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The effect of vestibular stimulation exercises on balance in children with Down syndrome.

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THE EFFECT OF VESTIBULAR STIMULATION EXERCISES ON BALANCE IN CHILDREN WITH DOWN SYNDROME

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ABSTRACT

EFFECT OF VESTBULAR STIMULATION EXERCISES ON BALANCE IN CHILDREN WITH DOWN SYNDROME

Sarah Sunderman

March 22, 2016

Children with Down Syndrome (DS) are delayed in motor development and coordination which contributes to poor balance. Purpose: The aim of this study was to investigate whether the utilization of vestibular stimulation exercises would influence balance in children with DS. Methods: Eighteen participants (13years ±4.923) completed the study. Group one consisted of 10 (6 male, 4 female) participants with DS and ranged in age from 5-14 years. Group two consisted of eight (4 male, 4 female) participants with DS and ranged in age from 15-20 years. Eight subtests of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) were used for pre and post-testing focusing on bilateral coordination, balance, running speed and agility, upper limb coordination, and strength. The intervention, the vestibular stimulation exercises, consisted of 15 exercise stations performed 2 times per week for 6 weeks. A trained instructor accompanied each subject during participation to reduce risk of injury. Results: Results indicated that group one had significant improvements in upper limb coordination (P=0.013) and speed and agility (P=0.001). Group two showed significant improvements in balance (P=0.009), upper limb coordination (P=0.003), and speed and agility (P=0.002). Conclusion: An early intervention that utilizes vestibular stimulation exercises may improve balance in children with Down Syndrome.

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INTRODUCTION

Statement of the Problem

Down syndrome (DS) is a genetic disorder due to an abnormality in the 21st chromosome. Although uncommon, Mosaic DS does occur as well. This form of DS occurs when an individual has some cells of the body that have trisomy 21, and other cells of the body have the typical number of chromosomes (Papavassiliou, Charalsawadi, Rafferty, & Jackson-Cook, 2015) It is estimated that the condition affects 1 in 1,000 to 1 in 1,200 births (Gupta, Rao, & S, 2011). It is the most common genetic cause of developmental disability that affects the gross motor and fine motor skills of children (Gupta et al., 2011; Shields, Dodd, & Abblitt, 2009). Motor dysfunction (such as poor balance, motor coordination and hypotonia), oculomotor disturbances, and vestibular deficits can also be present in individuals with DS (Costa, 2011). Engagement in regular physical activity by children with DS is not only essential for health but also attributes to a delay in the acquisition of motor skills and atypical motor patterns (Wang & Ju, 2002).

Individuals with DS are found to be less active than those without disabilities and as they age their physical activity decreases (Izquierdo-Gomez et al., 2014; Matute-Llorente, Gonzalez-Aguero, Gomez-Cabello, Vicente-Rodriguez, & Casajus, 2013). Factors that hinder participation of children with DS in programs were lack of appropriate programs where modifications are made, lack of parent education, and a widening gap in physical skills between children with DS and their peers (Barr & Shields, 2011).

Research has suggested that poor motor skills in children with DS are the result of joint ligamentous laxity (Livingstone & Hirst, 1986) and muscular hypotonia (Latash, Wood, & Ulrich, 2008). However, it has also been argued that these problems are a result from defects in balance control mechanisms (Connolly & Michael, 1986; Connolly, Morgan, Russell, & Fulliton, 1993). Being able to promote better walking balance and motor skills to increase physical capacity to participate in daily exercise and social activities is desirable (Wang & Ju, 2002).

Normal activities of daily life, such as running, can have head velocities of up to 550°/s, head accelerations of up to 6,000°/s^2, and a frequency of content of head motion from 0 to 20Hz. Only the vestibular system can detect head motion over this range of velocity, acceleration, and frequency. The vestibular system produces eye movements that compensate for brief, transient head movements. The optokinetic system compensates for prolonged, sustained head movements. Both of these systems play significant roles in postural control, balance, and motor coordination. (Berg, Becker, Martian, Primrose, & Wingen, 2012)

In a typically developed (TD) individual the vestibular receptors in the inner ear provide an accurate representation of the motion of the head in three dimensions. The information received from the vestibular receptors is then used by the central vestibular pathways to control reflexes and perceptions that are mediated by the vestibular system. Disorders that affect vestibular function result in abnormalities in these reflexes and lead to sensations that reflect abnormal information about motion from the vestibular receptors (Schubert & Minor, 2004). Due to an abnormality in the 21st chromosome the central nervous system is affected in a variety of ways (Galli et al., 2008). Rotating or accelerating head movement, which result in asymmetric stimulation of the neuroreceptors in the labyrinth, produce the vestibulo-ocular reflex (VOR). This reflex in particular stimulates the semicircular canals to mechanically integrate the sensed angular head acceleration and output head velocity information to the brain (Costa, 2011). Dysplasia of inner ear structures in individuals with Down syndrome is extremely prevalent. In a study by Intrapiromkul, Aygun, Tunkel, Carone, and Yousem (2012), inner ear anomalies were observed in 74.5% of patients. Malformed bone islands of lateral semicircular canal, narrow internal auditory canals, cochlear nerve canal stenosis, semicircular canal dehiscence and enlarged vestibular aqueducts were all detected as well (Intrapiromkul et al., 2012).

Purpose of Study

Vestibular rehabilitation refers to interventions such as adaptation exercises, repositioning techniques, and exercises to improve muscle force, gait, or balance (Schubert & Minor, 2004). Appropriate activity programs for young children with DS are uncommon. Being able to provide this population an appropriate program that would stimulate the vestibular system would impact their ability to perform ADLs, participate in organized sports activities, and also aid in their ability to join the work environment. Therefore, the purpose of this study is to investigate the effect of a vestibular stimulation exercise program on the balance, strength, speed and agility, upper limb coordination, and bi-lateral coordination in children with Down syndrome.

Research Question and Hypothesis

A) Do vestibular stimulating exercises improve balance in children with Down syndrome?

B) Six weeks of vestibular stimulation exercises done twice weekly will improve balance.

LITERATURE REVIEW

It has been well documented that children with DS achieve motor milestones later than children who are developing in the typical pattern. Milestones for children with DS are usually reported by their caregiver or by direct observation (Palisano et al., 2001). Floor sitting in a typically developed child has been reported to occur between 6-8 months (Kaga, 1999). Whereas in a child with DS this range is varies between 8.5 (Chen & Woolley, 1978) and 11.7 (Melyn & White, 1973) months. In a typically developed child, crawling has been reported anywhere between 7-10 months. Whereas in an infant with DS that time span varies much more greatly. It has been reported that this milestone has occurred at 12.2 months (Melyn & White, 1973) and 17.3 months (Fishler, 1964). Carr et al., (1970) found that by 15 months, 72% of children with DS could sit and 37% could crawl. In that same study it was also reported that by 24 months 98% of children could sit and 93% of them could crawl. In a study by Fishler (Fishler, Share, & Koch, 1964), it was reported that children with DS walked as early as 15 months, whereas in a study by Melyn (Melyn & White, 1973) it was reported that a child with DS is walking as late as 74 months. This large time span is much different from the 10-12 months reported by Kaga (Kaga, 1999) that typically developed children begin walking.

In a study by Gupta and colleagues (2011), the effect of a strength and balance training program in 23 children (7-15 years) with DS over a six-week period was investigated. A handheld dynamometer was used to measure the strength of hip flexors, hip abductors, hip extensors, knee flexors, knee extensors and ankle plantarflexors. Balance was measured using the balance subscale of the Bruininks Osteresky Test of Motor Proficiency. It was found that following a six-week exercise training program that children with DS were able to improve the strength of their lower limbs as well as their overall balance.

In a study by Tsimaras (Tsimaras & Fotiadou, 2004), 25 subjects with a mean age of 24.6 years participated in a training program that investigated the effect on muscle strength and dynamic balance by measuring peak torque, isokinetic muscle endurance, and dynamic balance on a Cybex II isokinetic dynamometer. This 12-week training program that met 3 times per week, included activities such as a standing long jump, walking on a line, walking across a balance beam, and standing on one foot, indicated that there was significant improvement in isokinetic peak torque of the lower extremities. In terms of dynamic balance, the findings in this study showed that the implementation of a training program can improve balance. Tsimaras concluded that the improvement in these abilities enables individuals with DS to become more sociable and capable of integrating themselves into the workplace. They also stated that future studies should contribute to the creation of more adequate and sufficient programs for the DS population.

Regular physical activity in the DS population is crucial to avoid cardiovascular disease as well as obesity. In addition to aiding in the prevention of the previously stated, self-concept and self-esteem are also improved with physical activity. In a study done by Shields et al., (2009), they sought to measure the amount and intensity of physical activity in children with DS over a seven-day period. They were interested to see if the children met the published guidelines on the amount of physical activity, which children should participate in daily. Through the use of accelerometers, it was observed that only 42.1% of the participants took part in at least 60 minutes of moderate to vigorous physical activity daily. Within this particular study, participants appeared to be more physically active that children who are typically developed. However, this could reflect the differences between European, Australian, and American children.

Individuals with DS are at risk for cardiovascular disease and obesity as well as a multitude of other conditions which put them at a higher risk for morbidity (Ashman & Suttie, 1996). Tasks which involve movement accuracy, reaction time, and speed of movement all appear to be deficient in individuals with intellectual disabilities (ID). Inui and colleagues (Inui, Yamanishi, & Tada, 1995), identified that individuals with DS showed difficulty in doing a tracking task. Carmeli (Carmeli, Bar-Yossef, Ariav, Levy, & Liebermann, 2008) sought to explore motor performances of individuals with ID by evaluating hand-eye coordination tests. They did this through testing hand throwing to memorized visual targets, fast hand-finger actions in reaction to visual events, grasping and transporting small objects, and accurate hand-finger movements. They found that scores for individuals with ID were significantly lower and less consistent than compared to those that are typical adults (TA). Poor motor coordination might have a negative impact on participation in recreational activities such as sports, taking part in the workforce, and also impact the fluency of activities of daily living (ADLs). By identifying early deficits in motor coordination, rehabilitation programs that enhance perceptual- motor coordination could be implemented (Carmeli, 2008).

Physical activity has been shown to aid in the fight against obesity. In a study by Vidoni, Lorenz, and Terson de Paleville (2013), the effectiveness of a vestibular stimulation movement program on typically developed preschool age children was completed. This was accomplished by incorporating a program known as Minds-in-Motion. This program involved components that tested balance, coordination, strength, and agility. Through this program it is thought that by doing the 15 movement activities the vestibular system is being stimulated (Meyer, 2012). After an 11-week intervention that last 30 minutes five days per week it was found that the experimental group improved dramatically compared to the control group who improved as well. Compared to each other the improvement of the experimental group was statistically significant. This program was shown to be appropriate for preschool aged children who are typically developed. However, due to the simplicity and benefits of this program it would also be an appropriate program for individuals with DS. Through this program, individuals would be able to improve upon balance, coordination, strength, and speed and agility.

METHODS

Subjects

A convenience sample of participants were recruited from two summer enrichment programs that provided programs specifically for individuals with DS. Participants consisted of 18 (10 male, 8 female) children with DS (13 years ± 4.923). Group one consisted of 10 (6 male, 4 female) participants, ranging in age from 5-14 years. Group two consisted of eight (4 male, 4 female) participants, ranging in age from 15-20 years. Selection criteria included: (1) availability on days and at times when the vestibular stimulation exercise classes were scheduled; (2) within the given age ranges of 4-20 years (3) able to walk independently (4) able follow verbal instructions; (5) have a diagnosis of DS. The study was approved by the institutional review board (IRB) of the University of Louisville. Prior to testing, a consent form was given to parents/guardians to read and review with time given to answer any questions. An informational meeting where testing procedures and vestibular exercises were explained was held for parents/guardians with the instructor prior to study.

Settings

Group 1

Group one took place during a summer enrichment program held at Down Syndrome of Louisville (DSL). DSL is a non-profit organization which serves individuals and the families of those with DS. They offer services to children from birth to end of life. Services that are provided range from healthy movement activities to a college connection program where individuals can attend college.

Pre and post testing was completed in an assigned room to minimize distractions for participants as well as maintain consistent surroundings throughout the study. The testing room was down a hall from participant's classrooms and contained five round tables, a couch, television, adult sized chairs in the front of the room as well as miscellaneous workout equipment in the back (elliptical and recumbent bike). The floors were wooden and one wall was made entirely of glass. The majority of activities were completed in the front of the room where there was adequate space and fewer distractions. Participants were escorted from their classrooms to the exercise room by the same investigator each time. This helped establish familiarity for the participant and aided in decreasing anxiety. Testing and intervention took place in the same room throughout the study. The participants in group one ranged in age from 5-14 years.

Group 2

Group two took place during a summer enrichment program at Dreams With Wings. Dreams With Wings is a program which serves individuals with intellectual and developmental disabilities. They provide early intervention programs for children as well as a multitude of services for adults ranging from supported employment and adult day services. Testing occurred in the back half of a large gymnasium at a local church. The front half of the gymnasium was the central gathering area for the summer enrichment program. This setup was not ideal and lead to some participant distractions. During testing the same researcher would take the participants from the front half of the gymnasium and take them to the testing area. The participants in group two ranged in age from 15-20 years.

Procedures

Prior to testing, two individuals were trained to assist in the data collection and testing procedure. They were asked to repeat important cueing to ensure the understanding of the procedure. Pre-testing occurred during the first day of the first week of the summer enrichment programs. Tests were performed in the same order for each participant during pre and post testing (‘Walking Forward on a Line’, ‘Standing on One Leg on a Line-Eyes Open’, ‘Standing with Feet Apart on a Line- Eyes Closed’, ‘Touching Nose with Index Fingers-Eyes Closed’, ‘Catching a Tossed Ball- Both Hands’, ‘Dropping and Catching a Ball-Both Hands’, ‘Knee Push-ups’, and ‘Stepping Sideways over a Balance Beam’). Test order was determined by layout of the testing room. Each testing session lasted approximately 10 minutes per participant.

Following pre-testing a six-week intervention program consisting of fifteen vestibular stimulation exercises took place two times per week. The intervention was done one-on-one.

Exercises were done in the same order every day, beginning with ‘Strong Arm Push’, then ‘Eye Can Convergence’, ‘Eye to Eye’, ‘The Beam Team’, ‘Jelly Roll’, ‘Puppy Dog Crawl’, ‘Monster Mash’, ‘Climb Every Mountain’, ‘Balance Board Bash’, ‘Electric Slide’, ‘Skip to My Lou’, ‘Cross Walk’, ‘Bean Bag Boogie’, ‘Jumping Jack Flash’, and finally ‘Step Back’. The order in which the participants were taken each day was based on their availability. After six weeks of intervention, post-testing was completed.

Testing

Due to lack of time, there was no familiarization trial. On the first day participants were shown each exercise one time and then practiced the exercise one time before official testing took place. All tests conducted were subtests within the Bruininks Oseretsky Test of Motor Proficiency (BOT2) (Bruinincks & Bruinincks, 2005) which has been shown to be a reliable and efficient measure of fine and gross motor control skills in the DS population. This test of motor proficiency has been validated in the DS population (Connolly & Michael, 1986; Connolly et al., 1993; Gupta et al., 2011; Wang & Ju, 2002). The subtests utilized within the BOT2 were balance ("Walking Forward on a Line", "Standing on One Leg on a Line- Eyes Open", and "Standing with Feet Apart on a Line- Eyes Closed"), bilateral coordination ("Touching Nose with Index Fingers- Eyes Closed"), upper limb coordination ("Dropping and Catching a Ball- Both Hands" and "Catching a Tossed Ball- Both Hands"), strength ("Knee Push-ups"), and speed and agility ("Stepping Sideways over a Balance Beam").

Balance

'Walking Forward on a Line': a line was taped on the ground (long enough for 6 steps to be taken on it). Participant stood with preferred foot on and parallel to the line. The participant placed their hands on their hips and then walked forward in a natural walking stride, with each step placing their foot on the line. A total of 6 steps were taken. A second trial was conducted only if the participant did not earn the maximum score of 6 correct steps on the first trial. A step was incorrect if the participant stepped off the line, failed to keep hands on hips, stumbled, or fell. If the previously mentioned occurred the trial was stopped, the participant was reminded of proper form, and the second trial was conducted.

'Standing on One Leg on a Line-Eyes Open': the participant stood with feet together, preferred foot on and parallel to a line taped onto the floor. Participant placed hands on hips and were instructed to raise their non-preferred leg behind him/herself. Knee was bent 90 degrees and shin parallel to the floor. Once this was achieved the examiner started a timer. If the participant's raised foot dropped below 45 degrees, failed to keep hands on hips, or stepped or fell off of the line then the timer was stopped. The maximum time that could be achieved was 10 seconds. A second trial was conducted if the participant did not earn the maximum score of 10 seconds on the first trial.

'Standing with Feet Apart on a Line- Eyes Closed'. The participant stood with feet together, preferred foot on and parallel to the line. They then were instructed to place their hands on their hips and take one natural step forward (placing their nonpreferred foot on the line as well). Once balance was achieved the participants were instructed to close their eyes. A timer was started once participant's eyes were closed and balance was achieved. The maximum time that could be achieved was 10 seconds. A second trial was only done if the maximum time of 10 seconds was not completed. The trial was stopped if the participant failed to keep hands on hips, opened his/her eyes, or if they stepped off of the line.

Bilateral Coordination

'Touching Nose with Index Fingers-Eyes Closed': the participant stood with feet together, arms straight out to the sides, index fingers extended with other fingers tucked in, and eyes closed. Participants were instructed to bend one arm (participants chose which arm they started with), touch index finger to the tip of his/her nose, and return arm to extended position. This was then repeated with the opposite arm. This process was repeated one additional time. Touches were performed with continuous movements and no extended pauses. A second trial was conducted only if the participant did not earn the maximum score of 4 correct touches on the first trial. A touch was scored incorrect if the participant opened their eyes, failed to maintain continuous movements, failed to touch tip of nose with index finger, failed to alternate arms, failed to extend arms fully after touching nose, or moved their head to meet their index finger. The trial was stopped if any of the above mentioned occurred and a second trial would then be conducted after reminding the participant of the proper form. Per the BOT2 protocol, the maximum number of trials was 2 and maximum raw score was 4 touches.

Upper Limb Coordination

'Catching a Tossed Ball- Both Hands': two parallel lines were taped on the floor 10 feet apart. Examiner and participant each stood behind a line and faced each other. The examiner tossed a tennis ball to the participant underhanded with a slight arc so the ball reached the participant between their shoulders and waist. Participant was instructed to catch the ball with both hands. This process was repeated a total of 5 times. The maximum number of catches were recorded, up to 5 (positive catches did not have to be consecutive). A catch was incorrect if the participant trapped the ball against his/her body, caught the ball with one hand, or dropped the ball. An attempt was re-administered if the participant missed the ball because it was thrown above the shoulders, below the knees, or outside the participant's reach in any direction.

'Dropping and Catching a Ball-Both Hands': the participant held a tennis ball with cupped hands and extended both arms in front of his/her body. The participant dropped the ball and after it bounced once on the floor, caught the ball with both hands. The participant was permitted to bend over or move to catch the ball. Participant repeated this process a total of 5 times and was not time limited. The number of correct catches was recorded (the catches did not have to be consecutive). A catch was counted as incorrect if the participant trapped the ball against his/her body or caught the ball with one hand.

Strength

'Knee Push-ups': participants knelt down on a knee pad and leaned forward to put their hands on the floor (hands were instructed to be directly beneath shoulders). The participants were instructed to cross ankles and raise feet off the floor. The participant's back and neck were to be in a straight line and eyes were to be looking at the floor. Participants were instructed to lower themselves to the floor (arms were to be bent to at least 90-degree angles) and then push themselves back up until arms were straight. Participants were instructed to continue this process for a total of 30 seconds. Timing and counting of the push-ups began when the participant demonstrated proper form. If the participant tired before 30 seconds had elapsed and was unable to continue, the participant was allowed to stop and the number of correct knee push-ups performed was recorded. A knee push-up was deemed incorrect if the participant allowed their back to sag or hips were lifted so that their back was not straight. If the previously mentioned occurred, the participant was reminded of proper form, and then continued on with the trial.

Speed and Agility

'Stepping Sideways over a Balance Beam': participant stood with feet together, next to a 2in high balance beam with their hands on their hips. Participant was instructed to step over the beam, one foot at a time, until both feet were placed on the floor on the other side. Then the participant stepped back over the beam, one foot at a time, returning to the original side. Participant continued to step back and forth over the beam, always stepping with one foot at a time. Participant was told to repeat this process for 15 seconds. The number of correct steps (each foot correctly placed counted as one step) performed in 15 seconds was recorded. A second trial was conducted only if the participant stumbled or fell during the first trial. A step was incorrect if the participant failed to keep hands on hips or failed to move one foot at a time. If the previous mentioned occurred the participant was reminded of proper form, and the trial was continued.

Table 1.
Scoring of BOT2

Bilateral Coordination						
Touching Nose with Index Fingers- Eyes Closed	Raw	0	1	2	3	4
	Point	0	1	2	3	4
Balance						
Walking Forward on a Line	Raw	0	1-2	3-4	5	6
	Point	0	1	2	3	4
Standing on One Leg on a Line- Eyes Open (sec)	Raw	0.0-0.9	1.0-2.9	3.0-5.9	6.0-9.9	10
	Point	0	2	2	3	4

Standing With Feet Apart on a Line- Eyes Closed (sec)	Raw	0.0-0.9	1.0-2.9	3.0-5.9	6.0-9.9	10						
	Point	0	1	2	3	4						
Upper Limb Coordination												
Dropping and Catching a Ball- Both Hands	Raw	0	1	2	3	4	5					
	Point	0	1	2	3	4	5					
Catching a Tossed Ball- Both Hands	Raw	0	1	2	3	4	5					
	Point	0	1	2	3	4	5					
Strength												
Knee Push-ups	Raw	0	1-2	3-5	6-10	11-15	16-20	21-25	26-30	31-35	>36	
	Point	0	1	2	3	4	5	6	7	8	9	
Speed and Agility												
Stepping Sideways Over a Balance Beam	Raw	0	1-2	3-5	6-9	10-14	15-19	20-24	25-29	30-39	40-49	>50
	Point	0	1	2	3	4	5	6	7	8	9	10

Intervention

The intervention consisted of the 15 stations of 'The Maze' based off of the program called Minds-In-Motion (Meyer, 2012). Currently there is very little published data on this program however, it is used in school systems across the country where it is believed to provide benefit to the children. The 15 stations were set up in the same place each day and one by one the participants made their way through the maze one time. Each intervention session took approximately 10 minutes per participant.

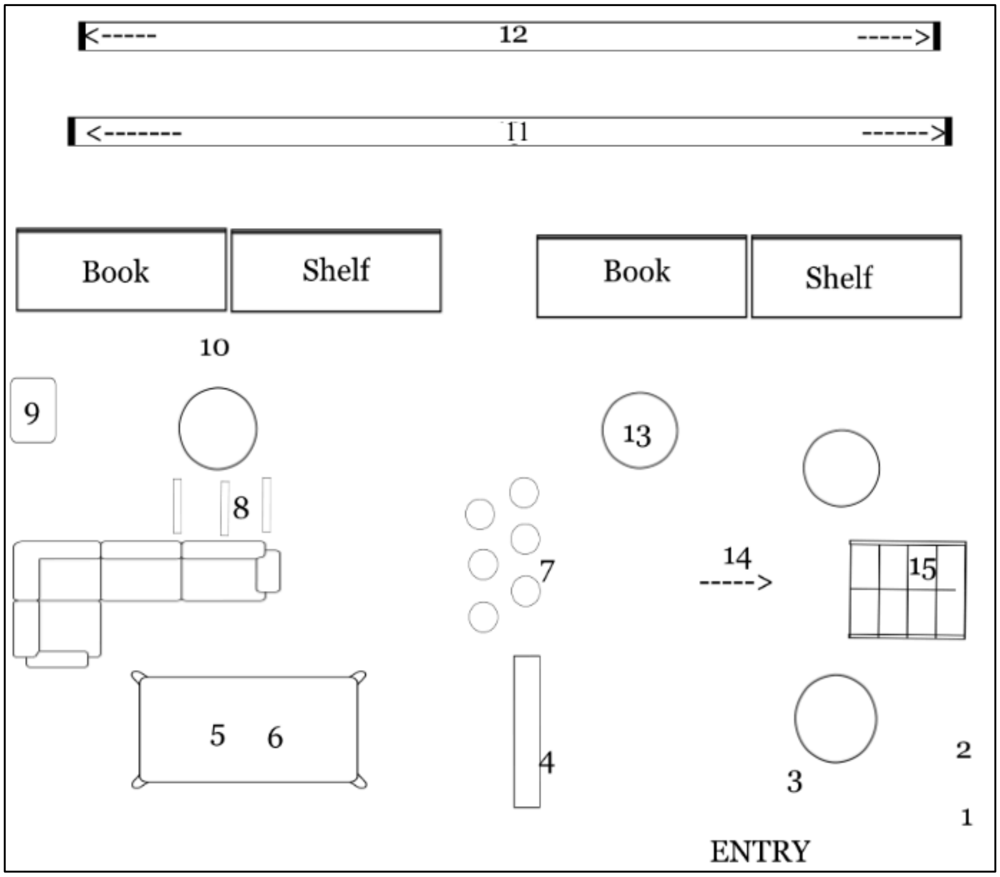
Group 1

Over the 6-week intervention participants from group one met at 9am on Monday and Wednesday mornings.

Figure 1.
Order of Intervention

	Label	
Exercise	Group 1	Group 2
Eye Can Convergence	1	2
Strong Arm Push	2	1
Eye-To-Eye	3	3
The Beam Team	4	5
Jelly Roll	5	7
Puppy Dog Crawl	6	8
Monster Mash	7	4
Climb Every Mountain	8	6
Balance Board Bash	9	11
Electric Slide	10	13
Skip to My Lou	11	14
Cross Walk	12	15
Bean Bag Boogie	13	9
Jumping Jack Flash	14	12
Step Back	15	10

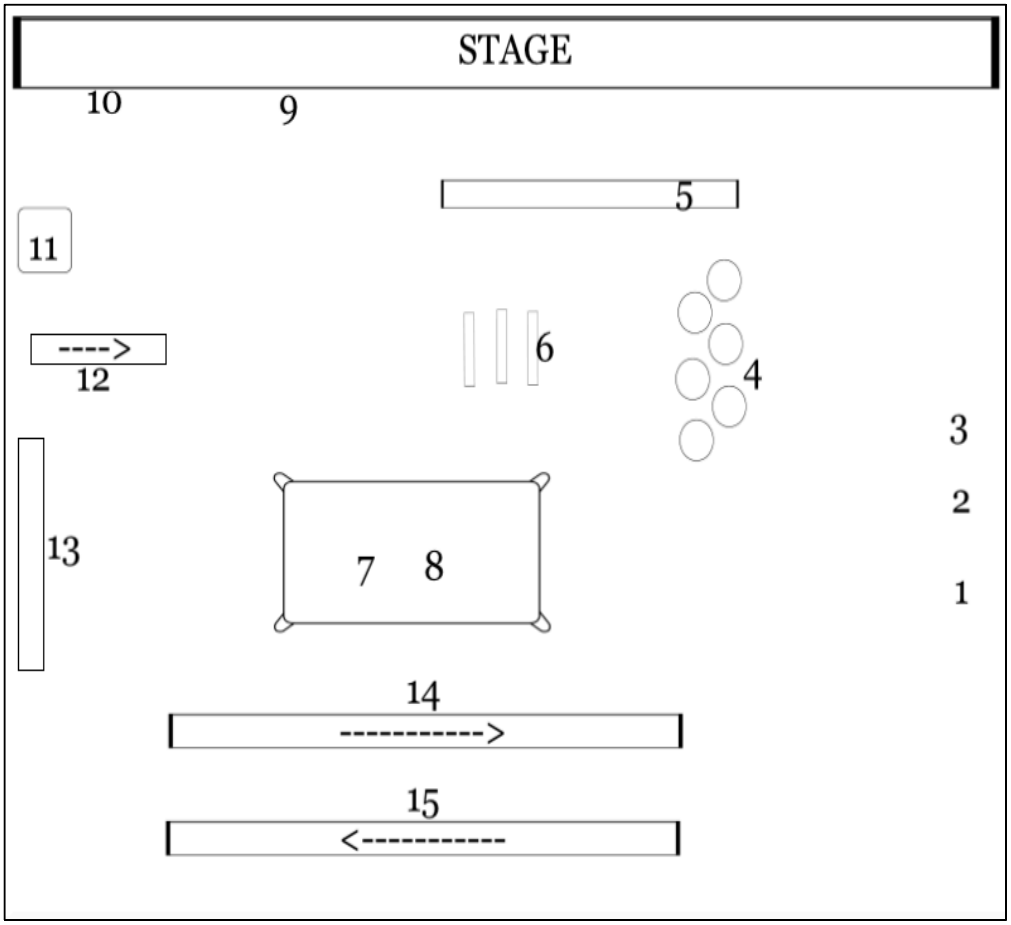
Figure 2.
Group One Layout of Room



Group 2

Group two met typically in the mornings, however depending on the schedule of the summer enrichment program sometimes met in the afternoons. The days of the week which they met also varied.

Figure 3.
Group Two Layout of Room



'Strong Arm Push': participants stood facing a wall, one foot in front of the other, then pushed against that wall with the palms of their hands. They were encouraged to push with as much force as possible for a count of 10 seconds.

'Eye Can Convergence': participants held a beaded string (3 beads affixed to a 5 foot string) perpendicular to their head. While holding the string in their hand they focused on each bead one at a time for a count of 10 seconds. This beaded string was made by using 1.5in foam balls and juke twine.

‘Eye to Eye’: participant stood in front of an examiner (14 inches away) and followed with his/her eyes the eye tracking pencil. The examiner did 2 horizontal, 2 vertical, 2 circles clockwise, 2 circles counterclockwise, 2 horizontal, and finally 2 convergence training movements (going in toward the nose).

‘The Beam Team’: participants walked along a balance beam. Participants were encouraged to have their arms extended out laterally to help maintain balance however, if they felt uncomfortable an examiner was there to assist them. This was done to reduce the risk of falling. Participants were told to focus on a specific target ahead of them throughout the exercise. A foam balance beam that measured 2 ½’’H x 5 ¼’’W x 15’’L was used for this station. Each section was connected by inserting a 6’’L plastic rod into pre-set holes. A total of eight sections were used to make the beam.

‘Jelly Roll’: participants laid down on a 4’x8’x2’ tumbling mat with their toes pointed and arms stretched out above their heads. They then rolled the length of the mat trying to maintain previously mentioned form.

‘Puppy Dog Crawl’: participants began by kneeling down on a 4’x8’x2’ tumbling mat with palms flat on the floor. They were instructed to crawl across the mat, all while be encouraged to move the opposite arm with the opposite leg at the same time.

‘Monster Mash’: participants stomped down as hard as they could on six 9-inch poly spot markers that were laid out on the floor. They stomped on each marker with one foot. They were encouraged to stomp with force.

‘Climb Every Mountain’: participants were faced with three hurdles of varying heights. Six 12in tall cones with 3 holes in each cone that held 28’’L poles were used. They were instructed to step over each hurdle in front of them. If necessary, the subjects were reminded that their feet should go over each hurdle rather than around the side of them. They were encouraged to step over each hurdle and have both feet planted on the ground before starting the next hurdle.

‘Balance Board Bash’: participants stood on a balance board maintaining balance for as long as they could. This balance board was only able to rotate from side to side. Their feet were placed equal distance from the center of the board. The examiner was paired with the participant to provide help if the they were to stumble or fall. The board was plastic with an anti-slip bottom to reduce the risk of the participant falling.

‘The Electric Slide’: participants side-stepped along a designated path all while they kept their eyes, face, feet and whole body parallel to the wall. Participants were encouraged to move sideways by taking a step to the side, then sliding the following foot along until it touches the lead foot. If needed participants were reminded that they should be as close to the wall as possible without touching it.

‘Skip to My Lou’: participants skipped down a designated lane. They were instructed to swing their arms cross laterally in an exaggerated fashion. They were told to raise their knees up high while skipping.

‘Cross Walk’: participants were instructed to slowly walk a given distance (distance for each group varied) lifting knees high while touch alternating knees with opposite elbows.

‘Bean Bag Boogie’: while walking along a given path, participants tossed a nylon reinforced bean bag straight up in the air and then caught it. Participants were encouraged to always follow the bag with their eyes.

‘Jumping Jack Flash’: participants came to a taped line on the floor. They were instructed to jump to the other piece of tape on the floor that was 3feet away (or as far as they could jump). Participants were instructed to land on both feet together at the same time.

‘Step Back’: participants were instructed to walk backward up a total of 3 stairs (they did this twice). The examiner was directly in front of them to provide assistance if needed. They were encouraged to try and not utilize the examiners help or use the handrail. Participants were also encouraged to look straight ahead and not at their feet.

RESULTS

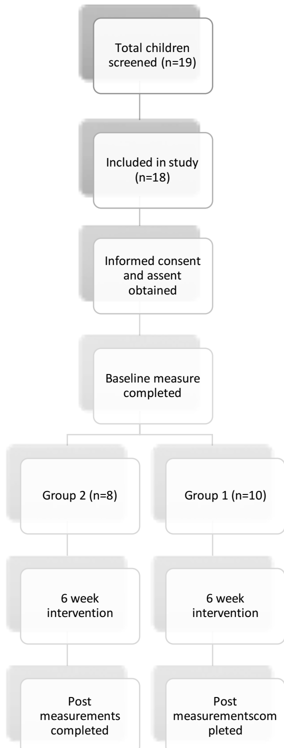
Nineteen participants started the study. One participant's data was excluded due to their inability to perform the required tasks. Anthropometric details of the participants are described in Table 1. Ten children were included in group one and eight children were in group two. Figure 1 demonstrates the flow through the study. Eighteen participants completed the program successfully. Statistical analysis was done utilizing an ANOVA and no significant differences were seen. A paired samples t-test was then run to further clarify differences.

Table 2.
Characteristics of participants

Characteristics	**Group 1 (n=10)**	**Group 2 (n=8)**
Gender	M=6, F=4	M=4, F=4
Age(years)*	9.9 (5-14)	18.375 (15-20)
Weight (kg)*	34.81 (24.09-49.64)	67.41 (45.27- 110.45)
Height (cm)*	133.35 (101.60-162.56)	159.07 (142.24-165.10)

*mean (range)

Figure 4.
Flow of Study



Group 1

All subtests done within the balance (‘Walking Forward on a Line’, ‘Standing on One Leg on a Line- Eyes Open’, and ‘Standing with Feet Apart on a Line- Eyes Closed’) were insignificant (p=0.343, p=0.394, and p=0.716 respectively). The subtest in strength, ‘Knee Push-ups’, did not elicit any statistical significance (p= 0.832). Within upper limb coordination the subtest ‘Catching a Tossed Ball- Both Hands’ was statistically significant with a p-value of 0.013. The subtest ‘Dropping and Catching a Ball- Both Hands’ was not (p=0.057). The subtest ‘Touching Nose with Index Fingers- Eyes Closed’ within bilateral coordination did not produce significance (p=0.343). The subtest

‘Stepping Sideways Over a Balance Beam’ within speed and agility did show statistical significance with a *p*-value of 0.001.

Group 2

The subtest ‘Walking Forward on a Line’ within balance showed statistical significance with a *p*-value of 0.009. However, the other tests within balance, ‘Standing on One Leg on a Line- Eyes Open’, and ‘Standing with Feet Apart on a Line- Eyes Closed’, did not show significance (p=0.347 and p=0.053, respectively). The subtest in strength, ‘Knee push-ups’, did not elicit any statistical significance (p=0.466). The subtest ‘Catching a Tossed Ball- Both Hands’ within upper limb coordination was significant with a *p*-value of 0.003. However, the other subtest within upper limb coordination, ‘Dropping and Catching a Ball- Both Hands’, did not show significance (p= 0.169). The subtest ‘Touching Nose with Index Fingers- Eyes Closed’ within bilateral coordination did not produce significance (p=.104). The subtest ‘Stepping Sideways Over a Balance Beam’ within speed and agility did show statistical significance with a *p*-value of 0.002.

Table 3.
ANOVA

		Significance
Touching Nose with Index Fingers- Eyes Closed	Pre	.687
	Post	.954
Walking Forward on a Line	Pre	.826
	Post	.492
Standing on One Leg on a Line- Eyes Open	Pre	.146
	Post	.379
Standing With Feet Apart on a line- Eyes Closed	Pre	.830
	Post	.543
Dropping and Catching a Ball- Both Hands	Pre	.441
	Post	.825
Catching a Tossed Ball- Both Hands	Pre	.345
	Post	.471

Knee Push-ups	Pre	.397
	Post	.843
Stepping Sideways Over a Balance Beam	Pre	.885
	Post	.645

Table 4.
Pre-post values and change in the tests of the BOT2

		Group One Median (range)	p-value	Group Two Median(range)	p-value
Touching Nose with Index Fingers- Eyes Closed	Pre	2.6 (0-4)	0.343	2.44 (0-4)	0.104
	Post	2.7 (0-4)		2.89 (0-4)	
Walking Forward on a Line	Pre	2.4 (0-4)	0.343	2.33 (1-4)	0.009*
	Post	2.8 (0-4)		3.22 (2-4)	
Standing on One Leg on a Line- Eyes Open	Pre	1 (0-2)	0.394	1.56 (0-3)	0.347
	Post	1.3 (0-4)		1.78 (1-3)	
Standing With Feet Apart on a line- Eyes Closed	Pre	1.8 (0-4)	0.716	1.56 (0-4)	0.053
	Post	2 (0-4)		2.56 (0-4)	
Dropping and Catching a Ball- Both Hands	Pre	1.5 (0-5)	0.057	2.44 (0-5)	0.169
	Post	3 (0-5)		2.89 (0-5)	
Catching a Tossed Ball- Both Hands	Pre	1.7 (0-5)	0.013*	2.56 (0-4)	0.003*
	Post	2.9 (0-5)		3.56 (1-5)	
Knee Push-ups	Pre	1.3 (0-5)	0.832	1.89 (0-5)	0.466
	Post	1.2 (0-6)		1.44 (0-4)	
Stepping Sideways Over a Balance Beam	Pre	3.4 (0-7)	0.001*	3.44 (0-5)	0.002*
	Post	4.5 (0-8)		5 (1-6)	

* denotes significance

Combined

When data from both groups were combined the subtest within balance, ‘Walking Forward on a Line’, elicited a significance of 0.018. Both subtests within upper limb coordination, ‘Catching a Tossed Ball- Both Hands’ and ‘Dropping and Catching a Ball- Both Hands’ showed significance, p=0.021 and p=0.000, respectively. The subtest ‘Stepping Sideways Over a Balance Beam’ within speed and agility was significant with a p-value of 0.000.

DISCUSSION

Group 1

In group one during the beginning of the six weeks, participants appeared to have difficulty performing the pre-tests. They showed a lack of understanding with the equipment that was used and they were also hesitant to interact with someone whom they were unfamiliar. In a study by Barr (Barr & Shields, 2011), it was identified that a facilitator for physical activity provided an opportunity for social interaction. As the six weeks progressed the participants that had difficulty performing tests and who showed hesitance around new people no longer exhibited those traits. Jones (2003) and Menear (2007) identified that because of lack of social and behavioral skills individuals with DS have been shown to be prevented from participating in physical activity. This study supports those previous findings in that DS individuals are disadvantaged when it comes to appropriate programming and having the opportunity to interact with new people. However, when given the opportunity they are able to thrive and improve.

Balance

In this study, the results showed that a vestibular exercise program can elicit significant improvement in speed and agility and upper limb coordination. In terms of balance there are multiple possible reasons as to why significance was not seen. In a previous study by Gupta et al. (2011) the ceiling effect was seen within the subtest 'Walking Forward on a Line'. They hypothesized that this was seen due to the median score itself already being a three, so there was no room for improvement. This is also the case within this study. The other two subtests within balance were 'Standing on One Leg on a Line- Eyes Open', and 'Standing with Feet Apart on a Line- Eyes Closed', within this particular population they had a hard time going from a test where their eyes were open to where their eyes closed and also from walking to standing still. In future studies tests of this nature should be split up better so that the participants do not confuse what is expected of them.

Bilateral Coordination

The subtest 'Touching Nose with Index Fingers- Eyes Closed' within bilateral coordination, there were two possible reasons for lack of significance; ceiling effect and the lack of understanding from participants to close their eyes. Some participants performed this particular subtest with ease; attaining a perfect score from the beginning. Other participants did not do well with occluding their vision. During the intervention none of the exercises involved the closing of the eyes. This could also be a reason as to why the participants did poorly test. This reaction was also seen in the study by Gupta (2011). Similar information was also reported by Cabeza-Ruiz et al. (2011) when they found that their participants showed difficulty when they had their eyes closed. They went onto say that those findings could be indicative of anomalies in the functioning of the vestibular apparatus of individuals with DS.

Upper Limb Coordination

Within upper limb coordination significance was seen within the subtest of 'Catching a Tossed Ball- Both Hands' (p-value of 0.013). This improvement was expected as a station of the maze, 'Bean Bag Boogie', involved the same type of movement. Both movements used the tracking of the eyes on a moving object and the coordination of the hands. In a study by Berg and colleagues (2012), the use of playing a Nintendo Wii investigated the motor outcomes in a child with DS. Through the use of the BOT-2, researchers found that upper limb coordination was improved. They attributed this to the precision of arm movements, timing, and manual dexterity.

The other subtest within upper limb coordination, ‘Dropping and Catching a Ball-Both Hands’, did not show significance (p-value of 0.057). This could have simply been due to the small sample size that was available to this study.

Strength

The subtest, ‘Knee Push-ups’, did not elicit any sort of significance (p-value of 0.832). This could be due to multiple reasons. The first being that none of the stations within the maze truly tested the participants strength. Due to the lack of crossover between the stations of the intervention and the pre and post testing tests, it is to be expected that no significance was seen. Another reason as to why no significance was seen could be due to the complexity of the ‘Knee Push-up’ movement. In a typical developed individual this is also holds true. Many different, and likely unfamiliar movements, are required to perform a correct knee push-up. The fact that participants did not perform this test accurately is not surprising. Tsimaras and Fotiadou (2004) measured muscle strength in individuals with DS by using a handheld dynamometer. This type of approach at measuring strength within this particular population appears to be more appropriate given the lack of complex movements as compared to a knee push-up.

Speed and Agility

The subtest within strength and agility, ‘Stepping Sideways over a Balance Beam’, showed a significance with a p-value of 0.001. This particular subtest had a significant amount of crossover with stations from the maze such as ‘Monster Mash’ and ‘Climb Every Mountain’. Fast paced and precise movements were required during both stations and correlated well with the ‘Stepping Sideways over a Balance Beam’. Lin and colleagues in 2012, utilized all of the subtests of speed and agility within the BOT-2. Individuals with DS were introduced to a six-week intervention program that consisted of three 35-min sessions and had two major components: five minutes of exercising on a treadmill and 20 minutes of exercise through the use of a Nintendo Wii (with 10 minutes of rest in between). After the intervention all subtests within speed and agility were shown to be significant.

Group Two

Balance

The subtest ‘Walking Forward on a Line’ elicited significance. Many of the stations within the intervention (‘The Beam Team’, ‘Balance Board Bash’, and ‘Step Back’) aided in this significance. Compared to previous research (Gupta) the ceiling effect was seen. The fact that significance was seen within this particular subtest suggests that the intervention did indeed aid in the improvement from pre to post testing.

Bilateral Coordination

During this particular test, ‘Touching Nose with Index Fingers-Eyes Closed’, participants were required to close their eyes. This detail showed to be a difficult concept to grasp for many of the participants. This same difficulty has been seen in previous studies as well (Cabeza-Ruiz et al., 2011; Gupta et al., 2011). Also, none of the intervention stations involved the occlusion of the eyes. In future studies involving activities which occluded the eyes would be helpful.

Upper Limb Coordination

The subtest 'Catching a Tossed Ball- Both Hands' showed significance (p-value of 0.03). This is very similar to what was seen in Group one's data. Inui and colleagues identified that individuals with DS have difficulty in performing a tracking task. Through the intervention with stations such as 'Bean Bag Boogie', 'Eye Can Convergence', and 'Eye to Eye', tracking of a moving object as well as a stationary object was done. Performing these tasks suggest that hand-eye coordination was improved upon.

Strength

Much like group one, the subtest within strength (Knee Push-ups) did not show any significance. The complex movement which was unfamiliar to the participants proved to be too in depth for the length of this study. Choosing a different measurement of strength from within the BOT-2 could have been more beneficial and a better representation of strength for this population.

Speed and Agility

The subtest within speed and agility, 'Stepping Sideways over a Balance Beam', showed significance with a p-value of 0.002. This particular test involves speed and precision; each of which was worked on in the stations of the maze. 'Monster Mash' and 'Climb Every Mountain' correlated well with this particular subtest. Through the implementation of these stations speed and agility performance increased. Lin and colleagues saw similar findings following a six-week intervention as well.

Combined

Balance

When comparing group one to group two, group two improved in the subtest 'Walking Forward on a Line'. This could be due to the large age difference between the two groups. In group one, where a participant was as young as 4 years old, balanced walking is much more difficult than it is for those in group two. This is in large part due to the amount of time that the participants have been walking throughout their life. Some individuals with DS do not begin walking until much later on in life (Melyn (1973) has reported it as late as 74 months). Another reason for the difference between the two groups is development of the vestibular system. Due to simply living longer group two had an advantage. Throughout their life they have stimulated the vestibular system (whether that be through play, organized activity, and walking). Group one simply has not lived as long so therefore they have not had the opportunity to stimulate the vestibular system. However, if an appropriate program would continue to be implemented in their life then they might be able to reach the same level as group two, except at a younger age.

Bilateral Coordination

Both groups did not show significance within this particular test. This could be due to the occlusion of the eyes. Many (if not all) of the activities which the participants perform on a daily basis do not involve the closing of the eyes. When asked to close their eyes and perform this test the concept was foreign. Implementing exercises where the eyes are closed in future studies or programs would be beneficial.

Upper Limb Coordination

Both group one and group two showed improvement in this area. This data suggests that at no matter the age upper limb coordination can be improved upon within this population. Through appropriately assigned tasks this can be achieved.

Strength

In a typical developed individual, a knee push-up is a commonly used test to measure strength. However, when used within this particular population, unless the participants are aware of the complex movements associated with a knee push-up, this particular test is inappropriate.

Speed and Agility

Within this population slow paced exercises that do not require a large amount of agility are the type of programs that are typically seen. In everyday life that is also the case. These findings suggest that this population is very capable of more strenuous and precise movements. Organized activities that incorporate a faster paced movement and agility should be incorporated.

CONCLUSION

One of the largest limitations of this study was the small sample size. This particular program worked in conjunction with the summer enrichment programs at Down Syndrome of Louisville and Dreams With Wings. Due to only being able to get participants from those two particular programs we were limited in those who were able to participate. Due to the small sample size we were unable to have a control group for this study. Another limitation of the study were the conditions in which the intervention took place. Group two's intervention took place in a large gymnasium. The conditions were not ideal (as the participants would sometimes become easily distracted when they would see their fellow classmates across the gym). The final limitation was the length of the study. Study length was not enough to ensure vestibular stimulation. Significance could have been neuromuscular rather than the vestibular system being stimulated. However, because of the length of the summer enrichment program, the study was only able to take place for six weeks.

Future studies should continue to investigate balance, bilateral coordination, upper limb coordination, strength, and speed and agility in individuals with DS. A longer study focused on each of the previously mentioned and how they impact an individual's ability to participate in organized sport, join the work force, and perform activities of daily living would be beneficial to this field of study.

Improvement in upper limb coordination, speed and agility, and balance were seen within this study. These findings support the appropriateness of The Maze as an intervention for this particular population. If performed on a regular basis starting at a young age, this program may impact individual's ability to join the work force, take part in organized sport, and perform daily tasks.

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