EFFECT OF BALANCE INTERVENTION ON POSTURAL CONTROL AND GAIT EFFICIENCY IN PRESCHOOLERS WITH DOWN SYNDROME

by

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ABSTRACT

The purpose of this study was to evaluate the effect that balance training can have on children with Down syndrome, specifically on their levels of postural control and gait efficiency. Eleven children with Down syndrome, ages 4-6, were recruited for this study. Before the intervention program began, baseline testing was performed for each participant using a force plate (BTrackS) and a timed up-and-go test. The intervention consisted of 30 minutes of balance activities per day, which took place four days a week for four weeks. Post-testing was performed after the last session. There was no statistical significance for the changes that were observed between pre and post test for the measured variables. However, changes were seen in the effect size which was calculated in order to determine if there was any change between baseline and post-testing for our small sample size. Some of the greatest differences we saw were decreased mean frequency and average time for timed up-and-go test. These results indicate that a short-term training intervention can be beneficial for both postural control and gait efficiency in children with Down syndrome.

TABLE OF CONTENTS

INTRODUCTION

Down syndrome (DS) is a genetic disorder that occurs due to the presence of an extra chromosome (Gupta, Rao, Sd, 2010). According to the Centers for Disease Control and Prevention, approximately one in every 700 babies in the United States is born with DS, which totals to roughly 6,000 new cases each year. Individuals with DS exhibit orthopedic, neuromuscular, cognitive, and perceptual impairments. DS is characterized by muscle hypotonicity and joint hypermobility, which affects muscle control, spatial awareness, and quality of movement (Tsimaras, Fotiadou, 2004). While the overall development of children with DS follows the same trends as that of typically developing children, it occurs at a much slower rate (Gemus, Palisano, Russell, Rosenbaum, Walter, Galuppi, Lane, 2001). By the age of five, the motor skill development of the child with Down syndrome is approximately two years behind that of the child without DS, and the performance of many activities will be 50-70% below the normal rate. An example of slower development is seen in the delayed onset of walking. On average, children with DS begin to walk roughly a year later than typically developing children (Ulrich, Ulrich, Angulo-Kinzler, Yun, 2001). From a physiological standpoint, specific neuromuscular abnormalities can be attributed for causing these motor delays. Such abnormalities can include generalized muscular hypotonia, the persistence of primitive reflexes beyond the normal disappearance with age, and slowed reaction times during voluntary movement (Shumway-Cook, Woollacott, 1985). These motor abnormalities are a contributing factor to the balance deficits seen in children with DS.

There are two types of balance that play a role in motor behavior and control. Static balance is the act of maintaining equilibrium for a single body position. Dynamic balance is concerned with keeping equilibrium while the body is in motion (Bass, 1939). Factors that can impact both types of balance include motor responses that affect coordination, and sensory information that comes from the somatosensory, visual, and vestibular systems (Davlin, 2004). The act of maintaining, achieving, or restoring balance is referred to as postural control. Postural control is required to establish and maintain dynamic balance that is needed to carry out daily functional activities (Lee, Lee, Song, 2016). It is considered a prerequisite for functional capabilities and motor skills and is necessary for efficient walking and carrying out activities of daily living (Berg, 1989). An efficient gait will have high demands for stability and postural control because it requires the ability to adjust the center of mass to a changing base of support in order to prevent falling.

Shumway-Cook and Woollacott (1985) compared postural development in children (ages 1-6) with and without Down syndrome. The children were divided into two groups based on age (15 months- 31 months and 4-6 years) and each participant was tested in three different sessions. The first two sessions observed postural responses to platform translations and rotations while the third session examined postural responses to different sensory conditions. The younger group was tested using simplified experimental procedures in comparison with the older group and EMG's were used to compare muscle activation. It was observed that children with Down syndrome had significantly slower onset latencies in muscle response and increased amounts of sway when compared to the typically developing children, in both age groups (Shumway-Cook and Woollacott, 1985). Response patterns were also more variable in the children with Down syndrome. This data shows that children with Down syndrome under the age of 6 experience significant deficits in postural control.

Further research has supported the finding that postural responses to loss of balance are slow and inefficient for maintaining stability in children with DS (Connolly, Morgan, Russell, Fulliton, 1993). This type of deficit can be problematic in situations where center of gravity is routinely disturbed. Such situations are common among the everyday lives of young children and can occur while out on the playground, moving in physical education class, or walking through a crowded hall or space. Stability is needed for children to be able to adjust to these perturbances and avoid injury (Rahman, Shaheen, 2010). Research shows that these postural control deficits evident in young children with DS persist throughout development. Further studies have been conducted investigating postural control in older populations with developmental delays. Vuillerme, Marin, and Debû (2001) studied postural control in teenagers with DS and found that this population had significantly greater amounts of sway during quiet stance when compared to typically developing teenagers, thus indicating postural control deficits. The early years of life are a critical time for all areas of development. The basic physical and cognitive skills that are achieved during these initial stages lay the foundation for future progress. Understanding the importance of this critical learning period is what has led researchers to investigate the potential of early intervention programs.

A popular area of study has been early intervention programs (EIPs) for infants with Down syndrome. These types of programs are typically implemented shortly after birth and can continue until a child reaches an age of three years old. The purpose is to promote overall development through building on a child's strengths and strengthening their weaknesses (Hadders, Blauw, 2005). Research in this area has been in strong support of these programs and has identified various improvements associated with the EIPs (Brinkworth, 1975, Connolly et al, 1993, Ulrich et al, 2001). After three years of age, many children with DS continue to undergo various levels and styles of physical therapy. There have been few examples of research conducted in attempts to evaluate the efficacy of strength and balance training in increasing both static and dynamic balance in individuals with DS. This area of research is important for therapists, parents, and teachers with the goal of helping children with DS improve functional mobility. In one study, researchers found that a combination of strength and balance training can improve both lower extremity strength and overall balance in children with DS (Gupta, Rao, Sd, 2010). While past research has shown that intervention programs can improve and advance development in young children with DS, there are few studies that have been conducted specifically looking at short term balance interventions for preschool-aged children with DS. This type of study would be beneficial to better understand the immediate effects of balance training. Interventions with the potential to improve balance in this population could lead to greater postural control which would in turn promote efficient gait and a lower fall risk.

OBJECTIVE

The objective of this study is to analyze the effect of balance intervention on postural control and gait efficiency in preschoolers with Down syndrome.

METHODS

Participants

Eleven students from the KinderFrogs school at Texas Christian University were recruited for this study. The students ranged in age from 4 to 6 years old (5.36 ± 0.67) and were all diagnosed as having Down syndrome. The group of students consisted of six males and four females. Exclusion factors for the study included children with cardiovascular conditions, dual diagnoses, and functional or hearing loss. Participants were recruited with the help of the KinderFrogs teachers via email announcements sent out to the parents. The parents of each participant signed a university approved consent form that included information regarding the study. Verbal assent from the children was also maintained before beginning activity within the study.

Apparatus

Balance Tracking System

Postural control was measured using the Balancing Tracking System (BTrackS). Although BTrackS is relatively new to the field of medical equipment, a study published in the *Journal of Biomechanics* evaluated the validity of the system. The authors confirmed that BTrackS can be considered a low-cost alternative for center of pressure measurements (O'Connor, Baweka, Goble, 2016). BTrackS is a force plate that can be used to measure postural sway in individuals. Postural sway can be defined as the changes in center of location of center of pressure over time and measurements indicate how well people can control their center of mass. The system provides a standard measure for amount of sway as well as a classification of suggested level of fall risk (high, medium, or low). The system also provides information regarding ten additional metrics that capture specific sizes, speeds, and consistencies of the balance performance. These variables allow for a more in-depth analysis of postural control. Measurements of the following variables are provided by the BTrackS: 95% ellipse area, mean velocity, mean distance, mean frequency, root mean square medial-lateral, root mean square anterior-posterior, range of medial-lateral, range of anterior-posterior, approximate entropy medial-lateral, approximate entropy anterior-posterior, and percentile. In general, smaller values for these variables would represent greater stability and ability to control postural sway. The testing sessions for BTrackS requires participants to stand upright with feet shoulder-width apart keeping balance for twenty seconds. The system combines three 20-second trials to provide averages for each variable.

Timed Up-and-Go

Gait efficiency was measured using a timed up-and-go test (TUG). This was a timed test to measure how long it took for the participants to rise out of a chair, walk a specified distance, then return to the chair and sit down. The children began by sitting in a pediatric-sized chair without armrests. They were then instructed to get up and go touch a paper star that was taped to the wall three meters away. After touching the wall, they had to turn around, walk back to their chair, and sit down. The time measurement began as soon as the instructed said “go” and ended when the student was sitting in the chair. The test is completed a total of three times for each participant to maintain an average time for an overall score. The TUG test has been validated as an appropriate way to assess functional mobility in children with Down syndrome (Nicolini-Panisson, Donadio, 2014).

Procedures

Each participant performed a pre-test to obtain baseline measures. The pre-testing included measuring postural control with the BTrackS and gait efficiency with the TUG test. All testing was done in the gym of KinderFrogs school. The start of the balance intervention followed the completion of baseline testing. The intervention was four weeks long and consisted of 30-minute training sessions that took place four times a week. All eleven students participated in the same intervention. The training activities were implemented into the daily physical activity timeslots that were part of the students’ regular school schedules. The intervention consisted of a variety of static and dynamic activities that each required some level of stability to perform. Activities included standing on one leg, tandem standing, heel-to-toe walking, walking on a balance beam, trampoline jumps, walking over hurdles, and bean bag catches. Additional activities were added to the program over the course of the four weeks to keep the intervention both challenging and entertaining for the kids. At the end of the four-week program, postural control and gait efficiency were reassessed using the same methods as baseline testing to evaluate any changes that occurred due to the effects of the training activities.

Design and Analysis

Descriptive statistics were used to describe the sample. All values are reported as mean $\pm$ standard deviation and all levels of significance were set to $p \leq 0.05$. To determine the effectiveness of the intervention, dependent samples t-tests were used. To better understand the magnitude and the difference regarding the treatment, Cohen's d effect sizes were also calculated. All analysis was completed using SPSS version 20.0.

RESULTS

Table 1 depicts the descriptive statistics for our sample. The group of 11 students had a mean height of 42.36 ± 2.5 inched and a mean weight of 46.73 ± 8.6 pounds. The data that was collected throughout the study is represented in Table 2. No statistical significance was found within the individual variables when comparing pre-test to post-test. Table 2 also includes the calculated effect size and change in percentage for each variable. These values indicate improvement from pre-test to post-test for various balance measurements. These improvements are also portrayed in Graph 1 which provides a visual representation of the BTrackS data. The graph shows decreased values for post-testing measurements which indicates less overall sway and therefore improved postural control. Graph 2 represents the changes observed between pre-test and post-test for the TUG test. The graph shows a decrease in total amount of time taken to complete the test, which indicates improvement in gait efficiency.

DISCUSSION

Balance Intervention

The balance intervention did not provide statistically significant results regarding improvements in balance. However, improvements were seen in the raw data collection when comparing pre-test and post-test values for the different variables. Graph 1 and graph 2 are visual representations of the changes we saw from before and after the intervention. They show overall improvements in multiple of our measured variables as calculated during post-testing. Further analysis was conducted to better understand the effects of our balance training. Due to our small sample, we calculated effect size for each measured variable and used this information to analyze differences between pre-test and post-test. A medium effect size was calculated for the changes in the timed up-and-go averages, and a large effect size was calculated for mean frequency, which represents the average number of loops used to cover the center of pressure (COP) data of the system. Small effect sizes were also observed in the following variables: 95% ellipse area, mean distance, RMS-ML, RMS-AP, range-ML, range-AP, and percentile. These effect sizes, as well as calculated percent change, represent the positive change that occurred as a result of our intervention. The results of this study are in support of other research conducted in this field that shows advantages of balance interventions.

Many of the intervention programs designed for children with DS are cut off around three years of age. While these programs have shown to be beneficial for the overall development of the children, there could be even more potential benefits if the programs were to continue throughout the lifespan. One study found that balance and gait ability remain significantly low for children with DS even after they learn to walk (Jung, Chung, Lee, 2017). The authors of this study drew conclusions that supported the concept of constant therapeutic intervention throughout the stages of development, with a specific focus on balance and gait. The results found in our own research further supported this idea of balance intervention. The changes that were observed from pre-test to post-test confirm that both postural control and gait of children with Down syndrome can benefit from simple intervention programs. Helping children with DS improve their balance is important for their safety and can lower their risk of falls or injury. Increased stability will help them to counteract the regular disturbances to center of gravity that are experienced in everyday life.

Limitations

The BTrackS system that was used to measure postural control in this study had a minimum weight requirement of 40 pounds. Some of the children who were originally recruited for this study did not meet this requirement, which led to ineligibility. The sample size was decreased to only eleven students. This small study sample did not allow for a control group. Another limitation was the short time frame. The researchers were given four weeks to implement the intervention program. Attempts to counteract this short duration limitation were made by increasing the frequency of the intervention. Lastly, the participants' cognitive ability levels imposed an additional limitation on the study. Individuals with Down syndrome typically experience cognitive deficits in addition to the previously discussed motor delays. The cognitive impairments acted as a limitation for our study because the students were easily distracted while they were supposed to be performing balance tests. Since we decided to focus our study on children between the ages of 4-6, it was often difficult to keep the participants' attentions.

Implications

The results of our study show that balance training for children with DS can have positive effects on their postural control and gait efficiency. These findings are beneficial because they can lead to limiting fall-risk and increasing safety for children with DS. Our research also supports the fact that balance-specific exercises can be easily implemented into PE courses or pediatric physical therapy. Our intervention program took place during the PE time block during the students' daily class schedules. This proved to be a convenient and effective way to increase levels of participation for each balance activity. Since the majority of the activities were dynamic and allowed for free range of movement, this helped keep the students interested. Having a wide variety of activities was also beneficial because it helped to avoid boredom and monotony. It is well understood that physical activity is important for individuals at every age. From this study we can infer that activities which are specifically intended to include a balance component can provide benefits to children with DS.

Another implication from this study is the importance of observing changes in specific measurements of balance as opposed to general classifications of fall risk levels. One of the features of the BTrackS is that it uses the collection of data for each subject to determine where the individual lands in terms of fall risk, as compared to what is considered standard measurements of balance. Each child in our study was categorizes as "high fall risk" at both pre-testing and post-testing. If we were to narrow our analysis to strictly looking at changes between levels of fall-risk, it is unlikely that we would ever produce positive results. The musculoskeletal abnormalities in children with DS are a major limiting factor for balance. For this reason, any improvements in balance seen in children with DS should be in comparison to past individual measurements, or to other groups of children with DS. The BTrackS system was useful in providing specific measurements for each variable because it allowed us to measure the differences seen within each individual student from pre-testing to post-testing. The fall-risk classification system was not particularly useful to us because it was comparing our participants to typically-developing children. It is important to understand that the intention of balance interventions is not to change the children's classification levels to "low-fall risk." Instead, any positive change that is seen between the different factors of balance is desired because of its potential to lower the actual fall risk of these children in comparison to their previous states.

Future Direction

Continued research needs to be done regarding this area of study to better understand the effects of balance intervention. Implementing a longer intervention has the potential to provide information regarding how much improvement is possible in children with Down syndrome, or if there is a certain cap that is based on the musculoskeletal limitations. Conducting a retention test would also be beneficial to understand the capability of the training effects to remain even after the intervention has ceased. A possible direction of research might be a similar structure of study that is geared towards an older population of children with Down syndrome. This would decrease the amount of limitation caused by the cognition levels of individuals that we observed in our study.

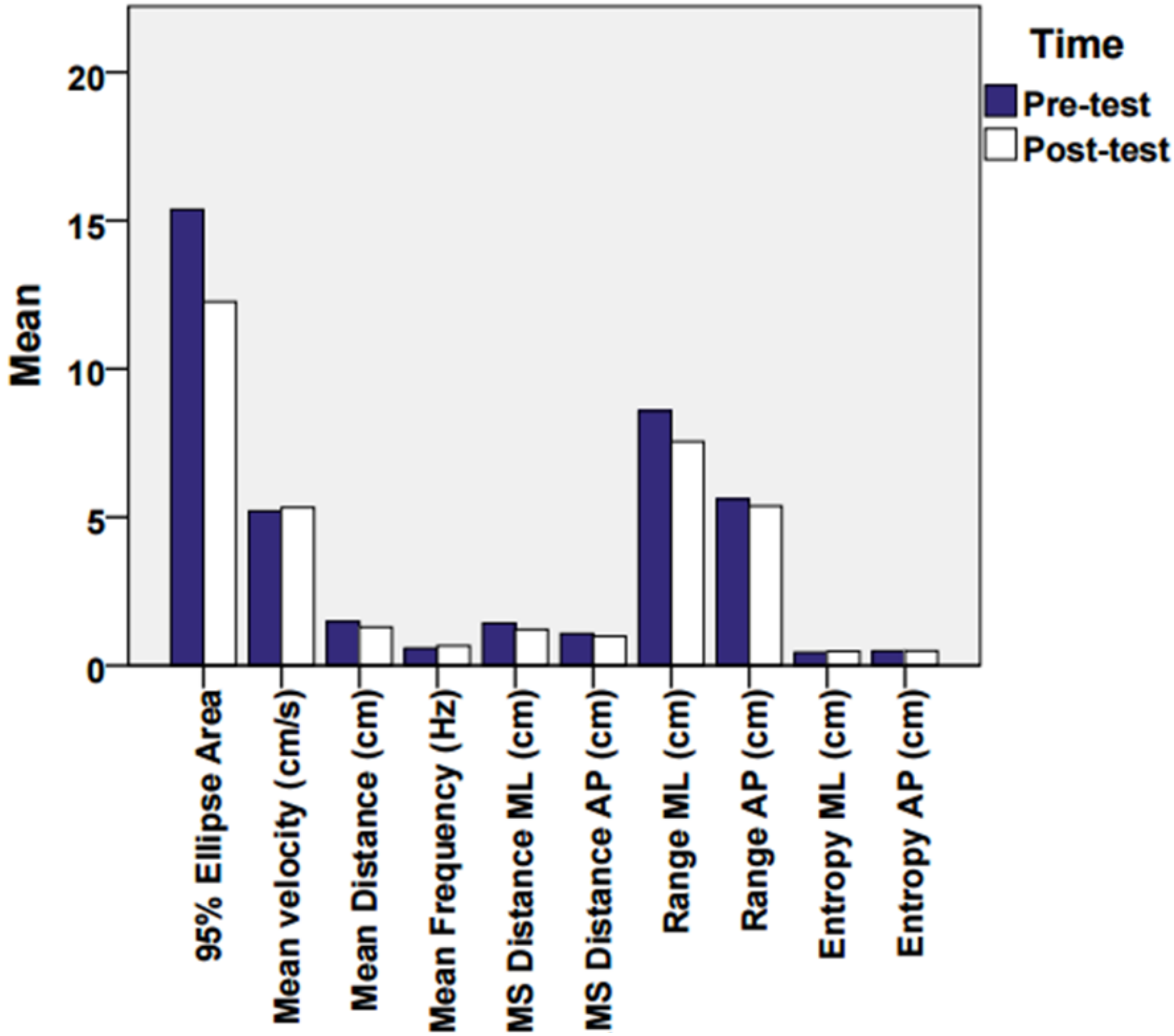
TABLE 1

	Minimum	Maximum	Mean ± Std. Deviation
Age (years)	4	6	5.36 ± .67
Height (in.)	40	49	42.36 ± 2.5
Weight (lbs.)	39.8	65	46.73 ± 8.6
BMI	16.14	23.19	18.20 ± 1.99
BMI %	71	99	88.7 ± 9.7

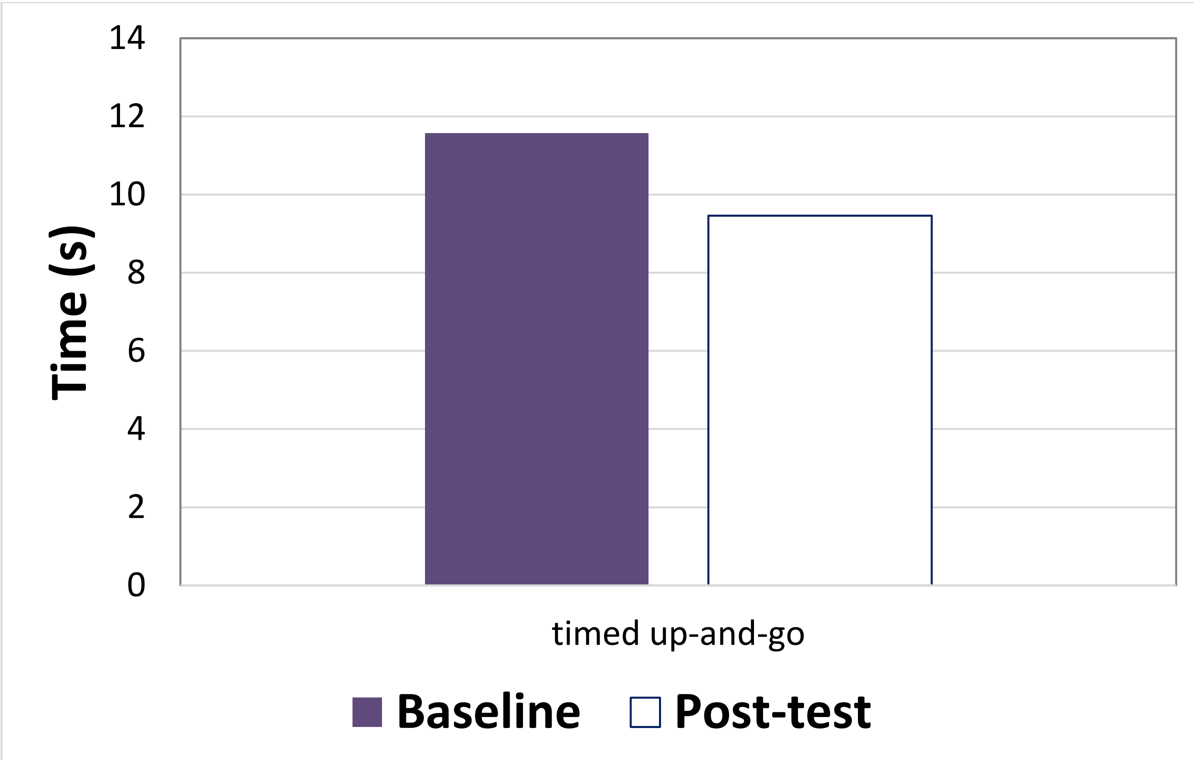
TABLE 2

Variable	Pre-test	Post-Test	p	ES	ES	%
95% Ellipse Area	15.37±11.69	13.46±12.63	0.681	0.17	small	14
Mean Velocity (cm/s)	5.21±1.83	5.45±2.16	0.772	0.12	negligible	-4
Mean Distance (cm)	1.48±.53	1.33±.53	0.49	0.29	small	11
Mean Frequency (Hz)	.58±.09	.66±.09	0.094	0.89	large	-12
RMS-ML (cm)	1.43±.68	1.24±.67	0.505	0.29	small	15
RMS-AP (cm)	1.08±.32	1.01±.29	0.562	0.22	small	6
Range-ML (cm)	8.58±4.29	7.62±4.08	0.592	0.24	small	13
Range-AP (cm)	5.60±1.66	5.00±1.95	0.511	0.35	small	12
Apx Entropy-ML (cm)	.44±.08	.48±.07	0.132	0.61	medium	-9
Apx Entropy-AP (cm)	.49±.05	.49±.04	1	0	negligible	0
Percentile	2.45±4.03	4.27±6.62	0.382	0.35	small	-43
TUG Average (s)	11.58±4.78	9.46±2.11	0.077	0.6	medium	22

GRAPH 1


Time
Pre-test
Post-test
Mean
20
15
10
5
0
95% Ellipse Area
Mean velocity (cm/s)
Mean Distance (cm)
Mean Frequency (Hz)
MS Distance ML (cm)
MS Distance AP (cm)
Range ML (cm)
Range AP (cm)
Entropy ML (cm)
Entropy AP (cm)

GRAPH 2



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