CRITICALLY APPRAISED TOPIC

FOCUSED CLINICAL QUESTION

For a 71-year-old male with left hemiparesis, is the use of auditory rhythmic simulation during gait training more effective than gait training alone for recovery of gait speed and symmetry within the first three months of stroke rehabilitation?

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CLINICAL SCENARIO

A 71-year-old male patient with left hemiparesis and associated gait impairments following a stroke is approximately one month post-stroke and in inpatient rehabilitation. Although he has regained enough functional strength and movement in his left upper extremity to effectively hold items, like a fork or toothbrush, he is most concerned about relearning to walk similarly to his prior level of function. The patient has progressed in physical therapy enough to be able to stand unassisted and even take forward steps with handheld assistance, but his gait velocity is significantly decreased, and his swing symmetry is poor when comparing his affected and unaffected limbs. He often has difficulty advancing his left leg without assistance and almost never advances his left leg at the same rate at which he is able to advance his right leg. During one of his treatment sessions, music was played while he was gait training on the treadmill to which he responded positively. His steps became more in rhythm with the song, and he was able to initiate advancement of his left leg more easily. Based on this patient's response to music and the associated improvements in gait that were observed throughout his time in inpatient rehab, this PICO question was formed to investigate the clinical efficacy of rhythmic auditory stimulation combined with gait training for the improvement of gait velocity and step symmetry in patients with hemiparesis post-stroke.

SUMMARY OF SEARCH

- Ten studies were identified that met the inclusion/exclusion criteria, nine of which were RCTs and one of which was a case study on a patient with a cerebellar stroke. Three of the RCTs with the highest-quality of evidence, based on the PEDro quality assessment scale, were selected for review and analysis.
- Rhythmic auditory stimulation (RAS) combined with gait therapy significantly improves gait velocity, stride length, and cadence, as well as balance in patients with hemiparesis in both the subacute and chronic period. In all three studies, reported effect sizes for gait velocity, stride length, and cadence all favored the experimental group (RAS) over the control group, which received conventional gait therapy alone. Two of the three studies also studied the effects of RAS combined with gait training on balance and reported an effect size in favor of the RAS group for balance. Additionally, one of the studies reported an effect size for patient-reported quality of life also favoring the RAS group.
- Future research studies should investigate the effects of RAS on gait parameters in patients with hemiparesis when combined with other gait training interventions, including bodyweight-supported treadmill training, aquatic therapy, stationary cycling, strength training, and functional electrical stimulation.[1] Future RCTs should be completed with larger sample populations and with proper blinding of assessors to increase validity. The effect of RAS combined with gait training should also be studied in other settings beyond the hospital or laboratory, such as outpatient clinics or in the community, in order to extend the research study to other patient populations.

CLINICAL BOTTOM LINE

The current evidence suggests that rhythmic auditory stimulation paired with gait training is more effective than gait training alone for the improvement of gait parameters such as velocity, cadence, and stride length among patients with hemiparesis after a stroke. Evidence supports combined rhythmic auditory stimulation and gait training for increased standing balance, as well. When treating patients with gait and balance impairments secondary to stroke, physical therapists should consider incorporating similar interventions to those used in these three studies in order to evaluate the effects of rhythmic auditory stimulation in the clinical setting.

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 Hemiparesis	Music Auditory input Auditory stimulation Auditory cue* RAS	No comparison	Gait Walk* Ambulat* Gait recovery Gait speed Gait velocity Gait symmetry Gait pattern

Final search strategy:

1. Stroke OR CVA OR "cerebrovascular accident" OR hemiparesis
2. Music OR auditory input OR auditory stimulation OR auditory cue OR RAS
3. Gait OR walk* OR ambulat* OR gait recovery OR gait speed OR gait velocity OR gait symmetry OR gait pattern
4. Subacute OR sub-acute OR 3-month OR 3 month*
5. #1 AND #2 AND #3 AND #4 **(only 3 results on Pubmed, 0 on CINAHL, 1 on AMED)**
6. #1 AND #2 AND #3 **(FINAL SEARCH)**

Databases and Sites Searched	**Number of results**	**Limits applied, revised number of results (if applicable)**
• Pubmed • CINAHL • AMED	64 34 14	Original search included #4 ("Subacute OR sub-acute OR 3-month OR 3 month*) but produced only 3 results on Pubmed, 0 results on CINAHL, and 1 result on AMED; Deleted #4 to broaden search

INCLUSION and EXCLUSION CRITERIA

Inclusion Criteria
➢ Population of individuals who are rehabilitating from a stroke ➢ Uses music, metronome, or some other type of auditory facilitation during gait training and compares with gait training without music, etc. ➢ Measures a specific aspect of gait—speed/velocity, symmetry (not necessarily both) ➢ Intervention randomized ➢ Applied at the community-level ➢ Study published in English *Modifications to Inclusion Criteria: ➢ Deleted "Interventions performed within 3 months of the patient's stroke (sub-acute period)" to also allow for studies that implemented the intervention in patients with chronic stroke ➢ Modified the gait measurement possibilities to include cadence, stride length, symmetry, and velocity, though the studies did not necessarily need to include all of those
Exclusion Criteria
➢ Studies performed on patients with other neurological impairments that are not stroke-related hemiparesis

- Abstracts
- Articles that are not in English
- Review articles without data on outcomes

*Modifications to Exclusion Criteria:

- Deleted "Case Studies" so that pertinent case studies could be included in results

RESULTS OF SEARCH

A total of 10 relevant studies were located and categorized as shown in the following table (based on Levels of Evidence, Centre for Evidence Based Medicine, 2011) using the PEDro quality assessment rating scale for RCTs and the Downs and Black quality assessment checklist (modified from Downs & Black, 1998) for the case study.

Summary of articles retrieved that met inclusion and exclusion criteria

Author (Year)	Study quality score	Level of Evidence	Study design
Song G-B, Ryu HJ (2016)[2]	7/11 (PEDro)	1b	RCT
Cha Y, Kim Y, Hwang S, Chung Y (2014)[3]	7/11 (PEDro)	1b	RCT
Suh JH, Han SJ, Jeon SY, et al (2014)[4]	8/11 (PEDro)	1b	RCT
Schauer M, Mauritz K-H (2003)[5]	7/11 (PEDro)	1b	RCT
Thaut MH, McIntosh GC, Rice RR (1997)[6]	7/11 (PEDro)	1b	RCT
Kim J-H, Park S, Lim H, Kim G, Moon-hyung P, Lee B (2012)[7]	7/11 (PEDro)	1b	RCT
Park IM, Oh DW, Kim SY, Choi JD (2010)[8]	6/11 (PEDro)	1b	RCT
Kim JS, Oh DW (2012)[9]	7/11 (PEDro)	1b	RCT
Thaut MH, Leins AK, Rice RR, et al (2007)[10]	8/11 (PEDro)	1b	RCT
Wright RL, Bevins JW, Pratt D, Sackley CM, Wing AM (2016)[11]	16/29 (Downs & Black)	4	Case study

BEST EVIDENCE

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

- Thaut MH, Leins AK, Rice RR, et al. Rhythmic auditory stimulation improves gait more than NDT/Bobath training in near-ambulatory patients early poststroke: A single-blind, randomized trial. (2007)[10]
- Cha Y, Kim Y, Hwang S, Chung Y. Intensive gait training with rhythmic auditory stimulation in individuals with chronic hemiparetic stroke: A pilot randomized controlled study. (2014)[3]
- Suh JH, Han SJ, Jeon SY, et al. Effect of rhythmic auditory stimulation on gait and balance in hemiplegic stroke patients. (2014)[4]

Reasons for selecting these studies were:

- These studies have the three of the highest study quality scores out of the 10 that fit the inclusion/exclusion criteria (and all are RCTs)
- They each compare gait training with rhythmic auditory stimulation (RAS) to conventional gait training without RAS
- All 3 studies include only participants who have had strokes (no other neurological conditions)
- All 3 studies' test and control groups received NDT/Bobath techniques as part of their PT intervention in addition to or alongside gait training
- All 3 studies include outcome measures that are pertinent to the clinical question—cadence, velocity, stride length; two included balance as an additional outcome measure; and a third measured swing symmetry as an additional outcome

SUMMARY OF BEST EVIDENCE

(1) Description and appraisal of "Rhythmic Auditory Stimulation Improves Gait More Than NDT/Bobath Training in Near-Ambulatory Patients Early Poststroke: A Single-Blind, Randomized Trial" by Thaut et al. (2007)[10]

Aim/Objective of the Study/Systematic Review:

The purpose of this study was to assess the clinical efficacy of rhythmic auditory stimulation (RAS) paired with gait training by comparing this method's outcomes to those of the commonly used NDT/Bobath method of gait training for gait velocity, cadence, stride length, and swing symmetry.

Study Design

- Single randomized controlled trial
- Participants randomly selected by a random number table from an eligible pool of participants in 2 research centers (one in Germany and one in U.S.)
- Random treatment allocation via computerized random number generators; concealed to both recruiter and training therapists
- Participants were informed of group allocations but blinded to purpose of assigned conditions
- Assessing PTs who performed Barthel Index and Fugl-Meyer Scale prior to training were all blinded
- 4 gait therapists per group to ensure consistent gait training; therapists not blinded to treatment conditions
- Participants were tested 1 day prior to start of training and 1 day after final training session (3 weeks of training total)
- Intention to treat analysis
- 2 tailed t-test comparisons for pretest (between groups)
- 2 tailed t-test comparisons for post-test (between groups)
- Levene's F test of variance performed

Setting

The study was performed in two different research centers—one in Germany and one in the United States.

Participants

- N= 78
- Convenience sampling, but randomly selected from eligible pool of 155 patients
- Experimental group (RAS): 43; Control group (NDT/Bobath): 35
- Gender: 41 males, 37 females
- Age: 69.2±11 years (RAS), 69.7±11 years (NDT/Bobath)
- Side of hemiplegia: 36 R, 42 L
- # days post-stroke (upon admission to study): 21.3±10.8 days (RAS), 22.2±14.7 days (NDT/Bobath)
- Location of stroke: 65 Middle cerebral artery, 8 internal capsule, 4 basal ganglia/thalamus, 1 subdural hematoma
- Both groups were similar at baseline (though the study does not specifically say they are "statistically similar" on all demographics):
  - Had lower extremity spasticity (either stage 4 or early stage 3 Brunnstrom)
  - Were within 4 weeks post-stroke
  - Could walk 5 stride cycles with HHA support (on non-paretic forearm, wrist, elbow at 90 degrees of flexion)
  - Baseline assessments:
    - Fugl-Meyer mean scores (combined balance and LE function): 33.3 (RAS), 31.4 (NDT/Bobath)
    - Barthel Index mean scores: 47.5 (RAS), 45.5 (NDT/Bobath)
- Dropout rate: 23% in one center, 10% in other center (due to hospital transfer, early D/C, medical complications, or personal reasons)

Intervention Investigated

Control

- Gait training according to NDT and Bobath principles (authors do not specify details of intervention)
- Control group participants given similar instructions for gait training but no RAS
- Dosage: 30 minutes, 5x/week for 3 weeks
- 4 trained therapists performed gait training in each research center
- Handheld assistance available per patient need throughout treatment

Experimental

- Use of metronome and music tapes in digital MIDI format for tempo (each with easily-modified tempo)
- Gait training session:
  - 1st quarter of session: RAS cueing frequency matched the patient's gait cadence
  - 2nd quarter of session: RAS cueing frequency increased in 5% increments while maintaining patient's balance
  - 3rd quarter of session: incorporated practice of adaptive gait patterns (steps, ramps)
  - 4th quarter of session: Periodically faded RAS cues to allow patient to gait train without temporal stimulus
- Dosage: 30 minutes, 5x/week for 3 weeks
- 4 trained therapists performed gait training in each research center
- Handheld assistance available per patient need throughout treatment

Outcome Measures (Primary and Secondary)

- Patients tested 1 day before 3-week training began and 1 day after 3-week training ended
- Gait testing was performed without RAS and consisted of:
  - 10m flat walkway (instructions regarding speed were not provided, so it is assumed to be comfortable, self-selected gait speed)
  - 2m on front and back end for acceleration and deceleration
- Primary gait parameters measured pre- and post- training:
  - Velocity (m/min)
  - Stride length (m)
  - Cadence (steps/min)
  - Swing symmetry (ratio of individual leg swing times, paretic vs non-paretic)
- Gait parameters measured with 4 contact foot sensors; data was stored online and entered into analysis software (no human assessors)

- Secondary outcome measure: patient satisfaction

Main Findings

Pretest means for RAS group:

- Velocity (m/s): 14.1 (SD 6.3)
- Stride length (m): 0.53 (SD 0.12)
- Cadence (steps/min): 53 (SD 10.8)
- Symmetry (swing ratio): 0.42 (SD 0.12)

Pretest means for NDT/Bobath group:

- Velocity (m/s): 13.0 (SD 5.9)
- Stride length (m): 0.50 (SD 0.12)
- Cadence (steps/min): 50 (SD 9.9)
- Symmetry (swing ratio): 0.40 (SD 0.12)

At pretest, there were no significant differences between the two groups for any of the four gait parameters—velocity (p=0.347), stride length (p=0.111), cadence (p=0.141), and symmetry (p=0.285).

After three weeks of gait training, post-test means for the RAS group were the following:

- Velocity (m/s): 34.5 (SD 9.1)
- Stride length (m): 0.88 (SD 0.21)
- Cadence (steps/min): 82 (SD 12.9)
- Symmetry (swing ratio): 0.58 (SD 0.05)

Post-test means for the NDT/Bobath group were the following:

- Velocity (m/s): 20.3 (SD 6.5)
- Stride length (m): 0.67 (SD 0.24)
- Cadence (steps/min): 60 (SD 9.9)
- Symmetry (swing ratio): 0.46 (SD 0.07)

Between group mean differences of change scores demonstrated greater improvements in favor of the experimental (RAS) group over the control (NDT/Bobath) group: 13.1 m/s, 95% CI [6.9, 19.3] for velocity, 0.18 m, 95% CI [0.13, 0.23] for stride length, and 19 steps/min, 95% CI [10.4, 27.6] for cadence. There was also a greater improvement of gait symmetry (swing ratio) in the experimental group compared to the control group—0.10, 95% [-0.04, 0.24]—but the mean difference between groups for this gait parameter was not significant since the confidence interval includes zero.

For the secondary outcome of patient satisfaction, both groups increased satisfaction throughout the study, but a significant main effect was found for the experimental (RAS) group (p=0.019).

Original Authors' Conclusions

Based on the significant improvements that were observed for gait velocity, stride length, cadence, and swing symmetry after three weeks of gait training, the use of rhythmic auditory stimulation during gait training is more effective than the NDT/Bobath gait training alone for the recovery of gait in hemiparetic stroke rehabilitation.

Critical Appraisal

Validity

This study scored 8/11 on the PEDro scale for methodological quality. The following are strengths and limitations of the study, in addition to an assessment of the study's level of internal and external validity:

Strengths:

- Treatment (rhythmic auditory stimulation with gait training) in the experimental group was compared to NDT/Bobath gait training in the control group, rather than just being compared to no gait training; an appropriate control group intervention increases the clinical significance of the study's findings
- Random allocation, concealed to both recruiter and treating therapists
- Blinding of assessors who performed the baseline testing of all participants
- Blinding of participants to the aim of each intervention
- Treating therapists were "unbiased" in regards to the two types of interventions since both interventions are considered valid treatments
- Intention to treat analysis was performed
- Experimental and control groups were not statistically different at pretest
- Total minutes of gait training performed throughout the 3 weeks was consistent between groups

Limitations:

- Authors do not address statistical power; they do not give a rationale as to why they included the number of participants that they included in the study
- Authors report statistically significant change but do not establish a minimally clinical important difference or power, so it is difficult to determine if observed effect is clinically important or not
- Due to the clinical nature of the study, neither participants nor therapists are blinded to the treatment intervention
- Dropout rate is 23% for one research center and 10% for the other research center, and though authors do not specify the total number of participants who dropped out of the study, it appears that less than 85% of participants completed the study
- No follow-up evaluation is performed beyond the post-test which makes it hard to assess long-term efficacy of RAS intervention

Internal Validity

- Experimental and control groups were statistically similar for demographic variables at pre-test which increases internal validity since study findings are most likely not due to differences in the groups' demographics at baseline
- Although neither participants nor therapists were fully blinded, final outcomes (gait parameters) were measured with an online analysis software, minimizing bias and increasing the study's internal validity
- Randomized and concealed allocation into groups increases internal validity by reducing risk of bias
- Instrumentation bias—potentially varying training styles of the 4 therapists could be a confounding variable that might decrease internal validity, though authors suggest the 4 therapists ensured consistency in training protocols and procedures (which would increase internal validity)

External Validity

- This is just one RCT, not a systematic review or meta-analysis, so the study's results are not necessarily generalizable for the larger population
- Given that this is a controlled study performed within a research center with patients who are specifically in subacute hemiparetic stroke rehab, the findings are fairly specific to this particular population and not as easily applicable to patients in the outpatient or community setting
- Therapists could give handheld assistance when needed, which may result in less functional and less carry-over to real-life gait

Interpretation of Results

- Overall, improvements in all four gait parameters were observed for both the experimental group and the control group from pretest to posttest. Although both groups demonstrated improvement, the between-group mean differences of change scores suggest that RAS is more clinically effective than the NDT/Bobath method for gait training with patients with hemiparesis in the subacute rehab setting.
- While the study's authors did not establish statistical power, it appears that there was, indeed, a large

effect size for velocity, stride length, and cadence in favor of the RAS group, as the group reflected significantly greater improvements from pretest to posttest for these three parameters in comparison to the control group. This suggests the clinical efficacy of rhythmic auditory stimulation in producing improvements in gait quality. A greater improvement in swing symmetry in the RAS group compared to the NDT/Bobath group was also demonstrated, but it failed to reach statistical significance since the confidence interval included 0.

- Given that the RAS intervention was compared to the commonly used and effective NDT/Bobath gait training method and still demonstrated statistically significant differences between groups for 3 of the 4 gait parameters, the study's findings were even more valid and convincing for RAS.
- The dropout rate seemed to be higher than what would be ideal, which decreases the validity of the study's results.
- Four therapists at each research center were trained in how to appropriately administer gait training to the study's participants with the aim of keeping the interventions consistent between participants and groups; however, since each therapist most likely has a different style and technique (in addition to room for human error) for gait training, despite the training, differences in administration may have been a confounding variable.

(2) Description and appraisal of "Intensive gait training with rhythmic auditory stimulation in individuals with chronic hemiparetic stroke: A pilot randomized controlled study" by Cha et al. (2014)[3]

Aim/Objective of the Study/Systematic Review:

The purpose of this study was to assess the clinical effectiveness of rhythmic auditory stimulation (RAS) paired with gait training compared to that of intensive gait training without RAS by evaluating respective changes in postural control, various gait parameters, and quality of life of individuals with chronic hemiparetic stroke.

Study Design

- Pilot randomized controlled trial
- Pretest-posttest design
- Random treatment group assignment with sealed envelopes to conceal allocation to participants
- Unclear as to whom the treating therapists were, how many there were, how/if they were trained, and whether or not they were blind to treatment group assignment
- Unclear as to whether or not outcome assessors were blinded or if assessors were the same as the treating therapists
- Participants were tested 1 day prior to start of training and 1 day after final training session (6 weeks of training total)
- Unclear in regard to intention to treat analysis
- Paired t-test for comparison of changes between pretest and post-test for each group (within group)
- Independent t-test for comparison of difference between postural control and gait performance post-training (between group)

Setting

Setting is not clearly stated

Participants

- N= 20
- Convenience sampling—recruited from a specific hospital
- Experimental group (RAS): 10; Control group: 10
- Gender: 6 males, 4 females (RAS); 6 males, 4 females (control)
- Age: 59.8±11.7 years (RAS), 63.0±14.1 years (control)
- Height (cm): 167.4±5.5 (RAS), 165.8±7.6 (control)
- Weight (kg): 67.0±11.2 (RAS), 66.9±10.2 (control)
- Mini-Mental State Examination score: 26.6±2.1 (RAS), 26.1±1.8 (control)
- Side of hemiplegia: 1 R, 9 L (RAS), 1 R, 9 L (control)
- # months post-stroke (upon admission to study): 14.5±5.5 (RAS), 14.7±5.4 (control)
- Both groups were similar at baseline (though the authors do not specifically say they are "statistically similar" on all demographics, p-values demonstrates no significant difference)
- No dropouts—all 20 participants were completed the study

Intervention Investigated

Control

- Gait training dosage: 30 minutes, 5x/week for 6 weeks
- Control group participants given similar instructions as the RAS group for gait training and performed gait for similar amounts of time and distance but with no RAS
- 2 therapists present to give physical and/or verbal assistance as needed
- Participants also received standard physical therapy including Bobath method and proprioceptive neuromuscular facilitation for 30 minutes, 5x/week for 6 weeks

Experimental

- Use of metronome and music tapes that were prepared based on participants' preferences of pop or country music; based on chosen preference, music specialist chose 3 songs in that genre with the same rhythm
- Baseline cadence measured 3 times every 2 weeks throughout the 6 weeks by having participants walk around track at self-selected pace for 2 minutes
- Metronome was played over the song's beat to enhance the participant's sense of rhythm and was set to match the participant's step pattern and cadence
- On the 3rd and 5th week, increased rhythm frequency by 5%
- Gait training dosage: 30 minutes, 5x/week for 6 weeks
    - 3-session cycles for the full 6 weeks
        - 2 sessions: intensive gait training with RAS
        - 1 session: intensive gait training without RAS
- 2 therapists present to give physical and/or verbal assistance as needed
- Participants also received stroke-specific physical therapy including Bobath method and proprioceptive neuromuscular facilitation for 30 minutes, 5x/week for 6 weeks

Outcome Measures (Primary and Secondary)

- Berg Balance Scale (BBS)
    - Assesses upright posture and balance with functional movement
    - Score range: 0-56
    - Higher score indicates more postural control and better balance
    - BBS has been shown to have good test-retest and interrater reliability and internal consistency with chronic stroke population
- Article does not detail how or by whom BBS was administered

- The following spatiotemporal parameters were measured:
    - Gait velocity (cm/sec)
    - Cadence (step/min)
    - Stride length on affected side (cm)
    - Double support period on affected side (% of cycle)
    - Stride length on less affected side (cm)
    - Double support period on less affected side (% of cycle)
- Spatiotemporal parameters were measured on the GAITRite (a 5-m electronic board with sensor pads)
    - Participants walked at a self-selected speed from one end of the board to the other
    - Stride parameters of five gait cycles were analyzed for each participant
    - Software used to process the data

- Secondary Outcome Measure: Stroke Specific Quality of Life scale (SS-QOL)
    - Patient-reported measure
    - 12 subscales—mobility, energy, upper extremity function, work/productivity, mood, self-care, social roles, family roles, vision, thinking, language, personality
    - Score range: 0-245
    - Score of "1" on each item indicates "total help" required, and "5" on an item indicates "no help needed"; lower scores associated with lower overall quality of life

Main Findings

Berg Balance Scale (BBS):

- RAS group
    - Pretest mean score: 43.5 (SD 8.2)
    - Posttest mean score: 48.5 (SD 7.7)
    - Within group mean difference in change: 5.0

- Control group
  - Pretest mean score: 41.9 (SD 6.9)
  - Posttest mean score: 43.6 (SD 7.0)
  - Within group mean difference in change: 1.7
- Between group mean difference in change: 3.3 in favor of RAS group

Significant improvements in BBS scores were observed in both groups, but the t-test analyzing between group mean differences in change demonstrates greater improvements in the RAS group over the control group (t=4.919, indicating greater evidence against the null hypothesis since "t" is large; p<0.001).

Spatiotemporal parameters:

- RAS group:
  - Gait velocity (cm/s): Pretest 37.4 (SD 19.7); Posttest 60.7 (SD 27.8)
  - Cadence (steps/min): Pretest 71.0 (SD 18.2); Posttest 87.2 (SD 23.3)
  - Stride length affected side (cm): Pretest 61.3 (SD 17.3); Posttest 79.8 (SD 18.3)
  - Stride length less affected side (cm): Pretest 60.9 (SD 16.9); Posttest 75.6 (SD 22.9)
  - Double support period on affected side (% cycle): Pretest 44.8 (SD 13.5); Posttest 32.6 (SD 10.1)
  - Double support period on less affected side (% cycle): Pretest 45.3 (SD 14.7); Posttest 32.8 (SD 10.4)
- Control group:
  - Gait velocity (cm/s): Pretest 37.9 (SD 18.3); Posttest 42.0 (SD 18.5)
  - Cadence (steps/min): Pretest 72.5 (SD 22.8); Posttest 76.8 (SD 25.3)
  - Stride length affected side (cm): Pretest 60.9 (SD 14.9); Posttest 65.0 (SD 15.1)
  - Stride length less affected side (cm): Pretest 60.4 (SD 14.6); Posttest 64.8 (SD 15.7)
  - Double support period on affected side (% cycle): Pretest 40.1 (SD 14.1); Posttest 39.2 (SD 11.8)
  - Double support period on less affected side (% cycle): Pretest 39.1 (SD 13.5); Posttest 36.9 (SD 9.6)
- Between group mean differences in change:
  - Gait velocity (cm/s): 19.2 (in favor of RAS group), p=0.024
  - Cadence (steps/min): 11.9 (in favor of RAS group), p=0.040
  - Stride length affected side (cm): 14.4 (in favor of RAS group), p=0.018
  - Stride length less affected side (cm): 10.3 (in favor of RAS group), p=0.126
  - Double support period on affected side (% cycle): 11.3 less (in favor of RAS group), p=0.005
  - Double support period on less affected side (% cycle): 10.3 less (in favor of RAS group), p=0.259

Similar to the BBS scores, improvements for all parameters were observed in both groups from pretest to posttest. Between group mean differences of change scores demonstrated greater improvements in the experimental (RAS) group over the control group, and all parameters except for stride length and double support period on the less affected side significantly improved in a larger amount in the RAS group than the control group.

Stroke Specific Quality of Life scale (SS-QOL)

- RAS group
  - Pretest mean score: 158.6 (SD 18.3)
  - Posttest mean score: 183.7 (SD 21.5)
  - Within group mean difference in change: 25.1
- Control group
  - Pretest mean score: 153.0 (SD 17.1)
  - Posttest mean score: 159.2 (SD 17.4)
  - Within group mean difference in change: 6.2
- Between group mean difference in change: 18.9 (in favor of RAS group)

Significant improvements in SS-QOL scores were observed in both groups, but the between group mean difference in change score demonstrates a greater improvement in the RAS group over the control group, p=0.000).

Original Authors' Conclusions

For patients with chronic hemiparetic after a stroke, intensive gait training with rhythmic auditory stimulation (RAS) produces greater improvements than intensive gait training alone in gait parameters including velocity, cadence, stride length on the affected side, and double support period on the affected side. In addition to improvements in gait, RAS paired with gait training also results in greater improvements in functional balance and patient-reported quality of life when compared to gait training without RAS.

Critical Appraisal

Validity

This study scored 8/11 on the PEDro scale for methodological quality. The following are strengths and limitations of the study, in addition to an assessment of the study's level of internal and external validity:

Strengths

- Treatment (rhythmic auditory stimulation with gait training) in the RAS group was compared to intensive gait training without RAS in the control group, rather than being compared to no gait training; an appropriate control group intervention increases the clinical significance of the study's findings
- Random assignment to treatment groups
- Allocation concealment for the participants
- RAS and control groups were not statistically different for demographic variables at pretest
- Physical therapy intervention was consistent between both the RAS group and the control group: both received Bobath method and proprioceptive neuromuscular facilitation for the same amount of time and number of sessions
- Gait training was consistent other than the intervention (RAS) for both the RAS group and the control group: both performed gait training for the same amount of time and the same distance and had two therapists present for assistance and feedback as needed
- No dropouts throughout the study

Limitations

- Unclear as to whom the therapists or assessors are, if they remained consistent throughout the study, or if they were trained prior to the study
- Random allocation to treatment group is only concealed to participants, not to recruiters or therapists
- Due to the clinical nature of the study, neither participants nor therapists are blinded to the treatment intervention
- Unclear as to whether or not both groups were significantly similar at baseline for BBS and spatiotemporal parameters
- "Intention to treat" not addressed
- Authors report statistically significant change but do not establish a minimally clinical important difference or power, so it is difficult to determine if observed effect is clinically important or not
- Sample size is small (N=20) which makes generalizability difficult
- Study's setting is not established, making reproducibility difficult
- No follow-up evaluation is performed beyond the post-test which makes it hard to assess long-term efficacy of RAS intervention

Internal Validity

- Experimental and control groups were statistically similar for demographic variables at pre-test which increases internal validity since study findings are most likely not due to differences in the groups' demographics at baseline
- Randomized assignment into treatment groups and concealed allocation for participants increases internal validity by reducing risk of bias
- Gait parameters were measured by the validated GAITRite and assessed by its software, minimizing bias that a human assessor might create and increasing the study's internal validity in this area
- The number of study testers and assessors and whether or not they were trained adequately before the study's commencement is not stated; if testers and assessors (for the Berg) are inconsistent in any way or if they are biased, this could decrease the internal validity of the study
- Patients nor therapists were unable to be fully blinded, decreasing internal validity

External Validity

- This is just one RCT, not a systematic review or meta-analysis, so the study's results are not necessarily generalizable for the larger population
- Study setting is not addressed, so whether the study participants are in an inpatient, outpatient, or community-based setting is unknown, making it difficult to generalize the study's findings to the hemiparetic stroke population beyond the participants in this study
- Gait was performed on the GAITRite which is not a functional assessment of gait since in the real world, stroke survivors will not be walking on a 5-meter board—this decreases external validity of the study's findings

Interpretation of Results

- Overall, improvements in Berg scores, SS-QOL scores, and all spatiotemporal parameters were observed for both the experimental group and the control group from pretest to posttest. Although both groups demonstrated improvement, the between-group mean differences of change scores suggest that RAS combined with intensive gait therapy is more clinically effective than intensive gait training alone for improving postural control, gait velocity, cadence, stride length and double support period on the affected limb, and quality of life of individuals with chronic hemiparetic stroke. Effect size is large in

favor of the RAS group for all parameters except stride length and double support period on the less affected limb, which is not expected to change much throughout the study.
- The study's findings have increased validity based off of the fact that the experimental group performed intensive gait training consistent in both time and distance with the gait training performed by the control group; and the only difference between groups was the RAS intervention, yet the RAS group still demonstrated statistically significant differences between groups for improvement of postural control, quality of life, and gait, in general. Had the control group received less or no gait training, one might contribute the study's findings less to the RAS and more to the differences in group treatment.
- Though results support the RAS intervention, the small sample size (N=20) and the unreported study setting make generalizability to the larger population of patients with stroke more difficult.
- Spatiotemporal parameters are measured on the GAITRite which provides an unbiased assessment of gait, but the study does not clearly address how the BBS is assessed. Inconsistent assessment of the BBS may be a potential source of bias that could ultimately decrease the clinical significance of the RAS group's larger improvements in BBS scores.

(3) Description and appraisal of "Effect of rhythmic auditory stimulation on gait and balance in hemiplegic stroke patients" by Suh et al. (2014)[4]

Aim/Objective of the Study/Systematic Review:

The purpose of this study was to use posturography to assess the clinical efficacy of rhythmic auditory stimulation (RAS) on gait parameters and standing balance control of patients with hemiparesis after stroke.

Study Design

- Single randomized controlled trial
- Means by which study participants were selected or recruited for the study is not addressed
- Random assignment to treatment groups via computerized random number generator; concealed to both recruiter and therapists
- Participants were informed of the treatment they would receive but blind to whether they were in the control or experimental group
- "Intention to treat" not addressed
- Mann-Whitney test and chi-square test were used to compare between group baseline demographic variables
- Wilcoxon signed rank test was used to compute within group mean differences for velocity, stride length, cadence, and balance
- Mann-Whitney test was used for between group mean differences

Setting

Setting is not clearly stated

Participants

- N= 16
- Participant selection process not addressed
- Experimental group (RAS): 8; Control group: 8
- Gender: 3 males, 5 females (RAS); 3 males, 5 females (control)
- Age: 61±14.48 years (RAS), 70.63±12.42 years (control)
- Side of hemiplegia: 3 R, 5 L (RAS); 3 R, 5 L (control)
- Type of infarction: 5 ischemic, 3 hemorrhagic (RAS); 6 ischemic, 2 hemorrhagic (control)
- # days post-stroke (upon admission to study): 386.38±283.22 (RAS), 224.25±213.03 (control)
- Mini-Mental State Examination score: 24.5±4.9 (RAS), 22.38±7.73 (control)
- No significant difference between groups for demographic data ($p>0.05$)
- No significant difference between groups at pretest in gait velocity, cadence, or stride length
- No significant difference between groups at pretest for overall stability index, anteroposterior index, and mediolateral index
- No dropouts

Intervention Investigated

Control

- Gait training (without RAS) for 15 minutes each session, 5x/week for 3 weeks
- Participant's guardian present during gait training

- Physical-therapist led NDT/Bobath training for 30 minutes each session, 5x/week for 3 weeks
- Posturography performed by having participant stand upright and barefoot on Biodex balance system with arms against body and feet with 20cm between them
    - 20-second trials in which participants attempted to maintain upright standing balance with dominant leg on the unstable part of the Biodex

Experimental

- Physical-therapist led NDT/Bobath training for 30 minutes each session, 5x/week for 3 weeks
- Gait training with RAS for 15 minutes each session, 5x/week for 3 weeks
    - Participant's guardian present during gait training
    - Musical Instrument Digital Interface software used to provide rhythmical stimulus during gait
    - Initial tempo matched participant's initial cadence and increased cadence
    - Gait training had 4 steps:
        - Step 1: 5-meter warm-up walk→3-minute rest→ 10-meter walk without rhythmic cueing
        - Step 2: 2-minute rest, 1-minute toe tapping, 10-meter walk with rhythmic cueing to the tempo of the participant's self-selected cadence
        - Step 3: 2-minute rest, 1-minute toe tapping, 10-meter walk with rhythmic cueing that is 5% increased from Step 2
        - Step 4: 2-minute rest, 1-minute toe tapping, 10-meter walk with rhythmic cueing that is 10% increased from Step 2
- Posturography performed by having participant stand upright and barefoot on Biodex balance system with arms against body and feet with 20cm between them
    - 20-second trials in which participants attempted to maintain upright standing balance with dominant leg on the unstable part of the Biodex

Outcome Measures (Primary and Secondary)

- Gait Parameters
    - Gait velocity (m/min)
    - Cadence (steps/min)
    - Stride length (m)
- Gait parameters calculated from the # steps and time to complete the 10-m walk

- Standing Balance Parameters
    - Overall stability index
    - Anteroposterior stability index
    - Mediolateral stability index
- Standing balance parameters assessed with the BioSway balance system and software; participants performed the test twice and the average of the two tests was taken
- Stability index is obtained by finding the variance of platform displacement (°) from a level position; high values for this outcome indicates more motion and decreased balance

- Though authors address how these outcome measures were assessed and calculated, they do not address by whom or where they were administered

Main Findings

Gait Parameters

At pretest, there were no significant differences between the experimental (RAS) group and the control group for cadence (p=0.674), gait velocity (0.382), or stride length (p=0.234).

At posttest, there also were no significant differences between the RAS group and the control group for cadence (p=0.115), gait velocity (p=0.574), or stride length (p=0.234). However, between group mean differences of change scores demonstrate larger and statistically significant improvement of the RAS group over the control group for gait velocity, cadence, and stride length.

Within group mean differences for gait parameters (negative number indicates gait parameters worsened between pretest and posttest):

- RAS group:
    - Cadence (steps/min): 5.24 (SD 4.95)
    - Velocity (m/min): 1.54 (SD 1.07)
    - Stride length (m): 0.01 (SD 0.01)

- Control group:
  - Cadence (steps/min): -1.83 (**this number appears to be reported incorrectly into Table 4; mean difference is calculated here but SD is unknown)
  - Velocity (m/min): -1.31 (SD 2.31)
  - Stride length (m): 0.00 (SD 0.41)

Calculated between group mean differences for gait parameters:

- Cadence (steps/min): 7.07 (in favor of RAS group), p=0.012
- Velocity (m/min): 2.85 (in favor of RAS group), p=0.012
- Stride length (m): 0.01 (in favor of RAS group), p=0.03

Standing Balance Parameters

At pretest, there were no significant differences between groups for overall stability index (p=0.225), anteroposterior index (p=0.442), or mediolateral index (p=0.959). At posttest, statistically significant improvements were observed in the RAS group for overall stability index (p=0.011), anteroposterior index (p=0.011), and mediolateral index (p=0.014). No significant improvements were observed in the control group for the three balance parameters. The calculated between group mean differences in change scores demonstrate significantly greater improvements in all three balance parameters for the RAS group over the control group.

Within group mean differences for balance parameters (negative number indicates decrease in variance in board displacement or increased balance):

- RAS group:
  - Overall stability index: -0.32 (SD 0.22)
  - Anteroposterior index: -0.25 (SD 0.12)
  - Mediolateral index: -0.22 (SD 0.20)
- Control group:
  - Overall stability index: 0.02 (SD 0.54)
  - Anteroposterior index: 0.06 (SD 0.23)
  - Mediolateral index 0.16 (SD 0.33)

Calculated between group mean differences for balance parameters:

- Overall stability index: 0.34, p=0.043
- Anteroposterior index: 0.31, p=0.016
- Mediolateral index: 0.38, p=0.006

Original Authors' Conclusions

When compared to conventional gait training alone, gait training with rhythmic auditory stimulation (RAS) demonstrated more significant improvements in gait velocity, stride length, cadence, and standing balance among patients with hemiplegia after stroke.

Critical Appraisal

Validity

This study scored 8/11 on the PEDro scale for methodological quality. The following are strengths and limitations of the study, in addition to an assessment of the study's level of internal and external validity:

Strengths:

- Treatment (rhythmic auditory stimulation with gait training) in the experimental group was compared to conventional gait training in the control group, rather than just being compared to no gait training; an appropriate control group increases the clinical significance of the study's findings
- Random assignment to treatment groups and concealed allocation to both recruiter and therapists
- Participants were blind to whether they were in the control or experimental group
- Experimental and control groups were not statistically different at pretest
- The total minutes of gait training performed throughout the 3 weeks was consistent between groups
- The total minutes of physical therapist-administered NDT/Bobath treatment throughout the 3 weeks was consistent between groups
- No study dropouts

Limitations:

- Intention to treat analysis not addressed
- Sample size is small (N=16) which makes generalizability difficult

- Study's setting is not established, making reproducibility difficult
- Due to the clinical nature of the study, neither participants nor therapists are blinded to the treatment intervention
- Although significant differences are reported, authors do not establish a minimally clinical important difference or power, so it is difficult to determine if observed effect is clinically important or not
- No follow-up evaluation is performed beyond the post-test which makes it hard to assess long-term efficacy of RAS intervention

Internal Validity

- Experimental and control groups were statistically similar for demographic variables, gait parameters, and standing balance parameters at pre-test which increases internal validity since study findings are most likely not due to differences in groups at baseline
- Randomized and concealed allocation into groups increases internal validity by reducing risk of bias
- Standing balance parameters were measured with the BioSway software, minimizing bias and increasing the study's internal validity in this area
- The number of study testers and assessors and whether or not they were trained adequately before the study's commencement is not stated; if testers and assessors (for gait parameters) are inconsistent in any way or if they are biased, this could decrease the internal validity of the study
- Patients nor therapists were unable to be fully blinded, decreasing internal validity

External Validity

- This is just one RCT, not a systematic review or meta-analysis, so the study's results are not necessarily generalizable for the larger population
- Study setting is not addressed, so whether the study participants are inpatient, outpatient, or community-dwelling is unknown, making it difficult to generalize the study's findings to the larger hemiparetic stroke population beyond just the participants in this study
- Standing balance was assessed on the BioSway device, and during this testing, participants stand with their arms by their side and are not required to perform any simultaneous functional task or divert their attention in any way; this is not a completely realistic measure of functional balance, making it more difficult to relate this study's findings on standing balance to other groups or community-dwelling individuals

Interpretation of Results

- Within group mean differences for gait parameters demonstrate that the RAS group improved in all three gait parameters. The control group means, however, decreased from pretest to posttest for cadence and gait velocity and remained the same for stride length. Although there are no statistical significant differences between the RAS and control groups at pretest or posttest for any of the three parameters, and effect sizes were not very large overall, effect size favored the RAS group for all three parameters.
- The mean difference of change for cadence in the control group appears to be recorded incorrectly in Table 4 of the study. Authors report a within group mean difference of 1.54 (SD 1.07) for cadence (steps/min), but considering the control group's mean cadence decreased over the training period from 53.53 (SD 16.78) to 51.70 (SD 20.03), the actual within group mean difference should read -1.83 (as stated in the Main Findings section). Effect size was calculated according to this corrected calculation.
- Within group mean differences for balance parameters for the RAS group demonstrate that the RAS group decreased the amount of variance in board displacement between pre- and posttest. In other words, the RAS group was able to maintain standing balance better in the mediolateral and anteroposterior directions, as well as demonstrate better overall standing stability. Within group mean differences for balance parameters for the control group, however, demonstrate that the group increased the amount of variance in board displacement from pre- to posttest, meaning they demonstrated greater loss of balance in the mediolateral and anteroposterior directions and showed decreased overall stability, in general. Between group mean differences in change scores reflect larger improvements for all three balance parameters for the RAS group in comparison to the control group.
- Although significantly larger improvements were observed in all balance parameters for the RAS group, improvement in "functional" balance is not necessarily indicated since participants' balance task involved standing stationary on the BioSway. Had the study tested participants' balance with the Berg Balance Scale or other functional balance outcome measures, more could be concluded about the participants' functional balance.
- Though the study has a small sample size (N=16), decreasing the study's overall external validity, the study's internal validity is increased slightly by the fact that participants were blinded to whether they were in the experimental group or control group. Blinding of participants in this way prevents participants from purposely trying harder or slacking and minimizes that particular source of bias.

EVIDENCE SYNTHESIS AND IMPLICATIONS

Implications for clinical practice:

Many research studies have been conducted that evaluate the clinical efficacy of rhythmic auditory stimulation for the rehabilitation of functional movement among patients of various neuropathologies[12] including stroke, Parkinson's disease, cerebral palsy, MS, and TBI.[3] External auditory cueing is thought to facilitate rhythmic movements by stimulating the motor system and eliciting a physiological, synchronized response.[3] Quality of evidence for the effects of rhythmic auditory stimulation combined with gait therapy on gait and/or balance specifically among patients with hemiparesis is medium- to high-level—numerous randomized controlled studies exist, yet the RCTs' sample sizes are limited and no systematic reviews or meta-analyses have yet been completed for this research topic.

This paper analyzes three RCTs that compare rhythmic auditory stimulation intervention to conventional gait training methods without rhythmic auditory stimulation in the hemiparetic stroke population. Based on these studies' findings, rhythmic auditory stimulation appears to be an effective intervention for gait and functional balance rehabilitation for a patient with hemiparesis. Specifically, rhythmic auditory stimulation intervention is associated with improvements in gait velocity, stride length, cadence, and swing symmetry, in addition to postural control, quality of life, and patient satisfaction. Though improvements over time in gait parameters and functional balance were also observed among the control groups who received conventional gait training, rhythmic auditory stimulation intervention consistently produced larger improvements from pre-training to post-training.

According to the CDC, almost 800,000 people in the United States have a stroke each year.[13] Many stroke survivors have impairments in strength, postural control, and gait as a result of the stroke.[3] Due to the high prevalence of stroke in the United States, it is not uncommon to encounter patients in the clinical setting who have stroke-related impairments, which makes the evidence presented in this paper clinically relevant. These findings suggest that patients who have hemiparesis after a stroke may achieve functional gait more quickly and effectively with the use of rhythmic auditory stimulation during gait training than they would with just gait training alone. Thaut et al. (2007) reported favourable outcomes for rhythmic auditory stimulation among patients with stroke who were in the subacute period (~22 days post-stroke).[10] Cha et al. (2014) reported similar findings for a sample population of individuals with chronic stroke (~14 months post-stroke).[3] The fact that favourable outcomes were observed for rhythmic auditory stimulation with gait training for patients with stroke both in the subacute and chronic periods suggests that this intervention is effective among patients with hemiparesis, regardless of time since the stroke.

Implications for Future Research

Although these three studies provide firm foundations for future research, future studies should test larger sample populations and research should be implemented in other settings beyond a hospital or lab, including outpatient and community-based therapy settings. With increased study participants and a variety of settings, the extent to which a study's findings can be generalized to the larger hemiparetic stroke population increases substantially.

Based on differences in results between the Thaut et al. (2007) study and the authors' previous study completed on the same research topic in 1997,[6] more significant improvements in gait parameters were observed after 6 weeks of gait training with rhythmic auditory stimulation than the 3 weeks of gait training completed in the more recent study.[10] Future studies could compare various treatment durations of gait training with rhythmic auditory stimulation to determine if improvements in gait and balance multiply with longer study duration and if there is a point at which improvements specific to the intervention begin to taper off. Long-term follow-up can also assist in assessing whether or not this type of intervention produces sustainable improvements in gait and balance. Along with duration of entire study, different treatment dosages within a session should also be compared to determine if more frequent gait training or longer sessions with rhythmic auditory stimulation achieve more effective recovery of functional gait.

Combining rhythmic auditory stimulation and gait training as an intervention for stroke rehabilitation has endless possibilities for future clinical research. Rhythmic auditory stimulation can be paired with other evidence-based gait training interventions such as bodyweight-supported treadmill training, aquatic therapy, stationary cycling, strength training, or even functional electrical stimulation.[1] Further research studies are necessary to determine the full extent of the clinical effectiveness of rhythmic auditory stimulation in gait rehabilitation.

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