J. Phys. Ther. Sci. 30: 1063–1068, 2018

The Journal of Physical Therapy Science

Original Article

The impact of auditory rhythmic cueing on gross motor skills in children with autism

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Abstract. [Purpose] This study aimed to investigate the effect of auditory rhythmic cueing on gross motor skills in children with autism. [Participants and Methods] A total of 30 autistic children aged 8–10 years with mild to moderate autistic features participated in this study. They were randomly allocated to either the control group (n=15), which underwent a specially designed physical therapy program, or the study group (n=15), which underwent the same program in addition to gait training with rhythmic auditory stimulation. To provide rhythmic auditory stimulation, combination of a metronome beat set to the child's cadence and rhythmic cueing from the MIDI Cuebase musical program was used. Both groups received 3 sessions per week for 3 months. The Bruininks-Oseretsky Test of Motor Proficiency 2nd Edition was used to assess gross motor skills at baseline and after 3 months of intervention. [Results] The study found statistically significant improvements in bilateral coordination, balance, running speed and agility, and strength in both groups after treatment. Moreover, there were statistically significant differences between the 2 groups, with the study group showing better improvement in all outcome measures. [Conclusion] Gait training with auditory rhythmic cueing elicited a positive effect on the gross motor skills of children with autism.

Key words: Rhythmic auditory stimulation, Gross motor skills, Autism

(This article was submitted Mar. 21, 2018, and was accepted May 15, 2018)

INTRODUCTION

Autism is a multisystem neurodevelopmental disturbance characterized by stereotyped behaviors, restricted interests, as well as impaired communication and social interactions[1)]. Children with autism exhibit a number of motor disabilities, including clumsiness and poor coordination, gait abnormalities, impaired execution of skilled motor tasks, and motor planning deficits due to neurofunctional abnormality of the cerebellum[2)]. Moreover, they demonstrate spatio-temporal errors of movement control, which may be ascribed to a perception-action coupling deficit leading to an inability to express their motor target into a functional pattern, as they exhibit single actions independently from each other[3, 4)].

Children with autism experience anticipatory movement deficits that manifest as differences in coordination and motor planning from their typically developing (TD) peers[5)]. Furthermore, they take a longer time to complete rhythmic action sequences than TD children[6, 7)]. Motor deficits in autism have a substantial relationship to communicative and social functions, as these skill areas depend on the integration of sensory and motor responses. Accordingly, targeting the motor deficits of children with autism during intervention is viewed as an essential part in enhancing the development of their motor and social interactions[8)].

Rhythmic auditory cueing alludes to an auditory sound signal with a fixed inter-stimulus interval, such as the output from a

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metronome[9]. Rhythmic auditory stimulation (RAS) is a training technique that enhances motor skills by providing rhythmic stimulation to the motor centers of the brain. It can coordinate the sensory perception and motor entrainment into complex cognitive processes and motor adjustments, as timing of movement plays a fundamental role in the control of motor and cognitive functions[10]. Rhythm not only activates the motor areas of the brain but also produces quick motor synchronization through an external rhythmic stimulation in persons with and without neurological impairments[11].

Music therapy may help children with autism enhance their capabilities in the core domains, including social engagement and verbal communication[12]. Although auditory rhythms have been implemented broadly in rehabilitation studies, it has not yet been used to promote motor functions in children with autism. Moreover, few studies have concentrated on therapeutic interventions for improving the motor abilities of children with autism. Therefore, the aim of the present study was to explore the impact of rhythmic auditory cueing on gross motor skills in children with autism.

PARTICIPANTS AND METHODS

A total of 30 children with autism (22 boys, 8 girls) participated in the current study. They were recruited from schools of special needs. Children were enrolled according to the following criteria: age 8–10 years and mild to moderate autistic features with a score ranging from 30 to 36.5 according to the Childhood Autism Rating Scale (CARS)[13]. All children underwent IQ assessment (Stanford Binet Test)[14] conducted by a psychologist. They had borderline IQ and were able to follow verbal instructions during the testing and treatment procedures. All children were able to walk independently for at least 10 m without a walking aid. Children were excluded from this study if they had auditory, visual, or respiratory deficits, or fixed deformities of the extremities.

The study was conducted according to the code of ethics of the World Medical Association (Declaration of Helsinki). Approval for this study was obtained from the Ethics Review Committee of the Faculty of Physical Therapy, Cairo University, Egypt (no: P.T. REC/012/001849). The parents of participating children were given an explanation about the purpose and procedures of the current study, and they provided signed informed consent forms indicating their approval for their child's participation before the initiation of the study. The participating children were randomly allocated into 2 groups with 15 children each by using a sealed envelope method. Control group A underwent a selected physical therapy program and study group B underwent the same program in addition to gait training with auditory rhythmic cueing.

The motor skills of all participants in both groups were examined using Bruininks-Oseretsky Test of Motor Proficiency 2nd Edition (BOT-2), which is a valid and reliable test of gross and fine motor proficiency in children between 4 and 21 years of age. It provides a comprehensive evaluation of motor skills, as it is composed of 8 subtests, 4 in the gross motor domain (i.e., bilateral coordination, balance, running speed and agility, and strength) and 4 in the fine motor domain (i.e., fine motor precision, fine motor integration, manual dexterity, and upper-limb coordination). It has 4 motor zone composites (fine manual control, manual coordination, body coordination, and strength and agility), and every composite incorporates 2 subtests[15]. Two motor area composites, including body coordination and strength and agility, were chosen to assess the gross motor skill proficiency of the children in the present study.

Body coordination composite incorporates aspects of coordination and control of the large muscles used in keeping posture and balance including bilateral coordination and balance subtests. Bilateral coordination subtest consists of 7 tasks that demand body control and simultaneous coordination of the upper and lower limbs such as tapping feet and fingers same sides synchronized and tapping feet and fingers opposite sides synchronized. Balance subtest involves 9 tasks that are essential for maintaining posture during standing and walking with a variety of challenges to the balance systems such as standing on one leg on a balance beam eyes closed and walking forward heel-to-toe on a line. Strength and agility composite incorporates aspects of fitness and coordination involved in competitive sports and other physical activities including running speed and agility and strength subtests. Running speed and agility subtest includes 5 tasks that are related to running speed, running and changing directions, as well as stationary and dynamic jumping skills such as shuttle run and stepping sideways over a balance beam. Strength subtest includes 5 tasks that measure the core, upper and lower limbs strength in both static positions as well as with dynamic movements such as standing long jump, knee push-ups, and sit-ups.

The items incorporated in each subtest of gross motor domain (bilateral coordination, balance, running speed and agility, and strength) were explained to every child before recording the scores. Each child was permitted to carry out a practice trial before the recording trials. Two recording trials were allowed for each item, and the trial with superior results was used for analysis. A raw score may be a number of corrective activities performed, or a number of seconds completed to achieve a certain task. Raw scores were recorded and converted into numerical point scores. The point scores of all items for each subtest were collected to obtain the subtest total point score. Finally, the subtest scale scores and standard score composites were obtained from the fitting tables included in the manual, as indicated by age and gender. All children were evaluated before treatment and after 3 months following the completion of the intervention period.

All children in both groups underwent a specially designed physical therapy program that lasted for 1 hour, 3 times/week for 3 months. The training program included strengthening exercises for the trunk and extremities, balance training from different positions, stoop and recover from standing, facilitation of anticipatory mechanism, gait training using different obstacles, and ascending and descending stairs on alternate feet. Children in the study group underwent gait training with RAS for 30 min/session, 3 times/week for 3 months. To apply the RAS protocol, the MIDI Cubase musical instrument digital

Table 1. General characteristics of the children in both groups

	Control group (n=15)	Study group (n=15)
Age (years)[a]	9.26 ± 0.65	9.32 ± 0.67
Height (cm)[a]	134.57 ± 5.30	135.73 ± 4.59
Weight (kg)[a]	29.67 ± 2.50	30.20 ± 2.78
CARS score[b]	32 (30–34)	33 (31–35)
Gender[c]		
Male	10 (66.67%)	12 (80%)
Female	5 (33.33 %)	3 (20%)

Data are expressed as mean ± SD[a]; median (interquartile range)[b]; number and frequency (%)[c]; CARS: Childhood Autism Rating Scale.

interface program along with a metronome was used to control the rhythmic tempo for each participant. The metronome beats were played over the music in order to enhance the rhythmic recognition for each child. The metronome set up was matched directly with the child's step pattern[16)]. The playback equipment and speakers were set in a quiet treatment room where the music was the most hearable.

The RAS intervention protocol incorporated the following established steps[17–19)]: (1) Each child walked barefoot along a 10-m walkway 3 times at the child's comfortable walking speed before RAS application. (2) Walking cadence (steps/min) was measured according to the gait parameters in step 1. (3) The rhythm of metronome beats was set to coordinate with the child's cadence acquired in step 2. (4) RAS was provided with the help of a music specialist, and each child was instructed to listen and tap the hands with the rhythmic stimulus for 1–2 min from the sitting position, to affirm that the child has become familiar and adapted to the rhythmic signaling. (5) Each child was instructed to walk 10 m, again 3 times, with RAS and adjust his/her steps to the metronome yield beat and music simultaneously, with a 1–3 min rest between walks according to the endurance level of the child. (6) After the synchronization concerning simultaneous steps with RAS was assured, the beat was altered to 5% higher than the favored cadence and each child walked 10 m again 3 times. (7) During the last 1–2 min of the training, each child walked again while RAS was diminished in order to observe the independent carryover impact. The therapists observed every child during gait training and provided feedback when necessary. Children in the control group trained for the same period and distance with the same directions in terms of speed change, but without RAS.

Data were analyzed using Statistical Package for Social Science, version 23 for Windows. Normality of data was assessed using the Shapiro-Wilk test. Demographic data including age, weight, and height were expressed as mean ± standard deviation (SD), whereas dependent variables (BOT-2 scores) were documented as median and interquartile range. Independent t-test was used to compare age, weight, and height between the 2 groups. Wilcoxon signed-rank test was used to compare the outcome measures (non-normally distributed data) within each group, whereas Mann-Whitney U-test was used for between-group comparisons for non-normally distributed data. Values with $p<0.05$ were considered statistically significant.

RESULTS

A total of 30 children with autism participated in the current study. They were randomly allocated into 2 groups (15 participants in the control group and 15 participants in the study group). No significant differences were found between the 2 groups in demographic and baseline characteristics, including age, weight, height, and CARS score, as shown in Table 1 ($p>0.05$). The results showed that there were no significant differences between the 2 groups in the baseline values of BOT-2 scores ($p>0.05$). Moreover, statistically significant improvement was observed in the 4 subtest scores and in the 2 composite scores when comparing the pre- and post-treatment values within each group ($p=0.01$ in the control group and $p=0.001$ in the study group). Furthermore, there were statistically significant differences in the post-treatment results of all outcome measures between the 2 groups with the study group showing better improvements ($p=0.001$), as demonstrated in Tables 2 and 3.

DISCUSSION

Children with autism have primary movement disorders that can lead to constraints in balance control abilities, bilateral coordination, and daily functioning[20)]. The present study investigated the effect of gait training combined with auditory rhythmic cueing on gross motor functions in children with autism.

The results of the present study showed significant improvements in the bilateral coordination, balance, running speed and agility, and strength subtests, as well as in the body coordination and strength and agility composites in both groups, but with more significant changes in the study group.

The improvement of gross motor skills in the RAS group could be clarified by the way that persons with autism exhibit

Table 2. Descriptive statistics and comparison of the scale scores of BOT-2 gross motor subtests within and between groups

Subtest	Control group		Study group	
	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
Bilateral coordination	4 (3–7)	5 (4–8)*	5 (3–7)	9 (7–12)*Ω
Balance	6 (5–9)	7 (6–9)*	7 (6–11)	13 (9–17)*Ω
Running speed & Agility	4 (3–8)	5 (4–8)*	5 (3–7)	9 (6–14)*Ω
Strength	7 (5–8)	8 (7–10)*	6 (3–9)	14 (10–17)*Ω

Data are presented as median (interquartile range);
*Significant difference between pre- and post-treatment values within each group ($p<0.05$);
ΩSignificant difference between both groups after the intervention ($p<0.05$).

Table 3. Descriptive statistics and comparison of the standard scores of BOT-2 gross motor composites within and between groups

Gross motor composite	Control group		Study group	
	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
Body coordination	28 (25–30)	29 (26–31)*	29 (27–32)	42 (34–49)*Ω
Strength & Agility	26 (25–34)	30 (27–34)*	25 (22–36)	40 (35–44)*Ω

Data are presented as median (interquartile range);
*Significant difference between pre- and post-treatment values within each group ($p<0.05$);
ΩSignificant difference between both groups after the intervention ($p<0.05$).

deficits in anticipatory preparation of movement due to deficient internal cueing[21]. Application of external auditory rhythm provides a temporal framework for planning of the motor output while at the same time decreasing the internal demands by providing accurate template intervals at every phase of the movement. This might enhance the efficiency and coordination of motion achieved through successful movement sequence induced from rhythmical walking[9].

Furthermore, the motor system is very responsive to excitation induced by the auditory-related framework[22]. The auditory system projects into motor structures in the brain producing entrainment between the rhythmic stimulus and the motor response. Moreover, rhythmic cueing can also enhance cortical plasticity, improving the structural and functional connectivity in the brain[23]. The utilization of rhythm may serve to encourage sensorimotor synchronization in autism as consistent application of auditory cueing for an adequate time span may enhance the coordinated motor response during walking[24]. Additionally, RAS may generate a feed-forward interplay precisely affecting the motor output in a predictive manner, leading to the response pattern becoming progressively automatized[25].

The results of the current study provide insight into how gait training with RAS influences functional abilities, as the repetitive musical sound patterns elicit the excitability of spinal motor neurons through the reticulospinal pathway, which are believed to adjust the balance through better muscular activation and movement control in order to modify the reactive feedback-driven motor coordination[24]. Furthermore, Horak[26] clarified that the medial geniculate nucleus related to the vestibular system mainly influences standing balance, therefore, when auditory stimulation signals conveyed to the medial geniculate nucleus of the vestibular system reach the auditory cortex in the temporal lobe, they stimulate the vestibular framework to improve postural control. As children with autism show latency of movement, exhibiting over dependence on proprioceptive feedback to preserve postural stability[27], auditory feedback through RAS would provide an adjustment through encouraging more efficient proprioceptive muscular control[22].

It is important to note that the results highlight that auditory musical signals combined with gait training had a significant effect on the gross motor skills in the RAS group. This could be explained by the findings of Thaut et al.[28], who inferred that musical cueing activates the temporary muscular control of movement frameworks by affecting the time and potentiating motor neuron discharge, reducing the sensation of muscular exhaustion, optimizing the movement execution through the consistency of its time-based cues, accelerating the response time through encouraged reaction expectation, and providing a sound-related reference for proprioceptive control mechanisms. These components may influence muscle strength, endurance, speed, coordination, motor planning, and functional motor abilities.

The results of the present study agree with previous studies that investigated the effect of RAS on motor rehabilitation. Yoon and Kang[29] concluded that treadmill with RAS training was effective in maintaining balance and gait in persons with stroke. Kwak[30] argued that RAS offers great challenge in maximizing motor training and overall functioning in persons with cerebral palsy. Moreover, Kim et al.[17] reported that RAS leads to a faster gait and improves temporal parameters in adults with cerebral palsy. Additionally, Thaut and Abiru[10] reported that several clinical studies have affirmed the effectiveness of

RAS in causing functional improvements in motor abilities in persons with stroke, Parkinson's disease, and traumatic brain injury.

The present study revealed that all children in both groups displayed improvement in their motor capabilities after intervention, which could be due to the impact of the selected physical therapy program. These findings agree with those of recent studies that have documented positive effects on balance, coordination, strength, and flexibility after participation in motor activities in children with autism[31, 32)].

The limitation of this study includes its small sample size, which makes it difficult to generalize the results to the entire population of children with autism. Therefore, further study with a large sample size is necessary to generalize these findings. Future studies are needed to investigate the potential impact of auditory rhythmic cueing on fine motor skills in children with autism, and RAS studies may incorporate electromyography evaluation to assess muscular activation during rhythmical walking.

In conclusion, rhythmic auditory cueing combined with gait training could be an effective therapeutic technique providing functional improvement in gross motor skills in children with autism.

ACKNOWLEDGEMENT

The authors would like to give special thanks to the children who participated in this study and their parents.

Funding

No funding was received for this study.

Conflict of interest

The authors declare no conflict of interest.

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