CRITICALLY APPRAISED TOPIC

FOCUSED CLINICAL QUESTION

In a 50 year old patient with hemiparesis as a result of a stroke, does treadmill walking with a posterior force provided at the pelvis increase propulsive force during gait compared to treadmill walking without a posterior pelvic force?

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CLINICAL SCENARIO

The patient is a 50 year old male with hemiparesis as a result of a stroke. He presents at inpatient rehabilitation with moderate weakness in his left upper and lower extremity and displays moderate exertion with walking due to difficulty with providing adequate propulsive force during gait. He has decreased step length on his left side, compared to his right, and has had great success in gaining improved gait mechanics through repetitive walking on the treadmill.

Many individuals who present at inpatient rehabilitation who have suffered from a stroke are limited by slow gait speed and limited endurance.[3] Gait training is a large focus for rehabilitation, especially with increasing gait speed and symmetry. Increasing propulsive force of the paretic limb is essential for improved gait mechanics. Providing a posterior force while walking on the treadmill may be an effective way to increase the force output demand on the paretic limb and restore propulsive force that can enable the restoration of a more normal gait.

SUMMARY OF SEARCH

- 3 electronic databases were searched and 10 studies were identified that met the inclusion and exclusion criteria, including 2 randomized controlled trials, 4 cross-sectional studies, and 4 single-group observational studies. Three of the studies found were reviewed in detail.
- There were significant short-term improvements in gait symmetry and muscle activity when alterations to the non-paretic side were implemented, such as increasing stride length and adding an ankle weight.
- There were no statistically significant improvements in forward propulsion or plantar flexor muscle activity with an inclined treadmill single-session training.
- Individuals post-stoke may be able to generate an increase in paretic limb muscle activity, therefore improving propulsive force through locomotor adaptability tasks by requiring the paretic limb to increase biomechanical output during the stance phase in gait.

CLINICAL BOTTOM LINE

There is currently no available evidence in the literature that aims to increase propulsive force during gait utilizing a posterior force provided at the pelvis in the post-stroke population. The best available evidence at this time suggests that altering the non-paretic lower limb by increasing stride length or adding an ankle weight during a short, single treadmill training session can enhance gait and muscular performance in individuals with hemiparesis following a stroke. Conversely, a single inclined treadmill training session without any direct alteration to the non-paretic limb failed to show improvements in plantar flexor activity both during and immediately after the treadmill training. Clinicians can use the information from these studies to guide their clinical intervention, but further high quality research is needed to study the generalizability of these treadmill training sessions on the stroke population, and to assess for any carry-over effect to assist with rehabilitation and the long-term application for gait symmetry.

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 "cerebrovascular accident" "cerebrovascular incident"	"A-P force" Posterior force Pull* force Anterior-posterior force	Walk Gait Ambulat* "overground walking"	Gait Walk "gait ability" "walking ability" Forward propulsion Group reaction force "propulsi" force" Propulsi" Forward progression

Final search strategy:

1. stroke OR CVA OR cerebrovascular accident OR cerebrovascular incident
2. walk OR gait OR ambulat*
3. forward propulsion OR ground reaction force OR propulsive OR propulsion OR forward progression
4. #1 AND #2 AND #3

Databases and Sites Searched	**Number of results**	**Limits applied, revised number of results (if applicable)**
PubMed	**130**	**None applied**
CINAHL	**79**	**English Language: 77**
Web of Science	**256**	**English Language: 255**

INCLUSION and EXCLUSION CRITERIA

Inclusion Criteria
• Observational/cross-sectional studies • Studies that attempt to alter gait • Studies that use an adult population (18+) • Measures changes in gait pattern (force, muscle activation, coordination) immediately after or during the intervention • Published in English
Exclusion Criteria
• Conference proceedings, letters to the editor, dissertations • Studies that involve adults with cardiopulmonary diagnosis • Studies that involve participants with additional orthopaedic diagnosis

RESULTS OF SEARCH

Summary of articles retrieved that met inclusion and exclusion criteria

Author (Year)	Study quality score	Level of Evidence	Study design
Hase, Suzuki, Matsumoto, Fujiwara & Liu (2011)	**MODIFIED DOWNS & BLACK 19/29**	**IIb**	**Single group, pre-post design**
Keisar, Reisman, Perumal (2011)	**MODIFIED DOWNS & BLACK 15/29**	**IV**	**Cross-sectional, randomized conditions**
Regnaux, Pradon, Roche, Robertson, Bussel & Dobkin (2008)	**MODIFIED DOWNS & BLACK 18/29**	**IIb**	**Single group, pre-post design measuring immediate effects, single session**
Awad, Reisman, Pohlig & Binder-Macleod (2016)	**JADAD SCALE 4/5**	**Ib**	**Randomized controlled trial**
Bonnyaud, Pradon, Zory, Bensmail, Vuillerme & Roche (2013)	**JADAD SCALE 2/5**	**Ib**	**Randomized controlled trial**
Hsiao, Knarr, Higginson & Binder-Macleod (2015)	**MODIFIED DOWNS & BLACK 13/29**	**IIb**	**Cross-sectional, observational design**
Feasel, Whitton, Kasslet, Brooks & Lewek (2011)	**MODIFIED DOWNS & BLACK 14/29**	**IIb**	**Single group, pre-post design measuring immediate effects, single session**
Clark, Neptune, Behram & Kautz (2016)	**MODIFIED DOWNS & BLACK 14/29**	**IV**	**Observational study, single session**
Hurt, Burgess & Brown (2015)	**MODIFIED DOWNS & BLACK 13/29**	**IIb**	**Cross-sectional, two group design, measuring immediate effects**
Phadke (2012)	**MODIFIED DOWNS & BLACK 19/29**	**IIb**	**Cross-sectional, two group design, repeated measure of immediate effects, single session**

BEST EVIDENCE

- **Clark, Neptune, Behram & Kautz (2016) –** This study specifically analyzes propulsive force, which makes it useful in attempting to answer the research question. This study aims to look the effects of increased step length on the non-paretic side in muscle activity and forward progression during walking. Clark et al., utilized a treadmill and found that there was greater neuromuscular activation on the paretic side as an immediate effect of the training sessions. This study utilizes the concept of altering gait pattern with a one-time treadmill training, to see what the implications are on forward progression and gait.
- **Phadke (2012) –** This study uses a single bout of incline treadmill walking to analyze the effects of muscle activity and propulsive force in post-stroke individuals during level ground walking through ground reaction force and electromyogram data. The authors are interested in the data during treadmill walking, immediately after, and 20 minutes after. Incline walking and a posterior pull at the pelvis may be comparable by improving push off during gait and facilitating forward progression of the paretic limb during the swing phase of gait.
- **Regnaux, Pradon, Roche, Robertson, Bussel & Dobkin (2008) –** This study manipulated one lower extremity in the post-stroke population, by adding a weight to the non-paretic leg during treadmill walking. The analyses of gait changes were done before, immediately after, and 20 minutes after the walking trials. Regnaux and his colleagues looked at the effects of a short, single session gait training on gait speed and symmetry. The subjects in this study were relatively typical of patients with stroke, with a mean age of 48.4 years which is comparable to a 50 year old male in the original research question.

SUMMARY OF BEST EVIDENCE

(1) Description and appraisal of Locomotor Adaptability Task Promotes Intense and Task-Appropriate Output from the Paretic Leg during Walking by Clark DJ, Neptune RR, Behrman AL, Kautz SA, 2016

Objective of the Study
The objective of the study was to determine if post-stroke participants will have a more symmetrical gait and an increase in plantar flexor muscle activity on the affected side with an adaptability task of taking a longer step with the non-paretic leg, when compared to normal walking.
Study Design
• This was an observational study, where participants were asked to come in for a single-session. • The authors did not specify how, when, or who did the screening process of the subjects. • Each participant was taken through steady-state walking and the adaptation gait, so group allocation was not used. • Electromyogram, kinetic, and kinematic outcomes measures were taken throughout the experiment. • Blinding of the assessor and statistician was not done for this study.
Setting
This study took place in an outpatient hospital setting at a clinical research center. The location of the clinic was not specifically stated.
Participants
• Participants were adults who were post-unilateral stroke, with chronic hemiparesis. • 15 total subjects participated in the study, 8 males and 7 females. • Mean (±SD) age of 59.9±11.9 years • Mean time since stroke was 39.8±34.3 months • Mean Fugl-Meyer lower extremity score, out of 34 points was 23.3±5.7 • Mean preferred overground walking speed was 0.54±0.25 meters per second. • Inclusion criteria: subjects had to be able to walk 10 meters, on flat ground, without an assistive device • Exclusion criteria: subjects could not participate in the study if they reported substantial pain, had contractures, significant sensory deficits, or cardiopulmonary symptoms that would inhibit the ability to follow the protocol of the study • The authors did not state their method of recruitment. • The authors did not specifically state how participants were obtained, but they were most likely a convenience sample. • Participants were allowed to use a semi-rigid ankle brace for ankle joint stability, if needed.
Intervention Investigated
Control
• All subjects participated in steady-state walking on the treadmill. • Participants walked on a treadmill with independent force plates on both the right and left side. • Movement was captured using modified reflective markers placed at specific anatomical landmarks and a 12-camera motion system. • Surface level electromyogram was used on both the paretic and non-paretic lower extremity. • Kinetic and kinematic data was collected throughout the walking trials using the VICON Workstation v4.5. • Participants walked for two 30-second steady state walking trials at their comfortable walking speed.
Experimental
• After the subjects performed the steady-state walking, they walked for a one minute trial at the same comfortable speed, but were told to take a longer step with their non-paretic side during every fifth gait cycle. • Electromyogram, kinetic, and kinematic data was collected the same way as described above. • Participants could not use the handrails during the steady-state walking or during the longer step length walking.

Outcome Measures

- Kinetic and kinematic data were collected at 200 Hz
- Forward progression during single-limb support in stance phase of gait was calculated by finding the distance between the pelvis center of mass and the center of mass of the trailing foot during heel strike.
  - Center of mass for the pelvis and foot were found by assigning marker trajectories on a skeletal model on Visual 3D
  - Forward progression ratio was calculated to assess the symmetry during each walking condition
- Anterior step distance was calculated during heel strike as the difference between the pelvis and leading foot center of mass.
- Step length was calculated as the sum of forward progression and anterior step distance.
- Propulsion is the time integral of the anteriorly directed horizontal portion of the ground reaction force.
- Neuromuscular activity was collected at 2000 Hz, during each walking condition through the use of bilateral surface electromyogram on the tibialis anterior, soleus, medial gastrocnemius, vastus medialis, rectus femoris, lateral hamstrings, medial hamstrings, and gluteus medius.
  - To avoid the effect of the non-paretic compensatory influences for support and propulsion during gait, the paretic limb electromyogram and propulsion data were averaged during the second part of the paretic limb support phase, when the paretic limb supports the body.

Main Findings

The main finding of the study was that by increasing step length on the non-paretic side there was an increase in propulsion, forward progression, and neuromuscular activity on the paretic limb, specifically in the plantar flexors.

- All subjects demonstrated at least a small increase in paretic forward propulsion with the long-step task (defined as ≥ 10%), when compared to the steady-state walking task.
- Average forward progression of the non-paretic side during steady-state walking was 15.10±4.22cm, and for the paretic side was 8.73±5.07cm (P<.001).
  - Prior to treadmill training the mean forward progression ratio for the group was 0.35±0.11 (where .5 would demonstrate symmetry in gait)
  - During the long-step length task, the mean forward progression ratio was 0.54±0.11
- Average increase in forward progression was 113% during the long-step task when compared to steady-state walking (P<.001).
- There was a positive correlation with an increase in the non-paretic step length and forward progression (r=.70, P=.003).
- When compared to the steady-state walking, the paretic limb propulsion increased 319% during the long-step task, 2.08±2.42Ns, 8.71±5.12Ns, respectively (P<.0001).
- Electromyogram amplitudes in the paretic limb increased when comparing the muscle activity of the long-step task and the steady-state walking task.
  - Tibialis anterior, 46.9%±62.4%; P=.04
  - Soleus, 54.7%±66.0%; P=.01
  - Medial gastrocnemius, 35.4%±50.4%; P=.04
  - Rectus femoris, 33.6%±30.1%; P=.02
  - Vastus medialis, 49.6%±50.2%; P=.01
- The change in muscle activation and the change in propulsion was significant only with soleus (r=.53, P=.08), medial gastrocnemius (r=.62, P=.05), and the vastus medialis (r=.52, P=.08).
- Forward progression was correlated to the change in medial gastrocnemius and soleus on the paretic side (r=.76; P=.02).

Original Authors' Conclusions

The authors concluded that taking long-steps with the non-paretic side during gait training, may be an effective task for post-stroke individuals with hemiparesis to increase muscle activation of the paretic side and improve gait symmetry. Individuals who are post-stroke may be able to make alterations in their gait that can have adaptive effects on the paretic limb. An increase in propulsive force during stance phase can result in a more symmetrical gait pattern and adaptability tasks can assist to engage locomotor control and can help to generate neuroplasticity recovery.

Critical Appraisal
Validity

This study was scored on the Modified Downs and Black Checklist. This measure is out of a total of 29 points and divided into five subscales which cover reporting, external validity, internal validity-bias, internal validity-confounding, and power. This study had a total score of 14/29 and presents with level IV evidence.

- Reporting: Hypothesis clearly described: Yes, main outcomes measures described: Yes, characteristics of patients clearly described: No, interventions clearly described: No, distributions of principle confounders described: No, main findings clearly described: Yes, estimates of random variability: No, adverse events reported: No, characteristics of patients lost to follow-up described: No, actual probability values: Yes,
- External validity: subjects asked to participate were representative of entire population: No, subjects who participated were representative of entire population: Yes, staff and facility were representative of treatment that patients receive: Yes
- Internal validity-bias: blind study subjects: No, blind those measuring outcomes: No, "data dredging" made clear: No, time period between intervention and outcome the same for case and controls: Yes, statistical tests appropriate: Yes, compliance reliable: Yes, main outcome measures accurate: Yes
- Internal validity-confounding: recruited from same population: Yes, recruited over the same period of time: Yes, randomized: No, randomization concealed from patients and staff: No, adequate adjustment for confounding in the analysis in main findings: Yes, losses of patients to follow-up taken into account: Yes
- Power: no power analysis reported

Due to the specific design of the study, each subject performed the steady-state walking first and the long-step task after. Varying the order in which these tasks were performed or doing another steady-state walk at the end of the long-step task would allow for the authors to determine if the differences found were due to a learning effect. In addition, there were no specifics in how the subjects were encouraged to take longer steps, which makes this study difficult to reproduce for further research or to be used in clinic. There was no follow-up condition to assess if the changes in plantar flexor muscle activity and improved gait symmetry had a lasting effect. All walking was done on the treadmill, so there is no evidence that the findings are transferable to overground walking. Lastly, individual participant data was not provided.

Since this was a single-session study, and there were no reported challenges with the participants performing the task, all subjects were retained. Overall, the study design and outcomes measured were appropriate for the aim of the study.

Interpretation of Results

The average increase in forward progression and paretic limb propulsion during the long-step task compared to the steady-state walking was 113% and 319% respectively, which was found to be statistically significant ($P<.001$, $P<.0001$, respectively). The mean forward progression ratio with steady-state walking was 0.35 ± 0.11, and 0.54 ± 0.11 during the long-step length task, which demonstrates that the gait was more symmetrical during the long-step task (0.5 would demonstrate symmetry in gait). Since there is no minimal clinical important difference for propulsion, it is difficult to determine if the results are clinically significant.

The authors found a positive correlation with the long-step task and forward progression ($r=.70$; $P=.003$). The study claims that the change in muscle activation in the soleus, medial gastrocnemius, vastus medialis, and propulsion are significant. However, the soleus and vastus medialis have a p-value of 0.08, which is greater than 0.05, indicating that the results observed may have been due to chance. Thus, the authors may have been inaccurate in assuming a statistically significant difference existed between long-step and steady-state walking. In addition, the authors never discussed how they decided on their specific sample size.

The results of this study support the use of increasing step length on the non-paretic side to increase forward progression, propulsive force, and muscle activity of the paretic limb to promote symmetrical gait. However, since this was an observational study it is difficult to define how it can be applied as an intervention in the clinical rehabilitation setting. The order in which the steady-state and long-step walking tasks was not varied, so the findings cannot be distinguished between a learning effect and a practice effect. Data was collected during the walking trials, and no post trial or follow-up analysis was done to assess for a lasting effect. The results found in this study are promising and clinically relevant, so further research should be done to assess its applicability in the rehabilitation setting.

(2) Description and appraisal of Immediate Effects of a Single Inclined Treadmill Walking Session on Level Ground Walking in Individuals After Stroke by Phadke CP, 2012

Objective of the Study
The objective of this study was to examine the effects of inclined treadmill walking on plantar flexor muscle activity. In addition, it aimed to assess whether 15 minutes of inclined walking on the treadmill will result in increased plantar flexor muscle activity during the late stance phase of the gait cycle, and if it can be utilized for propulsion during over-ground walking.
Study Design

• This was an observational study, where participants were asked to come in for a single-session
• The authors did not specify how, when, or who did the screening process of the subjects
• Each participant was taken through the same set of walking trials, so group allocation was not used.
    o Pre-over ground walking
    o 15 minutes of progressive incline plane walking at 2.5 degrees and 5 degrees of incline
    o Immediate post-over ground walking
    o 20 minutes post-over ground walking
• Electromyogram and force data were collected throughout the experiment
• Fugl-Meyer Assessment and the modified Ashworth scale were taken for stroke participants, although the study did not specify when these assessment were taken
• Blinding of the assessor and statistician was not done for this study

Setting
This study took place in an unspecified clinical research facility.
Participants

• Participants were adults who were either post-unilateral stroke, with chronic hemiparesis, or age matched healthy adults.
• 18 total subjects participated in this study
• Post-stroke participants (n=9):
    o Hemiparesis, 6 right side, 3 left side
    o Mean time after stroke 20.67±12.38 months
    o Mean age of 58±10 years
    o 7 male and 2 female
    o Mean Fugl-Meyer Assessment for Lower Extremity out of 34 points was 27 (range 22-33)
• Control participants (n=9):
    o Mean age of 57±10 years
    o 7 male and 2 female
• The authors did not specifically state how participants were obtained, but were most likely a convenience sample.
• Inclusion criteria for post-stroke participants: subjects had to be at least six months post-stroke, and had to be able to walk at least 10 meters. They could have no pre-existing heart condition, or self-reported condition that would affect their walking ability
• Exclusion criteria: authors did not state any specific exclusion criteria for participants
• No walking aids were used during this study

Intervention Investigated
Control
• This was a single-session, cross-sectional study, with a two group design, with interest in the repeated measure of immediate effects. • Surface electromyogram electrodes were adhered bilaterally to the medial gastrocnemius and the tibialis anterior, and muscle activity was collected throughout the trials • Three maximum isometric contractions of the dorsiflexors and plantar flexors were assessed using manual resistance, evaluated by the same assessor for all participants. • All participants were asked to walk at their preferred walking speed on an 8-meter walkway equipped with force plates for five trials. The average overground walking speed and ground reaction force were calculated across the trials and used as the baseline velocity for the overground walking. • Participants were attached to a harness throughout the treadmill walking trials, for safety. • Participants walked at their preferred walking speed throughout the treadmill training. • The participants walked, for 5 minutes, then walked at a 2.5 degree treadmill incline for 5 minutes, and then at a 5 degree treadmill incline for 5 minutes, for a total of 15 minutes of walking on the treadmill.

- If at any point during the trials a participant rated their perceived exertion as more than moderate on the 20-point Borg scale, they were asked to take a rest break, reduce the treadmill incline, or reduce their speed.
- Immediately after the 15 minutes of treadmill walking, participants were asked to perform five trials of overground walking on the 8-meter walkway to assess post-overground walking speed.
- After 20 minutes of sitting, participants performed 5 final trials of overground walking on the 8-meter walkway to assess the follow-up overground walking speed.
- Information about who provided the assessments or calculated the data, as well as when or where the study was done was not provided.

Experimental

- Post-stroke group went through the same procedure as the control group (listed above), but were scored on the lower extremity Fugl-Meyer Assessment and the modified Ashworth scale to provide information on functional mobility.
    - The assessor and the sequence in which these assessments were taken was not provided.

Outcome Measures

- Electromyogram and ground reaction forces were sampled at 2 kHz using the Lab-View software and were processed using Microsoft Excel templates.
- Stance and swing phases were identified during treadmill walking using the vertical ground reaction forces from the force plates embedded in the treadmill.
- Stance phase was identified in the overground walking trials on the 8-meter walkway
    - Swing phase could not be identified because each foot only landed once on each force plate
- Propulsive impulse was calculated for each leg by calculating the integral of the horizontal ground reaction force.
    - Percent propulsion was calculated by dividing the propulsion of the individual leg by the sum of both legs propulsive forces and multiplying the quotient by 100.
    - Average peak propulsion for each trial was also calculated, by calculating the percent body weight.
- Estimated magnitude of electromyogram signal was calculated during treadmill walking by finding the area under the curve during the last third of the stance phase for the medial gastrocnemius (push-off) for the overground walking trials, and for the first half of the swing phase for tibialis anterior (toe clearance) during the treadmill walking.
    - Tibialis anterior data could not be measured during overground walking because swing phase duration could not be measured using the 8-meter walkway force plates.
- Muscle activity during gait was normalized by taking the integrated electromyogram averages during the central time interval of peak activity (300msec for medial gastrocnemius, and 200msec for tibialis anterior) during the maximum voluntary contractions.
- Friedman tests were used to determine the impact of the treadmill incline on muscle activation and to assess whether muscle activity and overground propulsion were influenced by the treadmill training for both immediately after the walking trials and 20 minutes after.
- Wilcoxon's tests were performed as appropriate.
- Description of who performed the measures and calculated the data was not provided.

Main Findings

The main finding of the study was that there was a significant increase in medial gastrocnemius activity during treadmill walking during the higher inclines in the control subjects and the non-paretic side of the stroke participants.

- Self-selected overground walking speed of stroke and control subjects was 0.90±0.1 m/sec, and 1.43±0.23 m/sec, respectively.
- Self-selected treadmill walking speed of stroke and control subjects was 0.63±0.16 m/sec, and 0.87±0.19 m/sec, respectively

Effect of Incline

- As the incline increased the medial gastrocnemius activity increased in both limbs in the control group ($P<0.025$).
    - At the 2.5 degree incline there was a 38% and 34% increase plantar flexor activity in left and right limbs, respectively ($P<0.025$ and $P<0.035$).
    - At the 5 degree incline the corresponding increases were 54% and 106% ($P<0.025$).
- A similar pattern was seen on the non-paretic side of the stroke participants ($P<0.025$).
    - At the 2.5 degree incline there as a 26% increase in plantar flexor activity.
    - At the 5 degree incline there was a 42% increase in plantar flexor activity.
- No changes were found for medial gastrocnemius activity on the paretic side ($P>0.245$) with any amount of incline.
- Tibialis anterior muscle activity on the paretic side increased by 13% at the 2.5 degree incline and by 28% at the 5 degree incline ($P<0.025$).

- A similar pattern was seen on the non-paretic side, but the increases were not significant ($P>0.122$).
- Tibialis anterior muscle activity was relatively unchanged throughout the trials for the control group.

Carryover to Overground Walking

- There was no significant change in overground walking speed after the treadmill walking ($P<0.05$).
- In the control group, there was no change in medial gastrocnemius activity or in propulsion after the inclined treadmill walking.
- In the stroke group, there was no change in muscle activity after the inclined treadmill walking.
  - Propulsive force of the non-paretic limb increased ($P<0.025$).
  - Propulsive force slightly decreased on the paretic limb after the treadmill.

Original Authors' Conclusions

The authors concluded that an increase in treadmill incline augmented medial gastrocnemius activity during the last stance phase of gait, but not for the paretic limb of the post-stroke participants. The decrease in paretic limb medial gastrocnemius muscle activity during the 5 degree incline walking suggests that the plantar flexor demand must be compensated for elsewhere, such as increased hip flexion. The post-stroke participants self-selected walking speed on the treadmill was lower when compared to overground walking speed (0.63±0.16 m/sec, 0.90±0.1 m/sec, respectively), which decreases the amount of force needed to push-off. Perhaps the slower treadmill walking speed was not challenging enough to show an increase in electromyogram response in the paretic limb. The authors discussed that other factors, including posterior foot placement, improved gait symmetry, and loading on the paretic limb may also increase paretic limb propulsion and should either be measured or altered in future studies.

Critical Appraisal

Validity

This study was scored on the Modified Downs and Black Checklist. This measure is out of a total of 29 points and divided into five subscales which cover reporting, external validity, internal validity-bias, internal validity-confounding, and power. This study had a total score of 19/29 and presents with level IIb evidence.

- Reporting: Hypothesis clearly described: Yes, main outcomes measures described: Yes, characteristics of patients clearly described: Yes, interventions clearly described: Yes, distributions of principle confounders described: Yes, main findings clearly described: Yes, estimates of random variability: Yes, adverse events reported: Yes, characteristics of patients lost to follow-up described: No, actual probability values: Yes,
- External validity: subjects asked to participate were representative of entire population: No, subjects who participated were representative of entire population: Yes, staff and facility were representative of treatment that patients receive: Yes
- Internal validity-bias: blind study subjects: No, blind those measuring outcomes: No, "data dredging" made clear: No, time period between intervention and outcome the same for case and controls: Yes, statistical tests appropriate: Yes, compliance reliable: Yes, main outcome measures accurate: Yes
- Internal validity-confounding: recruited from same population: Yes, recruited over the same period of time: Yes, randomized: No, randomization concealed from patients and staff: No, adequate adjustment for confounding in the analysis in main findings: Yes, losses of patients to follow-up taken into account: Yes
- Power: no power analysis reported

There were limitations to this study. The treadmill and overground walking speeds were not matched, which could affect the carryover of the inclined walking and the low treadmill degree incline could have hindered the response of the medial gastrocnemius to increase forward propulsion. Since different speeds were used for the preferred overground walking speed and treadmill walking speed in both the control and the post-stroke group (with the treadmill walking speed being slower), it is difficult to determine if the lack of increased muscle activity with increased treadmill incline was not found because the treadmill walking speed was not challenging enough to increase plantar flexor muscle activity.

The post-stroke participants used in this study were high-functioning so the results of the study cannot be generalized to lower functioning stroke patients. Maximal voluntary contraction was used to normalize gait electromyogram data which might not have been effective because in post-stroke participants it is likely that that gait muscle activity exceeds the maximal contraction muscle activity. The lack of kinematic data made the interpretation of the propulsion difficult, and compensatory strategies such as hip hiking, circumduction, and relative paretic foot placement may have affected the plantar flexor activity.

Information about specific brain lesion location was not collected, and the location of the lesion could affect the degree of which motor adaptation could occur. Data on the post-stroke participants was provided in a table, but there was no individual data provided for the control participants, so assessment of control participants confounding variables to match that of the post-stroke group was not available. Subject 9 has no reported post condition or follow-up condition data provided, and the reason for the lack of information is not provided. No blinding of the statistician was mentioned, which could result in bias. In addition, there was no power analysis to detect the sample size needed to reduce the risk of type II error.

This is a cross-sectional, two group design, so each participant performed the same procedure of overground walking, 15 minutes on the treadmill, followed by the two overground walking trials that were twenty minutes apart. Everything was done in the same order so the data between the two groups are comparable. Since this is a single-session study, and there were no reported challenges with the participants completing the walking trials, all subjects were retained. The same assessor was used for measuring maximum voluntary contractions, which demonstrates consistency. In addition, because of the simplicity of the study, the study should be able to be replicated for further investigations and could be utilized in any clinical setting with a treadmill if found to be effective. Overall, the study design and outcomes measured were appropriate for the objective of the study.

Interpretation of Results

The results support the need for further investigation of utilizing a treadmill inclined walking to increase plantar flexor muscle activity. A significant increase in medial gastrocnemius muscle activity was found with a greater treadmill incline in both the right and left lower extremities in the control group ($P<0.025$) and on the non-paretic side of the post-stroke participants, but not on the paretic side. This suggests that compensation strategies, such as increasing hip flexion, were most likely utilized to make up for the increase in force required of the paretic limb to overcome the incline and provide adequate leg swing.

Hip kinematic and kinetic data would be useful to determine if compensatory strategies were indeed used on the paretic limb. It is also possible that the medial gastrocnemius does not have the adequate muscle activation required to provide enough force output to generate sufficient power for forward propulsion, therefore creating the need for additional compensatory strategies. There was no power calculated to determine the sample size needed to detect a significant difference between the groups. Without a power analysis there is no way to know if a nonsignificant effect is due to a lack of power or if there is no actual effect. This study suggests that chronic stroke patients cannot increase medial gastrocnemius activity by increasing the treadmill incline to 2.5 degrees and 5 degrees with 5 minutes at each incline at the tested treadmill walking speed.

Although there was no immediate carryover effect of the increase in medial gastrocnemius activity from treadmill walking to overground walking, either in the control group or the non-paretic side of the post-stroke group, it is possible that an increase in training time, or perhaps multiple trials may be useful to induce a carryover effect to overground walking. Due to the findings of the study, and the nature of the observation design, there is currently not enough evidence to support the use of this as an intervention for gait training rehabilitation for individuals with hemiparesis, following a stroke.

(3) Description and appraisal of Effects of Loading the Unaffected Limb for One Session of Locomotor Training on Laboratory Measures of Gait in Stroke by Regnaux JP, Pradon D, Roche N, Robertson J, Bussel B, Dobkin B, 2008

Aim of the Study

The aim of the study was to explore the clinical effects of attaching a weight to the non-paretic lower limb during a short, single-session of gait training.

Study Design

- This was a single-session, observation study, with a pre-post test design measuring the immediate effects.
- All individuals at the specific setting, who had their first stroke, were tested as potential subjects.
- The authors did not specify who performed the screening or when the screening process took place.
- Each participant was asked to do a treadmill walk and the 10-Meter Walk test two days before the resisted walking, and then performed the 20 minute training session, so group allocation was not used.
- Kinetic, kinematic, and ground reaction force data was recorded before, immediately after, and 20 minutes after the walking trials.
- Three-dimension gait analysis was carried out throughout the walking trials.
- Blinding of the assessor and statistician was not done for this study.

Setting

This study took place at an inpatient unit of an unspecified hospital.

Participants

- Participants were adults who were post-unilateral stroke.
- 10 total subjects participated in the study.
  - 8 males and 2 females
  - 7 participants had a lesion on the left side, 3 had a lesion on the right side
  - 9 of the participants had an ischemic stroke, 3 out of the 9 had a hematoma in addition to the ischemia, and 1 participant had a haemorrhage injury.
  - The vascular localization was middle cerebral artery for 7 participants, anterior communicating artery for 1 participant, posterior communicating artery for 1 participant, and middle cerebral artery and anterior communicating artery for 1 participant.
- Mean age of 48.4 years, 95% CI=40.88-55.92 years
- Mean time since stroke was 4.3 months, 95% CI=3.4-5.25 months
- Mean body mass index of 25.02, 95% CI=22.26-27.78
- This was a purposive sample where participants were recruited from an inpatient unit at a hospital and screened for the inclusion criteria.
- Inclusion criteria: 1) diagnosis of an ischemic brain injury or intracranial haemorrhage by magnetic resonance imaging or computed tomography less than 1 year after the beginning of the stroke; 2) ability to walk 10 meters without the use of a gait assistive device; 3) significant gait deficit, defined at less than 0.6 m/s over ground walking velocity; 4) no impaired comprehension or severe neuropsychological disorders.
- Exclusion criteria: musculoskeletal impairments that limit hip mobility, knee extension, or plantar flexion to neutral, and any other neurologic condition besides the unilateral stroke.

Intervention Investigated

Control

- All subjects participated in the same resisted walking.
- Two days before testing each subject performed a 10 minute treadmill walk at the individual's preferred walking speed, which was determined by a 10-Meter Walk Test.
- The day of the resisted walking participants walked on the same treadmill at the same preferred speed, with a weight attached to their non-paretic ankle.
  - 2 kg weight used for females and a 4 kg weight used for males.
- Treadmill speed remained constant for 20 minutes, with a rest break of 1 to 3 minutes provided to all participants at minute 7 and 14.
- Subjects were instructed to hold the treadmill railing with the non-paretic upper extremity.
- Information of who supervised and provided the training was not provided.

Experimental

- Participants performed three consecutive walking trials on a 10-meter walkway embedded with force plates: before the treadmill weighted walking (pre-condition), immediately after (post-condition), and after a required sit for 20 minutes, and then walk on the walkway again (follow-up condition).

Outcome Measures

- Joint kinetics and kinematics were assessed through a three-dimensional gait analysis system using six cameras and 25 reflective markers at specific anatomical landmarks.
- Two force plates were embedded in the walkway floor to measure ground reaction forces.
  - Ground reaction force and three-dimensional gait analysis was collected at the same time at a rate of 1000 Hz.
- Three dimensional kinematics and ground reaction force data was analysed during the three consecutive walking trials at the pre-condition, post-condition, and follow-up condition.
- Root mean square of the vertical ground reaction force was calculated for each leg during initial contact and foot-off gait phases.
- Coefficient of variation, which estimates the fluctuation in gait and motor performance, was calculated.
  - A decrease in coefficient variation with training, would imply performance improvement.
  - A maintenance or increase in coefficient variation, would imply a lack of change or a reduction in motor performance.
- A statistical analysis for each lower extremity was calculated for the following variables: temporospatial (speed, step-length, and cadence), kinematic (hip, knee, ankle range of motion in the sagittal plane), and vertical ground reaction force.
- An analysis of variance for a one factor repeated measure was calculated to determine any significant differences in variables listed above during the pre, post, and follow-up conditions
- The limit of significance was set at P=0.05

Main Findings

The main finding of this study was that a single-session of treadmill walking at the individual's preferred walking speed, with a mass attached to the non-paretic ankle, contributed to significant changes in gait.

- All participants demonstrated a significant increase in overground walking speed (P<0.001).
  - Pre-condition: Mean=0.33 m/s, 95% CI=0.24-0.43 m/s
  - Post-condition: Mean=0.39 m/s, 95% CI=0.30-0.48 m/s; P<0.05
  - Follow-up condition: Mean=0.42 m/s, 95% CI=0.31-0.55 m/s; P<0.001
  - No significant difference between the post and follow-up condition
- Step length significantly increased for the paretic leg (P<0.01), and the non-paretic leg (P<0.01) after the treadmill training session. Step length changes were calculated as a percent of pre-condition values.
  - Paretic side: +12.12% in the post condition, and +14.71% in the follow-up condition
  - Non-paretic side: +12.66% in the post condition, and +21.82% in the follow-up condition
- Cadence significantly increased (P<0.01) after the treadmill training session. Cadence changes were calculated as a percent of pre-condition values.
  - Post condition: +6.23%
  - Follow-up condition: +9.46%
  - The coefficient of variation did not differ between the pre, post, and follow-up conditions for step length or cadence.
- There was a statistically significant different in duration of stance phase for the paretic leg (P<0.001) and for the non-paretic leg (P<0.05).
  - Post condition: stance phase decreased by 16.07% in the paretic leg (P<0.01) and by 10.20% in the non-paretic side
  - Follow-up condition: stance phase decreased further by 17.37% in the paretic leg (P<0.001) and by 13.10% in the non-paretic side (P<0.05).
  - No significant difference in step length, cadence and duration or stance phase was found between the post and follow-up condition.
- The mean vertical ground reaction force of the paretic limb increased by 6.5% in the post condition (P<0.05) and by 8.5% in the follow-up condition (P<0.01).
  - There was no significant difference in vertical ground reaction force for the non-paretic limb between the pre-condition and after the treadmill walking (P>0.05).
- There was a statistical significant increase in range of motion of the non-paretic hip, knee, ankle, and paretic knee in the post-condition (P<0.05), and a statistically significant increase in range of motion of the non-paretic hip, knee (P<0.001) and paretic hip (P<0.05).
  - There was no statistically significant changes in range of motion between the post and follow-up condition.

Original Authors' Conclusions

The authors concluded that a brief treadmill training with a weight on the ankle of the non-paretic lower extremity can enhance the gait ability of individuals with hemiparesis following a stroke. The training strategy used in this study was effective in improving specific spatiotemporal, kinetic, and kinematic measures. The authors discussed the need for further investigation to assess the effects of treadmill training, training with an added ankle weight, and repetitive training.

Critical Appraisal

Validity

This study was scored on the Modified Downs and Black Checklist. This measure is out of a total of 29 points and divided into five subscales which cover reporting, external validity, internal validity-bias, internal validity-confounding, and power. This study had a total score of 18/29 and presents with level IIb evidence.

- Reporting: Hypothesis clearly described: Yes, main outcomes measures described: Yes, characteristics of patients clearly described: Yes, interventions clearly described: Yes, distributions of principle confounders described: Yes, main findings clearly described: Yes, estimates of random variability: Yes, adverse events reported: No, characteristics of patients lost to follow-up described: No, actual probability values: No
- External validity: subjects asked to participate were representative of entire population: No, subjects who participated were representative of entire population: Yes, staff and facility were representative of treatment that patients receive: Yes
- Internal validity-bias: blind study subjects: No, blind those measuring outcomes: No, "data dredging" made clear: No, time period between intervention and outcome the same for case and controls: Yes, statistical tests appropriate: Yes, compliance reliable: Yes, main outcome measures accurate: Yes

- Internal validity-confounding: recruited from same population: Yes, recruited over the same period of time: Yes, randomized: No, randomization concealed from patients and staff: No, adequate adjustment for confounding in the analysis in main findings: Yes, losses of patients to follow-up taken into account: Yes
- Power: power analysis reported

The use of a set 2 kg ankle weight for women and a 4 kg ankle weight allowed for simplicity of the study. However, this should be adjusted individually by a percentage of the individual's force output ability, because it does not take into account the various muscle activation abilities of the participants. In addition, there was no control group used to see if improvements made in gait were a result of learning, practice effect, or test familiarization. The authors did not address how they decided on the sample size of their study.

Since this was a single-session study and there were no reported complications with participant's completing the walking trials, all subjects were retained. Each participant performed the treadmill walking trials at their individual preferred walking speed, which allowed for independent catering of the resisted walking to assess for individual effects, rather than assigning a set velocity that might not have been appropriate for all participants. Lastly, the steps done in the study were described well and easy to implement for further research or in the clinical setting. Overall, the study design and outcomes measured were appropriate for the aim of the study.

Interpretation of Results

The results support the use of adding weight to the non-paretic limb during a steady 20 minute treadmill walk to improve gait performance in individuals with hemiparesis following a stroke. The set-up used in this study could be utilized in most clinical settings and can be easily implemented and replicated with individuals who meet the inclusion criteria. However, the objective of the study was to assess the short-term effects of restraining the non-paretic limb in individuals with an early stroke. The results cannot be generalized to the entire stroke population and long-term effects were not assessed. Repetitive training or increased training time may be needed to see lasting effects.

The increase in walking speed, step length, cadence, alteration in kinetic variables, and improved weight bearing ability on the paretic limb is a promising outcome for future interventions for the stroke population. Because of the small sample size and lack of long-term outcome data, the protocol used in this study would not be clinically appropriate to implement for the expectation of long-term alterations in gait. The presence of short-term after effects during the post and follow-up condition, indicated that learning has occurred to influence gait. However, the duration of this learning effect is unknown and should be studied further.

The mean pre condition gait speed was 0.33 m/s (95% CI=0.24-0.43 m/s), which is a very slow gait speed, and this increased significantly ($P<0.001$) to 0.39 m/s (95% CI=0.30-0.48 m/s) in the post condition and increased further to 0.42 m/s (95% CI=0.31-0.55 m/s) in the follow-up condition. A small minimal clinically important difference for gait speed in stroke patients is 0.06 m/s, and a substantial meaningful change is 0.14 m/s.[11] While the speed in the follow-up condition is still considered a slow speed (age-matched healthy adult ambulated at about 1.05 m/s), the participants had an increased gait speed of 0.09 m/s from the pre-condition to follow-up, which is clinically significant, after only a 20 minute walking trial, and 20 minutes of rest. A slow gait speed is associated with a reduction of step length and cadence, which can lead to compensatory strategies to alter the gait pattern. This study demonstrates that individuals with stroke are able to increase their gait speed by increasing both their step length and cadence on both the paretic and non-paretic side.

The study also found a significant increase in vertical ground reaction force on the paretic leg after the weighted walking trials ($P<0.01$) in both the post and follow-up condition, which is also associated with an increase in gait speed. This suggests that the participants were able to support more weight on their paretic lower extremity during the overground walking even after the treadmill training was completed. Therapeutic interventions that alter the non-paretic limb may be effective in producing favorable rehabilitation outcomes for individuals who are post-stroke.

EVIDENCE SYNTHESIS AND IMPLICATIONS

Evidence Synthesis

The reviewed evidence suggests that individuals with hemiparesis following a stroke may be able to generate an increase in muscle activity and propulsive force of the paretic limb through locomotor adaptability tasks such as increasing stride length or adding an ankle weight on the non-paretic lower extremity to augment the biomechanical output of the paretic limb. During inclined treadmill walking only the plantar flexors on the non-paretic side had a significant increase in muscle activity to assist with propulsion, which contributes to slow and asymmetrical walking. Compensatory strategies during gait are a common rehabilitation challenge that occurs during gait training, so steady-state walking may not be an appropriate training stimulus to regain full locomotor ability post-stroke. Compensatory strategies will limit improvements in functional mobility and should be measured and limited when possible.[8] After stroke, it is common to see plantar flexor weakness that reduces the force produced for forward propulsion, which results in compensations from other joints, such as the hip, to propel the limb and center of mass forward during gait.[10] There is currently no available evidence in the literature that attempts to utilize a posterior force provided at the pelvis to increase propulsive force in the post-stroke population.

Clinical Implication

The clinical implication of the reviewed studies is that there is a possibility of short-term improvements in motor performance to facilitate symmetrical gait after a stroke through the use of task-specific training. Clarke et al[8] uses a locomotor task of increasing stride length on the non-paretic limb to significantly increase forward progression by 113% and increase paretic limb propulsion by 319% during a short bout of training. However, the carry-over effect after training was not assessed to overground walking, so there is no evidence to demonstrate that this would be an appropriate task to improve biomechanical output in overground gait training. Regnaux et al[3] utilized a similar concept as Clarke and his colleagues, altering the non-paretic lower extremity by adding an ankle weight during a short, single-session of treadmill gait training, which resulted in a significant increase in overground walking speed immediately and after 20 minutes of the gait training. These were both observational studies, so clinicians should utilize additional evidence as well as their clinical judgement prior to implementing these trials as interventions.

A short, single-session of inclined treadmill training with a maximum incline of five degrees was found to be ineffective in improving plantar flexor activity on the paretic side in the post-stroke participants, and it had no carryover effect in propulsion or muscle activity to overground walking.[10] It is possible that compensatory strategies were utilized by the participants, which reduced the additional stimulus needed on the paretic limb to implement adaptation, or perhaps the treadmill speed or incline was not significant enough to see the desired effect. The evidence reviewed in these three studies utilized post-stroke participants with a mean age of 59.9 years,[8] 58 years,[10] and 48.4 years,[3] and a mean time post-stroke of 39.8 months,[8] 20.67 months,[10] and 4.3 months.[3] The mean age of the studies are typical for first time stroke patients, such as the patient in the original clinical question. However, clinicians need to use their clinical judgement when implementing interventions based off of these studies, since many of the participants utilized were chronic stroke patients, with only one study utilizing inpatient rehabilitation participants.

Implication for Future Research

Observational studies provide clinicians with practical concepts that could be utilized during post-stroke rehabilitation, but further information would be useful to determine the effectiveness of these studies as interventions. Prospective research should be done using quality randomized controlled trials that utilize interventions, to assess the effectiveness of locomotor adaptability tasks on individuals post-stroke through different stages of rehabilitation. Much of the current research related to the clinical question are observational studies, which causes challenges in answering the clinical question because they are not reliable in determining the effectiveness of these trials as interventions in the general stroke population; they do, however, help to enlighten clinical practice.

Specifically, future research should isolate interventions during different stages of locomotor rehabilitation to determine what approach is most effective during the different stages in rehabilitation (acute versus chronic hemiparesis). In addition, larger sample sizes should be utilized as well as specific baseline characteristics of the participants such as specific lesion location, which could affect the degree of motor adaptation that can occur. Lastly, the studies did not address how long the adaptations effects occurred for, or if a dose/response relationship exists.

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