CRITICALLY APPRAISED TOPIC

FOCUSED CLINICAL QUESTION

In a 65-year old woman with decreased gait speed due to stroke, is an intervention including centre of mass stability effective in improving functional mobility?

AUTHOR

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CLINICAL SCENARIO

In the general neurological unit, I noticed many stroke patients were discharged ambulating with persistent, slow, asymmetric gait. Even if they were able to achieve even close-to-normal walking speeds, a recurring pattern noticed was a stop-and-go energy-consuming gait. This pattern was not only exhausting to patients, but it also decreased their dynamic balance capabilities and likely would cause secondary musculoskeletal issues down the road. One patient in particular received inpatient therapy services for 2 weeks post-stroke and scored just below the stroke cut-off score for risk of falling in the TUG. Undeniably, there is further progression to be made in outpatient therapy services. However, if there are improvements that could be added to her gait training, then potentially her total amount of therapy required may be reduced and her functional mobility improved. Force at the COM specifically during gait training is an intervention I did not witness while on rotation. Furthermore, this potential therapeutic intervention offers clinicians a feasible means to improve their patients' community ambulation abilities and therefore physical activity by addressing a dysfunction that they may be over-looking (that is, COM progression).

SUMMARY OF SEARCH

[Best evidence appraised and key findings]

- Three databases were searched and ten relevant studies were identified including: 2 RCTs, 2 cross-sectional observational studies, 3 quasi-experimental designs and 2 non-experimental case-control designs and 1 non-experimental cohort design. After critical appraisal, 3 studies were reviewed in detail.
- Interventions with CoM manipulation included functional electrical stimulation with treadmill walking, visual CoM biofeedback and overground robotic walking assistance.
- These interventions demonstrated improvements one or more of the following: gait parameters, balance, faster walking speeds and gluteus medius and tibialis anterior strength.

CLINICAL BOTTOM LINE

Currently, the best evidence suggests that an intervention involving manipulation of CoM during ambulation can improve some aspects of function for a chronic stroke survivor. Use of visual biofeedback regarding CoM movement and treadmill walking with concurrent functional electrical stimulation of the paretic gluteus medius and tibialis anterior are two potentially beneficial training interventions in terms of gait quality improvement. If feasible, providing propulsive forces at the CoM during overground walking with use of an engineered robotic device may specifically facilitate faster walking speeds, however this is obviously dependent on access to a safe, tested robotic device. Clinically, a PT could incorporate interventions revolving around the CoM into some of their gait training sessions with the potential to improve overall gait quality with use of established outcome measures for justification. This may be especially useful in patients with notable compensatory patterns involving the CoM.

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

The above information should fit onto the first page of your CAT

SEARCH STRATEGY

Terms used to guide the search strategy			
Patient/Client Group	**I**ntervention (or Assessment)	**C**omparison	**O**utcome(s)
Stroke CVA Cerebrovascular accident	Gait Walk* Ambulat* Center of mass Pelvic stability Stabiliz*	(no comparison)	Mobility Function Speed velocity

Final search strategy:

Show your final search strategy from one of the databases you searched. In the table below, show how many results you got from your search from each database you searched.

1. Stroke OR cerebrovascular accident OR CVA
2. Gait OR walk* OR ambulation OR ambulate* OR mobility OR speed
3. Center of mass OR pelvic stability OR stabiliz*
4. #1 AND #2 AND #3

Databases and Sites Searched	**Number of results**	**Limits applied, revised number of results (if applicable)**
Pubmed	219	Added "[TIAB]" after "center of mass" = 134 Added search line stating "function* OR capacity" = 63 Added to 3rd line: "posture OR postural stability" = 289
CINAHL Plus with Full Text	20	Added limit that "center of mass OR pelvic stability OR stabilize" appears in abstract = 19
Academic Search Premiere	33	Added criteria "center of mass OR pelvic stability OR stabilize" appears in abstract = 29

INCLUSION and EXCLUSION CRITERIA

Inclusion Criteria
• Randomized controlled trials, controlled trials, uncontrolled trials • Published up to July 2015 • A protocol with physical intervention • A literature review of gait post-stroke • Studied a "stroke, chronic stroke or post-stroke" population • Measured gait speed, kinematics, functional mobility and/or gait impairments • Investigated centre of mass (COM), pelvic movement and/or stability at the COM or pelvis as an intervention • Published in English

Exclusion Criteria
• Studies that involved non-ambulatory adults • Studies that involved stroke participants with other diagnoses that limit their functioning (other neurological, cardiopulmonary, or orthopedic conditions) • Case studies or case series • Abstracts, conference proceedings, letters to the editor, dissertations

RESULTS OF SEARCH

Summary of articles retrieved that met inclusion and exclusion criteria

For each article that meets your inclusion and exclusion criteria, score for methodological quality on an appropriate scale, categorize the level of evidence, and note the study design (e.g., RCT, systematic review, case study).

Author (Year)	Study quality score	Level of Evidence	Study design
Kyung-Pil Na et al. (2015)[1] Evidence that a horizontal force at the upper body CoM improves gait and dynamic balance more than treadmill training alone; statistically significant difference between control and experimental groups TUG scores	**5/11 (PEDro)**	**4**	**RCT**
Carmen E Capó-Lugo et al. (2012)[2] Demonstrates that intervention involving COM stability using overground robot is able to increase patients' ability to walk at maximal speeds due to reduced fear of falling and increased perceived safety.	**7/11 (PEDro)**	**1b**	**Cross-sectional observational study**
Firas Massaad et al. (2010)[3] After a 10-hour training program with CoM biofeedback, the vertical CoM displacement decreased by 10%, which was associated with a marked 30% decrease in walking energy cost, a 47% increase in paretic knee flexion in swing, a 10% decrease in muscle work and furthermore, at 6 month follow-up, maintenance of decreased energy cost (15%) with respect to pre-training gait analysis.	**13/29 (Downs&Black)**	**4**	**Quasi-experimental design (Pilot Study)**
Peggy R Trueblood et al. (1989)[4] PNF-driven pelvic exercises were imposed as 4 sets of 5 graded resistance movements with 1-minute rest breaks. Gait analysis was done prior to exercises, immediately after exercises and 30-mins after exercises. Overall response to treatment showed significant gait improvement immediately after intervention	**5/11 (PEDro)**	**4**	**Quasi-experimental study**

but was not maintained at 30-min post-test.			
Toshiki Kobayashi et al. (2012)[5] Investigated only 5 post-stroke patients and how their walking changed with and without use of AFO. Use of an AFO significantly increased vertical displacement of the COM during stance phase of gait on the affected leg. Also there was a significant increase in gait speed & bilateral step length along with a significant decrease in step width while wearing an AFO. Authors suggest that displacement of the COM can therefore potentially serve as a useful measure to evaluate the effect of an AFO together with other gait parameters.	**14/29 (Downs&Black)**	**4**	**Quasi-experimental design (Pilot study)**
Rumpa Boonsinsukh et al. (2009)[6] Authors showed that light touch stimulus for optimal force loading through a cane improves lateral stability during stroke gait. This demonstrates rationale for augmented sensory information targeted to facilitate activation of weight-bearing muscles on the paretic leg during the stance phase for improved stability.	**18/29 (Downs&Black)**	**2b**	**Cross-sectional observational study**
Min-Kwon Cho et al. (2015)[7] Participants who underwent treadmill training with FES (functional electrical stimulation) of gluteus medius and TA had greater improvement in GM and TA muscle strength, balance function and in gait function compared to those who underwent treadmill training + FES of the TA only and treadmill training only.	**6/11 (PEDro)**	**2b**	**RCT**
G. Stoquart et al. (2012)[8] By observation, the patients expend more energy to walk than healthy subjects and this increase in energy cost was not explained by their slow walking speed but rather by mechanical work required for the non-paretic LE to lift the body's center of mass while it is in stance phase. From findings, authors propose potential benefit to interventions involving COM manipulation to reduce energy costs of walking.	**14/29 (Downs & Black)**	**2b**	**Non-experimental case-control design**
Aline Araujo do Carmo et al. (2015)[9] CoM trajectory was altered in post-stroke individuals compared to healthy norms in	**13/29 (Downs & Black)**	**2b**	**Non-experimental Case-control**

both the swing and stance phases of the paretic LE. In stance phase on paretic LE, CoM vertical and forward displacement was less, while the lateral displacement was greater. Lower CoM elevation during stance may be due to spasticity and/or muscle weakness. Finally, faster change of CoM's lateral velocity seen in post-stroke patients could possibly explain the increased energy expenditure others studies report.			
Yi-Chung Pai et al. (1994)[10] Stroke participants underwent SLS trials while CoM movement was measured. There was no significant difference between peak displacement of CoM between stance phases on the paretic and non-paretic sides. Higher failure rates of SLS on the paretic side were, therefore, found to be due to inability to *maintain* CoM over BOS, rather than how far the CoM was displaced on either side.	**16/29 (Downs & Black)**	**4**	**Non-experimental cohort**

(All 10 articles should appear in the reference list at the end)

BEST EVIDENCE

The following 3 studies were identified as the 'best' evidence and selected for critical appraisal. Reasons for selecting these studies were:

- **Carmen E Capó-Lugo et al. (2012)**[2] This study included detailed participant characteristics, thoroughly reported why and when adherence was poor, described their intervention is great depth, randomized order of conditions for each participant, included a table further defining their outcomes of interest, normalized force production to each individual, tested equipment in pilot study using healthy norms and reported *individuals* scores on outcomes along with group means and SD. Additionally, after calculating the 95% CI between robotic push-mode and treadmill speeds, this study proves to have a very narrow CI, indicating higher level of evidence according to Jewell.[11]
- **Firas Massaad et al. (2010)**[3] Though this study is only a pilot study, it is one of the only investigations that actually includes a feasible intervention. In other words, though it lacks external validity and has lower power, it is the most relevant article related to this clinical question. Its strengths include: report of actual probability values, assessment of valuable outcomes including walking energy cost, vertical CM displacement, kinematics, and EMG activity before and after treatment, thorough description of participants, detailed procedural reporting, patient-matched conditions (i.e. comfortable walking speed) and 6 month follow-up.
- **Min-Kwon Cho et al. (2015)**[7] This study was actually a RCT, a rarity in the literature for this topic. It lacked blinding, but did randomly allocate participants to difference groups, used reliable and valid outcomes and reported ICC's, described its protocol in-depth even down to exact electrode location, reported actual p values and maintained consistent measurements of all participants (no drop-outs).

SUMMARY OF BEST EVIDENCE

(1) Description and appraisal of Maximum walking speeds obtained using treadmill and over-ground robot system in persons with post-stroke hemiplegia" **by** Carmen E Capó-Lugo, Christopher H Mullens and David A Brown, 2012.[2]

Aim/Objective of the Study/Systematic Review:
The aim of the study is to test a robotic system (the KineAssist Gait and Balance Training System™) that works to

"push" subjects forward at very high over-ground walking speeds (up to 2.0m/s) while providing the safety of harness support and careful pelvic-drop detection system.[1] With that, this study aimed to determine the capacity of stroke survivors to walk at faster walking speeds on a treadmill versus overground with robotic pushing assistance.

The author's also aimed to test three hypotheses: 1) that participants would walk at faster speeds with the robotic system in "push mode" than selected maximal walking speeds over-ground and 2) that step length and cadence would increase with incremental increases in speed and 3) to observe what speeds consistently produced a loss of balance.[1]

Study Design

[e.g., systematic review, cohort, randomised controlled trial, qualitative study, grounded theory. Includes information about study characteristics such as blinding and allocation concealment. When were outcomes measured, if relevant]

Note: For systematic review, use headings 'search strategy', 'selection criteria', 'methods' etc. For qualitative studies, identify data collection/analyses methods.

This study was a cross-sectional observation study because four different conditions were tested in each individual in one session: 1) over-ground 5-meter walk test (5-MWT) at self-selected comfortable walking speed (SCWS) and 2) maximal speed (SMWS) 3) a graded treadmill 5-MWT and 4) an over-ground graded 5MWT with the KineAssist pushing at the centre of mass ("push mode").

Setting

[e.g., locations such as hospital, community; rural; metropolitan; country]

The study's testing took place in the Department of Physical Therapy and Human Movement Sciences at Northwestern University, where recruitment was done by an individual licensed physical therapist.

Participants

[N, diagnosis, eligibility criteria, how recruited, type of sample (e.g., purposive, random), key demographics such as mean age, gender, duration of illness/disease, and if groups in an RCT were comparable at baseline on key demographic variables; number of dropouts if relevant, number available for follow-up]

Note: This is not a list of the inclusion and exclusion criteria. This is a description of the actual sample that participated in the study. You can find this descriptive information in the text and tables in the article.

A purposive sample of 18 post-unilateral stroke individuals were recruited from a local database and all 18 completed the study entirely (9 males, 9 females). All the participants were medically stable and had residual hemiplegia from their stroke. The participants were able to walk without an AD, but were permitted to use AFO's. However, the authors failed to report how many of the participants were tested with their AFO's in place.

With that, the average age of individuals was 59 ± 14 years. The average months post-stroke of participants was 127 months (ranging from 30 months to 292 months) and there were 11 L and 7 R paretic sides. Average comfortable walking speed was 0.70m/s ranging from 0.24 to 1.07m/s. Functional measures were also taken at baseline and included the BBS (average 46, SD=12) and the LE Fugl-Meyer (average 20, SD=3). Fugl-Meyer scores ranged from 12 to 25 (with a maximum of 34)[12] while BBS scores ranged from 5 to 55 (maximum score 56).[13]

The authors failed to review the various types of strokes the participants had outside of mentioning all participants sustained a "unilateral" stroke.

The investigators did an additional "mini-experiment" on seven healthy control subjects using the KineAssist to characterize the force requirements that were necessary to interact with the KineAssist during the "push mode" versus the non-"push mode". All healthy controls were "non-impaired" individuals with an average age of 26 ± 3 years. No control subject had any musculoskeletal, cardiovascular or neurological impairment/pathology that affected their gait performance.

Intervention Investigated

[Provide details of methods, who provided treatment, when and where, how many hours of treatment provided]

Control

This study did not have a control intervention and experimental condition, but rather tested subjects in 4 different conditions. The four conditions are outlined below in the “experimental” section.

Experimental

Post-stroke participants were tested by the primary author. The participants performed walking trials overground with and without the KineAssist and on the treadmill. Before and after each trial, HR and BP were taken to ensure adequate cardiovascular functioning was maintained.

Overground, a 5-MWT at SCWS and SMWS was conducted on an 8 meter walkway. For each speed, 3 trials were conducted for each subject. Time to complete the 5MWT was recorded with stopwatch and the steps taken were manually counted.

Treadmill walking entailed a graded 5-MWT-which was manually tracked by a 5-meter distance measured on the treadmill belt. Harness support was provided for safety however, no body-weight support was provided by the harness unless a fall occurred. The treadmill trial started with a speed matched to the subject’s SCWS and the speed was increased by 0.2 m/ s until there were 3 consecutive failures OR a speed of 2.0 m/s was reached. A “failure” in the treadmill 5 MWT was: inappropriate walking posture (leaning forward, backwards or resting on the harness system), handrails grabbing, a fall causing the system to catch the individual, moving the feet outside the treadmill belt width and/or refusal to walk at a faster speed. After 3 consecutive failures at one set speed, the speed was reduced until 3 successful trials at a specific speed were accomplished.

In the overground, robotic walking trials the participants were attached to the robotic device via harness and walked over the same 8 meter walkway as the basic overground 5MWT trial. The KineAssist is able to detect falls as a drop in the pelvis, stop a fall by activating its harness system and simultaneously stop moving forward. The “push mode” was characterized as the mobile base being moved from a resting position to a target speed in a relatively quick acceleration period (1-2 seconds). Participants were able to become familiarized with the robotic device by practicing self- induced falls (which aimed to increase their trust of the system), free walking to get used to the harness, and walking in the “push mode” at comfortable speeds.

In the “push mode” trial, participants began by completing a graded 5-MWT at their SCWS (calculated from their overground 5- MWT). The speed of the KineAssist was increased by 0.2 m/s for each successful walking trial until the participant reached a speed that resulted in 3 consecutive failure trials. A failure was a loss of balance resulting in a drop of 3 inches of the pelvis, a loss of balance in which the system had to catch the individual, or participant refusal to walk faster. After 3 consecutive failures, the speed was reduced until 3 successful trials were observed at some consistent speed.

Mini-experiment: The conditions used in the mini-experiment on healthy controls included walking in the robotic device on a 14-meter walkway, with data only recorded for the middle 10 meters. There was no mention of who tested the healthy controls. First, subjects walked at their own selected walking speed with the robot in non-push mode at slow, comfortable and fast speeds repeated 3x each. Then, during “push mode”, when the robot pushes the individual to walk at a specified speed at the pelvis, the subjects performed the same speed walking trials again 3x each. Walking speeds were presented in a random order.

Horizontal force sensed at the pelvis was recorded from the robotic device at 100 samples/sec using an EKG data acquisition system. The force provided at the pelvis was normalized to duration of the steps, and an average across trials for each individual was performed.

Outcome Measures (Primary and Secondary)

[Give details of each measure, maximum possible score and range for each measure, administered by whom, where]

The primary investigator collected the following data in the same lab that the study occurred in. Average self-selected comfortable walking speed (SCWS) and average self-selected maximal walking speed (SMWS) were calculated from the overground 5 MWT trials. Top walking speed (TWS) was the highest speed an individual reached in any single trial overground, on the treadmill and in the robotic device. This was only collected from 9 individuals as other participants either refused to walk faster or could not use the system properly.

In each trial, the time and number of steps were recorded and the walking speed (m/s), average step length, and average cadence were calculated. Speed was calculated by dividing distance by time needed to complete that distance. Step length was calculated using the 5-meter distance and dividing by the number of steps recorded (m/step). Number of steps divided by time was used for cadence (steps/sec).

Main Findings

[Provide summary of mean scores/mean differences/treatment effect, 95% confidence intervals and p-values etc., where provided; you may calculate your own values if necessary/applicable]

Top walking speeds were highest in the "push mode" condition, with an average speed of 1.92 ± 0.06 m/s. In the graded treadmill condition, 1.67 ± 0.11 m/s was found to be the top speed and in the SMWS overground condition, top walking speeds averaged 1.19 ± 0.09 m/s. Average top speeds were significantly different between the "push mode" condition and the graded treadmill condition, while each were significantly different than SMWS overground top walking speeds. ($p<0.05$)

Average step lengths at TWS were similar across all three conditions.

Cadence across three conditions were significantly different: in the "push mode" 3.53 ± 0.22 steps/s was the average-which was significantly faster than the average cadence in the treadmill condition (2.74 ± 0.19 steps/s). Both of these TWS cadence averages were significantly faster than the overground condition: 1.89 ± 0.08 steps/s ($p<0.05$).

SCWS while overground across all participants had a mean of 0.67 ± 0.04 m/s. Matched comfortable walking speeds were similar in the "push mode" trial (0.66 ± 0.04 m/s) and in the treadmill trial (0.67 ± 0.04 m/s) ($p > 0.05$).

Average step lengths during the overground walking at SCWS (0.45 ± 0.03 m/step) were significantly longer than those in the SCWS trials using the treadmill (0.40 ± 0.03 m/step) and robotic "push-mode" (0.40 ± 0.02 m/step) ($p<0.05$). Also during SCWS trials using the treadmill and the robotic "push-mode", there was a significantly higher cadence compared to their overground SCWS (1.42 ± 0.05 steps/sec), where treadmill cadence was 1.58 ± 0.05 steps/sec and "push mode" cadence was 1.57 ± 0.07 steps/sec ($p<0.05$).

Top walking speed (TWS) visually (by graph) had the most pronounced effect from condition to condition. Mean difference between over-ground TWS and "push mode" TWS was (1.8 - 1.2)= 0.6m/s and between over-ground and treadmill TWS mean difference was (1.75 – 1.2)= 0.55m/s. Between overground and "push mode" conditions, cadence was (3.2 - 1.9)= 1.3m/s. Between overground and treadmill conditions, mean difference was (2.8 - 1.9)= 0.9steps/sec.

The mini-experiment using healthy controls led the authors to conclude that the force applied at the pelvis by healthy participants during walking in the robotic device required less force generation during the "push mode" at a given speed than when walking in the non-push mode. Overall, while in the "push mode", the same amount of force was produced regardless of the walking speed in which they were "pushed".

Original Authors' Conclusions

[Paraphrase as required. If providing a direct quote, add page number]

The authors concluded that stroke patients can achieve significantly faster walking speeds when walking on the treadmill 2.6x greater) and with the overground robotic device in "push-mode" (3x greater) compared to overground self-selected maximal walking speeds. Many participants were even able to walk at 2.0m/s, which is the maximum speed permitted by the device. Additionally, participants walked with larger step lengths and slower cadences when walking over-ground at self-selected maximal walking speeds.

Critical Appraisal

Validity

[Identify the strengths and limitations of the study, including potential sources of bias. Comment on the overall methodological quality (including the score) as you determined from your assessment of the article. Comment on anything you believe was missing in the paper.]

The strengths of the study include full disclosure of participants that did not complete all walking conditions. Furthermore, the authors took into account psychological considerations when interpreting their findings, such as fear of falling leading to lower achieved top walking speed. The authors also used common functional measures (BBS and Fugl-Meyer) to better establish baseline information about each participant and repeated these measures if they had not been conducted in the past year. Another strength was that individual step length and cadences were reported for every participant, along with the respective R^2 value. The authors did complete an a priori analysis to ensure that participants were safe before completing the study. A post-hoc Tukey-Kramer analyses with a significance $p<0.05$ was also utilized-which allowed the authors to fully test the various differences during each walking condition in terms of speed (SCWS, SMWS, TWS), average step length and cadence.

Limitations of this study are found in its methods. Calculation of cadence and step length were made such that individual limb difference would not be detected. Furthermore, not all of the stroke participants actually completed the maximal walking speed conditions using the treadmill or robot, leading to a smaller number of final data sets to analyse. Due to its very small sample size, the study cannot be generalizable and has lower power. Additionally, the participants' ranged in their functional capabilities, making the within-group variance higher and the power lower.

The overall methodological quality of this paper is fair, as the study was lacking in the participants' heterogeneity even though all were post-stroke.

It seems since there was analysis of force production in the healthy non-impaired mini-experiment, this should have also been summarized in the post-stroke participants. Since stroke patients are a population that struggles with propulsion of the paretic limb, this could have added valuable information regarding use of the KineAssist.

Interpretation of Results

[This is YOUR interpretation of the results taking into consideration the strengths and limitations as you discussed above. Please comment on clinical significance of effect size / study findings. Describe in your own words what the results mean.]

The results of this study mean that stroke patients can walk at higher maximal speeds when given the safety and consistency of treadmill or robotic pushing devices. EMG activity was not collected, so actual force production assumptions cannot be made. Furthermore, there is nothing functional about walking overground with a robot to facilitate forward propulsion. That being said, if the robotic device does in fact facilitate force production, it may not be ideal to use during clinical training, when we want muscle groups to be activated. In other words, further indication of clinical use could be assumed if there was additional information about the amount of carry-over from using the KineAssist to overground walking.

Additionally, there is no metabolic data or participant report of ease of conditions. While the "push-mode" may facilitate faster walking speeds, it may be uncomfortable to participants and increase energy expenditure due to having to make adjustments in response to external cues to walk forward.

Finally, as mentioned before, even if the robotic device does facilitate power production for forward propulsion, this does not seem a clinically desirable effect as training typically focuses on improving and increasing force production so that patients can move independent and not rely on external support. Regarding fear of falling, a harness or LiteGait type-device could easily be used in a clinical setting and offer the same anxiety-reducing effects.

(2) Description and appraisal of Reducing the Energy Cost of Hemiparetic Gait Using Center of Mass Feedback: A Pilot Study **by** Firas Massaad, Thierry M. Lejeune and Christine Detrembleur, 2010.[3]

Aim/Objective of the Study/Systematic Review:

This study aimed to test a new method of reducing energy expenditure in hemiparetic gait patterns post-stroke: center of mass biofeedback. Specifically, biofeedback was intended to promote active reduction of excessive vertical center of mass (CoM) displacement during walking.

Study Design

[e.g., systematic review, cohort, randomised controlled trial, qualitative study, grounded theory. Includes information about study characteristics such as blinding and allocation concealment. When were outcomes measured, if relevant]

Note: For systematic review, use headings 'search strategy', 'selection criteria', 'methods' etc. For qualitative studies, identify data collection/analyses methods.

The study was an observational cohort study. No blinding or randomization occurred and all subjects received the same treatment intervention for the same frequency and duration. Outcomes were measured before and after each training session, indicating that this study was a cohort study.

Setting

[e.g., locations such as hospital, community; rural; metropolitan; country]

The study setting was not specified. However, due to the equipment utilized in this study, it is presumable that testing occurred in a lab setting.

Participants

[N, diagnosis, eligibility criteria, how recruited, type of sample (e.g., purposive, random), key demographics such as mean age, gender, duration of illness/disease, and if groups in an RCT were comparable at baseline on key demographic variables; number of dropouts if relevant, number available for follow-up]

Note: This is not a list of the inclusion and exclusion criteria. This is a description of the actual sample that participated in the study. You can find this descriptive information in the text and tables in the article.

This study recruited a purposive sample of chronic, hemiparetic stroke patients (at least 6 months after injury) from an unknown setting. All subjects exhibited increased CoM displacement during walking, yet were able to walk on a treadmill without an assistive device at an average pace of 2.8 ± 0.9 km h^{-1}. After inclusion and exclusion criteria were applied, a total of 2 men and 4 women were enrolled in the study. Ages of participants were 47 ± 13 years and time since injury was 159 ± 98 months. Average height of subjects was 1.7 ± 0.1m and weight was not reported. There were 4 left cerebrovascular accidents (CVA's) and 2 right CVA's. Degree of neurological impairment was determined by scores on the Stroke Impairment Assessment Set (SIAS) with an average score of 56.5, ranging from 47-67. The authors did not mention the psychometric strength of this classification tool, however the literature suggests that the SIAS has high reliability, concurrent and predictive validity and is responsive to changes.[14] Each of the participants had report of rehabilitation experience, and were considered to be "plateaued" in their recovery. No drop-outs were reported and follow-up of training sessions was consistent across all subjects.

Intervention Investigated

[Provide details of methods, who provided treatment, when and where, how many hours of treatment provided]

Control

This study did not have a control intervention and experimental condition, but rather implemented the same treatment sessions to each participant.

Experimental

The training sessions were 30 minutes each and occurred 3 times a week for 6 weeks, a total of 18 sessions. It was not mentioned who conducted these training sessions. Sessions were divided into 3,10 minute walking intervals with a 5 minute seated rest break between each interval or when requested by the subject. Training consisted of walking on a motorized treadmill at a consistent, comfortable pace with simultaneously visual feedback regarding vertical CoM displacement. All subjects wore a safety harness while walking, but no body weight support was provided. The only instruction given was to attempt to decreased the CoM displacement, however the authors failed to mention who provided this verbal cue and how frequently it was provided. The CoM was visually represented by a marker over the mid-sacrum, which was videotaped posteriorly and projected onto a screen projector in front of the subjects. Continuous verification that the subjects were successfully reducing their vertical CoM displacement was done via computation of CoM displacement from ground reaction forces.

Training sessions were made progressively more challenging via increasing the duration. Training walking intervals increased approximately 5 minutes every 2 weeks as tolerated to achieve a 40-45 minute consecutive walking trial by the end of the study. Rest was still provided when necessary at these later stages.

Outcome Measures (Primary and Secondary)

[Give details of each measure, maximum possible score and range for each measure, administered by whom, where]

This study conducted a 1) gait analysis, 2) metabolic energy consumption, 3) electromyogram (EMG) activity, 4) 3D kinematics, and 5) ground reaction forces while the subjects walked on the treadmill before and after each training session. Also, 6) vertical displacement of the CoM was calculated during each session as well as before and after each session.

1) Gait analysis was completed before and after each training session and is described in detail by Massaad et al.[15]

2) Metabolic cost during walking was collected from an ergospirometer from which oxygen consumption and carbon dioxide production data were recorded. The net metabolic cost of walking (C_{net}) (J $kg^{-1}m^{-1}$) was calculated by dividing the energy expended above the resting energy by the walking speed. Energy expended above the resting value was calculated by subtracting the standing energy consumption from the energy consumption value from at least 3 minutes of steady metabolic state.

3) EMG data was collected from the vastus lateralis, biceps femoris, tibialis anterior, and medial gastrocnemius muscles in both lower limbs of each subject. Average EMG activity of each muscle was calculated as well as co-contraction index between antagonistic leg muscles. Namely, the biceps femoris and vastus lateralis of the thigh and tibialis anterior and medial gastrocnemius of the shank were used for co-contraction calculated, expressed as the percentage of the walking stride in which the muscle pair was activated simultaneously.

4) Three-dimensional kinematic data was collected with 6 infrared cameras (set at 100 Hz). These cameras captured 20 reflective markers-which represented specific anatomical landmarks and were then used to compute angular displacements during the walking trials.

5) Ground reaction forces were collected from force plates on the treadmill, however these measures were used as a means to calculate the vertical CoM displacement. Vertical CoM displacement was calculated in a mathematical integration that took into account vertical CoM acceleration, vertical components of the ground reaction forces and the weight of the subject. The amplitude of the CoM displacement was measured from the paretic step and the non-paretic step.

Main Findings

[Provide summary of mean scores/mean differences/treatment effect, 95% confidence intervals and p-values etc., where provided; you may calculate your own values if necessary/applicable]

Treatment effect on the net metabolic cost was determined by use of a paired t-test, whereas all other paretic-non-paretic measures were processed with a 2-way repeated measures analysis of the treatment and the affected side. Tukey's post hoc tests were also used when appropriate.

During training sessions with CoM biofeedback, amplitude of vertical CoM displacement was decreased from 0.045 ± 0.01 to 0.033 ± 0.01 m, a 30% decrease. Even after training sessions in which subjects walked without biofeedback, amplitude of vertical CoM displacement decreased from 0.045 ± 0.01 to 0.04 ± 0.01 m ($P = .005$), a 10% decrease. Specifically, a significant decrease in the amplitude of displacement was noted in the non-paretic limb after training sessions, with a change from 0.039 ± 0.01 to 0.035 ± 0.01m ($P=0.016$). The same was true for the paretic limb, however the decrease was not statistically significant with a decrease from 0.030 ± 0.01 to 0.027 ± 0.01 m ($P = .074$).

Kinematically, the main statistical change was observed while the non-paretic limb was in stance and the paretic limb in swing phase. Here, there was a 47% increase in paretic knee flexion when the CoM reached its maximum displacement, improving leg clearance. Numerically, this change in knee flexion was from 21 ± 15° to 31 ± 14° ($P = .008$).

Metabolic cost post-gait training program revealed a significant 30% decrease in the net energy cost (C_{net}), from 3.86 ± 1.7 to 2.66 ± 1.0 J kg^{-1} m^{-1} ($P = .009$). A final change noted was a significant decrease of muscle co-contraction in the thigh muscles of 15% and 10% in the non-paretic and paretic limbs respectively.

Mechanical work as measured by EMG also decreased from baseline to training program completion. This was estimated as the sum of the external work necessary to move the CM relative to the surroundings and the internal work to move body segments relative to the CM. The authors calculated a 10% reduction, changing from 0.76 ± 0.2 to 0.68 ± 0.1 J kg^{-1} m^{-1}. Co-contraction post-training also improved, particularly in the thigh muscles. In the paretic limb, shank co-contraction from pre- to post-training changed from 21 ± 16 to 18 ± 17. Paretic thigh co-contraction changed from 44 ± 9 at pre-training to 39 ± 13 post-training. Changes were also observed in the non-paretic limb going from 27 ± 12 to 21 ± 9 and from 40 ± 7 to 34 ± 10 in the shank and thigh, respectively.

A 6-month follow-up of participants revealed that the participants maintained reduction in energy expenditure as subjects were still walking with 15% less energy consumption than their baseline values prior to study participation.

Original Authors' Conclusions

[Paraphrase as required. If providing a direct quote, add page number]

The authors conclude that this 6-week intervention of treadmill training with CoM biofeedback is effective at reducing paretic walking energy consumption. They cite that the specifics of this intervention offer many learning benefits to participants as it promotes close-to-normal movements and includes task specificity, intensive practice (repetition), and focused attention. Explanation of the noted reduction in energy expenditure after the training program included: decreased mechanical work by the muscles, increased paretic knee flexion and decreased muscular co-contraction. Regarding knee flexion specifically, the authors pose the thought that this lead to greater ground clearance of the paretic limb and therefore reduced need to compensate by elevating the CoM to clear the paretic limb. For each proposal, the authors do make note that the reduction in energy expenditure seen in their subjects could have been due to one or more other factors outside of this study's intention.

The authors also conclude reduced energy expenditure resulting from this training program is long-lasting and likely indicates sustained motor learning, as indicated by their 6-month follow-up with participants.

Critical Appraisal

Validity

[Identify the strengths and limitations of the study, including potential sources of bias. Comment on the overall methodological quality (including the score) as you determined from your assessment of the article. Comment on anything you believe was missing in the paper.]

Despite its strengths, this study only offers level-4 evidence. Its overall quality is poor, with a 13/29 score on the Down's and Black quality assessment tool. The strengths and weaknesses highlighted by this assessment tool are outlined below, along with additional factors that affect this study's clinical application.

The authors included a thorough description of their biofeedback intervention, including a picture diagram of the set-up and the visual that subjects saw during training. Another strength, in the statistical realm, was that the authors reported individual p-values for their various outcomes, rather than just the cut-off value. However, even with exceptional p-values, it cannot be concluded that these results are *clinically* meaningful. There was no report of clinical importance as none of the outcomes used in this study are commonly used in a clinical setting, which presents another major limitation. The authors do not provide estimates of random variability for the main outcomes nor do they provide estimates of power.

There were two components of this study's intervention that were validated, but by the authors themselves, increasing the likelihood of bias. The authors themselves validated the specific biofeedback method used in this study and used the same gait analysis method as a preceding study that they conducted.

The main limitation of this study is it's small sample size, reducing applicability. This limit is also due to the lack of detailed information regarding the participants. The main focus of this study is investigate a method to reduce CoM displacement, yet the authors failed to specifically describe the degree to which these participants' CoM were displaced during their average walking. Application to additional patients is also limited due to lack of report of use of orthoses and use of assistive device(s). These patients were considered to be "plateaued" in their recovery, so there remains question of whether biofeedback may be effective at a more acute stage of recovery, when learning and plasticity is already occurring in a rehabilitation program. The authors do make note of this knowledge gap. Finally, the authors made no mention of the setting in which training was performed. Distractibility of the environment likely affects the strength of this intervention.

Another limitation of this study is that its methods are not cohesive with a clinical environment (use of a camera system and projector). Though these items are not commonly found in a rehabilitation center, the authors do highlight that the cost of installing said equipment is low, especially compared to the potential benefit it can bring patients. Finally, though the results were statistically impressive, there was no conclusion of clinical importance and the methodology certainly does not appear to be feasible in a normal treatment facility.

Interpretation of Results

[This is YOUR interpretation of the results taking into consideration the strengths and limitations as you discussed above. Please comment on clinical significance of effect size / study findings. Describe in your own

words what the results mean.]
This study indicates that a treadmill intervention with biofeedback about CoM displacement can be potentially effective in reducing gait abnormalities as well as associated energy expenditure in hemiparetic gait. The pre- to post-training changes for net energy cost were especially notable, with a mean difference of 1.2 J kg^{-1} m^{-1}. It is difficult, however, to make clinical interpretations based on this value specifically, as PTs often do not compute net energy cost. In fact, it is mentioned that many of the outcomes of this study are not clinically valuable as they are not commonly used in a practice setting. One measure that is used clinically is knee flexion angle observed during gait. Specifically, paretic knee flexion during the swing phase of gait. In this study, the mean increase in paretic knee flexion was 10^{o}. With the post-training knee flexion measures being 31 ± 14°, the maximum paretic knee flexion achieved was 45^{o}, which is still below the peak knee flexion value of 65^{o} during normal gait. While the improvements seen in this study may have been enough to reduce CoM fluctuations, it is still difficult to say whether or not these improvements are clinically significant for this population. This intervention cannot be assumed to be consistently effective however, as this study's sample size is very small. Also, the diversity of impairments post-stroke cannot be forgotten. Nonetheless, implementation of a treadmill with CoM biofeedback may be indicated in chronic stroke patients that exhibit stop and go-like gait patterns, much like pumping the breaks frequently in a moving car. Providing feedback about CoM movements may help paretic patients become more aware of their mechanics and help them actively control their CoM. In doing so, the patient may also alter muscular mechanical work, thereby reducing co-contraction and faulty movement patterns during walking. The effects may or may not be maintained after training has ceased. Application of a CoM biofeedback, treadmill intervention should be done cautiously. It can facilitate improved gait kinematics and "smoother" walking patterns in more functionally independent post-stroke patients. Biofeedback about the CoM may also facilitate patient-induced active clearance of the effected lower extremity. Using this type of intervention in the acute stages post-stroke or with more involved stroke patients (i.e. use an assistive device or orthoses) should be done cautiously. This intervention may be beneficial in an outpatient setting, where a private room may be available for training.

(3) Description and appraisal of Treadmill gait training combined with functional electrical stimulation on hip abductor and ankle dorsiflexion muscles for chronic hemiparesis **by** Min-Kwon Cho, Jung-Hyun Kim, Yijung Chungb, Sujin Hwang, 2015.[7]

Aim/Objective of the Study/Systematic Review:
The aim of this study was to investigate if gait and balance performance can be altered in individuals with chronic hemiparesis after undergoing treadmill training (TT) with functional electrical stimulation (FES) applied to the paretic lower extremity.
Study Design [e.g., systematic review, cohort, randomised controlled trial, qualitative study, grounded theory. Includes information about study characteristics such as blinding and allocation concealment. When were outcomes measured, if relevant] Note: For systematic review, use headings 'search strategy', 'selection criteria', 'methods' etc. For qualitative studies, identify data collection/analyses methods.
This study was a randomized control trial that included randomization of each subject into one of three groups, one of which was a control group. The authors achieved random allocation to groups by having each participant pick a sealed envelope before the start of the training intervention. There was no blinding or allocation concealment that took place. Outcome measures used to establish baseline status were implemented at the beginning of the study only, whereas gait and endurance outcome measures were implemented pre- and post-training.
Setting [e.g., locations such as hospital, community; rural; metropolitan; country]

The setting of this study was described as a “calm and well-organized therapy room.”p75

Participants

[N, diagnosis, eligibility criteria, how recruited, type of sample (e.g., purposive, random), key demographics such as mean age, gender, duration of illness/disease, and if groups in an RCT were comparable at baseline on key demographic variables; number of dropouts if relevant, number available for follow-up]

Note: This is not a list of the inclusion and exclusion criteria. This is a description of the actual sample that participated in the study. You can find this descriptive information in the text and tables in the article.

The authors were thorough in establishing the baseline characteristics of each participant (N=31). Investigators recruited a purposive sample of chronic, hemiparetic stroke patients. Participants’ characteristics were described based on group allocation. The three groups were 1) treadmill training with functional electrical stimulation of the gluteus medius and tibialis anterior (TT+ FES of GM + TA), 2) treadmill training with functional electrical stimulation of the tibialis anterior (TT+FES of TA) and 3) treadmill training only (TT). 10 subjects (7males and 3 females) were in the first two groups and 11 subjects (5 males 6 females) were in the third (TT) group. All subjects were chronic stroke survivors with hemiparetic gait who’s post-stroke duration ranges were 22.5 ± 12.6, 22.5 ± 14.1, 21.6 ± 6.7 months for the three separate groups (TT+ FES of GM + TA, TT+ FES of TA, TT, respectively). Average ages of participants, in the same respective group order were 57 ± 9.1, 53.3 ± 9.2 and 57.8 ± 7.9. There were a total of 14 infarction-induced strokes (with 4, 5, and 5 subjects in groups 1, 2 and 3 respectively) and a total of 17 hemorrhage-induced strokes (with 6, 5 and 6 in the same respective group order). There were 15 left strokes and 16 right strokes. Baseline measures of the berg balance scale (BBS) revealed scores of 46.7 ± 7.5, 47.8 ± 4.3 and 49.3 ± 6.0 for the same respective groups. The mean strength of the TA for the TT+ FES of TA group (2.7 ± 2.4) seemed to be lower compared to the other two groups’ mean strength of 4.4 ± 3.7 and 4.0 ± 3.7. Conversely, the GM strength for the first group (TT+ FES of the GM + TA) seemed to be greater (8.9 ± 3.2) than the other two groups’ (7.5 ± 2.4 and 7.3 ± 2.4). The authors explained that a dynamometer was used to capture each subject’s isometric GM and TA strength. Mini-mental state examination scores appeared to be relatively even for all groups with average scores of 27.1, 27.1 and 26.3 across all three groups.

Intervention Investigated

[Provide details of methods, who provided treatment, when and where, how many hours of treatment provided]

Control

The control group (group 3) for this study only walked over the treadmill without any use of FES, as the other two groups received. Though there was not explicit blinding done, the participants in the control group also wore electrodes over their paretic GM and TA along with a foot switch under their paretic heel, but received no stimulation. Familiarization training was done on the treadmill (Fitex505) and a harness was worn at all times.

The authors failed to mention who conducted the training sessions for any of the three groups. All three groups underwent 20 sessions of their respective intervention for 30 minutes, 5x/week for 4 weeks. In addition to this, all three groups had 1hour of physical therapy 5x/week for 4 weeks. For all subjects, treadmill speed was selected based on each individual’s average selected comfortable walking speed, however the authors did not specify how they determined this. Progressions were made weekly, with increases of 0.1km/hr per week during the training period.

Experimental

This study had two experimental groups who both underwent treadmill training (TT), but differed in simultaneous FES treatment. For both groups 1 and 2, the same familiarization training on the treadmill and with the harness system was done as with the TT group (group 3). Electrodes were applied to the gluteus medius (GM) and tibialis anterior (TA) muscles on all of the subjects on their paretic sides. FES was only applied to the TA in group 2, where it was applied to both the GM and the TA in group 1. Surface FES was done using a symmetric biphasic wave at a frequency of 40 Hz and 200 μs pulse width. The authors cited a protocol from another study to describe how they determined individuals’ FES intensity.[16] Again for all groups, including the control, a switch was attached under the heel of the paretic limb. The GM was stimulated upon initial stance phase, or when the foot switch was turned on with heel strike, while the TA was set to be stimulated during initial swing phase, or when the foot switch was de-activated as the heel was lifted. The stimulation that occurred at either muscular site was produced from a burst pattern with a ramp up and down lasting 0.5s. Again, subjects of groups 1 and 2 walked on the treadmill at their pre-determined comfortable walking pace and the same aforementioned speed progressions were made weekly.

Outcome Measures (Primary and Secondary)

[Give details of each measure, maximum possible score and range for each measure, administered by whom, where]

There were some outcomes already discussed that were used to further define and compare subjects baseline characteristics (BBS, MMSE and dynamometer strength of the GM and TA). The authors did not specify who conducted the measures. Scores on the BBS from this studies participants at baseline ranged from 39.2 - 55.3, almost reaching the maximum score of 56.[13] It has been suggested that the cut-off score for the BBS in stroke populations be 45/56, which would indicate that some of these participants have compromised safe ambulation capabilities.[13] The mini-mental state examination, was also used to rule out subjects who were not cognitively safe to participate in this study, with a cut-off score of $\geq$21. The authors did not specify why this was chosen as the cut-off score.

In addition to these measures, the investigators included evaluation of subjects' walking endurance with use of the 6-minute walk test (6MWT). Cut-off scores have not been established for the 6-MWT, however there are many studies validating its use with stroke patients and there is an established minimally clinically important difference (MCID) of 34.4 meters.[17] Additionally, with use of a GAITRite system, the investigators collected the following spatiotemporal measures: cadence, gait velocity, stride length, temporal and spatial symmetry, double support percentage and single support percentage. The authors did not specify if this system was in the same therapy room in which subjects received treadmill training.

A final scale was implemented to capture the gross strength of individuals' lower extremities: the Medical Research Council (MRC) scale. The scale was obtained for the following 5 muscles separately: hip abductor, knee flexor, knee extensor, ankle dorsiflexion and plantarflexor. Scores were added up to a maximum sum score of 25 for the paretic lower extremity.

Main Findings

[Provide summary of mean scores/mean differences/treatment effect, 95% confidence intervals and p-values etc., where provided; you may calculate your own values if necessary/applicable]

There were a few significant changes that occurred across the TT + FES of GM +TA (group 1), TT + FES of TA (group 2) and TT (group 3) groups. The authors compared the aforementioned spatiotemporal parameters from pre-training to post-training for each group, and compared the degree of changes between each group.

Two measures, gait velocity and cadence, were significantly different between all three groups. There was a significantly larger change of gait velocity in group 1 (19.8 cm/s) compared to group 2 (10.2cm/s) and group 3 (1.0cm/s) and likewise a significantly larger change in cadence in group 1 (16.1 steps/min compared to 7.4 and -1.1 steps/min for the other respective groups). There were no significant changes in stride lengths between the groups.

The % single support time of the paretic side was significantly higher in group 1 (change value of 5.3%) compared to group 2's (1.6%) and group 3's (0.8%) change values after training. Percentage of single support time of the paretic side was not different between groups.

Temporal and spatial symmetry improved significantly in group 1 (change values of 0.1 and 0.2, respectively) compared to group 2 and group 3, who had no change in values.

Again group 1 improved their times on the 6 MWT significantly more than group 2 and group 3 with change scores of 46.85m, 12.57m and 11.68m, respectively.

GM and TA strength improved in group 1 with change values of 1.4kg and 1.7kg, respectively. Though greater improvement was seen for group 1, the TA strength gains were not significantly greater than those in group 2 (1.6kg) and in group 3 (0.1kg). GM strength for group 2 and 3 were significantly different than group 1's measures at change values of 0.2kg and 0.1kg, respectively.

MRC scores, reported again as change values, were 2.7 and 1.3 points for groups 2 and 3, respectively. Again, group 1's change values of 4.3 points were significantly greater than the other two groups. Also, group 2's change scores were significantly greater than group 3's.

The BBS was implemented again at the end of the study. Group 1's change value of 5.2 points demonstrated a more significant improvement than seen in group 2's (2.3 points) and group 3's (1.7 points) scores.

Original Authors' Conclusions

[Paraphrase as required. If providing a direct quote, add page number]

Group 1, who received treadmill training and FES of the paretic GM and TA, demonstrated significantly greater improvements than the other two groups on multiple fronts: GM and TA muscle strength, balance function and gait function. Gait function in group 1 was specifically improved in terms of gait velocity, cadence, single support time, temporal asymmetry and spatial asymmetry. Stride length did seem to be shorter during treadmill walking compared to overground, however, there were no improvements in stride length in the paretic or non-paretic sides. Likewise, there were no changes in double support time.

Overall, this intensive intervention is another option to consider when aiming to improve strength of the paretic GM and TA. Specifically, facilitating functional strength development of the GM is beneficial as this muscle holds the important role of maintaining the body's center of mass throughout gait. This is especially vital in stance phase on the paretic side for stroke populations. This strength gain is likely what lead to improvements in dynamic balance in group 1 of this study. Likewise, strength gains in the TA musculature of group 1 improved respective participants postural stability and ability to clear the paretic limb in swing phase.

Critical Appraisal

Validity

[Identify the strengths and limitations of the study, including potential sources of bias. Comment on the overall methodological quality (including the score) as you determined from your assessment of the article. Comment on anything you believe was missing in the paper.]

This study did isolate its subjects to chronic post-stroke individuals. Within this defined population, there can still exist much diversity in presentation and functional ability. Within the participants of this study, there still was a broad range of balance performance as well as GM and TA strength in each group, increasing the external validity for application to the stroke population. Another benefit that was also unique to this study was that it actually implemented a control group, which further highlights the effectiveness of the authors' interventions. The participants were defined with well-established outcome measures that are also well-supported in this population. This facilitates justification of a clinician to implement this type of intervention with a patient that may present similarly to the subjects of this study.

Some limitations of this study lie in its applicability to a clinical scenario. The subjects were well-defined by the authors overall, yet there was no mention of the subjects' use of assistive devices or orthotics outside of the training program. Another distinguishing characteristic about this study is its great intensity. Specifically, this study also included 1hour/day, 5x/week of physical therapy outside of the investigators control. This poses another source of bias to this intervention in that some participants may have received additional training related to the outcomes of this study, where others may not have. Finally, this study lacked a follow-up, which leaves the question of long-term maintenance of improvements unanswered.

With those strengths and weaknesses in mind, this study presents with a score of 6/11 on the PEDro scale. Using this scale highlighted weaknesses in lack of allocation concealment and lack of blinding of assessors and subjects.

The authors did describe areas of further research, but failed to discuss the limitations of their study. Some of these include uncontrolled physical therapy interventions outside of the study, uncontrolled activity of the participants outside of time spent in intervention training and in physical therapy sessions, any discrepancies noticed between the group members (i.e. more motivation or familial support in group 1) and different assessors for the pre- and post-test measurements, to name a few.

Interpretation of Results

[This is YOUR interpretation of the results taking into consideration the strengths and limitations as you discussed above. Please comment on clinical significance of effect size / study findings. Describe in your own words what the results mean.]

Group 1 had improvements across the board in terms of gait and overall function. The change values for group 1's 6MWT were not only significantly greater compared to the other two groups, but they were also the only one's who's score exceeded the stroke-established MCID of 34.4m[17] as they had a mean difference from pre- to post-training of 46.8m. Unfortunately, MCID's have not been established for manual muscle testing (MRC) or the BBS.

That being said it seems that treadmill training with concurrent functional electrical stimulation of the paretic GM and TA is a feasible and potentially beneficial intervention to apply to a patient post-stroke, however caution should be used as its clinical effectiveness was only evaluated using one measure: the 6MWT. Strengthening the GM facilitates control of the CoM and therefore forward progression of the pelvis during walking activities. Strengthening the GM and the TA facilitate paretic limb clearance during swing phase, creating a more fluid, normalized gait pattern. Those individuals post-stroke who are able to walk independently without the use of an assistive device may be appropriate for this type of intervention. Specifically, if those individuals present with abnormal gait patterns and noticeable pelvic drop during the paretic-side stance phase of gait may benefit. It also seems this intervention may even be appropriate for the more acute stroke patient, who can use the treadmill's handrails for support if they normally require and assistive device. However, this application should be approached with caution.

EVIDENCE SYNTHESIS AND IMPLICATIONS

Interventions involving CoM manipulation for improved gait outcomes have many limitations. Firstly, limits within the available literature include predominance of case studies, lack of interventional studies and lack of control groups and randomization. Another factor that complicates conclusions about this type of intervention was the diversity of methods selected. Future researchers should consider creating interventions including the CoM that already exist in the literature to establish more concrete findings and make improvements on completed studies. Additionally, more trials should include CoM interventions in a more acute population, as none of the aforementioned studies recruited acute patients. Further more concrete clinical application of these interventions would be possible if trials recruit a well-defined cohort of stroke patients and include use of clinical outcomes with well-established values and MCID's.

Taking these findings into account, the aforementioned clinical scenario requires further assessment of what specific limitation is causing the decreased gait speed. It is evident that a force at the body's center of mass (namely, the pelvis) may facilitate achievement of faster walking speeds by changing kinematics.[1] By altering the body's margins of stability at the center of mass, the body is required to make adjustments to maintain balance, which may also cause more consistent, symmetrical gait patterns.[1] That being said, perhaps with patients who have more advanced goals in terms of speed and balance, use of a support system with pelvic progression cueing may allow them to maximize their self-selected speed and therefore improve kinematically and functionally. Engineered robotic devices such as the one discussed in Capó-Lugo is likely limited to university-affiliated facilities or laboratory settings, so clinical application of this method will likely be rare.

For a patient who exhibits exceptional "bobbing" while walking (i.e. excessive vertical displacement), biofeedback training to facilitate control of CoM displacement may be of benefit.[3] This may be the most feasible option clinically, as it only involves some form of live visualization of the patient's CoM movement.[3] This may be especially beneficial in those patients who fatigue quickly from walking due to faulty gait patterns. Individuals who demonstrate weakness in the GM and/or TA of their paretic limb may have consequential gait abnormalities and decreased dynamic stability. Both of these functional limitations may be improved with a training intervention involving functional electrical stimulation and concurrent treadmill walking.[7] Strength, gait and balance improvements were seen after implementing this study at an intensive rate (5hrs/week). That being said, this type of intervention may only be successful in an inpatient setting.

Due to the nature of these interventions and the quality of the current evidence, the aforementioned interventions should be applied with caution and thorough assessment of the patient's capabilities. The studies discussing these interventions recruited only higher level stroke subjects, so application to those who require walking assistance should be done even more conservatively. Another concern clinically, that must not be forgotten is the likely chaotic and distracting environment of a rehabilitation gym. When applying these interventions, environmental distractions should be taken into account to optimize patient safety.

Notes

- *This section synthesizes your appraisal of your articles; you may mention other related research that you have read or that supports your interpretation and discussion of this evidence. Please be sure to address the quality of the evidence available to guide clinical practice related to your PICO question. Discuss the implications for clinical practice and research.*

- *Students may wish/need to discuss implications with clinicians or peers for suggestions*
- *This section should be ¾-1 page*
- *Be sure to address <u>both</u> implications for clinical practice and future research (separately)*

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