately.

I would still take some amount of caution with these results due to the amounts of heterogeneity across the high intensity exercise intervention groups and with some risk of bias and low reliability due to small sample sizes in specific outcome measures. There are limitations in both this systematic review and the current available evidence, with the authors calling out the need for more large high-quality RCTs to be conducted on this topic. I believe that while there are limitations, this review demonstrates a strong case for the use of high intensity exercise for stroke patients.

Applicability of Study Results

This review and meta-analysis is very relevant to the diagnosis, population, intervention, comparison, and outcome in my clinical question. The intervention is very applicable for use in the clinic, and this study also presented an easy to follow protocol that was proven to be effective. Additionally, cycle ergometry and treadmill training are both modes of high intensity training that would be easily implemented in the clinic as it already features the necessary equipment. Based on the results of significantly increased walking distance, speed, and stride length and safe implementation, I would definitely consider the use of high intensity exercise as a primary intervention for improving walking in the clinic. More research is still necessary for optimal outcomes, programs, and protocols among various subgroups however I think this review does a good job of laying a foundation of evidence to set up effective implementation into clinical practice. Additionally, it demonstrates the applicability of this intervention for acute, subacute, *and* chronic stroke patients.

SYNTHESIS AND CLINICAL IMPLICATIONS

High intensity exercise/high intensity training has been demonstrated as an effective intervention for improving ambulatory function in stroke patients. Systematic reviews by Luo, et al. (2019) and by Mah, et al. (2022) demonstrate significant improvements in gait related primary outcomes such as 6MWT walking distance, gait speed, and stride length compared to exercise at lower intensities, normal physical therapy, and usual physical activities.[5,7] Additionally, no adverse effects were reported across both reviews. Both of these systematic reviews consisted of randomized controlled trials and no significant differences were noted between groups for pain, fall risk, and other secondary outcomes.[5,7] This evidence indicates that not only is HIE/HIT effective for improving function, it is relatively safe for clinical practice as well.

Further implications for research include the necessity for more high-quality trials with large patient populations, standardized outcome measures, and longer follow up periods to measure retention. Additionally, there is a need for specific rehab parameters to implement optimal high intensity exercise. Various modes have been shown to be effective including treadmill and cycle ergometry training, namely, and further research on the effects of different modes of HIE on lower limb functional outcomes is still unclear.

In conclusion, I believe that the available evidence from these two reviews has sufficiently answered my clinical question of: *"In stroke patients (P), is high-intensity training (I) more effective compared to low/moderate intensity training and no training (C) for improving ambulatory function (O)?"* While there are some limitations that I noted above and more research is needed, there is moderate evidence that suggests, yes, high intensity training is safe and more effective for improving walking in stroke patients than training/exercising at lower intensities.

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