ORIGINAL ARTICLE

Biomechanical Investigation of The Effect of Rhythmic Auditory Stimulation on Walking Skills in Children with Cerebral Palsy

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ABSTRACT

Purpose: This study was conducted to investigate whether the effect of rhythmic auditory stimulation, which consists of different rhythm patterns, on the walking ability of children with Cerebral Palsy, creates a difference on walking ability in terms of biomechanics and what the effect degrees are on this difference.

Materials and Method: The study is an experimental research design conducted on 12 male spastic quadriplegia children with a mean age of 13 ± 3.5. Applications were made in the motion analysis laboratory to test the walking ability. The subjects were asked to walk freely and according to rhythm respectively. Images were recorded and analyzed with 10 cameras (330 fps) using the three-dimensional motion analysis system Vicon Motion Capture and Nexus2 as pre and post test. Rhythmic auditory stimulus walking test was performed in Bounce Metronom software program with 2, 4 and 6 beat (moderato) rhythms. SPSS 22 software program was used for statistical analysis, paired sample t-Test for comparison of differences between tests, and ANOVA test for repeated measures. Results were evaluated at the ($p < 0.05$) significance level.

Findings: In our study, according to the paired sample t-test results, significant differences were found in terms of adaptation and application to the rhythms of children with Cerebral Palsy in walking skill ($p<0.05$). The subjects showed improvements in gait parameters with 4 and 6 beat rhythms. It was observed that 2-beat rhythms were less effective on the walking ability of the subjects than the 4 and 6-beat rhythms. With 6-beat rhythms; Significant improvement was detected in limp index, single and double support phases. With 4-beat rhythms; Significant improvements were observed in the parameters of double step duration, double support, single support and limp index. In addition, according to the repeated measurements ANOVA test results, it was seen that 4 and 6-beat rhythms positively affect the gait parameters of the subjects.

Results: It was determined that rhythmic auditory stimulation had a positive biomechanical effect on the gait parameters of children with Cerebral Palsy, compared to 2-beat rhythm, 4 and 6-beat rhythmic auditory stimulation had a positive effect on the spatial and temporal parameters of CP children's walking ability.

Keywords: Rhythm, Cerebral palsy, walking, Gait Analysis

INTRODUCTION

The act of walking is one of the most important skills that a person needs in meeting the most basic needs, daily activities and social relationships. The ability to walk is a dynamic result of the interaction of skeletal and neuromotor systems. The periodic and temporal variability of the contractions and relaxations that cause a movement, namely the dynamic nature of the movement, is explained as the movement rhythm. Movements in the human body are complex events created by the nervous system and movement claim to have motıon within a set of rules. In this structure, the rhythm of the movement is important in itself. Because the main element that allows the movements to flow and to take place in a certain order is rhythm. Rhythm is an important factor in determining the movement flow, performing movement, developing it and transforming it into a pleasurable one. [1]

Cerebral Palsy (CP) is a non-progressive disease that occurs in the baby or fetal brain, limiting activities as a permanent impairment in the development of movement and posture. It is known that motor disorders in cerebral palsy are due to many factors such as spasticity, dystonia, muscle contraction, bone defects, coordination problems, lack of selective movement control and muscle weakness. Neuromotor limitations that develop in CP patients cause limitations in movement activities such as posture and walking. [2] Therefore, secondary gait disturbance is present in CP patients. [3]

Damage to the cerebral cortex in CP patients affects the normal course of the motor control system. It causes symptoms such as abnormal gait, imbalance, muscle weakness, muscle cramps, and fatigue. Impairment in motor control and balance is one of the most common findings in researches. In particular, there may be changes in walking ability and patients may suddenly switch to a different type of walking. Therefore, gait analysis evaluation helps not only in diagnosing gait deficiencies and also it is help in treatment planning. [4]

Today 2-Dimension and 3-Dimension Clinical gait analysis are using to motor analysis systems. Basically, it reveals the patient's deficiencies in walking ability by collecting and analyzing a large amount of quantitative data on gait characteristics of the patient. The cycle of walking (gait) is the term describing the roving phase of walking. It is more complex with every cerebral palsy gait pattern being solitary to each individual like our fingerprints. There are many reasons that our walking elements differs amongst us however there are still core parts that can be calculate and evaluated by podiatrists, clinicians, or scientists. The walking period is the events that occur between the contact of one foot with the ground and the second contact of the same foot with the ground. Clinical gait analysis; It provides detailed information on the four main data types recorded simultaneously: spatiotemporal, kinematic, kinetic and electromyography. Standardized clinical videos are usually recorded with digital video cameras synchronized with the opto-electronic system. [5]

Perry in her study said that pathological gait often occurs as a result of the disappearance of the following five main conditions for normal walking.

1. Ensuring stability in the discharge phase.
2. Ensuring sufficient distance of the foot from the ground during the swing phase.
3. Ensuring proper anterior position of the foot in the end of swing phase.
4. Ensuring sufficient step distance.
5. Energy conservation[6]

Dynamic measurements (kinematic and kinetic) of the movements can be made by three-dimensional gait analysis. By using three-dimensional gait analysis, more detailed and measurable information can be obtained and the primary, secondary and compensatory changes that cause gait difference can be clearly revealed. 3-D gait analysis is based on the transfer of gait data to a computerized environment with cameras at many different angles, active or passive optical motion capture system, pointing devices placed at certain anatomical points compatible with the joint axis. The detection of pointing devices by two or more cameras enables the creation of three-dimensional coordinates in real time with an accuracy of 1 mm with the automatic digitization technique.[5]

As a result of biomechanical models, first of all, time and distance parameters created during the walking cycle are obtained (table 1). Then, the angular variables created by the joints in three dimensions are collected as kinematic data. Sagittal plane shows flexion-extension movement, frontal plane adduction-abduction movement, and transverse plane internal-external rotation movement. Based on the kinematic data, walking degrees such as Gait Profile Score, Movement Analysis Profile or Gait Deviation Index can be calculated.[7,8] Dynamic or kinetic data describe the forces created by the patient during walking.[9]

Table 1. Time / distance parameters of walking

Walking velocity	m/s
cadence	step/min
Stride length	m
Step length	m
Step width	m
Step time	s
Stride time	s
Single support	%
Double support	%

In CP patients, spastic, central nervous system and skeletal disorders limit the normal control movement system and destroy their rhythmic gait pattern. In this case, music and rhythm cause unconscious perception at the subcortical level of the brain with outer ear activity, and it helps to regulate the movement control system by stimulating the lower levels of the brain (basal ganglia, cerebellum, brainstem, spinal cord).[10,11]

Although there are many studies in the literature that show the effects of music therapy on neurological disorders, there is no study investigating the effect of different rhythms on walking ability and the degree of this effect in terms of biomechanics. This study was carried out in order to determine to what extent different rhythms will affect the walking ability of children with CP and to examine this effect from a biomechanical point of view.

MATERIALS AND METHODS

This study; It is an experimental research design carried out on 12 CP children living in Tehran with a mean age, height and weight of 13 ± 3.5, 1.62 ± 0.13, 42.57 ± 2.35. Children with a level I level according to the gross motor function classification system (GMFCS), who do not have visual and hearing loss, and who do not have mental retardation to prevent communication with them (according to the disabled board health report) were invited to the study. Children who underwent lower extremity fractures or muscle-tendon and bone operations, who were exposed to any pharmacological agent that would inhibit spasticity, had cardiac instability, respiratory problems, and those with lower extremity joint contractures that would prevent them from walking in the laboratory were excluded from the study, and seven subjects whose conditions were suitable were determined. The subjects and their families were informed before the study and the volunteer participation form was signed. In addition, permission was obtained from Sharif University of Technology Javad Movaffaghiyan Neuroscientific Research Center to conduct the study.

Tests were carried out in Tehran Movaffaghiyan Movement and Gait Analysis Center. Each subject was subjected to pre-test and post-test. The main outcome criterion of the study was whether rhythmic auditory stimulation had a biomechanical effect on the gait parameters of CP children. Vicon Motion Capture and Nexus2 software system with 10 cameras (330 fps) were used in the evaluation. The subjects were asked to walk forward on track. Bounce Metronum software program was used for rhythmic auditory stimulation application. The pace of the walks and the walking time of the track were determined as Moderato (medium speed) by the researcher. While the subjects were asked to walk freely three times in a row for the pre-test, for the post-test, the subjects were stimulated with the rhythms announced from the outdoor loudspeaker and were asked to walk along these rhythms.

For auditory rhythmic stimulation, the subjects were first walked three times in a row with 2-beat rhythms. The same practice was repeated with 4 and 6 beat rhythms. For the analysis, the best values of the subjects in both free (pre-test) and different rhythm stimulated (post-test) walking skills were taken into consideration. The walking platform was 8 meters long and 1.5 meters wide. 18 reflective passive markers were affixed to different parts of the subject's body as indicated in Table 2 and as seen in Figure 1. Movements were recorded by motıon capture system.[5,14] The data recorded by the kinematic analysis system was processed with the Nexus2 software program. Walking activities (heel contact and paw separation) were obtained using a foot speed algorithm.[15] Then, walking parameters in Table 1 were examined.

The data obtained as a result of the study were analyzed with SPPS 22 with $\alpha = 0.05$. Shapiro-Wilk test was used to control the normal distribution of variables. Paired-sample t-Test to examine gait parameters for each rhythm before and after administration, and percentage improvement or regression of each parameter was calculated to compare to the combined effects of rhythms. Results were compared with repeated measures ANOVA test and Bonferroni post-hoc test.

Table2. Markers for the spine and lower extremity

C7	7th Cervical vertebral
T10	10th thoracic vertebral
LPSI / RPSI	Left / Right Posterior Superior Iliac
LTHI / RTHI	Left / Right Thigh
LKNE / RKNE	Left / Right Knee
LTIB / RTIB	Left / Right Tibia
LANK / RANK	Left / Right Ankle
LHEE / RHEE	Left / Right Heel
LASI / RASI	Left / Right Anterior Superior Iliac
LTOE / RTOE	Left / Right Toe

Figure 1 Reflective passive marker

When the findings in Table 3 are examined, it is seen that there are statistically significant decreases in the values of opposite foot lift, double stride length, stride length and limp index in walking skill with 2-timed rhythms. Significant increases were observed in double support, single support and step width values. In the walking skill performed with 4-time rhythms, statistically significant decreases were observed in the values of opposite foot lift, double stride length, single support, stride length and limb index, while significant increases were observed in the values of double stride duration, double support and stride width. On the other hand, in the walking skill performed with 6-beat rhythms, statistically significant decreases were observed in the values of opposite foot lift, double support, single support and limp index, whereas statistically significant increases were observed in the values of double step duration and step width.

In Table 4, the biomechanical effects of rhythmic stimulation at 2, 4 and 6 times moderato speed on the walking ability of the subjects were examined according to the ANOVA test results. According to the results of comparisons between tests, it is seen that auditory rhythmic stimulation with 4 and 6 times mostly affects the gait parameters of the subjects positively. The least positive effect was seen in 2/4 rhythmically stimulated walking ability. It is known that music culture is effective in the formation of this difference, because in the geography where the subjects live, 4/4 and 6/8 melodies are much more than 2/4 melodies in the traditional music culture. This situation in providing rhythmic harmony in walking skill is remarkable.

RESULTS

variables	Free / Rhythmic Stimulation	rhythms / Moderato					
		2/4 rhythm		4/4 rhythm		6/8 Rhythm	
		Mean ± SD	P	Mean ± SD	P	Mean ± SD	P
Cadence (step/min)	Pre-test Post-test	106.67±6.50 90.70±4.34	0.001*	106.67±4.14 86.23±3.12	0.001*	106.67±7.45 91.72±4.45	0.003*
Velocity (m/s)	Pre-test Post-test	0.40±0.05 0.26±0.06	0.001*	0.40±0.05 0.30±0.02	0.001*	0.40±0.05 0.42±0.02	0.001*
Double support time (s)	Pre-test Post-test	1.13±0.30 1.13±0.44	0.445	1.13±0.30 1.39±0.21	0.001*	1.13±0.30 1.31±0.12	0.001*
Opposite foot lift (%)	Pre-test Post-test	13.33±0.12 11.25±0.13	0.005*	13.33±0.12 11.38±0.17	0.001*	13.33±0.12 12.74±0.09	0.001*
Double step length (m)	Pre-test Post-test	0.45±0.05 0.30±0.03	0001*	0.45±0.05 0.29±0.04	0.001*	0.45±0.05 0.44±0.09	0.130
Double support (s)	Pre-test Post-test	0.24±0.02 0.35±0.08	0.001*	0.24±0.02 0.50±0.05	0.001*	0.24±0.02 0.22±0.03	0.001*
Single support (s)	Pre-test Post-test	0.48±0.05 0.59±0.05	0.001*	0.48±0.05 0.46±0.03	0.001*	0.48±0.05 0.47±0.06	0.001*
Step length(m)	Pre-test Post-test	0.28±0.02 0.20±0.03	0.040*	0.28±0.02 0.22±0.03	0.001*	0.28±0.02 0.28±0.03	0.391
Step width (m)	Pre-test Post-test	0.23±0.02 0.28±0.07	0.250	0.23±0.02 0.28±0.02	0.028*	0.23±0.02 0.28±0.03	0.001*
Limp index	Pre-test Post-test	1.13±0.02 1.01±0.02	0.001*	1.13±0.02 0.94±0.04	0.001*	1.13±0.02 1.01±0.04	0.001*

DISCUSSION

The most important factor in improving the walking ability of children with Cerebral Palsy is a comprehensive understanding of their pathological gait and an accurate observation of their gait. Studies investigating the effects of music and therefore rhythm in the treatment of patients with neurological disorders are frequently encountered in the literature.[16] Especially, Rhythmic Auditory Stimulation (RIS) technique has been reported to have positive results in the walking ability of patients with neurological disorders.[4,17]

Rhythm music therapy is used to increase the smoothness of regular continuous movement tasks such as walking in people with movement disorders.[12] Using the physiological effects on the motor system by music therapy

helps to improve motor control, function, stability, balance and movement patterns in the rehabilitation and treatment of patients with neurodegenerative and movement disorders.[16]

some studies on this subject, hearing-stimulated rhythmic patterns increase the stimulation ability of spinal cord movement neurons through spinal knitting and reduce the response time of the muscles according to the movement command.[32] CP patients' nerve messages increase harmonization and facilitate synchronization.[28,33] It has been determined that the use of RIS has positive effects on walking and walking-related physical therapy practices in Parkinson's patients and continues after the treatment is over.[29,30] In studies conducted on patients with neurological disorders, it has been stated that musical therapy has a healing effect on gait parameters of these patients.[27] However, in some studies in the literature, there are differences in the music and rhythmically stimulated walking test results of different neurological patients. This situation is thought to arise from the nature of the disease.

In order to understand pathological gait patterns and identify problematic muscles and patterns, it is imperative that the music therapist has a strong theoretical understanding of the normal and pathological gait as well as clinical experience and use basic measurement techniques.[18] In this study, using basic measurement techniques, it was investigated whether auditory rhythmic stimulation made a biomechanical difference to the walking ability of CP children and the degree of effect within this difference.

The aim of treatment in CP and neurological diseases is to increase the walking speed, increase the stride length and decrease the double support phase time.[18-20] Therefore, the relationship between the increase in tempo and the increase in speed is important in order to develop walking skill. It has been found that music therapy used in Parkinson's disease, stroke, huntington's disease and traumatic brain injuries generally improves gait performance.[21]

According to studies, it has been stated that Rhythmic Auditory Stimulation (RIS) application generally affects cadence directly, and indirectly affects other walking parameters such as step length, double support, single support and walking speed.[22] It has been stated in the literature that the increase of 0.14 m/sec observed for walking speed can be accepted as a significant effect according to the clinical results.[23]

Although it is observed that all rhythms we use in CP children's rhythmically stimulated walking ability have a positive effect on gait parameters in general, each rhythmic stimulation has different effects. Cadence increased 18.35% only in 6 beat rhythms, while speed improved 2.70% and 8.43% in 4 and 6 beat rhythms. While there was a 7.50% improvement in 4-beat rhythms and 11.30% in 6-beat rhythms in the percentage of double-step progression, In 2/4 rhythms, a decrease of -6.60% was determined. It can be thought that rhythmic stimulation provides a rapid synchronization in speed and cadence by activating areas of the central nervous system. Because in Rehabilitation practices, music is an effective tool for the correction of gait. Rhythmic stimulation provides an opportunity to predict the time interval of the next movement by guiding the person to make constantly repetitive movements.

McIntosh et al., In their research to examine whether the rhythm of music has an effect on speed, frequency and stride length on the walking ability of Parkinson's patients, revealed that auditory stimulation has positive effects on walking rhythm and stride length.[19] Kwak examined the effects of auditory rhythmic stimulation with four-beat music in children with Cerebral Palsy and reported improvements in speed, stride length and gait symmetry.[18] Baram et al. Used auditory feedback control to improve gait in MS patients in their study, and found that they had a positive effect on patients after applying auditory feedback on stride length and walking speed.[24]

While 2-timed rhythmic stimulation had a positive effect (30,40%) in opposite foot lifting and 4-timed stimulation had positive effect (40,12%) and 6-timed rhythmic stimulation had 60,40% percent improved. Although the biggest positive effect is seen in 6-time rhythmic stimulation, all rhythmic stimulation had high positive effect on the opposite foot lifting is striking.

All three rhythm patterns appear to have a negative effect on the percentage of double stride length progression. In the double support time parameter, the increase of 4.6% with 2-timed rhythmic stimulation, 8.30% decrease with 4-beat rhythmic stimulation, and a decrease of 20.83% with 6-timed rhythmic stimulation were observed. The positive effect of the double support time parameter on walking ability in rehabilitation functions is determined by the decrease in values. Therefore, the increase in the 2-beat rhythmic stimulation and the decrease in the 4 and 6-beat rhythmic stimulation are indicative of the positive effects.

Conklyn investigated the effects of 6 weeks of music therapy on gait parameters in MS patients. The researcher did not use special rhythm patterns as in our study, and the subjects only walked with music. They found improvements in tempo, walking speed, stride length, and double stride length.

The positive effect of rehabilitation in step width and single support parameters is again determined by decreases in values. It was observed that 2 and 4 beat rhythmic stimulation in step width had negative effect but 6-beat rhythmic stimulation had positive effect, and in the percentage of single support, 4 and 6 beat rhythms had a much more positive effect despite all the three rhythmic stimulations.

In order to control walking parameters more easily, external music can guide the contraction of the muscles during the heel contact and push phases. In healthy subjects, it is easy to increase the velocity of a walk relative to the speed of music. It is one of the important results of our study that this situation has a similar effect on people with movement disorders.

One of the main purposes in improving walking skill in rehabilitation methods is increasing the step length. In our study, it was determined that 2-beat rhythmic stimulation did not have a positive effect (-21.75%) on the stride length parameter, but 4-beat rhythmic stimulation had a positive effect (21.75%) and 6-time rhythmic stimulation with a positive increase (21.70%). In addition, all three different

rhythmic stimuli we used in our study had a positive effect on the limp index.

Seifadinin et al. Stated in their study that one-day musical therapy with different rhythms had a positive effect on gait parameters of MS patients. They observed that 6-beat rhythms had a significant decrease in walking speed, a partial decrease in stride length, and an increase in the duration of double support, and stated that using less complex simple rhythm forms at the beginning of the treatment period could be more effective.[26]

In another study, Tauth et al. Reported an improvement in walking skills after using Rhythmic Auditory Stimulation with Parkinson's patients.[10] Mcintosh et al., Maclean et al., And Kwak examined the effects of musical therapy on walking skills in SP children and the elderly.[19,19,28]

Peng et al. Stated in their study that rhythmic and sensory applications strengthened the duration of movement and the extensor muscles of the lower extremity in children with spastic diplegia during the training and recovery process.[31]

As a result, it was determined that auditory rhythmic stimulation has biomechanically effective in walking ability, and we can say that the spatial and temporal parameters of walking ability developed by 4 and 6-beat rhythms in Cerebral Palsy patients, In addition, it is a striking result that musical structure in the natural environment who constitute the subject group of our study has more effective perception in the rhythmic harmony of the SP children. Therefore, for an effective auditory rhythmic stimulation rehabilitation, it is thought that determining the tempo close to the normal gait of the patients, choosing the rhythmic patterns that the patient is familiar with in his natural environment, and also increasing the rhythm diversity in the continuation of the treatment will be beneficial for the patient.

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