Original Article

Efficacy of Rhythmic Auditory Stimulation on Balance in Children with Cerebral Palsy: A Randomized Controlled Trial

Aksarapak Panompornpanich, Nopawan Sanjaroensuttikul and Apiphan Iamchaimongkol
Department of Rehabilitation Medicine, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Bangkok, Thailand

ABSTRACT

Objectives: Evaluate efficacy of rhythmic auditory stimulation (RAS) on balance in children with cerebral palsy.

Study design: Randomized controlled trial

Setting: Sri-Sangwan School, Bangkok, Thailand

Subjects: Children with cerebral palsy, GMFCS levels I to III

Methods: Participants were randomly allocated into RAS and control groups. All participants underwent a physical therapy involving exercises and gait training for 3 weeks. RAS group received gait training with RAS. We measured Timed Up and Go-In Children (TUG-IC), Pediatric Balance Scale (PBS), Gross Motor Function Measure (GMFM-66), and gait velocity.

Results: 22 cerebral palsy aged 7-15 years were divided into control and RAS, 11 participants per group. Results revealed improvement of TUG-IC, PBS, and GMFM-66 in both groups. The median (95% CI) difference between before and after training of TUG-IC were 1.51 (-16.35, 21.77) second in control and 0.90 (-29.38, 25.76) second in RAS. The differences in PBS were 1.5 (0.03-3.96) in control and 1 (-3.84, 1.84) in RAS. The change of GMFM-66 was 3.5 (0.38, 5.61) in control and 3 (-3.78, 3.78) in RAS. Whereas gait velocity only increased in control group. RAS showed no statistically significant improvement in TUG-IC, PBS, and GMFM-66. While control group only significantly increased PBS and GMFM-66 ($p = 0.047$, $p = 0.027$), no significant difference in TUG-IC or gait velocity. Comparison between RAS and control revealed no significant difference in TUG-IC, PBS, GMFM-66, or gait velocity.

Conclusions: The addition of RAS to physical therapy may not improve efficacy of training beyond effects of physical therapy alone.

Keywords: cerebral palsy, gait, music, physical therapy modalities, postural balance

ASEAN J Rehabil Med. 2024; 34(1): 9-14.

Introduction

Cerebral palsy is a group of neurological disorders that affect muscle tone, movement, and posture caused by non-progressive injury to the developing brain. Possible causes of cerebral palsy include infections, brain hypoxia, brain injuries, toxins or teratogenic agents, and genetic disorders.[1,2] The reported incidence of cerebral palsy is 1.5-3.5 out of 1,000 live births.[3,4] These conditions result in problems in ambulation, balance, and coordination between the upper and lower extremities, impacting daily routine, family relationships, and school activities and consequently affecting individuals' mental and emotional state.[2,3,5,6]

Regarding the difficulties in ambulation, balance, and coordination between the upper and lower extremities mentioned above, many previous studies have examined ambulation and movement in children with cerebral palsy. These studies have revealed various abnormal gait patterns, including asymmetrical gait, shortened step or stride length, slow gait velocity, loss of balance ability, uncontrollable body movements, and rhythm perception impairment.[7,8]

There are currently several approaches to treating children with cerebral palsy that aim to rehabilitate patients to support their ability to help themselves and maintain their physical ability as much as possible. The rehabilitative approach for each patient will be carefully considered regarding their abnormality. However, using more than one method together is common because there is no evidence that any method is clearly better than the others.[9]

Rhythmic auditory stimulation (RAS) aims to improve movement and gait patterns by offering auditory cueing to the patients. The auditory rhythms during RAS promote motor cortex area functioning, which positively affects gait and balance.[9-15] Studies in various countries have examined the outcome of gait patterns using RAS in children and adults with movement disorders caused by neurological diseases, stroke, Parkinson's disease, cerebral palsy, and traumatic brain injuries. It has been reported that RAS improves gait ability in patients, including steps per minute, stride length, gait velocity, and symmetrical gait pattern.[9-15]

In addition to improving gait patterns, previous studies reported that RAS enhanced balance in adults with stroke, Parkinson's disease, and cerebral palsy.[15-17] However, no previous studies have examined whether RAS improves balance in children with cerebral palsy. Therefore, the current

Correspondence to: Apiphan Iamchaimongkol, M.D. Ramathibodi Hospital 270 Rama 6 Road, Thung Phayathai Subdistrict, Ratchathewi District, Bangkok 10400, Thailand; E-mail:apiphan.iam@mahidol.ac.th

Received: May 28, 2023 Revised: September 1, 2023 Accepted: October 17, 2023

study examined the efficacy of rhythmic auditory stimulation on balance in children with cerebral palsy.

Methods

Study design

This study was approved by the Human Research Ethics Committee, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Bangkok, Thailand, and was registered on ClinicalTrials.gov (NCT05455970).

Participants

Children with cerebral palsy were recruited from Sri-Sangwan School in Bangkok, Thailand. Inclusion criteria were used to select patients who had been diagnosed with cerebral palsy, aged 7-15 years, with gross motor function classification system (GMFCS)[18] levels I to III, and the ability to follow commands, and for whom both the patient and their guardian provided written consent to participate in the study. Exclusion criteria were used to exclude patients who had spinal surgery or lower extremities surgery or received chemo-denervation injection targeting the lower extremities within six months before participating in the study, patients who suffered from spinal or pelvic bone injury within six months before participating in the study, patients who received intrathecal baclofen pump implantation, patients who had another neurological deficit with severe movement disorder, and cases in which the patient and their guardian did not give consent.

Due to none of the previous studies between RAS and children with cerebral palsy, the sample size of this study was calculated based on data from a pilot study, three children per group, and the fact that this study aims to compare the means of the control versus the experimental group. The sample size was calculated using Timed Up and Go-In Children (TUG-IC) test scores with a mean difference of 5.31 and standard deviation of 3.39 as a variable by setting the alpha level at 0.05, a beta level at 0.2 and applying an estimated patient dropout rate of 20%. The results indicated a total required sample size of 22 patients divided into two groups of 11.

Randomization

Participants were divided into a control group and an RAS group by blocks of four randomization means with a computer program. Group allocations were placed in a sealed envelope and assigned to participants by blinded physical therapists at Sri-Sangwan School.

Materials

1. Metronome program
2. Time Up and Go-In Children (TUG-IC) test[19]
3. Pediatric Balance Scale (PBS) test[20]
4. The Thai version of Gross Motor Function Measurement-66 (GMFM-66)[21]

Intervention

After randomization, the researchers recruited patients and obtained consent after providing information about the study procedures to patients and their guardians. General information regarding age, gender, weight, height, underlying disease, records of surgery, records of medicine used, and GMFCS level was collected and assessed by the researchers.

Before undergoing the rehabilitation program, the participants were examined by a blinded outcome assessor to evaluate TUG-IC, PBS, GMFM-66, and gait velocity.

Participants from both groups underwent a rehabilitation training program involving stretching and strengthening exercises of hip and knee muscles such as gluteus medius, gluteus maximus, quadriceps, hamstrings, and gastrocnemius muscles. The program contained three sets of exercises, each containing ten movements with a 3-minute break between sets.[22,23] The control group then underwent gait training by ground walking training in the 30 meters-ambulation practice area for 30 minutes per day, five days a week, for three weeks in total, with partial weight bearing and permission to use walking aid equipment during training. In the RAS group, the rhythmic tempo was calculated by determining the number of steps per minute (cadence) for each participant that resulted in beat per minute and using the metronome to make the rhythm for cueing during ambulation training for 30 minutes per day, five days a week, for three weeks in total. The frequency and duration of training refer to previous study of RAS training in children with cerebral palsy.[7]

Participants from both groups received training from Sri-Sangwan School's physical therapists team, who had expertise in rehabilitation training and movement training in children with cerebral palsy. Each participant was received the same protocol and looked after by a team of physical therapists to ensure their safety. Patients could take breaks during training if they were fatigued.

Three weeks after completing rehabilitation training, each participant was re-assessed on the TUG-IC, PBS, GMFM-66, and gait velocity. All participants were examined by the same assessor at the beginning and the end of the training, as shown in Figure 1.

Outcome measurements

The current study sought to evaluate the balance in children with cerebral palsy. The primary outcome was TUG-IC scores, which assessed functional balance and mobility in children. The secondary outcomes were the pediatric balance scale (PBS), gross motor function measurement-66 (GMFM-66), and gait velocity, which represent functional mobility and gait stability.

Time Up and Go-In Children (TUG-IC) test.[19]

The participant sits straight with their back against a chair and their hands on their lap. When the researcher gives a signal, the participant stands up, walks straight ahead on a flat surface for 3 meters, goes around a specified object,

and walks back to the starting point. The time is measured (in seconds) from standing up from the chair to returning to the beginning sitting posture. During the test, the participant walks at their average speed and repeats it three times to determine the average score, with a 1-minute break between trials. The participant is allowed to use a walking aid. The reliability for the TUG-IC was high, with intraclass correlation coefficients (ICC) ranging from 0.970-0.995.

Pediatric Balance Scale (PBS) test[20,24]

The participant performs 14 sitting and standing postures, including sitting to standing, standing to sitting, transfers, standing unsupported, sitting unsupported, standing with eyes closed, standing with feet together, standing with one foot in front of the other, standing on one foot, turning 360 degrees, turning to look behind, retrieving an object from the floor, placing an alternate foot on a stool, reaching forward with an outstretched arm. Each posture was assessed on a 0-4-point scale, with a total possible score of 56 points. The PBS has high reliability with ICC > 0.9.

Gross Motor Function Measurement-66 (GMFM-66)[21]

The participant performs five movement activity categories to assess gross motor function: lying and rolling, sitting, crawling and kneeling, standing, walking, running, and jumping. There are 66 postures in total. Each posture is assessed on a 0-3-point scale, with a total possible score of 186 points.

Gait velocity[25]

The participant walks straight on a flat floor for 14 meters at their self-selected comfortable speed. The starting and finishing points are 2 and 12 meters, respectively. The time taken to walk 10 meters is calculated to determine the gait velocity (kilometers per hour).

Statistical methods

We analyzed participants' general information using descriptive statistics, and data were presented as the number, percentage, mean, standard deviation (SD), median, and Interquartile range (IQR) for gender, GMFCS, age, TUG-IC, and gait velocity. We conducted comparisons of the following variables before and after training using STATA version 16, the Wilcoxon signed-rank test: TUG-IC, PBS, GMFM-66, and gait velocity. We compared differences in variable data between the RAS and control groups before and after training using quartile median regression, with a value of $p < 0.05$ considered to indicate statistical significance.

Results

In the present study, 22 eligible participants completed the training program (11 in the control and 11 in the RAS groups). The baseline characteristics of the patients included gender, GMFCS, age, topography, TUG-IC, PBS, GMFM-66, and gait velocity. The results revealed that most patients were male, the average GFMCS level was level III, and the average age was 1-11 years. The median TUG-IC, PBS, GMFM-66, and the mean gait velocity between groups at baseline showed no significant differences, as shown in Table 1.

As shown in Table 2, a comparison between median TUG-IC scores before and after the training program revealed improvements of 1.51 and 0.90 seconds in the control and RAS groups, respectively; however, these differences did not reach significance within groups ($p = 0.77$ and $p = 0.90$, respectively).

The median differences in PBS scores between before and after training in the control and RAS groups were 1.5

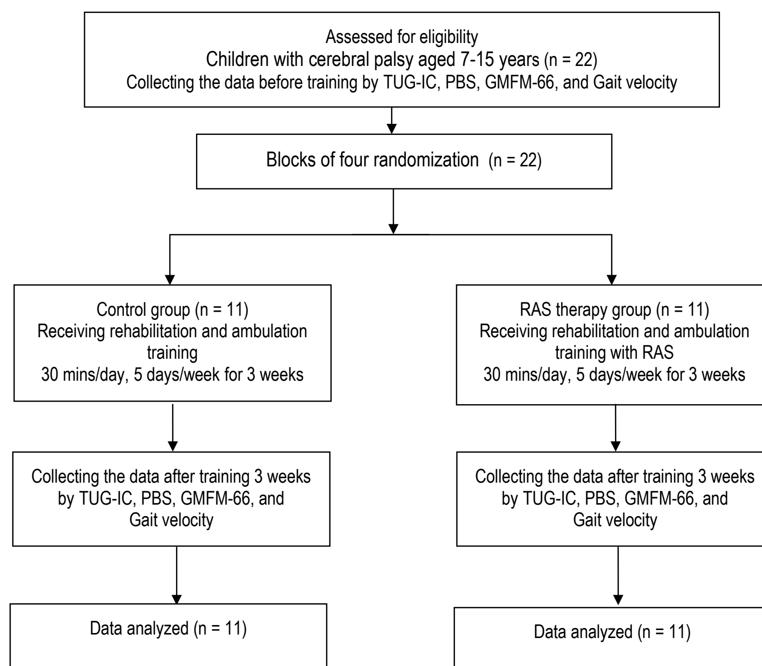

Figure 1. Protocol of research flow diagram

Table 1. Demographic and clinical characteristics of participants

Characteristics	Control (n = 11)	RAS (n = 11)	*p*-value
Gender, No (%)			0.55
Male	8 (72.73)	7 (63.64)	
Female	3 (27.27)	4 (36.36)	
GMFCS, No (%)			0.56
1	1 (9.09)	0 (0)	
2	3 (27.27)	4 (36.36)	
3	7 (63.64)	7 (63.64)	
Topography, No (%)			0.56
Spastic diplegia	7 (63.64)	8 (72.73)	
Spastic hemiplegia	4 (36.36)	3 (27.27)	
Age[1], year	11.24 (2.12)	10.30 (2.08)	0.29
TUG-IC[2], second	26.18 (11.09, 61.95)	41.98 (11.94, 53.02)	0.57
PBS[2]	18 (9.5, 31)	23 (10, 35)	0.82
GMFM-66[2]	123.5 (94, 146.5)	115 (90, 149)	0.83
Gait velocity[1], km/hr	2.22 (1.12)	2.07 (0.99)	0.73
Cadence[1], step/min	83.79 (34.78)	77.82 (19.86)	0.29

[1]Mean (standard deviation); [2]Median (interquartile range)

RAS, Rhythmic auditory stimulation; GMFCS, gross motor function classification system; TUG-IC, Time Up and Go-In Children; PBS, Pediatric Balance Scale; GMFM-66, Gross Motor Function Measurement-66

Table 2. Outcome measurement difference

Characteristics	Control (n = 11)	RAS (n = 11)	*p*-value
ΔTUG-IC[1], second	1.51 (−0.80, 11.45)	0.9 (-1.00, 8.38)	0.50
ΔPBS[1]	1.5 (0.00, 3.00)*	1 (1.00, 2.00)	0.75
ΔGMFM-66[1]	3.5 (0.00, 4.00)*	3 (1.00, 5.00)	0.49
ΔGait velocity[1], km/hr	0.02 (-0.16, 0.27)	-0.15 (-0.44, 0.04)	0.50

*Significant difference in outcome measurement between before and after training. PBS; $p = 0.047$, GMFM-66; $p = 0.027$

[1]Median (interquartile range)

RAS, Rhythmic auditory stimulation; GMFCS, gross motor function classification system; TUG-IC, Time Up and Go-In Children; PBS, Pediatric Balance Scale; GMFM-66, Gross Motor Function Measurement-66

and 1, respectively, and the median differences in GMFM-66 scores between before and after training in the control and RAS groups were 3.5 and 3, respectively. This result indicated that both PBS and GMFM-66 exhibited improvements in both groups after training, with significant increases in the control group ($p = 0.047$ and $p = 0.027$ for PBS and GMFM-66, respectively). The differences in the RAS group did not reach statistical significance ($p = 0.47$, $p = 1.00$ for PBS and GMFM-66, respectively).

Unlike other outcomes, only the median differences between before and after training of gait velocity in the control group were improved by 0.02 km/hr. In the RAS group, the median gait velocity was decreased by 0.15 km/hr after training. However, there was no significant difference between before and after training in the RAS or control groups ($p = 0.97$, $p = 0.66$, respectively).

Comparisons of TUG-IC, PBS, GMFM-66, and gait velocity before and after training revealed no significant differences in either group.

The current results indicated that the control group showed significant increases in PBS and GMFM-66 scores after training, whereas no significant changes were observed in TUG-IC or gait velocity. In contrast, the RAS group showed no significant differences between before and after training in any of the outcomes. Comparisons of the control and RAS groups revealed no significant differences between groups in TUG-IC, PBS, GMFM-66, or gait speed.

Discussion

There were previous studies of a rhythm-based approach for improving gait patterns in patients with cerebral palsy in both children and adults. However, only Efraimidou et al.[15] examined the effects of music and rhythms on the balance of adult athletes with hemiplegic cerebral palsy. The results revealed increased balance ability using the TUG and Berg balance scale (BBS), significantly improving the music and rhythmic movements training group. This previous finding differs from the results of the current study, which indicated that TUG-IC improved after training in both groups. Several differences between the Efraimidou et al.[15] study and the current study could have contributed to the lack of significant changes. First, the participants in Efraimidou's study were adult athletes with hemiplegic cerebral palsy between the ages of 22 and 50, with GMFCS levels I-II.

In contrast, in the current study, the participants were children with cerebral palsy between the ages of 10 and 11, and 65% of participants had spastic diplegia and GMFCS level III. Thus, the patients in the current study had lower ambulation abilities than those in the previous study. Moreover,

Efraimidou used rhythms for training at 90 beats per minute, in conjunction with rhythmic auditory stimulation walking practice at 70 beats per minute before the actual training. In the current study, due to younger participants, the rhythms were calculated from the pace of each participant from 30-147 steps per minute, and no rhythmic auditory stimulation practice was performed before the actual training. This difference may have improved the ability of the patients in Efraimidou's study to walk during RAS training, resulting in a significant change after training.

The differences in median TUG-IC scores before and after training in the control and RAS groups were 1.51 and 0.90 seconds, respectively. However, the difference between groups did not reach significance. Carey et al.[19] reported that variation in TUG-IC scores has a minimum clinically significant difference (MCID) of 0.22-5.31 seconds. Therefore, training in both groups can improve the efficiency of functional balance in children with cerebral palsy. The median PBS score before and after training in this study in the control and RAS groups increased by 1.5 and 1, respectively, with a significant change in the control group but not the RAS group. However, according to Chen et al.[24], the MCID for variation in PBS has a range of 3.66-5.83. Thus, the current results revealed that only physical therapy training resulted in a statistically significant improvement in balance, but this improvement is not clinically significant.

The current study used GMFM-66 assessment to detect developmental changes in movement. After training, GMFM-66 showed an increase in both groups, with a significant difference in the control group but no significant difference in the RAS group. According to Oeffinger et al.[26], the MCID of GMFM-66 is 0.8. Hence, patients in both groups' current study tended to have a clinically significant effect after training, although the GMFM-66 improvement in the RAS group did not reach statistical significance.

In the current study, as mentioned above, gait velocity was decreased after training in the RAS group. In contrast, a study by Kwak et al.[7] reported that RAS training improved gait performance in children with spastic cerebral palsy GMFCS level I-III compared with the gait training exercise, with significant improvements in gait velocity, step length, and symmetrical gait pattern. The factors causing this discrepancy between the present findings and those of Kwak's study may be related to differences in the RAS techniques used in each study. In Kwak's study, the rhythms were calculated from each participant's pace, and the rhythm rate was increased by 5% in the first week, 10% in the second week, and 15% in the third week. In contrast, in the current study, we used rhythms that were calculated from the pace of each participant and fixed the rhythm for the whole session. Gait velocity is enhanced by increasing cadence or stride length. However, the current study aimed to improve balance without increasing cadence, and the decrease in gait velocity may represent an increase in gait stability as in Katz-Leurer et al.[27]

In summary, the results showed improvement in functional balance in children with cerebral palsy after receiving physical therapy programs in both the control and RAS groups, with more improvement in the control group. RAS is a multiple-stimulation method using auditory-motor synchronization. The children should have the ability and attention to follow the rhythm. This problem caused the children in the control group to concentrate on ambulation training rather than RAS. Nonetheless, no significant efficacy difference between RAS and physical therapy after training exists.

Limitations

More than half of the participants in the RAS group were unable to follow rhythmic cueing at the beginning of each session, and one of three participants could not maintain the rhythm's speed for 30 minutes. Therefore, to avoid muscle fatigue, participants in the RAS group took more breaks than the control group, decreasing training time. In the control group, participants could adjust the speed and rhythm by themselves.

Recommendations

Children with cerebral palsy most commonly exhibit problems in ambulation, and a practice period before implementing new techniques may improve outcomes. In this study, there is no pre-exercise auditory stimulation, unlike other previous studies. Therefore, future studies should provide pre-training auditory stimulation. In some previous studies, the speed of walking and frequency of cadence may have been elevated during therapy, and such practice should be integrated with future studies.

Conclusion

Adding RAS to physical therapy may not improve training efficacy compared with physical therapy alone.

Acknowledgment

The authors acknowledge all of the physical therapists at Sri-Sangwan School for the effort and valuable time they devote to looking after and improving the lives of underprivileged children.

References

1. Rosenbaum P. The definition and classification of cerebral palsy: Are we any further ahead in 2006?. NeoReviews [Internet]. 2006 [cited 2023 Aug 12];11:e569-e574. Available from: https://publications.aap.org/neoreviews/article-abstract/7/11/e569/87112/The-Definition-and-Classification-of-Cerebral?redirectedFrom=fulltext doi: 10.1542/neo.7-11-e569
2. Rosenbaum P, Paneth N, Leviton A, Goldstein M, Bax M, Damiano D, et al. A report: The definition and classification of cerebral palsy April 2006. Dev Med Child Neurol Suppl [Internet]. 2007 [cited 2023 Aug 12];109:8-14. Available from: https://pubmed.ncbi.nlm.nih.gov/17370477/

3. Odding E, Roebroeck ME, Stam HJ. The epidemiology of cerebral palsy: incidence, impairments and risk factors. Disabil Rehabil [Internet]. 2006 [cited 2023 Aug 12];28:183-91. Available from: https://pubmed.ncbi.nlm.nih.gov/16467053/ doi: 10.1080/09638280500158422
4. Eunson P. Aetiology and epidemiology of cerebral palsy. Paediatr Child Health [Internet]. 2012 [cited 2023 Aug 12];22:361-366. Available from: https://www.sciencedirect.com/science/article/abs/pii/S1751722212000893 doi: 10.1016/j.paed.2012.05.008
5. Fairhurst C. Cerebral palsy: the whys and hows. Arch Dis Child Educ Pract [Internet]. 2012 [cited 2023 Aug 12];97:122-31. Available from: https://pubmed.ncbi.nlm.nih.gov/22868578/ doi: 10.1136/edpract-2011-300593
6. Parkes J, White-Koning M, Dickinson HO, Thyen U, Arnaud C, Beckung E, et al. Psychological problems in children with cerebral palsy: a cross-sectional European study. J Child Psychol Psychiatry [Internet]. 2008 [cited 2023 Aug 13];49:405-13. Available from: https://pubmed.ncbi.nlm.nih.gov/18081767/ doi: 10.1111/j.1469-7610.2007.01845.x
7. Kwak EE. Effect of rhythmic auditory stimulation on gait performance in children with spastic cerebral palsy. J Music Ther [Internet]. 2007 [cited 2023 Aug 12];44:198-216. Available from: https://pubmed.ncbi.nlm.nih.gov/17645385/ doi: 10.1093/jmt/44.3.198
8. Ahl LE, Johansson E, Granat T, Carlberg EB. Functional therapy for children with cerebral palsy: an ecological approach. Dev Med Child Neurol [Internet]. 2005 [cited 2023 Aug 12];47(9):613-9. Available from: https://pubmed.ncbi.nlm.nih.gov/16138669/ doi: 10.1017/S00121622050012102
9. Kim SJ, Kwak EE, Park ES, Cho SR. Differential effects of rhythmic auditory stimulation and neurodevelopmental treatment/ Bobath on gait patterns in adults with cerebral palsy: a randomized controlled trial. Clin Rehabil [Internet]. 2012 [cited 2023 Aug 12];26:904-14. Available from: https://pubmed.ncbi.nlm.nih.gov/22308559/ doi: 10.1177/0269215511434648
10. Kim SJ, Kwak EE, Park ES, Lee DS, Kim KJ, Song JE, Cho SR. Changes in gait patterns with rhythmic auditory stimulation in adults with cerebral palsy. NeuroRehabilitation [Internet]. 2011 [cited 2023 Aug 12];29:233-41. Available from: https://pubmed.ncbi.nlm.nih.gov/22142756/ doi: 10.3233/NRE-2011-0698
11. Thaut MH, McIntosh GC, Rice RR. Rhythmic facilitation of gait training in hemiparetic stroke rehabilitation. J Neurol Sci [Internet]. 1997 [cited 2023 Aug 12];151:207-12. Available from: https://pubmed.ncbi.nlm.nih.gov/9349677/ doi: 10.1016/s0022-510x(97)00146-9
12. Shin YK, Chong HJ, Kim SJ, Cho SR. Effect of Rhythmic Auditory Stimulation on Hemiplegic Gait Patterns. Yonsei Med J [Internet]. 2015 [cited 2023 Aug 12];56:1703-13. Available from: https://pubmed.ncbi.nlm.nih.gov/26446657/ doi: 10.3349/ymj.2015.56.6.1703
13. Hayashi A, Nagaoka M, Mizuno Y. Music therapy in parkinson's disease: Improvement of parkinsonian gait and depression with rhythmic auditory stimulation. Parkinsonism & Related Disorders [Internet]. 2006 [cited 2023 Aug 12];1:576. Available from: https://www.researchgate.net/publication/240024936_Music_therapy_in_Parkinson's_disease_Improvement_of_Parkinsonian_gait_and_depression_with_rhythmic_auditory_stimulation doi: 10.1016/j.parkreldis.2006.05.026
14. Ghai S, Ghai I, Schmitz G, Effenberg AO. Effect of rhythmic auditory cueing on parkinsonian gait: A systematic review and meta-analysis. Sci Rep [Internet]. 2018 [cited 2023 Aug 12];8:506. Available from: https://pubmed.ncbi.nlm.nih.gov/29323122/ doi: 10.1038/s41598-017-16232-5
15. Efraimidou V, Sidiropoulou M, Giagazoglou P, Proios M, Tsimaras V, Orologas A. The effect of a music and movement program on gait, balance and psychological parameters of adults with cerebral palsy. Int J Phys Educ Sports Sci [Internet]. 2016 [cited 2023 Aug 12];31. Available from: https://www.researchgate.net/publication/309576459_The_effect_of_a_music_and_movement_program_on_gait_balance_and_psychological_parameters_of_adults_with_cerebral_palsy doi: 10.7752/jpes.2016.04217
16. Suh JH, Han SJ, Jeon SY, Kim HJ, Lee JE, Yoon TS, Chong HJ. Effect of Rhythmic Auditory Stimulation on Gait and Balance in Hemiplegic Stroke Patients. NeuroRehabilitation [Internet]. 2014 [cited 2023 Aug 21];34:193-9. Available from: https://content.iospress.com/articles/neurorehabilitation/nre1008 doi: 10.3233/NRE-131008
17. Song JH, Zhou PY, Cao ZH, Ding ZG, Chen HX, Zhang GB. Rhythmic auditory stimulation with visual stimuli on motor and balance function of patients with Parkinson's disease. Eur Rev Med Pharmacol Sci. [Internet]. 2015[cited 2023 Aug 21];19:2001-7. Available from: https://pubmed.ncbi.nlm.nih.gov/26125261/
18. Palisano R, Rosenbaum P, Walter S, Russell D, Wood E, Galuppi B. Development and reliability of a system to classify gross motor function in children with cerebral palsy. Dev Med Child Neurol [Internet]. 1997 [cited 2023 Aug 20];39:214-23. Available from: https://pubmed.ncbi.nlm.nih.gov/9183258/ doi: 10.1111/j.1469-8749.1997.tb07414.x
19. Carey H, Martin K, Combs-Miller S, Heathcock JC. Reliability and Responsiveness of the Timed Up and Go Test in Children With Cerebral Palsy. Pediatr Phys Ther [Internet]. 2016 [cited 2023 Aug 20];28:401-8. Available from: https://pubmed.ncbi.nlm.nih.gov/27661230/ doi: 10.1097/PEP.0000000000000301
20. Franjoine MR, Darr N, Held SL, Kott K, Young BL. The performance of children developing typically on the pediatric balance scale. Pediatr Phys Ther [Internet]. 2010 [cited 2023 Aug 20];22:350-9. Available from: https://pubmed.ncbi.nlm.nih.gov/21068635/ doi: 10.1097/PEP.0b013e3181f9d5eb
21. Hensangvilai K, Yankai A, Angsupaisal M, Intachome R. Reliability in using the modified Gross Motor Function Measurement-66 Thai version by Physical Therapy students. Arch AHS [Internet]. 2009 [cited 2023 Aug 20];21:169-85. Available from: https://he01.tci-thaijo.org/index.php/ams/article/view/66172
22. Tardieu C, Lespargot A, Tabary C, Bret MD. For how long must the soleus muscle be stretched each day to prevent contracture? Dev Med Child Neurol [Internet]. 1988 [cited 2023 Aug 20];30:3-10. Available from: https://pubmed.ncbi.nlm.nih.gov/3371569/ doi: 10.1111/j.1469-8749.1988.tb04720.x
23. Verschuren O, Ada L, Maltais DB, Gorter JW, Scianni A, Ketelaar M. Muscle strengthening in children and adolescents with spastic cerebral palsy: considerations for future resistance training protocols. Phys Ther [Internet]. 2011 [cited 2023 Aug 20];91:1130-9. Available from: https://academic.oup.com/ptj/article/91/7/1130/2735071 doi: 10.2522/ptj.20100356
24. Chen CL, Shen IH, Chen CY, Wu CY, Liu WY, Chung CY. Validity, responsiveness, minimal detectable change, and minimal clinically important change of Pediatric Balance Scale in children with cerebral palsy. Res Dev Disabil [Internet]. 2013 [cited 2023 Aug 20];34:916-22. Available from: https://pubmed.ncbi.nlm.nih.gov/23291508/ doi: 10.1016/j.ridd.2012.11.006
25. Graser JV, Letsch C, van Hedel HJA. Reliability of timed walking tests and temporo-spatial gait parameters in youths with neurological gait disorders. BMC Neurol [Internet]. 2016 [cited 2023 Aug 20];16:15. Available from: https://pubmed.ncbi.nlm.nih.gov/26830919/ doi: 10.1186/s12883-016-0538-y
26. Oeffinger D, Bagley A, Rogers S, Gorton G, Kryscio R, Abel M, Damiano D, Barnes D, Tylkowski C. Outcome tools used for ambulatory children with cerebral palsy: responsiveness and minimum clinically important differences. Dev Med Child Neurol [Internet]. 2008 [cited 2023 Aug 20];50:918-25. Available from: https://pubmed.ncbi.nlm.nih.gov/19046185/ doi: 10.1111/j.1469-8749.2008.03150.x
27. Katz-Leurer M, Rotem H, Lewitus H, Keren O, Meyer S. Relationship between balance abilities and gait characteristics in children with post-traumatic brain injury. Brain Inj [Internet]. 2008 [cited 2023 Aug 20];22:153-9. Available from: https://pubmed.ncbi.nlm.nih.gov/18240044/ doi: 10.1080/02699050801895399