Journal of Music Therapy, XLIV (3), 2007, 198–216

Effect of Rhythmic Auditory Stimulation on Gait Performance in Children with Spastic Cerebral Palsy

Eunmi Emily Kwak, MME, MT-BC
Michigan State University

The purpose of this study was to use Rhythmic Auditory Stimulation (RAS) for children with spastic cerebral palsy (CP) in a clinical setting in order to determine its effectiveness in gait training for ambulation. RAS has been shown to improve gait performance in patients with significant gait deficits. All 25 participants (6 to 20 years old) had spastic CP and were ambulatory, but needed to stabilize and gain more coordinated movement. Participants were placed in three groups: the control group, the therapist-guided training (TGT) group, and the self-guided training (SGT) group. The TGT group showed a statistically significant difference in stride length, velocity, and symmetry. The analysis of the results in SGT group suggests that the self-guided training might not be as effective as therapist-guided depending on motivation level. The results of this study support three conclusions: (a) RAS does influence gait performance of people with CP; (b) individual characteristics, such as cognitive functioning, support of parents, and physical ability play an important role in designing a training application, the effectiveness of RAS, and expected benefits from the training; and (c) velocity and stride length can be improved by enhancing balance, trajectory, and kinematic stability without increasing cadence.

Rhythm is an essential element of music. Through simple observations of human behavior, people recognize that rhythmic music, even something as simple as toe tapping, influences human beings to synchronize movement. Even though the effect of rhythm on outward physical movement has long been evident, recent advances in technology and a culmination of medical research have revealed the role of auditory stimulation as an internalized timekeeper for rhythmic patterned movements (Thaut, 2005). The purpose of this research is to use rhythmic auditory stimulation (RAS) for children with spastic cerebral palsy (CP) to determine functional outcome effectiveness in gait training for ambulation. RAS uses music as an external time cue to regulate body movement.

CP is a collection of motor disorders resulting from brain damage before the age of two, when brain development is relatively complete (Taylor, 1993). In the general U.S. population, the prevalence of CP is 1.4 to 2.4 per 1,000 persons (Pellegrino, 1997). According to the United Cerebral Palsy Association, it is estimated that there are more than 500,000 Americans with CP (Taylor, 1993). Prevalence of CP is not influenced by factors such as culture, ethnic group, or socioeconomic status.

Significant features of participants with CP are impaired movement in ambulation that involves gait and upper body coordination, as well as problems with balance. A normal gait requires at least 30 major muscles working at exactly the right times and with exactly the right force to take two steps. Common problems in gait for those with spastic CP include ineffective gait patterns, such as short stride length; asymmetrical gait, slowness, impairment in coordination, and unnecessary body movement. Because of lack of muscle use, the degree of muscle weakness (atrophy) progresses throughout a child's development. Physical therapy is often recommended for children with CP to maintain and improve their physical functions. RAS has been found to be effective in an adjunctive role or as a sole method to increase the effectiveness of traditional physical therapy for ambulation in adult rehabilitation settings. CP patients encounter difficulties with coordination and muscle control similar to those experienced by rehabilitation patients, which suggests that RAS may be beneficial if used to enhance traditional physical therapy treatments.

RAS is defined as:

> A neurologic technique using the physiological effects of auditory rhythm on the motor system to improve the control of movement in rehabilitation and therapy. RAS is mostly used in gait therapy to aid in the recovery of functional, stable, and adaptive walking patterns in patients with significant gait deficits due to stroke, Parkinson's disease, traumatic brain injury, effects of aging, or other causes. (Thaut, 2005, p. 139)

The key element of RAS is the phenomenon of auditory entrainment, that is, the body's ability to synchronize its movements rhythmically. External auditory activity is mediated by internal unconscious perceptual shaping at the subcortical level, and can arouse and raise the excitability of spinal motor neurons mediated by auditory-motor circuitry at the reticulospinal level (Pal'tsev & El'ner, 1967; Rossignol & Melvill Jones, 1976; Thaut, 1997a). The human body is a creative and resourceful organism and one of its most promising features, with regard to RAS, is that the various components of the brain are not connected by means of only one pathway; therefore, the brain does not completely stop working when one part is damaged or injured. When a part of the brain does not work properly, the brain finds a way to compensate for compromised functioning.

Damage to the motor cortex in a person with CP disturbs the normal process for the motor control system; in addition, the lower function motor control system could also be affected by brain damage. When the gait pattern of a person with CP is not rhythmic, it is likely that the internal timekeeper is not working. In these types of situations, RAS has been used to help regulate the motor control system by stimulating lower-level brain functions of the basal ganglia, cerebellum, brain stem, and spinal cord for patients with Parkinson's and other diseases. No conclusive evidence has been published, however, for using RAS in a clinical setting for children diagnosed with CP.

The RAS model is well defined by the Center for Biomedical Research in Music (CBRM) at Colorado State University. Research at Colorado State has demonstrated RAS effects in adult rehabilitation settings based on studies with Parkinson's disease, stroke, Huntington's disease, and traumatic brain injuries (Hurt, Rice, McIntosh, & Thaut, 1998; McIntosh, Brown, Rice, & Thaut, 1997; McIntosh, Thaut, & Rice, 1996; Thaut, 1997b). There is a need, however, to determine the functional outcomes of RAS in a range of populations with physical disabilities, including those diagnosed with CP, mental retardation, developmental delay, and physical deterioration due to aging. Though there are many applications for RAS, this study compared the effectiveness of RAS enhanced ambulation with traditional ambulation training in children with CP.

Treatments such as drug therapy, nerve injections, and orthopedic surgery are commonly used to treat spasticity to improve gait performance; yet, to date, there is no singular treatment that is most promising in reducing movement problems (Taylor, 1993). Unpredictability of results plagues those who attempt to treat individuals with spastic CP. The nature of CP and the complexity of brain function disturbance make treatment outcomes difficult to predict. Often, drug therapy causes drowsiness as a side effect, and injections of alcohol, phenol, or botulinum toxin are only effective for 6 months or less. Sometimes, corrective orthopedic surgery results in deformity of the antagonistic muscles (Miller & Bachrach, 2006).

RAS is a promising option within music therapy because the application of rhythm may organize an individual's gait and improve gait patterns. RAS training may be particularly beneficial because it has no negative side effects. In addition, it is cost-effective when compared to other treatments, and can be used in conjunction with other treatment modalities, or as an independent treatment because it is a noninvasive procedure.

A review of the literature revealed only one previous study with seven cerebral palsy patients in a home training setting. Results indicate improved velocity, cadence, stride length, and symmetry, as well as kinematic improvements of knee and hip ranges of motion and trajectories (Thaut, Hurt, Dragon, & McIntosh, 1998). The current study attempts to establish applications for using RAS in daily training with a music therapist, or as self-guided training, for establishing the validity of the research modality, and for adding to the theoretical basis of RAS. Investigation of the effectiveness of RAS for children with CP will help researchers learn appropriate applications for RAS and define the possibilities and limitations of RAS in clinical settings. The research questions are as follows: Does RAS enhance physical therapy for children with spastic cerebral palsy? Specifically, does it influence cadence, increase stride length, increase velocity, and improve gait symmetry? Is there a difference between the control, therapist-guided training group (TGT), and self-guided training group (SGT)?

Method

Participants

Thirty participants who have spastic CP ranged in age from 6–20 years old were enrolled in Chungju Hae-Hwa School for children with physical disabilities in Korea and participated in physical therapy for gait training at school. All were ambulatory but needed to stabilize gait and gain more coordinated movement. The control group ($n = 10$) received conventional gait training from a physical therapist while a music therapist observed. The therapist-guided training group (TGT, $n = 10$) received conventional gait training enhanced by RAS from both a physical therapist and a music therapist. The self-guided training group (SGT, $n = 10$) received conventional gait training from a physical therapist, and RAS self-guided training; a music therapist observed. Due to their illnesses, inconsistent school attendance, and lack of a posttest, five participants did not complete the experiment. Therefore, results were studied based on nine participants each in the control group and the TGT group, and seven participants in the SGT group.

Setting

For the pre and posttests, a 14-meter walkway was marked at 10 meters for test measurement with a 2-meter allowance for acceleration and 2-meter allowance for deceleration. Unrestricted space such as a playground, hallway, and slope (not stairs) at the school were used for gait training.

Equipment

Computer with cakewalk program. Cakewalk Pro Audio 8.0 is MIDI program which can provide variable tempo changes of recorded music used to accommodate the various cadences of each participant's gait. There were three basic melodies: "Dixie Land," "When the Saints Go Marching In," and a blues-style selection. All three songs have a basic steady beat pattern with 4/4 meter and have been recorded using quarter notes equal to 100 bpm. Since a majority of children with CP walk slower than typically developed children, the music was recorded slower than normal walking tempo (105 to 120 steps per minute). This slower tempo allows for a possible variation of tempo range from 80 bpm to 120 bpm.

Metronome. A metronome was used to confirm the accuracy of the tempo and assist in synchronizing participants during the warm-up activity in TGT and SGT.

Drums. A djembe was used by the therapist to emphasize the fundamental beat in the prescribed music. An open tone and a closed tone were used to produce different acoustics for the right foot and left foot. Clapping was also used for the same purpose. When a participant's cadence fell below 65 steps per minutes, to avoid excessively slow music, the cadence was multiplied by 2 as a tempo for the RAS music, and then the actual cadence was emphasized by drumming or clapping. For instance, a participant who walked 45 steps per minute had a music tempo of 90 beats per minute, and the drumming or clapping was maintained at 45 beats per minute.

Stride Analysis System. The accurate measurement of motor function and disability in patients is important in determining the efficacy of therapeutic interventions. Although clinical rating scales and simple timed tests of motor function are widely used to assess motor response to therapy, precise measurements for analyzing the effectiveness of music therapy interventions are necessary. The Stride Analyzer has been developed by B & L Engineering Inc. a group associated with Rancho Los Amigos Hospital (Norkin, 2000). The Stride Analyzer is a microprocessor/PC system designed to record foot-floor contact data by means of four pressure sensitive switches placed under the heel, at the heads of the first and fifth metatarsals, and at the big toe. It then calculates and compares gait parameters. Permanent records of the gait parameters and foot-floor contact patterns can be printed immediately following each test or later at the researcher's convenience. The Stride Analyzer is designed to analyze the following walking parameters: cadence, stride length, velocity, gait cycle, gait symmetry, and foot contact pattern.

Procedure

Pretest and posttest for all three groups. After all 30 participants signed consent forms, pretests were administered. During the pretest, while a participant was seated, the proper-sized footswitches were placed in the participant's shoes, and a recorder was attached to a belt placed around the participant's waist. Participants were asked to walk at their most comfortable tempo. When the participant walked into the test area, a manual trigger activated the data recorder and data was collected while the participant moved through the test area. Pretests were used as baseline data and for producing the prescribed music for each participant in the experimental groups. After completion of training, posttests were performed in the same way as pretests. All participants were asked to walk at their most comfortable tempo.

The prescribed music for RAS training. Based on the pretest, observation, and conference with the physical therapist, the tempo of the music was increased 5% above each participant's current walking tempo for the first week of training, or decreased, or retained at the current cadence depending on client's needs. The tempo was increased if balance and gait pattern tended to be better when a faster step was taken, just as riding a bicycle is easier at a faster speed. The tempo of the music was increased by 10 % from the baseline for the second week, and 15 % for the third week.

The increase in 5% from the current cadence was decided by a "Weber fraction". The "Weber fraction" is the percentage of the different thresholds obtained for different sensory stimulus. For example, in other to perceive the difference between electric shocks, a person needs to have 1.3% difference between them. In comparison, to taste sodium, 8.3% difference is needed. It was found that the Weber fraction for auditory time perception is 5% from 0.4 sec to 2.0 seconds. Beyond this range, the fraction is remarkably higher; however, the cadence of participants in this research was between 37 (1.62 seconds between steps) and 145 (0.41 seconds between steps) steps per minute. The imperceptible changes in the tempo of the music were essential to make training as comfortable as possible (Epstein, 1985; Getty, 1975; McBurney & Collings 1977). For the TGT group, the music was played through the computer's sound system. For the SGT group, the music was recorded on three cassette tapes and distributed to the participants. When a participant had a problem with gait posture such as toe walking due to muscle contracture, and/or spinal deformities, the tempo of the music was either decreased or maintained for the first week. Depending on their progress, tempo changes of the prescribed music were made every week.

Difference between the Therapist-Guided Training group (TGT) and the Self-Guided Training (SGT) Group. Both experimental groups used RAS technique for gait training, but the delivery of RAS technique was different; while the music therapist is actively involved with participants with verbal instructions and reinforcement, the music therapist was presented to SGT as an observer. Instead of warm-up exercise for the SGT group, muscle strengthening exercise using PSE and TIMP was took place. Other differences between TGT and SGT are illustrated in Table 1.

Procedure for RAS training for the Therapist-Guided Training Group (TGT). Sessions for each participant were held for 30 minutes five days a week, for three weeks. The general application for RAS training for TGT was consistent as possible, depending on a participant's ambulation ability, and total walking time. Individual organization for a session, total walking time and distance, and tempo

TABLE 1
Differences Between TGT and SGT

Difference	TGT	SGT
The presence of a music therapist	A music therapist is present and provides verbal instructions and reinforcement	A music therapist is present as an observer
The use of drum	A drum is used to emphasize the fundamental beat	None
Sound source	A computer speaker system is used to play the prescribed music during the entire session	Tape player and head phone set are used for playing the music
Environmental setting	One-to-one sessions in hallway or slope	Two–Three in a group and train together in hallway, slope or play ground
Muscle strengthening exercise	Depending on individual needs, physical therapist and the music therapist develop muscle strengthening exercises using PSE[a] and TIMP[b]	None

[a] Patterned Sensory Enhancement.
[b] Therapeutic Instrument Music Playing.

of the music were recorded and reported. During the entire session, prescribed music for the participant based on the Cakewalk program was played to increase the effect of entrainment. Basic organization for a 30-minute session was as follows.

Procedure for RAS training for the Self-Guided Training Group (SGT). At the first session, a tape and instructions were given to the participants and they were encouraged to participate during 3 weeks of training. The researcher demonstrated how they can feel the beat and how they can walk with the prescribed music. The music therapist was present during the self-training to record the duration of the training. The application below describes how sessions occurred. The therapist did not actively intervene with the training after the initial session. The participants were asked to follow the instructions and walk with the prescribed music for 30 minutes of daily self-training.

Procedure for the control group. A pretest and a posttest were administered for the participants in the control group. During the 3-week experiment, the participants in the control group had conventional physical therapy with the researcher present as an observer.

Results

During a 3-week research study, gait parameter, cadence, stride length, velocity, and symmetry ratio data were collected using the Stride Analyzer. In addition, pre and posttest data, and observations and information from parents and staff gathered during each treatment episode were recorded and used to answer the questions posed in this study.

Does RAS Training Influence Cadence?

Cadence was the element that the researcher used to adjust RAS training based on each participant's ability. Depending on the participants' gait performance, the treatment goals were to increase cadence in 9 cases, to decrease cadence in 4 cases and to maintain cadence in 3 cases. It was requested by the physical therapist at the school that some participants did not need to increase their cadence and some participant's cadence were faster than normal gait parameter due to their insecurity in balance, therefore unlike planned procedure, cadence needed to be adjusted depending on the participants. Cadence increased approximately 5% in the TGT and SGT groups and decreased by 1.2% in the control group (see Table 2). The results of a paired-sample *t*-test, however, indicate that there was no statistical difference between pre and posttest in the cadence within the groups (see Table 5).

Does RAS Training Increase Stride Length?

Stride length of a person with CP is often smaller than a normal person's stride length (Perry, 1992). Stride length improved approximately 15.8% overall. While the STG group showed only approximately 8% increase, the TGT group showed a 29.48% increase in stride length as shown in Table 3. The paired-samples *t*-test indicates that improvement of stride length in the TGT group was statistically significant ($t = -3.109$, $p = 0.014$), whereas the other groups did not show any significant differences (see Table 3).

Does RAS Training Increase Velocity?

Velocity, in general, improved from 20.73% (see Table 4) primarily in the TGT group. The results indicate improvement between pretests and posttests was 36.49% in the TGT group, 15.83% in the SGT group, and 9.44% in the control group. A paired-sam-

TABLE 2

Results of t *Test for Cadence Depending on Control, TGT and SGT Groups*

Group	*M*	*SD*	*t* value	2-tail significance
Control	1.1074	13.5551	0.245	0.813
TGT	–5.2667	28.0788	–.563	0.589
SGT	–5.2786	11.8615	–1.177	0.284

TABLE 3

Results of t *Test of Stride Length Depending on Control, TGT and SGT Groups*

Group	*M*	*SD*	*t* value	2-tail significance
Control	–5.2E-02	0.17948	–0.871	0.409
TGT	–0.20183	0.19474	–3.109	0.014*
SGT	–6.1E-0.2	0.19467	–0.829	0.439

* $p < 0.05$.

TABLE 4

Results of t *Test for Velocity Depending on Control, TGT and SGT Groups*

Group	*M*	*SD*	*t* value	2-tail significance
Control	– 2.8870	11.6944	–0.741	0.480
TGT	–11.1296	11.0245	–3.029	0.016*
SGT	–5.6179	9.2366	–1.609	0.159

* $p < 0.05$.

TABLE 5

Results of t *Test for Symmetry Depending on Control, TGT and SGT Groups*

Group	*M*	*SD*	*t* value	2-tail significance
Control	–8.0E-03	0.14251	–0.168	0.870
TGT	–0.13211	0.17020	–2.329	0.048
SGT	–8.0E-02	0.18258	–1.160	0.290

* $p < 0.05$.

ple t-test showed a difference between groups in improved velocity. The improved velocity in the TGT group was statistically significant ($t = -3.029$, $p = 0.016$), as illustrated in Table 4, whereas the other groups showed no significant difference. This indicated that the improvement in the TGT group was much greater than the improvement made by the other groups.

Does RAS Training Improve Symmetry?

Symmetry was calculated based on data collected by the Stride Analyzer. The shorter swing time of one leg from toe-off to heel strike was divided by the longer swing time of the other leg. Gait symmetry improved approximately 16.97% in the TGT group, and 9.92% in the SGT group, whereas the control group only increased by 0.91% as seen in Table 5. A paired-samples t-test indicated statistical significance in improving symmetry in the TGT group ($t = -3.029$, $p = 0.016$), whereas the other groups showed no significant difference. In addition to an increase in velocity and stride length, this indicates that the improvement in the TGT group is much greater than the improvement made by the other groups (see Table 5).

Is There A Difference between the Control, Therapist-Guided Training (TGT), and Self-Guided Training (SGT) Groups?

A one-way analysis of variance (ANOVA) was used to answer the research question regarding gait parameter improvement between the control, therapist-guided training (TGT), and self-guided training (SGT) groups. No significant difference between the groups was identified. This result is demonstrated in Table 6.

Data were analyzed using a paired-samples t-test, an independent-samples t-test, and an analysis of variance. In general, the therapist-guided training (TGT) group showed a significant difference

TABLE 6

Comparison Improvement of Gait Parameters between Control, TGT and SGT Groups

Variable	SS	df	MS	f	2-tail significance
Cadence	234.405	2	117.203	0.299	0.744
Stride length	0.123	2	6.141E-02	1.714	0.203
Velocity	315.476	2	157.738	1.346	0.281
Symmetry	7.847E-04	2	3.924E-04	1.292	0.295

in the paired-samples *t*-test within the therapist-guided training group. There were no significance difference on measures in other tests used for analysis; however, differences in velocity, cadence, and stride length were observable and indicated a positive outcome with the methods of this study (see Table 6).

Discussion

One of the objectives of the research was to define the details of RAS delivery techniques. During the 6-week intensive study, there were approximately 100 individuals with CP at Chungju Hae-Hwa School and only about 40 were ambulatory. The researcher observed their unique body movement; not only their gait but their whole-body movement patterns. It was obvious that each child had distinct and elaborate movement characteristics. Often, unique patterns were found in a child's body movement, as they used their left or right side. Individual gait problems were much more complex than the researcher expected. Influencing the treatment and results were deformation of the bone structure, abnormal muscle contracture at each of the major joints, balance, and equilibrium variations among individuals. General application for children with CP was difficult to establish, except the basic premise that the use of RAS music could stabilize and enhance their gait performance. Based on the result from the research, observation, and literature review, a schema for determining an individual RAS training application were developed (as shown in Figure 1).

Comments on the Research Procedure

During the experiment, it became clear that qualitative data collected could help clarify outcomes. The observation made by the researcher along with information from the school, medical personnel, and parents identified issues which impeded therapeutic gains. During the preparation for this study, concerns focused on participants' neurological damage and how RAS could affect gait training for persons with CP. The individual characteristics and personality of participants were not considered as factors when determining training application; however, it became clear during this study that certain characteristics in individual participants are essential in tailoring the training application and the expected outcomes. These characteristics included cognitive functioning, balance and equilibrium, assistive walking device, severity of condi-

A recommendation for RAS training application.

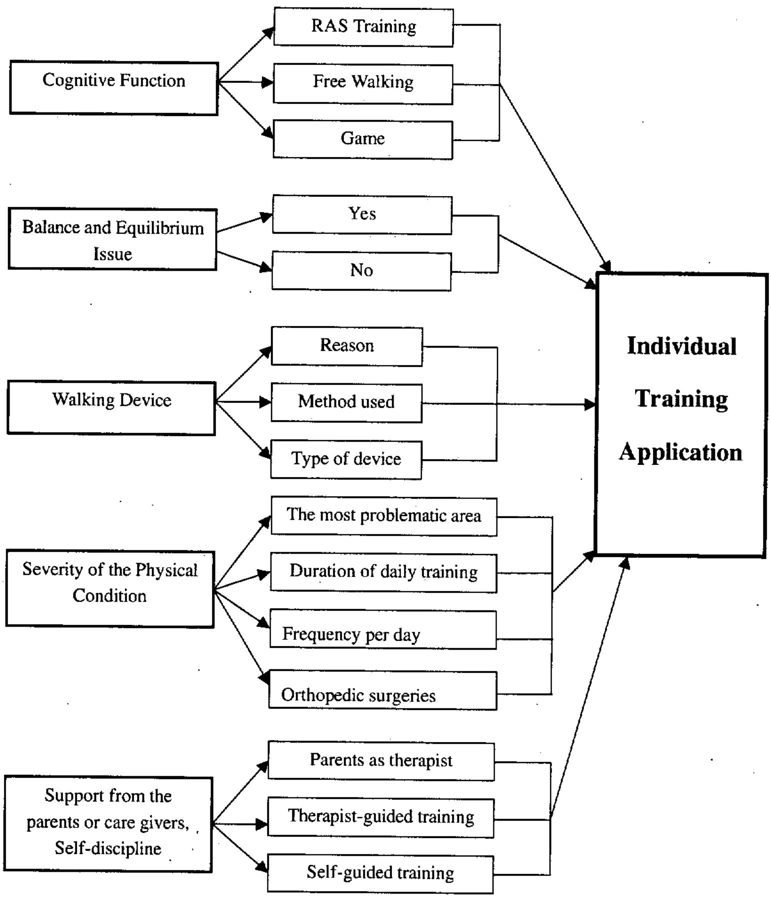

FIGURE 1.
A recommendation for RAS training application.

tion, history of orthopedic surgeries, personality, self-discipline, and support from parents or caregivers. Figure 1 illustrates some possible variables that influence a training application. The summary of the findings from this study follow.

A participant's cognitive function greatly influenced training application effects. The researcher found that Piaget's stages of cognitive theory readily applied to observations of the participants in the study (Smith, Cowie, & Blades, 2003). If the participant was cognitively under six-years old, the participant did not display strong self-discipline and the training was most successful when it was designed as an interesting game, such as pretending to be a soldier or walking to shop at imaginary stores (Berger, 1994). If a participant's cognitive function was less than one-year, free walking in a spacious room with a suitable sound presentation system was most appropriate for encouraging them to walk as they pursued a toy or an attractive object.

Balance and equilibrium issues required further investigation to improve participant's gait performance. If the participant suffered from these issues a set of exercises for enhancing balance and equilibrium reflex is required in the training application. They first need to learn to walk slowly by practicing "stepping and standing, stepping and standing" in order to improve a sense of equilibrium. Walking backward was especially helpful for balance and equilibrium. Exercise with inclining and declining slopes was useful to improve ability to balance and sustain equilibrium. In addition, a descending slope or stair is especially difficult for most people with a pathological gait. Practicing on a declining slope or stair encouraged the clients to cope with the fear of falling.

An assistive walking device necessitated an altered application of RAS. There are mainly two reasons for using assistive walking device: balance problems or muscle weakness problems. Consequently, the application was changed to accommodate their needs. In addition, there are different types of assistive walking devices, such as a four-wheel walker vs. two-wheel walker, and different methods for pushing a walking device such as lifting up a walker or rolling a walker. A person who has strong upper body strength excessively compensates their lower body weakness resulting in a deteriorating lower body condition. Those details were noted to tailor an individual application. It was important to incorporate an appropriate assistive walking device technique into gait training for participants to prevent further deterioration.

In consideration of all these factors, severity of the physical condition determines the types of muscle strengthening exercises, and duration of exercise time. Although the frequency of daily training during a day was kept to once a day because of their weaknesses, some participants showed the need to break down the daily training to twice a day. It is also important to accommodate a participant's orthopedic surgeries, especially if they have occurred within the past year. During the year, participants are in recovery; therefore rapid changes in body posture, recurrence of the spasticity of the operative muscles, and potential spasticity of the compensatory muscles are predicted. Depending on the changes, the training application was promptly adjusted.

Support from parents or caregivers, self-discipline, and personality of the participant seemed to influence outcomes, especially for the self-guided training group. Without strong support from the parents or caregivers and sheer determination of the participants, RAS training was less effective for the self-guided training group.

Recommendations

The most important factor in gait training for a person with CP is a comprehensive understanding of the person's pathological gait and scrupulous observation of their gait. To acquire information about the participant, contacts with the physical therapist, parents, and medical professionals are very beneficial. To understand their pathological gait patterns and pinpoint problematic muscles and patterns, it is imperative that the music therapist have a strong theoretical understanding of normal and pathological gait as well as clinical experience, and utilize basic measurement techniques.

Secondly, it is strongly recommended that when RAS training for a client with CP is designed and conducted, close cooperation should be established with the client's physical therapist because of the complexity of CP. To identify the effectiveness of RAS, the possible training application, and expected benefits from the training, individual characteristics such as cognitive functioning, support of parents, and physical abilities need to be taken into account. Participants' natural behavioral tendency (e.g., compliant, aggressive, negative) and participants' desire to improve also need to be taken into account for an individualized RAS training application. Third, duration and frequency of training must fit within a range of 10–20 minutes and up to twice a day based on the participant's physical condition. The fixed time of 30 minutes in this study was too long based on clients' laborious walking, especially for participants in the Self-Guided Training (SGT) group who solely walked as exercise for 30 minutes. A majority of participants requested shortening the duration of training, and even though the researcher encouraged them to finish the training tape, it often appeared to be laborious.

A final recommendation is to emphasize cadence. The relationship between increase in cadence and increase in velocity is important in application development for gait training. The results of RAS in Parkinson's disease, stroke, Huntington's disease, and traumatic brain injuries generally suggest that increased cadence would improve gait performance (Thaut et al., 1993; Thaut, McIntosh, & Rice, 1997; McIntosh et al., 1997; Miller & Bachrach, 1996). This does not appear applicable for spastic CP patients; in this study most participants enhanced their gait performance without increases in cadence. This may occur because a child with CP never learns to walk "correctly" or "normally." Unlike CP, the other populations studied experienced normal gait patterning prior to the onset of their illnesses and could have some undamaged cortical cells that could re-establish old motor pathways as well as form new motor pathways. Children with CP must rely on their damaged motor pathways, and RAS helps to develop new motor pathways. For the same reason, it is assumed that three weeks of RAS training for spastic CP patients is not sufficient to regulate their new gait pattern to become an ingrained gait pattern.

Future Research

It was found that using a drum with the prescribed music was very effective. However, because of clients' unstable gait, the therapist needed to be ready to assist to prevent falls or other needs. An assistant therapist or another helper should be available to play the drum. Clapping, however, worked very effectively in the current experiment to emphasize the downbeat, instead of a drum. When the clients' cadence were less than 65 steps per minutes, the prescribed RAS music was set at double the cadence to avoid excessively slow music, and drumming or clapping emphasized the actual cadence.

While the Stride Analyzer gives more details regarding foot contact pattern and allows researchers to understand overall body movements, some prospective participants might not be able to use it. Five prospective participants became uncooperative when the apparatus for the Stride Analyzer was attached to their shoes or feet were unable participated the experiment. Therefore, a manual measurement method needs to be considered to attain the gait parameters of participants through observations in relaxed environments.

During the experiment, the following three areas were identified as potential research projects. First, using patterned sensory enhancement (PSE) and therapeutic instrumental music playing (TIMP) were very useful in this experiment for strengthening and stretching muscles as a part of gait training but was not found to be documented in the literature. In this study, one of the major differences (beside therapist's present) between TGT and SGT was the muscle strengthening exercises. Initially, this component of gait training was added instead of warm-up exercise for SGT group, however, when the school physical therapist engaged with music therapy sessions, she really valued the potential possibility of using PSE and TIMP and used this part of RAS training to improve particular muscle groups. She was very impressed and pleased by the exercise progress and results. Therefore it is necessary to investigate the role of PSE and TIMP in RAS training.

Second, many individuals with CP cannot expect total independence. For instance, in special school of 101 students, only 32 walk independently, 24 use a wheelchair, and 45 use other walking devices. The neurologic effect of RAS for gait could transfer to upper body movement and posture reflex for CP through PSE and TIMP. The use of music combined with physical therapy for infants, toddlers, and adults with CP need to be examined.

Third, gait analysis in CP is usually focused on abnormal movement patterns, but in this study, four cases out of 25 had balance problems which were not considered in the research application. This, however, is an important factor to improve gait performance in children with CP. Many children with CP who are not able to walk often have difficulty sustaining normal posture reflexes that include the righting reactions and equilibrium reactions. This ability is essential to maintain balance and thus to achieve stable standing and walking. The possibility of the neurologic effect of auditory stimulation in problems with righting reactions and equilibrium reactions needs to be researched.

Conclusion

The purpose of this study was to use RAS with children with spastic CP in a clinical setting in order to determine its functional outcome effectiveness in gait training for ambulation. As mentioned above, a normal gait requires at least 30 major muscles working at exactly the right times and with exactly the right force to take two steps. Abnormalities in any one muscle can result in a pathological gait (Miller & Bachrach, 2006; Perry, 1992; Taylor, 1993). The effect of central nervous system lesions in mobility of a person with CP is unpredictable, and there are many variables that could affect the functional outcomes of different individuals' mobility, with the result that the gait pattern for each individual with CP is unique.

The exact mechanism and the neural basis of the synchronization of rhythmic physical movement such as finger-tapping or walking to an external auditory cue is not fully understood at present. The results of this study, however, support three conclusions:

> RAS does influence gait performance of people with CP. Individual characteristics such as cognitive functioning, attitude, support of parents, and physical ability play an important role in designing a training application, the effectiveness of RAS, and expected benefits from the training, and stride length, velocity, and gait symmetry could be improved by enhancing balance, trajectory, and kinematic stability without increasing cadence.

Individuals have their own internal timekeeping mechanism for certain body movements. The analysis of the results from this study strongly suggests that increasing the cadence, in other words, changing the current internal timing, needs to be done very cautiously. Results suggest that it would be safer to maintain an individual's current cadence when an irregular foot contact pattern exists because this indicates balance and equilibrium problems, or when a pattern shows no floor contact on some part of the foot, which indicates muscle contracture or body deformation.

This research suggests that RAS may be very promising in gait training for children with CP. The matter at hand is to figure out how to apply it to their gait training. Continued research, however, is needed to explain how RAS enhances body posture and kinematic stability of gait performance.

References

Berger, K. S. (1994). *The developing person through the life Span* (3rd ed.). New York: Worth Publishers.

Epstein, D. (1985). Tempo relations: A cross-cultural study. *Music Theory Spectrum, 7,* 34–71.

Getty, D. (1975). Discrimination of short temporal intervals: a comparison of two models. Perception and Psychophysics 18, 1–8.

Hurt, C. P., Rice, R. R., McIntosh, G. C., & Thaut, M. H. (1998). Rhythmic auditory stimulation in gait training for patients with traumatic brain injury. *Journal of Music Therapy, 35,* 228–241.

McBurney, D. H., & Collings, V. B. (1977). *Introduction to sensation/perception*. Englewood Cliffs, NJ: Prentice-Hall.

McIntosh, G. C., Brown, S. H., Rice, R. R., & Thaut, M. H. (1997). Rhythmic auditory motor facilitation of gait patterns in patients with Parkinson's disease. *Journal of Neurology, Neurosurgery and Psychiatry, 62,* 22–26.

McIntosh, G. C., Thaut, M. H., & Rice, R. R. (1996). Rhythmic auditory stimulation as entrainment and therapy technique: Effects on gait of stroke and Parkinson's disease patients. In R. Pratt & R. Spintge (Eds.), *Music medicine: Vol. 2* (pp. 145–152). St. Louis, MO: MMB Music.

Miller, F., & Bachrach, S. J. (2006). *Cerebral palsy: A complete guide for caregiving* (2nd ed.). Baltimore, London: The Johns Hopkins Press Ltd.

Norkin, C. C. (2000). Gait analysis. In S. B. O'Sullivan & T. J Schmitz (Eds.), *Physical rehabilitation: Assessment and treatment* (4th ed.) (pp. 257–331). Philadelphia: F. A. Davis.

Pal'tsev, Y. I., & El'ner, A. M. (1967). Change in the functional state of the segmental apparatus of the spinal cord under the influence of sound stimuli and its role in voluntary movement. *Biophysics 12,* 1219–1226.

Pellegrino, L. (1997). Cerebral palsy. In M. L. Batshaw (Ed.), *Children with disabilities* (pp. 499–528). York, PA: The Maple Press Co.

Perry, J. (1992). *Gait analysis*. Thorofare, NJ: SLACK.

Rossignol, S., & Melvill Jones, G. (1976). Audiospinal influences in man studied by the H-reflex and its possible role in rhythmic movement synchronized to sound *Electroencephalography and Clinical Neurophysiology, 41,* 83–92.

Smith, P. K., Cowie, H., & Blades, M. (2003). *Understanding children's' development* (4th ed.), Oxford, Cambridge, Mass.: Basil Blackwell.

Taylor, F. (1993). Cerebral palsy: hope through research. In K. Bellenir (Ed.), (1997), *Congenital disorders sourcebook, Vol. 29* (pp. 119–177). Omnigraphics.

Thaut, M. H. (1997a). Rhythmic auditory-motor facilitation of gait patterns in patients with Parkinson's disease. *Journal of Neurology, Neurosurgery and Psychiatry, 63*(1), 22–26.

Thaut, M. H. (1997b). Rhythmic auditory stimulation in rehabilitation of movement disorders: A review of current research. In D. J. Schneck & J. K. Schneck (Eds.), *Music in human adaptation* (pp. 223–230). Blacksburg, VA: Virginia Polytechnic Institute and State University.

Thaut, M. H. (2005). *Rhythm, music, and the brain: Scientific foundations and clinical applications*. NY: Routledge.

Thaut, M. H., Hurt, C. P., Dragon, D. & McIntosh, G. C. (1998). Rhythmic entrainment of gait patterns in children with cerebral palsy [Abstract]. *Developmental Medicine and Child Neurology 40*(78), 15.

Thaut, M. H., McIntosh, G. C., & Rice, R. R. (1997). Rhythmic facilitation of gait training in hemiparetic stroke rehabilitation. *Journal of Neurological Science, 151,* 207–212.