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Effectiveness of rhythmic auditory stimulation along with stretching and muscle strength training on jump gait and balance in spasticcerebral palsy child -a single case study

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Abstract
Background: Cerebral palsy is a common developmental disorder first described by WILLIAM JOHN LITTLE in 1840s. It is an "umbrella term covering a group of non-progressive, but often changing, motor improvement syndromes secondary to lesions or anomalies of brain arising in early stages of development". In spastic diplegia, both the motor corticospinal and the thalamocortical pathways are affected.
Objectives: The study's primary objective was to find out the effectiveness of rhythmic auditory stimulation along with stretching and muscle strength training on jump gait and balance in spastic cerebral palsy child.
Subject and Method: The pre-test and post-test single case study design was used. The subject selected for the study was a 6year old boy who was diagnosed with spastic cerebral palsy. The child had jump gait with anterior pelvic tilt (APT) and hip and knees are excessively flexed at early stance of gait and impaired balance during mobility. The ankle was in equinus, but he was able to walk without support but looses balance often. The child received passive stretching and muscle strength training along with Rhythmic Auditory Stimulation for 8 weeks for 4 days a week. The effectiveness of the treatment was measured using Gross Motor Function Measure (GMFM) and Paediatric Balance Scale (PBS). The data were collected and documented at the interval of every 2 weeks for 8 weeks. The pre-test and post-test values will show the significance.
Result: The pre-test and post-test values of jump gait and balance was measured by paediatric balance scale and gross motor function measure. The pre-test values of paediatric balance scale and gross motor function measure was 38 and 67.93% and the post-test values are 47 and 85.39% respectively. As the result the rhythmic auditory stimulation along with stretching and muscle strength training significantly reduced jump gait and improved balance. The statistical report shows significant improvement in gait and balance
Conclusion: There was a significant improvement in gait and balance following the application of Rhythmic Auditory Stimulation, Stretching and muscle strength training for 8 weeks in spastic cerebral palsy child with jump gait.
Clinical implications: Rhythmic Auditory Stimulation along with Stretching and muscle strength training was found to produce significant effect on jump gait and balance in child with spastic cerebral palsy.
Abbreviations: RAS- Rhythmic Auditory Stimulation, PBS- Paediatric Balance Scale, GMFM- Gross Motor Function Measure

Keywords: Spastic cerebral palsy, jump gait, balance, Rhythmic Auditory Stimulation, stretching, muscle strength training, Paediatric Balance Scale, Gross Motor Function Measure

Introduction
Cerebral palsy is a common developmental disorder first described by WILLIAM JOHN LITTLE in 1840 [1]. It is a leading cause if childhood physical disability, mainly affects physical function in children [2]. Cerebral palsy is primarily a disorder of movement and posture. It called as "umbrella term covering a group of non-progressive, but often changing, motor improvement syndromes secondary to lesions or anomalies of brain arising in early stages of development" [1]. The prevalence of cerebral palsy is estimated with an incidence of 2.11 per 1000 live births. Ratio of affected male to female is 4:1 Nearly 15-20% of physical disabled children are affected by cerebral palsy in INDIA, (2017) the estimated incidence is

is around 3/1000, live births. In this the spastic cerebral palsy is the most common and accounts for 70- 75% of individuals. The diplegic is most common form of spastic CP at 30-40% [3]. There are various types of gait patterns seen in spastic diplegic cerebral palsy on sagittal kinematics. The classification of gait patterns was based on the position of the ankle, followed by that, knee, hip and pelvis. The jump gait is the second most common type of gait pattern in spastic cerebral palsy with characteristic features of the ankle is in equinus, particularly in late stance. The knee and hip are excessively flexed in early stance and then extend to a variable degree in late stance, but never reach full extension. The pelvis is either within the normal range or tilted anteriorly and the undergo less amount of surgeries. The prevalence of jump gait accounts for about 9% in the children[4]. Risk factors of cerebral palsy can be divided into various categories such as anti-natal, perinatal and postnatal, some of the risk factors are Premature and low birth weight, Multiple gestation, Birth asphyxia, Vaginal bleeding at time of birth Head trauma, Seizures, Meningitis, Coagulopathies, Hypoxia Apgar score less than 7 after birth etc. [5, 6]. The common signs that occur in children with cerebral palsy are shaking, excessive drooling or difficulties with swallowing or speaking, unusual way of crawling, lack of coordination when performing voluntary movements, abnormal muscle tone, either too stiff(or) too lax, that affects the sitting to standing postures and gait etc. The child may have additional difficulties such as problem with hearing, problem with eye sight commonly squints and vision problem, epilepsy may develop in one of the three children with cerebral palsy[7]. The clinical diagnosis of CP is made by an awareness of risk factors, regular developmental screening of all high-risk babies, obstetric and perinatal histories, review of developmental milestones, and a through neurological examination and observation of the child in various positions is mandatory. In the further evaluation of the child with CP, an EEG is obtained and Neuroimaging studies such as MRI, cranial ultrasonography are carried out. Orthopaedic evaluation is a must as muscle. imbalance and spasticity cause subluxation/dislocation of the hips, equines deformities, contractures and scoliosis [8, 9]. Children with cerebral palsy require a long-term medical care and medical team. Common treatments are medications, nerve injections, physical therapy, occupational therapy, surgeries like orthopaedics, and cutting of nerve fibres etc. [10, 11].

On exploration of the literature several treatment options have been described to improve gait and balance in cerebral palsy physiotherapy treatment such as Stretching and Mobility Exercises, Sensory Integration, Biofeedback, Roods Approach, Neuro Developmental Therapy, Proprioceptive Neuro Muscular Facilitation, Muscle Strength Training, rhythmic auditory stimulation, Task oriented approaches such as treadmill exercise etc. are given to children with CP. Besides the technique showed above the rhythmic auditory stimulation, passive stretching and strength training showed better results [12, 13].

Rhythmic auditory stimulation (RAS) refers to a technique of neurologic music therapy that uses rhythmic sensory stimuli. As a timing cue to gait movement and motor control system in the brain, RAS has been successfully used to alter temporal gait parameters. The action of RAS is auditory-motor synchronization in the reticulospinal tract, it contends that spinal motor neurons are reorganized by synchronized external stimulation like the oscillator phenomenon in the gait cycle. Internal unconscious perceptual shaping occurs at the subcortical level, arousing the excitability of spinal motor neurons mediated by auditory-motor circuitry at the reticulospinal pathway. Therefore, disturbance in an individual's internal time-keeper function can be counterbalanced by external temporal cues. In patients with spastic CP, damage to neural pathways disturbs normal control of the motor system. Alteration of these neural pathways can be achieved through abnormal walking experiences that eventually lead to changes in muscle performance. If the gait pattern of patients with CP is not rhythmic nor symmetric, it is likely that the pyramidal and extra pyramidal system does not systematically cooperate, and therefore the internal time-keeper is not effectively working during gait performance, which suggests that the reticulospinal tract does not properly function. The processing of brain structures such as basal ganglia, cerebellum, and brain stem can be regulated by RAS, and the auditory cue may bypass the damaged basal ganglia or subcortical neural pathways. Accordingly, repeated RAS with equal intervals allows the continuous and efficient movement during gait cycle [14]. Stretching is a general term used to describe an therapeutic maneuver designed to increase mobility of soft tissues and subsequently improves range of motion (ROM) by elongating structures that have adaptively shortened and have become hypomobile over time [15]. Muscle strength can be defined as the ability of skeletal muscle to develop force for providing stability and mobility within the musculoskeletal system, so that functional movement can take place.16 Muscle strength training can be defined as "methods to increase one's ability to exert or resist force". Several types of resistance can be used for strength training [17].

Even though several studies have been conducted the efficacy of different treatment approaches, in this study it is attempted to the analyse the benefit of combining the rhythmic auditory stimulation along with stretching and muscle strength training to improve gait and balance in child with spastic cerebral palsy.

Methodology study design

This study design was a single case study.

Case history

A six years old male boy with spastic cerebral palsy was reported to outpatient department of ppg college of physiotherapy with a chief complaint of abnormal and unsteady walking pattern. As narrated by the mother he was a normal vaginal birth child and the birth weight was 2.9 kg. After 3 weeks he had history of head trauma and was admitted in hospital to take treatment and was discharged. He had delayed mile stones of creeping, crawling, sitting, standing and walking. Baclofen was added to relax the muscles and he underwent general physiotherapy treatment of stretching and general mat activities. At present the child had a complaint of abnormal and unsteady walking pattern. On observation the child was mesomorphic, the symmetry of the child was actively maintained. He was alert and well oriented to time, place surrounding and had postural instability. Mild contractures are seen in ankle plantar flexors, knee and hip flexors and hip adductors. The child had jump gait with anterior pelvic tilt (APT) and hip and knees are excessively flexed at early stance of gait and

impaired balance during mobility. The ankle was in equinus, but he was able to walk without support but looses balance often. On palpation the muscles are hypertonic and the spasticity was pronounced at lower limbs. On examination there was no relevant findings on higher motor and cerebellar examination. On spino-motor assessment he was at grade 1+ spasticity according to Modified Ashworth Scale and reflex grading 3+ on lower limbs and the muscle strength of lower limbs was 3+ according to oxford grading. On functional assessment the child falls under grade II under Gross Motor Function Classification System (GMFCS), Paediatric Balance Score was 38 and Gross Motor Function Measure score of domain D and E was 67.93%. Currently diazepam is taken to reduce muscle spasm.

After completing the physiotherapy assessment, the treatment plan was formulated to improve jump gait and balance by using passive stretching, strength training and rhythmic auditory stimulation along with home program.

Methods

The need and the objective of the study was clearly explained to the ethical committee of PPG college of physiotherapy and permission was obtained. The treatment was conducted at the out patient department of PPG college of physiotherapy outpatient department Coimbatore. This study was a single case study and the subject was 6 year old boy. The demographic characteristic the subject is shown in table 1. The study was clearly explained to his parents and after that informed consent form was received for the study.

The patient received passive stretching and muscle strength training along with RAS for 8 weeks that is 1hour 30 mins a day for 4 days a week. in order to study the effectiveness of therapeutic interventions two outcome parameters were chosen These include Gross Motor Function Measure (GMFM) to asses improvements in gait and Paediatric Balance Scale (PBS) to assess improvement in balance. The data were collected and documented at the interval of every 2 weeks for 8 weeks are listed in (table 2 and 3).

Description of technical interventions

Passive stretching

The stretching was given to the tight muscle groups. To this patient stretching was given to following muscle groups such as Flexors of hip, Abductors of hip, Hamstring muscles, Calf muscles. Each stretch was maintained for 10-15 seconds hold period followed by 10 seconds rest period for 15 repetitions. The entire duration of this therapeutic intervention lasted for 20- 25 minutes.

Strength training

The strength training was provided to weaker muscle groups. The resistance were provided to increase the strength of the muscle. The resistance was provided with thera band and weight cuffs. The resistance of the band was increased from yellow band to red after the interval of 4 weeks. Each exercise was done for 14 repetitions with 10 seconds hold period followed by 10 seconds rest period. The entire duration of this therapeutic intervention was 30 minutes.

Rhythmic auditory stimulation

Before starting the treatment the child was assessed for music induced seizure as music is used. The child responds well with music during assessment. In this intervention the child walks in treadmill for 4 minutes with specific metronome connected in the music system, then the child walks in plain ground for 3 minutes with same metronome. The metronome was slightly greater than the normal cadence of the child after 6 weeks the metronome was increased greater than 40% than the normal cadence was added to the training.

Data analysis

The demographic presentation of the subject is shown in table 1

Table 1: Patient description

S NO	Patient description	Measures
1	Age (years)	**6** years
2	Gender	boy
3	Height (cm)	115 cm
4	Weight(kg)	26 Kg
5	BMI	19

Table 2: Data analysis of Paediatric Berg Balance Scale

Outcome measure	Day 1	2nd week	4th week	6th week	8th week
Paediatric Balance Scale	38	41	43	45	47

Table 3: Data analysis of Gross Motor Function Measure

Outcome measure	Day 1	2nd week	4th week	6th week	8th week
Gross Motor Function Measure	67.93	72.48	76.52	80.33	85.39

Result

The pre-test value of Paediatric Balance Scale was 38 and Gross Motor Function Measure was 67.93 and the post-test values of Paediatric Balance Scale and Gross Motor Function Measure was 47 and 85.39 respectively.

Discussion

Cerebral palsy is a common developmental disorder first described by WILLIAM JOHN LITTLE in 1840s.1 It is a leading cause if childhood physical disability, disorder of movement and posture2. Cerebral palsy is primarily a disorder of movement and posture. It called as “umbrella term covering a group of non-progressive, but often changing, motor improvement syndromes secondary to lesions or anomalies of brain arising in early stages of development. In spastic cerebral palsy due to abnormal tone and contractures the mobility is often disturbed [1].

In 2020 KIM *et al*: they did a study on the effect of RAS by comparing the use of simple vs complex chords. Thirteen adult patients with CP received gait-training program with RAS, which consisted 30-min sessions, a three times a week for 4 weeks. Six patients in the simple RAS group received basic chords for cueing and seven patients Risk of bias for non- RCT sin the complex RAS group received diversified chords. After RAS, spatiotemporal gait parameters including velocity, cadence and stride length increased significantly, but no differences were observed between the groups. Interestingly, patients in the complex RAS group showed significantly greater ankle plantar flexion at push-off than patients in the simple RAS group. This study supported that rhythm is important for gait control, and that the level of complexity of music, which affects perception

of music, may have influenced dynamic ankle movement [18].

In 2019 MERETE AARSLAND FOSDAHL *et al*; they have conducted study with ambulant children with cerebral palsy (CP) often develop impaired gait, and reduced active knee extension is often a part of the problem with the aim to evaluate the effect of a combined intervention program including stretching and progressive resistance exercise (PRE) targeting active knee extension on gait function, in children with spastic CP. Thirty-seven children (21 boys, 16 girls, mean age 10.2 (±2.3) years), classified by Gross Motor Function Classification System I–III, were randomized to an intervention (n = 17) and a comparison group (n = 20).

The intervention group received a 16-week combined exercise program (3 sessions per week) including stretching of hamstrings and PRE targeting the lower extremities, followed by a 16- week maintenance program (1 session per week). Gait function was evaluated by three- dimensional gait analysis (3DGA); knee, hip and pelvic kinematics in the sagittal plane, step length and speed, Gait Deviation Index (GDI), and Six-Minute Walk test (6MWT) at 0, 16, and 32 weeks. There was a significant increase in gait distance measured by 6MWT within both group [19].

In 2022 opdahil vera straete *et al* did a study to investigate if a combination of strength training and stretching in lower extremities improves gross motor skills in ambulant children with CP. The studies were found through PubMed, SPORT discus and Medline. Participants included, were children with CP, GMFCS level I-III, age 4-18 years. Studies had to include a training program incorporating both strength training and stretching in the lower extremities. Eight studies were included in this review. Six of these studies showed a significant improvement on gross motor skills. All studies investigating GMFM showed significant improvements, and 3 out of 7 studies investigating gait function, indicated a significant improvement of at least 1 of the gait variables. Thus this study proves that the combination of strength training and stretching seem to improve gross motor skills in ambulant children with CP based on improved GMFM [20].

This present study and the previous studies concluded that, stretching along with muscle strength training and rhythmic auditory stimulation have positive effects on functional mobility, gait and improving balance in spastic cerebral palsy children. The stretching is designed to increase mobility of soft tissues and subsequently improve range of motion (ROM) by elongating structures that have adaptively shortened and have become hypomobile over time [15]. An increased ROM could result in the muscle being able to generate more muscle force capacity from an increase in fibre length. When a muscle has been in a shortened position or immobilised following injury, shortening occurs and the muscles become quite resistant to stretch [21]. Static stretching is one of the safest and most commonly performed stretching to increase muscle length. This type of stretch is applied slowly and gradually at the relatively constant force to avoid eliciting stretch reflex. The resultant increase in muscle length is related to viscoelastic behaviour. This behaviour is proportional to the magnitude of applied load [22]. Stretching is important because it is believed to provide many physical benefits, including improved flexibility, improve range of motion, improved muscle or athletic performance, reduce spasticity, injury prevention, promotion of healing [23]. The muscle weakness is seen in spastic cerebral palsy. The skeletal muscle tissue is adaptive to mechanical load, one of the best treatment options for muscle weakness is strength training using resistance. Initial strength improvements through strength training results from neural adaptations but it can eventually elicit significant adaptations in muscle mass in healthy adults [17, 24]. The rhythmic auditory stimulation refers to a technique of neurologic music therapy that uses rhythmic sensory stimuli. As a timing cue to gait movement the action of RAS is auditory-motor synchronization in the reticulospinal tract. Internal unconscious perceptual shaping occurs at the subcortical level, arousing the excitability of spinal motor neurons mediated by auditory-motor circuitry at the reticulospinal pathway. Therefore, disturbance in an individual's internal time-keeper function can be counterbalanced by external temporal cues. Alteration of these neural pathways eventually lead to changes in muscle performance. If the gait pattern of patients with CP is not rhythmic nor symmetric, it is likely that the pyramidal and extra pyramidal system does not systematically cooperate, and therefore the internal time-keeper is not effectively working during gait performance, which suggests that the reticulospinal tract does not properly function. The processing of brain structures such as basal ganglia, cerebellum, and brain stem can be regulated by RAS, and the auditory cue may bypass the damaged basal ganglia or subcortical neural pathways. Accordingly, repeated RAS with equal intervals allows the continuous and efficient movement during gait cycle [14].

In this present study rhythmic auditory stimulation along with stretching and muscle strength training was given to improve gait and balance in spastic cerebral palsy child. The treatment begins with stretching followed by muscle strength training and rhythmic auditory stimulation 4 days a week for 8 weeks. The pre-test and post-test values were measured using Paediatric Balance Scale and Gross Motor Function Measure. The statistical report shows significant improvement in gait and balance. As a result the Rhythmic Auditory Stimulation, Stretching and muscle strength training improved jump gait and balance in spastic cerebral palsy child.

Limitations

1. This study was with a single case
2. This study consist of only two intervention but in real case scenario the treatment consist of variety of intervention and its summation effect may be better than present intervention.
3. This study was limited to spastic cp.
4. There was no follow up in this study.

Suggestions

1. Further studies have to be conducted with the large group and more comparative studies and combined intervention studies have to be conducted for better use of interventions
2. The scope of this combined intervention can be applied for other types of cerebral palsy.
3. The rhythmic auditory stimulation with stretching and muscle strength training can be used with splints for sustained effects and to prevent spastic recoil.
4. The study assessed only short term progress of the patient. Long term follow up is needed to evaluate the

differences in condition of the patient from current status.

Conclusion

Hence, this study concluded that after 8 weeks of treatment there was statistically significant in the application of rhythmic auditory stimulation with stretching and muscle strength training plays an important role in reducing jump gait and improving balance in subject with spastic cerebral palsy.

Conflicts of interest

No potential conflict of interest was reported by the authors.

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Nothing to report.

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