POSTURAL CONTROL IN CHILDREN WITH AUTISM

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ABSTRACT

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This dissertation investigated how balance and postural stability in children with autism spectrum disorders differed from age matched children in three related studies. The clinical balance assessment, the Multi-Directional Reach Test (MDRT) was used as a tool to measure maximum reach distance in the forward, backward, right and left directions in standing with the feet stationary. Test-Retest Reliability was determined to be acceptable in typically developing children with this quick and useful tool for assessing dynamic standing balance. Significant correlations were found between maximum reach and height, weight and age of the typical subjects indicating that as children grow older and taller, they can reach further from their base of support without a loss of balance. The difference seen between gender in typically developing children was likely due to slightly older average age of females in the study rather than a true gender difference. The MDRT was used to determine if there was a difference between two children with autism spectrum disorder and their age, height and weight matched peers. Indeed, the typically developing children outperformed their autistic counterparts in all directions measured. Because postural control is a foundation for the development of fine and gross motor skills for engagement in occupation including daily living skills and school related fine motor skills such as writing, it is important that occupational therapists

consider dynamic balance as part of our assessment when we work with children on the autism spectrum for whom this area is often impaired.

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CHAPTER I

INTRODUCTION

There is extensive literature on children with autism spectrum disorders (ASD). Within this literature, however, there is limited study of posture and balance in children with ASD and even less on the impact that deficits in postural control and balance have on motor development and participation. The primary indicators of ASD according to the DSM-IV are abnormal social interaction, communication impairments and stereotypical behavior. Abnormal motor function is not considered to be one of the hallmark criteria to diagnose autism; however, there is a growing body of literature that indicates the prevalence of motor impairment and the need to address these deficits to improve early detection and intervention. Decreased performance of the postural control system is often seen in individuals with ASD (Fournier, Kimberg, et al., 2010). Impairment in postural control has a critical impact on overall motor development and with fine motor control, in particular (Flatters et al., 2014). The problem is that there is not a reliable and easy method of measuring postural control; therefore, the ability to measure postural control in both typically developing children and those with ASD with a simple, reliable measure is crucial to provide a starting point for intervention to address deficits occurring in postural control that affect overall function.

The Multi-directional Reach Test (MDRT) is a clinical balance assessment used to measure maximum reach distance in the forward, backward, left, and right directions in standing with the feet stationary. It is a simple, reliable, and valid tool to assess movement in these four directions, and while it has been used to assess the limits of stability in adult populations, there is limited information related to the pediatric population (Tantisuwat et al., 2014). This dissertation investigated postural control in typically developing children and then compared the results to those of children with ASD.

CHAPTER II

LITERATURE REVIEW

ASDs represent a wide range of conditions that present with an equally wide range of deficits. The number and severity of the symptoms of ASD can differ from mild to severe with core features of social impairment, communication difficulties, and stereotyped behaviors being required for the diagnosis of an ASD. The spectrum of disorders poses many difficulties for researchers because the population affected is so heterogeneous. The medical conditions that may affect a child with ASD include: motor and sensory impairments, seizure disorders, immunological and metabolic abnormalities, sleep problems, and gastrointestinal symptoms (U.S. Department of Health and Human Services, 2011).

Although social and communication deficits are among the defining characteristics of ASDs, many of the children also have abnormal motor functioning. (Bhat et al., 2011) These difficulties include decreased fine motor skill performance as well as poor postural control and balance, which are decreased relative to normal controls. Additionally, Bhat et al. provide support for the link between motor and social impairments, which indicates that early motor limitations inhibit social interaction and development. In the discussion of postural stability and balance Bhat et al. (2011) state that delays are evident in postures of toddlers and those deficits remain pervasive into adults and older children (Fournier, Hass et al., 2010; Molloy et al., 2003) There is a large body of research on deficits found in children with ASDs; however, there is a limited body of research, particularly in occupational therapy literature, on the impact of postural control and balance on function in children with autism spectrum disorders.

Minshew et al. (2004) and Molloy et al. (2003) studied postural control in children with autism using force platform technology. In each study, postural stability was found to be reduced under different visual and somatosensory inputs presented to the participants. Although their methodology differed because these studies used customized force platforms, the evidence in both the Minshew et al. study and the Molloy et al. study indicates that postural control in children with ASD was decreased when compared with normal controls, particularly when vision was occluded. Memari et al.'s (2013) more recent article, published on postural stability of children with autism compared postural sway in children with ASD and typically developing children. They found significant differences in patterns of postural sway between typically developing children and children with ASD. Interestingly, they also found that while age impacts the amount of postural sway in typical children, there was not a significant association with age and postural stability of the children with ASD.

Fournier, Hass et al. (2010) published "Motor Coordination in Autism Spectrum Disorders: A Synthesis and Meta-Analysis." Their findings show that deficits in motor coordination are associated with ASD. The outcome measures they evaluated were motor coordination, arm movement, gait, and postural stability. This analysis emphasized the importance of the postural control system stating:

> an immature postural system may severely limit the emergence and performance of other motor skills. In particular, coordinated hand/head movements and the inhibition of reflexes may constrain the ability to develop mobility and hand manipulation skills; motor capabilities critical to quality of life measures. (Fournier, Hass et al., p. 1235)

Despite these findings, motor coordination receives much less attention in the research than the social and communication factors in ASD. Without a stable base, more sophisticated skills are extremely difficult to master.

There is limited research in the occupational therapy literature addressing postural control and balance not focused on a sensory integration perspective, there are several notable exceptions, though one study is focused postural control in sitting while completing a task and comparing typically developing children and children with ASD and two other studies are not specific to children with ASD. An article in *Occupational Therapy International* by Funahashi et al. (2014) investigated postural sway in children with ASD and their typically developing counterparts. Children were in the seated position on a fabricated force platform while completing a set of functional tasks. The aim of the research was to investigate if improved postural control in sitting impacted performance considering that school aged children perform many of the school tasks while sitting. While there was no significant difference in time needed to complete tasks, center of pressure (COP) deviation was larger in the ASD group. Their study confirmed that postural sway was increased in children with ASD; however, it postulated that perhaps increased sway was a compensatory strategy since increased time to complete tasks did not correlate with increased sway in all areas. Given that increased sway is seen in computerized posturography in children and adults with ASD in standing, the possibility that some of that movement may be a compensatory strategy opens an interesting question for future examination.

The studies not specific to children with ASD were both published in the journal *Physical and Occupational Therapy in Pediatrics*. The first article is Gabriel and Mu (2002) “Computerized Platform Posturography for Children: Test-Retest Reliability of the Sensory Test of the VSR System.” The second study was “Exploring the Comparability of the Sensory Organization Test and the Pediatric Clinical Test of Sensory Interaction for Balance in Children" by Gagnon et al. (2006). Both studies looked at balance in typical children using a computerized platform posturography system, which was developed to provide a quantitative measure of the motor system and how the input of the vestibular, visual, and somatosensory systems relate to postural stability (Gabriel & Mu, 2006). A relatively small population of children (n = 18) participated in the Gabriel and Mu study to determine test-retest reliability of the sensory test on the NeuroCom VSR system. The sensory test utilized four out of six of the sensory conditions used in the Sensory Organization Test (SOT), which systematically manipulates sensory information while analyzing postural sway of the child. The small study population may affect the generalizability of the results; however, reliability and validity were excellent and exceeded adult norms in the system’s manual. The Gagnon et al. study (n = 16) compared the results of the SOT to the results of a traditional, clinic-based balance assessment, the Pediatric Clinical Test of Sensory Interaction for Balance (PCTSIB). Findings in this study are again likely limited by the small study population; however, it found that the computerized assessment and clinic-based assessment measure different and complementary information about the ability of the typically developing child to maintain balance. These studies do not include children with ASD, but they do provide a base on which further studies can build. Computerized posturography is considered the gold standard in the assessment of postural control; however, the importance of assessment using less expensive and more accessible methods cannot be underestimated.

One of the low-cost options for assessing postural stability is the Multidirectional Reach Test (MDRT). The MDRT was developed by Newton in 2001 as a practical measure to look at stability in the elderly. It was compared to several other well-known tools including the Berg Balance Test (BBT) and the Timed Up & Go (TUG) and found to be valid and reliable (Newton, 2001). An additional study by Holbein-Jenny et al. (2005) confirmed the reliability and validity of the BBT and the MDRT in the elderly population. An additional assessment in that study, the Activities Specific Balance Confidence Scale (ABC) was a self-report measure that was not found to measure the postural or motor control component of balance, but rather the subject's confidence in his or her own balance. Tantisuwat et al. (2014) also discussed the usefulness of the MDRT as a tool to assess postural control and balance particularly in the population over 60 years of age. The investigators looked at Asian adults aged 20-79 and found that beyond the 30s, there is a reduction in all reaching distances in all directions tested. They found no significant differences in young and middle-aged subjects, but the most apparent differences in the limits of stability were found after age 60 in the forward, left, and right directions. The backward limits were found to have the lowest values in all age groups and the greatest value of the MDRT in the forward direction. Each of these studies found that the MDRT was a useful tool to assess postural control in the adult population. The specific aims of the current research are to 1) determine test-retest reliability of the MDRT with a typically developing pediatric population; 2) to determine if there are significant differences between age groups; and 3) to determine if there are differences in matched typically developing children vs. children with ASD.

CHAPTER III

METHODOLOGY

The purpose of the three related studies in this dissertation was to determine how balance and postural stability in children with ASD differed from age matched typical children. A further purpose was to begin to identifying methods of assessing balance and stability in this population of children. Initially, the specific aims of the research included the use of the NeuroCom Balance Master's computerized posturography system to assess typically developing children and children with ASD; however, due to difficulty in finding families willing to disrupt routines and schedules for a testing session at TWU Houston's balance lab, this part of the study was eliminated. The revised aims were as follows:

1) Determine the Test-Retest Reliability of the MDRT when used with a typically developing pediatric population, and to determine if differences existed among the four MDRT directions,

2) Determine the difference between typically developing children of different ages, in broad age categories of less than 12 years of age and more than 12 years of age,

3) Determine the difference between age matched children who are typically developing (TD) and children with ASD on the MDRT.

These studies looked at postural control in TD children and in children with ASD in three related studies. Study 1 was the Test-Retest Reliability of the MDRT in the forward, backward, left, and right directions with a sample of TD children. The MDRT was tested twice with one practice trial prior to the recorded trials. This study was used to establish pediatric norms for comparison to the children with ASD in Study 3. Study 2 was to determine if there was a significant difference between TD children below age 12 and above age 12 on the MDRT. In both studies, movement forward, backward, left, and right was studied with an average of two trials taken after a practice trial. Finally, Study 3 was to determine if there were differences between two children with ASD and their TD age-matched peers when comparing results in the MDRT in all four directions.

Population

The population for this study included two groups of children. In Studies 1 and 2, there were 35 typically developing children between the ages of 5.91 and 15.42 years of age with 16 males and 19 females. In Study 3, there were two males diagnosed with ASD between the age of 5.42 and 6.17 with two matched peers. All the children in the studies were required to understand verbal instructions and comply with simple commands such as, “stand still and try not to move your feet,” which was a challenge for both the TD younger children in the data set and the children with ASD. Children with autism were between the age range of 5 to 7. They could not have a co-existing neurological condition including but not limited to conditions such as cerebral palsy or Down Syndrome, orthopedic issues that impact balance, vision or hearing impairments, and children who are unable to follow two-part verbal instructions in either English or Spanish.

Instruments

The instrument used in the studies was the MDRT, which is a tool used to determine the limits of stability in four directions, forward, backward, left, and right. Measures were taken to see how far an individual can shift their center of gravity (COG) with their feet stationary in all four directions of movement. Administration instructions for the MDRT are noted in Appendix A.

Procedures

Participants were recruited from a suburban community and school district via email, neighborhood blog, and through personal contacts. Testing was completed in a community clubhouse and on an elementary school campus. Permission was granted by the school district to recruit from and utilize their facility. Consent was obtained from all parents and assent was obtained from children over the age of 7. Anthropometric information of height (inches) and weight (pounds) along with birth dates were collected prior to testing. Participants were barefoot for all trials and asked to stand next to a wall where a yardstick was placed on the wall at the level of the acromion process. Children were provided with an explanation and demonstration, as needed. To measure forward reach, they were asked to raise arm to shoulder height and an initial measurement was taken at the index fingertip; then the child was asked to lean as far forward as possible without moving their feet, pausing to allow the investigator to record measurement. With the same starting position, the person then leaned as far backward as possible. Left and right reach were measured with the child's back to the wall, left or right arm abducted to 90 degrees and then the subject leaned as far to the appropriate side as possible. Verbal instructions to the subject included, “without moving your feet or taking a step, reach as far (direction given) as you can and try to keep your hand along the yardstick.” Instruction varied to indicate forward, backward, left, and right. Trials One and Two were recorded in inches following the practice trial.

Data Analysis

Data analysis to determine if the MDRT is a reliable tool when used with a pediatric population, differences between age groups, and the differences between TD children and those children with autism was initiated by entering data into Excel 2016. The statistical analyses were conducted using IBM SPSS Statistics (version 25) for Windows. Descriptive statistics were obtained for the values of the MDRT in all directions.

For Study 1, test-retest reliability and associations between the MDRT and age, weight, and height were determined by calculating Pearson product moment correlation coefficients. For the relationship between average MDRT and gender, point-biserial correlations were calculated. Also, a repeated measures one-way ANOVA was conducted on the average MDRT data to determine if there was a difference among the four directions. For Study 2, independent *t*-tests were completed to determine if there was a significant difference between the two groups of participants based on age. For Study 3, descriptive data was analyzed to compare the two matched pairs of participants. The alpha level for all analyses was set at .05.

CHAPTER IV

RESULTS

The subjects of the three studies consisted of 35 TD children and two children with autism. The 37 children included 18 males and 19 females. The descriptive characteristics including age, height and weight and the descriptive statistics for all the subjects are included in Table 1.

Table 1

Anthropomorphic Data of all Participants. (*N* = 37)

Central Tendency	Age (years)	Height (in.)	Weight (lbs.)
Mean	9.85	54.32	77.84
Median	9.5	53.00	66.40
Mode	12.42	53.00	59.00
Std Deviation	2.87	7.08	31.83
Minimum	5.42	44.25	44.00
Maximum	15.42	70.00	165.00

Study 1 assessed the Test-Retest Reliability of the MDRT when used to determine the maximum distance a subject was able to reach in the forward, backward, left, and right directions. For this study, 35 TD children completed two trials in each direction. The averages for the two trials in each direction are presented in Table 2 along with the correlations between the first and second trials. Strong correlations were found between

Trial 1 and Trial 2 in all directions. The forward direction had the largest mean value at 12.60 inches, while the backward direction had the smallest mean value at 7.83 inches. The strongest relationship between Trial 1 and Trial 2 was found when participants were asked to reach to the right with a r = .912. This can be interpreted as 83% of (r^2) of the variance Trial 1 was shared with Trial 2 when the participants were reaching to the right.

Table 2

MDRT Test-Retest Reliability for all Directions-Typically Developing Subjects

N = 35	Mean (inches)	Standard Deviation (inches)	Minimum (inches)	Maximum (inches)	Pearson Correlation (r)	Sig Value
Forward	12.60	2.11	8.63	16.5	0.748	≤0.001
Backward	7.83	1.95	4.63	12.50	0.811	≤0.001
Left	11.14	2.57	5.75	15.50	0.838	≤0.001
Right	11.26	3.19	4.75	16.25	0.912	≤0.001

The question of whether the MDRT is reliable was addressed by looking at trials in all directions and the correlations between trials. Next, the correlations between the various MDRT average directions and age, height, weight, and gender were calculated. The results from these calculations can be found in Table 3. As expected, as the participant grew taller and older there was a significant positive correlation with the forward, left, and right directions. There was also a positive correlation between weight and the forward, left and right directions of the MDRT; however, this is expected with an increase in height. Finally, there was a significant relationship between the female gender and higher scores in the forward and right directions. However, the sample of typically developing males was 5.91 years and the females were 7.25 years of age This difference would explain the gender relationship to the MDRT.

Table 3

MDRT Correlations with Age, Height, Weight, and Gender for all Directions-Typically Developing Subjects

	Age	Sig. value	Height	Sig. value	Weight	Sig. value	Gender	Sig. value
Average Forward	**.704*****	<0.001	**.675**	<0.001	.614	<0.001	**.521**	.001
Average Backward	.231	.182	.364	.032	.216	.213	.328	.054
Average Left	**.707*****	<0.001	.711	<0.001	.551	.001	.251	.145
Average Right	**.594****	<0.001	.682	<0.001	.511	.002	.362	.033

Note. To determine if there were correlations between age, height, weight, and gender and maximum reach, values were compared in each direction to those parameters. Significance is designated by *** for moderate correlations and ** for weaker correlation.

Lastly, a repeated-measures one-way ANOVA was conducted to determine if significant differences existed among the four directions of the MDRT when typically developing children were tested. Due to an issue with Sphericity, the Greenhouse-Geisser results are given. There was a significant difference among the average directions at $F(2.2, 75.02) = 52.38$, $p \leq .005$. Follow-up pairwise comparisons revealed significant differences as shown in Table 4. All comparisons were significant except when the average of right was compared to the average of left.

Table 4

Pairwise Comparisons-Typically Developing Subjects

Direction	Direction Comparison	Mean Difference	Standard Error	Sig	Lower Bound	Upper Bound
Forward	Backward	4.775	.388	≤.000	3.687	5.863
	Right	1.346	.395	.010	.241	2.542
	Left	1.464	.309	≤.000	.597	2.331
Backward	Right	-3.429	.510	≤.000	-4.856	-2.001
	Left	-3.311	.448	≤.000	-4.565	-2.057
Right	Left	.118	.287	1.000	-.687	.923

*The mean difference is significant at the .05 level.

Study 2 analyzed whether significant differences in average MDRT directions existed when comparing children under 12 years of age and 12 years of age or older. There were 22 children in the under 12 group and 13 children who were 12 years or older. Significant differences were found for three of the four MDRT directions, with the older group outperforming the younger group. Descriptive and *t*-test results can be found in Tables 5 and 6.

Table 5

Descriptive MDRT Data by Age Group

Direction	Age Group	*N*	Mean	Standard Deviation
Average Forward	Under 12	22	11.653	1.652
	Over 12	13	14.212	1.851
Average Backward	Under 12	22	7.602	2.048
	Over 12	13	8.212	1.791
Average Right	Under 12	22	9.761	2.682
	Over 12	13	13.789	2.289
Average Left	Under 12	22	9.994	1.950
	Over 12	13	13.077	2.368

Table 6

Age Group Differences in the MDRT (N = 35)

Average Direction	Mean Difference (inches)	Standard Error Difference	Calculated t value (df=33)	Significance (2-tailed)
Forward	2.56	0.60	-4.25	≤0.005
Backward	-0.61	0.69	-0.80	0.380
Right	3.08	0.89	-4.52	≤0.005
Left	3.08	0.74	-4.17	≤0.005

Study 3 looked at the differences in the limits of stability using the MDRT between two male subjects with autism and two typically developing males who were matched by gender, age, height and weight. Anthropomorphic data is seen in Table 7.

Table 7

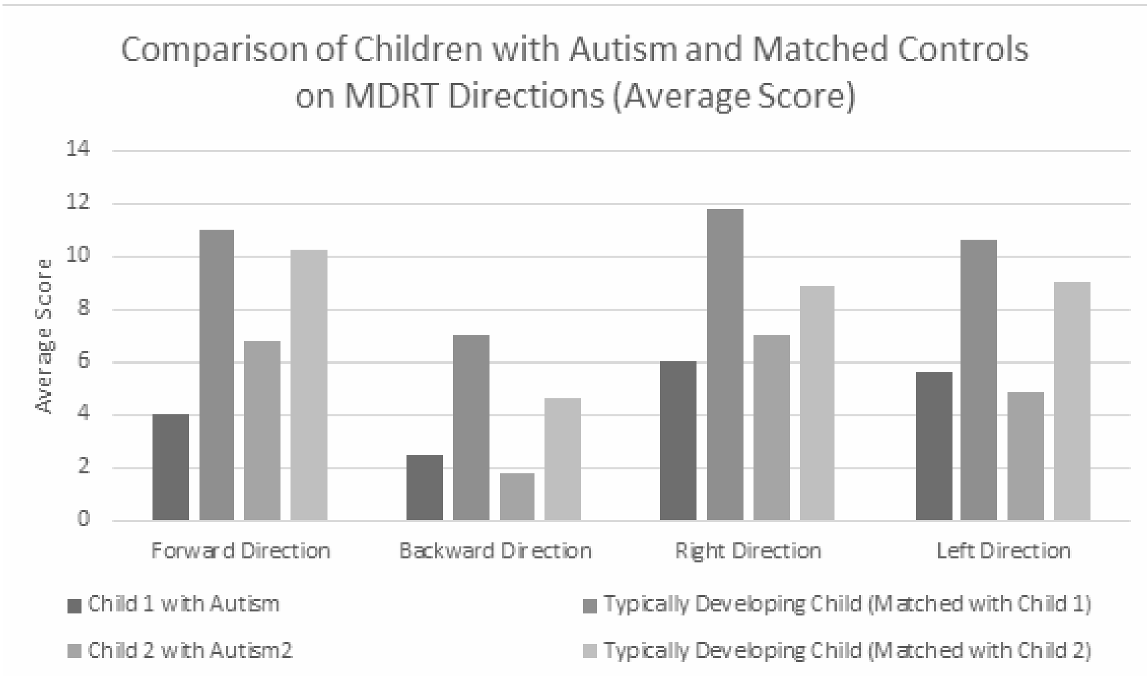
Anthropomorphic Data for Subjects with Autism and Typically Developing Matched Subjects

Child	Age	Height (inches)	Weight (lbs.)
Child 1-ASD	6.17	44.25	44.0
Child 1-TD	6.08	48.50	51.6
Child 2-ASD	5.42	46.75	51.0
Child 2-TD	5.91	47.75	51.4

There were differences in the average scores of the MDRT trials in all directions noted between the children with autism and their typically developing matched subjects, noted in Figure 1. In all directions tested by the MDRT, the typically developing children outperformed the children with ASD. The mean difference in forward direction limits of stability between the subjects with autism versus typically developing subjects was 5.35 inches, for the backward direction it was 3.69 inches, left 4.50 inches and right 5.94 inches.

Figure 1

Comparison of Children with Autism Spectrum Disorder and Matched Controls on MDRT



CHAPTER V

DISCUSSION

Implications

This dissertation included three related studies that looked at postural control in TD children and in children with ASD to determine a method of clinical assessment of postural control that can be used with children who have autism spectrum disorders. The first study established Test-Retest Reliability of the MDRT for typically developing children. Study 2 determined that there are significant differences between TD children below age 12 years and above age 12 years on the MDRT. In both Studies 1 and 2, movement forward, backward, left, and right was studied with an average of two trials taken after a practice trial. Finally, the third study determined that there are differences between two children with ASD and their TD age-matched peers when using the MDRT in all four directions.

It is well established that children with autism spectrum disorders demonstrate difficulties with social interaction and communication. These indicators, along with the presence of stereotyped behavior are hallmarks of the disorder. Less well recognized and well researched are the deficits in postural control that impact children with ASD. These deficits, while less well documented, are equally impactful on a child's ability to function and perform the activities that are part of their daily lives, including fine motor tasks in the school and home setting and self-care activities among many others. Castarelli et al. (2016) and Flatters et al (2014) found that motor and postural control deficits impact critical areas of function including social functioning and overall manual dexterity. This dissertation sought to determine a method of measuring postural control that was easily done in a clinical setting and did not rely heavily on technology-based platforms, which are considered the gold standard in the assessment of postural control (Gabriel & Mu, 2002).

The MDRT is a clinical balance assessment that has been used with the adult population for almost two decades, yet there is very little research to establish it as an effective tool for use with the pediatric population. Developed by Newton in 2001, the MDRT was created to provide a tool that was easily administered to older adults across many settings (Newton, 2001). It is a reliable tool in the population that measures balance and level of stability in the anterior-posterior and in the medial-lateral directions rather than only the forward direction as seen in other balance tests including the Forward Reach Test (FRT). In the population of TD children in Study 1, the Test-Retest Reliability was found to have high significant correlations between trials in all directions. Additionally, as expected, there were correlations found between age, height, and weight in most directions. Because height and weight typically increase with age, it was expected that those factors would increase, as would the maximum reach when tested in all directions of the MDRT. The forward, left, and right directions were all found to have strong correlations with these factors. The exception to this being with backward movement which did not correlate well with other factors. Sharma et al.(2018) found similar results in their study of South Asian children of 5 to 12 years of age with age, impacting forward movement the most significantly and backward movement the least. Similarly, Tantisuwat et al. (2014) also found decreased differences between backward movement across the age groups and the most stability in the forward direction. This lack of correlation to backward movement to age across studies in both young and old is likely due to the biomechanical factors of decreased backward excursion of the ankle and foot and therefore is less likely to change as age, height, and weight change. Also, of importance was the fact that in the pairwise comparisons of the TD subjects, there was a significant difference between all directions, except right and left, indicating that the ability to move laterally was comparable regardless of direction. This indicates that it is important to test limits of stability in all four directions, though lateral movement is similar in both directions.

The comparison of TD children less than 12 years of age and over 12 years of age in Study 2 confirmed the correlations seen in Study 1 to age, height, and weight. As expected, the children over 12 years demonstrated the ability to move farther out from their base of support than younger children in the forward, right, and left directions. Backward movement was not significantly different between the two groups, which was interesting and somewhat unexpected given the broad age groups.

Study 3 sought to identify the differences between the children with ASD and their matched peers were noted in all directions of movement indicating that the children with autism are less able to move outside of their base of support than their TD peers. This decreased postural control impacts the child's ability to move through their environment safely, perform weight shifts during activities of daily living or transitions and to maintain a stable base for a wide range of fine motor tasks that are critical to the occupation of childhood.

Clinical Relevance

The implications of decreased postural control and balance in children with autism encompasses many areas of function that are dependent on a stable base to complete those tasks successfully. The inability to stabilize the trunk impacts children with autism's functional performance throughout their day. An activity such as getting dressed includes balance challenges inherent in position changes to don clothing, especially lower body clothing, socks and shoes. School aged children may have to move into and out of vehicles to get to school and walk safely through crowded environments to get to their classrooms. Of course, in the school setting, there is generally an expectation of maintaining a seated position and shifting the base of support to obtain needed supplies in a desk or basket under the chair and then perform fine motor tasks such as writing, coloring and cutting with accuracy and precision. All of these demands occur while significant social interactions are expected. Motor difficulties in children with ASD also influence ability to translate the social information (Casartelli et al., 2016). The aforementioned activities and demands all take place within the first hour of a typical day. Clearly, there are many challenges for the population of children with ASDs. Postural stability and balance are critical building blocks on which motor coordination is built. The ability to quickly measure and quantify postural control in children with ASDs will give practitioners an extra tool to use to improve outcomes in many areas of function for children with autism. Clinically, providing a more stable postural base from which to perform functional tasks can have a tremendous impact on the child's success in functional tasks. For families of children with ASD, small improvements in function can have a big impact on the daily quality of life, which is ultimately the goal of occupational therapy.

Limitations

The studies in this dissertation are limited by the decreased sample size, particularly in the children with autism. Additionally, because the caregivers of the children with autism were unable or unwilling to disrupt routines in such a way that would have been required to utilize the NeuroCom Balance Master, there is not a comparison between the MDRT and the computerized posturography platform, which would have provided additional information on the postural control of the subjects with autism and their matched peers.

Future Directions

Future research should include a broader sample of typical children to provide solid age group norms for children in increments of one to two years. Additionally, while the sample was representative of the suburban area of Houston, it is quite likely that balance and postural control are different in other areas of the state and country. A significant increase in the number of children with autism would also increase the power of the study to compare to their typically developing peers using the MDRT. The use of the

NeuroCom Balance Master or similar computerized platform to compare the data of the MDRT to the results of a more sensitive instrument would provide additional information that may enhance the information on the postural control and lead to more accurate clinical treatment plans.

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APPENDIX A

Administration of the Multidirectional Reach Test (MDRT)

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Administration of the Multidirectional Reach Test (MDRT)

- All subjects will be bare footed for trials.
- Height will be measured using a tape measure mounted on the wall.
- Weight will be measured using a floor scale.
- A yardstick is placed horizontally in a telescoping tripod or the wall at the level of the subjects' acromion process
- Forward reach: the subject is placed near but not touching the wall and lifts an outstretched arm to shoulder height, pauses for an initial reading at the tip of the index finger and then reaches as far forward as possible
- Backward reach: starting position is the same as the forward reach; however, the person leans as far backward as possible
- Left/Right reach: starting position with back to the wall, right or left arm is abducted and subject leans as far right or left as possible.
- Verbal instructions to the subject include, "without moving your feet or taking a step, reach as far (direction given) as you can and try to keep your hand along the yardstick". Instruction will vary to indicate forward, backward, left and right.
- Measurement will be taken using the start and end position of the index finger of the outstretched hand and the difference represents the total reach for that direction.
- Feet are maintained flat on the floor shoulder width apart. If the feet move, the trial is discarded.
- 3 trials will be administered, the first is a practice trial and the following two trials are averaged and recorded. Subjects are bare footed.

APPENDIX B

Data Collection Sheet-MDRT

APPENDIX B

DATA COLLECTION SHEET-MDRT

SUBJECT ID (SPC and number):

Month/Year of Birth:

AGE:

GENDER:

DIAGNOSIS:

HEIGHT:

WEIGHT:

MDRT DATA:

Forward
- Initial measurement:
- Final measurement:
- Difference:

Backward
- Initial measurement:
- Final measurement:
- Difference:

Right
- Initial measurement:
- Final measurement:
- Difference:

Left
- Initial measurement:
- Final measurement:
- Difference: