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Assessment Of Functional Throwing Ability In Individuals With Low Expressive Autistic Spectrum Disorders

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ASSESSMENT OF FUNCTIONAL THROWING ABILITY IN INDIVIDUALS WITH LOW EXPRESSIVE AUTISTIC SPECTRUM DISORDERS

By

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ABSTRACT

Impairments in social interaction, communication and repetitive, restricted behaviors are seen in individuals with Autistic Spectrum Disorders (ASD). No study has ever determined the differences in movement patterns of individuals with Low Expressive Autistic Spectrum Disorder (LE-ASD) while throwing a ball. If differences in throwing patterns between an LE-ASD population and a typically developing population are determined, then the more thorough description of ASD movement impairments would be evident. Furthermore, these differences could demonstrate that older individuals with LE-ASD have a deficit in movement patterns rather than a delay. **PURPOSE:** To compare throwing kinematics in an adult LE-ASD group (18.5 ± 1.9 yo) with an age-matched control group (19.5 ± 0.5yo) over four throwing distances to determine whether the differences in throwing ability are due to a motor deficit associated with the disorder. **METHODS:** Eight LE-ASD participants and the nine control participants threw a 0.06 kg reflective ball (dia. = 6.5 cm) a total of 12 times to a researcher that was 1.52, 3.04, 4.56 or 6.08m away. Each participant threw the ball to all 4 distances 3 times each, in a randomized order. All of the throws were conducted with the dominant arm (right) and success was recorded based on if the researcher could comfortably catch the ball without moving any distance. Spherical reflective markers (dia. = 10 mm) were placed on the base of the 5th metatarsal, left/right lateral malleolus, lateral femoral epicondyle, left/right greater trochanter, radial tuberosity, left/right acromion process, and the base of the 5th metacarpal. A six-camera motion analysis system (Oqus, Qualysis AB; Sweden) tracked marker locations within 0.5 mm and resulting 3D coordinates were computed. A stick figure representation of the participant was displayed and each trial could subsequently be viewed from any vantage point. Throwing trials were scored utilizing a previously reported throwing rubric used to assess development of overhand throwing abilities. **RESULTS:** Control subjects performed throwing trials with 100% accuracy compared to only 60.2% accuracy of LE-ASD group. Individuals with LE-ASD had 66.67% success at 1.52m, 55.56% success at 3.04m, 51.85% success at 4.56m and 29.63% success at 6.08m. The control subjects also demonstrated increased step and trunk action compared to LE-ASD individuals. **DISCUSSION AND CONCLUSION:** The throwing pattern of LE-ASD individuals was drastically different from the control group. The experimental group

had no stepping action or trunk action and therefore was not able to throw the ball to the further distances. Since there was no stepping or trunk action, individuals with LE-ASD relied heavily on elbow extension to propel the ball forward. The immature throwing pattern could be due to a lack of core strength or the inability for the individuals to cross the midline. Although further research needs to be done to assess the correlation between throwing function and performing daily tasks and the therapies to correct these issues, this study found that adults with LE-ASD have an immature throwing pattern that is consistent within their disorder, and is drastically different from those without any neurodevelopmental disorder.

Contents

Introduction

Autism Spectrum Disorders (ASD) is an umbrella term that refers to a number of neurodevelopmental disorders. These disorders share similar characteristics, which include varying levels of impairments in communication, reciprocal social interaction and restricted, ritualistic, and repetitive behaviors.[1-2] These impairments represent a number of disorders within ASD, including Autism, Asperger's Syndrome, and Pervasive Developmental Disorder-Not Otherwise Specified.[3] Based upon the severity of the impairments and/or the individual's ability to thrive independently, ASD is considered a spectrum, ranging from High Functioning Autistic Spectrum Disorders to Low Expressive Autistic Spectrum Disorders (LE-ASD).[4] ASD was reported to be caused by environmental factors, but it is now believed to be a neurodevelopmental disorder. As of 2009, the estimate for the rate of ASD increased from less than 10 in 10,000 people to as high as 110 in 10,000 people and this rate may be increasing.[5] Matson & Kowalski found that the increase in prevalence was caused by differences in diagnostic tools and more awareness of the disorder.[2] Although the etiology of ASD is still unknown and the diagnosis is highly subjective, contemporary research is focused on understanding these disorders and why the prevalence rates are rising.[6]

ASD is subjectively diagnosed based on the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR 4th). This classification scheme contains categories with specific requirements in the areas of social interaction, communication, behavioral qualities and delays in functioning for all of the disorders encompassed in ASD. The requirement for behavioral or movement qualities in Autistic Disorder (AD) is that there must be impairments in one out of the following four requirements.

- Encompassing preoccupation with one or more stereotyped and restricted patterns of interest that is abnormal either in intensity of focus
- Apparently inflexible adherence to specific, nonfunctional routines or rituals
- Stereotyped and repetitive motor mannerisms (e.g., hand or finger flapping or twisting, or complex whole-body movements)
- Persistent preoccupation with parts of objects.

Using these categories and requirements, physicians and psychiatrists are able to indentify ASD, and more specifically AD in children during childhood.[3]

Studies show that children and adults with ASD display specific types of movement impairments and tendencies.[6,7,8,9] Some of these tendencies include decreased balance, impaired motor coordination, postural stability problems, lower scores on motor functioning tests and gait deviations.[10] Fournier et al. reported that individuals with Autistic Disorder (AD) displayed tendencies associated with decreased movement during the preparation and planning stages of locomotion, decreased upper and lower extremity motor function and decreased dynamic balance while in locomotion.[1] These deficits in motor coordination and movement impairments show that individuals ranging from toddlers to young adults with AD have impaired motor capabilities and may be less coordinated.[1] Due to these disordered movement patterns, everyday tasks such as walking are altered in such a way that an individual with ASD may not be able to thrive independently.

One of the most important movement patterns for living independently and impacting the quality of life is the ability to walk. Damasio & Maurer show that the gait within AD is similar to that of an individual with Parkinson's Disease (PD), while Esposito & Venuti show that it is similar to individuals with Cerebellar Ataxia (CA).[11,12,13] Individuals with PD display gait patterns that are asymmetric, variable, and display failure to develop postural stability before gait initiation. These gait patterns are associated with premature muscle innervations and can sometimes lead to a phenomenon known as gait freezing, or when it appears that an individual cannot move their feet from the ground.[14] Gait in individuals with CA is marked by decreased balance while taking steps, a widened step base, a decreased step frequency and increased time while in double leg support.[15] Although these studies have somewhat conflicting results between the comparison of AD gait to PD and CA gait, they both indicate that individuals with AD may have neurological impairments that cause gait impairments. These impairments can cause individuals with AD to spend time in therapy to improve their gait and other motor impairments.[1]

Other typical movement impairments in ASD include a decreased or immature postural system. An immature postural system can cause impairments in coordinated movements such as hand/head movements. These movements involve motor coordination for activities of daily living (ADLs) such as eating, brushing teeth, or other functional abilities such as throwing a ball. A deficit in the ability to develop these skills may lead to a decrease in reflex mobility further diminishing the ability to perform ADLs. The inability to thrive independently or have a high quality of life is unlikely when an individual cannot develop hand manipulation skills due to a neurological deficit.[16]

Several studies have focused on childhood movement impairments and differences in ASD, but only a few have focused on adult movement patterns.[7,8,9,17] Fournier et al. indicated that movement impairments can slightly decrease with age, but it is unknown whether this is due to natural development, interventional programs, or both.[1] Pan tried to determine what types of interventions decrease these motor impairments, but without consistent intervention, it is hard to examine the outcome with many different dependent variables. However, Pan reported that regular physical activity increased health behaviors and movement patterns for individuals with ASD.[17]

Although several studies have investigated movement patterns, no study has ever investigated throwing patterns in LE-ASD in adults.[1,6,7,17] It is hard to determine whether or not movement patterns in throwing are different in LE-ASD adults because of a functional neurological inability, or whether it is caused by lack of opportunity. If individuals with LE-ASD cannot perform ADLs, they may not have had the opportunity to participate in any type of physical activity.[16] There are also few studies that show whether or not motor capabilities increase with age, and it is also unknown as to what can cause these increases of capability. Also, there has never been an examination of throwing movement in adults with LE-ASD.

The purpose of this study was to examine a population of LE-ASD adults' ability to throw a ball compared to a population of adults without any type of neurodevelopmental disorder. The diagnosis for LE-ASD does not currently take into consideration movement patterns as much as communication and social deficits.[18] According to Ben-Sasson et al., if patterns such as gait or throwing ability could be determined, the diagnosis and treatment of ASD could include specific, unique movement patterns.[19] This study set out to determine if young adults with LE-ASD had different throwing patterns compared to individuals without any disorder. The findings of this study will contribute to contemporary understanding of upper extremity movement profiles in LE-ASD. Specifically the age range studied corresponds to an age when these individuals would stop formal schooling. This study will determine if upper extremity motor coordination problems exist in LE-ASD and if subsequent therapy sessions are warranted.

Methods

All participants and/or legal guardians granted formal informed consent in a study design that was approved by Sacred Heart University Institutional Review Board (IRB). Eight ASD adults (18.5± 1.9 years old) were recruited to participate in the study. All eight ASD participants were diagnosed with LE-ASD. Ten control participants from Sacred Heart University, age matched at 19.5± 0.5 years old, with no neurodevelopment disorders agreed to participate.

Both the eight LE-ASD participants and the ten control participants threw a 0.06 kg reflective ball (dia. = 6.5 cm) a total of 12 times to a researcher that was 1.52, 3.04, 4.56 or 6.08m away. Each participant threw the ball to all 4 distances 3 times each, in a randomized order. All of the throws were conducted with the dominant arm (right) and success was recorded based on if the researcher could comfortably catch the ball without moving any distance. Spherical reflective markers (dia. = 10 mm) were placed on the base of the 5th metatarsal, left/right lateral malleolus, lateral femoral epicondyle, left/right greater trochanter, radial tuberosity, left/right acromion process, and the base of the 5th metacarpal. A six-camera motion analysis system (Oqus, Qualysis AB; Sweden) tracked marker locations within 0.5 mm and resulting 3D coordinates were computed. A stick figure representation of the participant was displayed in QTM Manager (Qualisys AB) and each trial was subsequently viewed from several vantage points (Figure 1). Qualitative analysis of each throw was scored according to the rubric established by Robertson.[20] (Tables 1, 2)

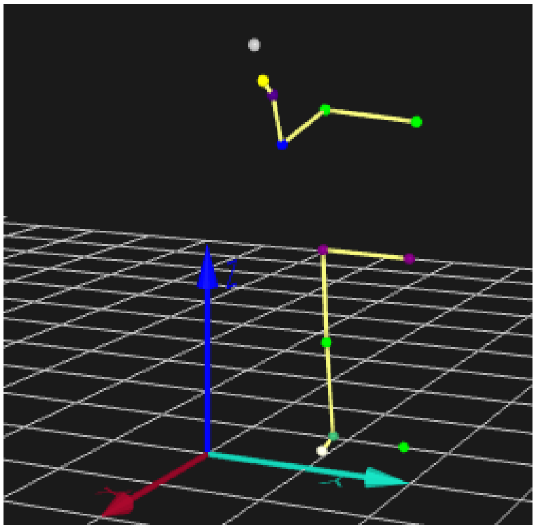

Figure 1. *Stick Figure Example*

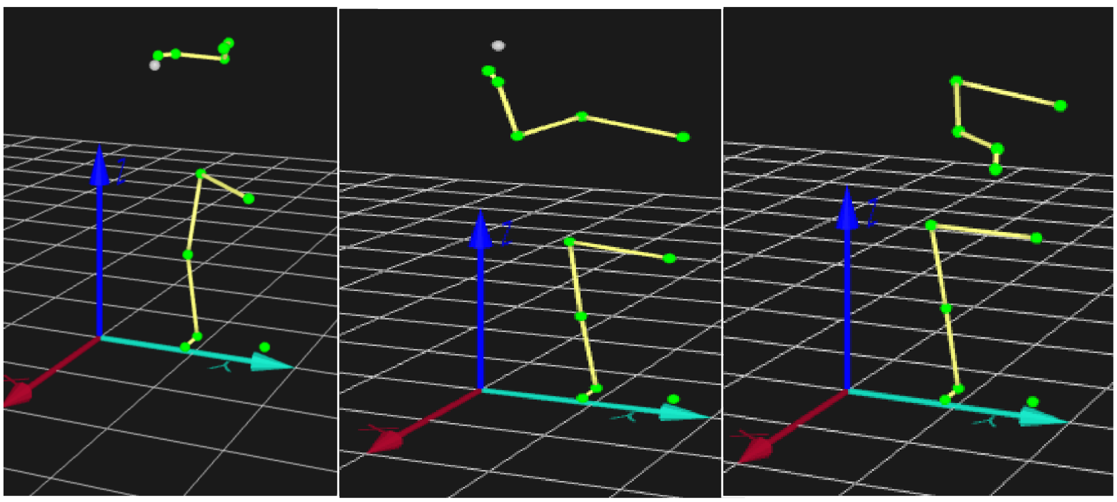

Figure 2. *Control Throwing Phases*

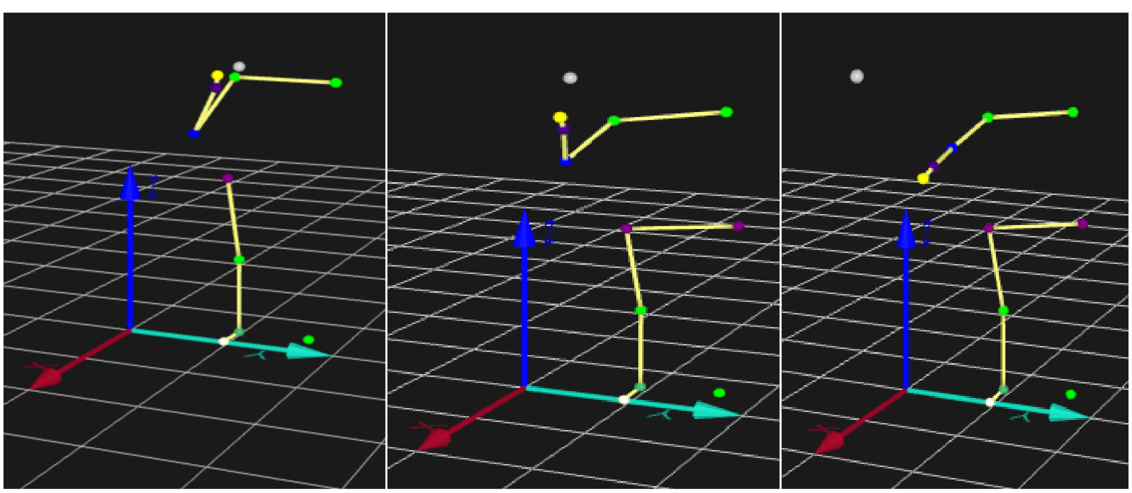

Figure 3. *Experimental Throwing Phases*

Table 1. *Step Action Component of Throwing Scores*[20]

Level 1	No step. The child throws from the initial foot position.
Level 2	Ipsilateral step. The child steps with the foot on the same side as the throwing hand.
Level 3	Contralateral, short step. The child steps with the foot on the opposite side from the throwing hand.
Level 4	Contralateral, long step. The child steps with the opposite foot a distance of over half the child's standing height.

Table 2. Trunk Action Component of Throwing Scores[20]

Level 1	No trunk action or forward-backward movements. No twist-up precedes the arm movement. If trunk action does occur, it accompanies the forward thrust of the arm by first extending and then flexing at the pelvis.
Level 2	Upper trunk rotation or total trunk "block" rotation. The spine and pelvis both rotate away from the intended line of flight and then simultaneously begin forward rotation, acting as a unit or "block."
Level 3	Differentiated rotation. The thrower twists away from the intended line of ball flight and, then, begins forward rotation with the pelvis while the upper spine is still twisting away

Scoring rank for trunk action and step action were determined based on the 3D stick figure representations in Qualysis QTM software. A Pearson's chi-square analysis was computed to determine significant differences between throwing actions between the control and the experimental groups. In order to do this type of analysis trunk scores and stepping scores were converted from a rank variable to a categorical variable. Therefore, scores greater then 1.0 were converted to a 2.0 regardless of number above. A score of 1 represented an immature throwing pattern and a score of 2.0 represented a mature throwing pattern. All statistical analyses were computed in SPSS (IBM: Chicago, IL) and a significance value of 0.05 was set.

Results

At the 1.52m throw distance there was a significant association between group membership (LE-ASD, control) and whether or not trunk rotation was mature $\chi^2(1)=3.503$, $p<0.05$. This indicates that control subjects demonstrated a non-immature trunk pattern (mean rank score=1.21), while LE-ASD group displayed immature trunk patterns (mean rank score=1.00). However, there was not a significant association between group membership and stepping action $\chi^2(1)=9.294$, $p<0.05$. In terms of throw outcome the control group was perfect at all attempts, while only 55.6% of LE-ASD throws were successful.

At the 3.04m throw distance there was a significant association between group membership (LE-ASD, control) in terms of trunk rotation $\chi^2(1)=10.848$, $p<0.05$ and stepping action $\chi^2(1)=6.605$, $p<0.05$. These numbers indicate that the control group displayed a mature trunk pattern (mean rank score=1.64) and a mature stepping pattern (mean rank score=1.61) compared to the control group who displayed immature trunk (mean rank score=1.05) and stepping patterns (mean rank score=1.14). The control group also had 100% accuracy while throwing to this distance, while the LE-ASD group only had 55.56% accuracy.

At the 4.56m throw distance there was a significant association between group membership (LE-ASD, control) in terms of trunk rotation $\chi^2(1)=28.625$, $p<0.05$ and stepping action $\chi^2(1)=10.367$, $p<0.05$. These numbers show that the control group demonstrated a mature trunk pattern (mean rank score=1.93) and a mature stepping action (mean rank score=1.82), while the LE-ASD group demonstrated an immature trunk pattern (mean rank score=1.00) and immature stepping action (mean rank score=1.13). The control group was able to successfully deliver all throws to the target perfectly, while the LE-ASD group was only able to deliver the ball to the target with 51.85% accuracy.

At the 6.08m distance there was a significant association between group membership (LE-ASD, control) in terms of trunk rotation $\chi^2(1)=23.131$, $p<0.05$ and stepping action $\chi^2(1)=9.022$, $p<0.05$. This again shows that the control group displayed a mature trunk rotation pattern (mean rank score=2.00) and a mature stepping pattern (mean rank score=1.70), while the control group displayed an immature trunk rotation pattern (mean rank score=1.04) and an immature stepping pattern (mean rank score=1.08). The control group had perfect accuracy while throwing to this distance compared to the LE-ASD who threw with 29.63% accuracy.

Within the LE-ASD group, there were no significant differences in trunk pattern or stepping pattern throughout all four distances (Table 5), indicating that their throwing pattern was immature regardless of distance.

Within the control group, there were no significant differences in stepping pattern throughout the four distances (Table 5). Indicating that the control group displayed a mature stepping pattern throughout all four distances. However, between the four distances there were significant differences in trunk action, indicating that during the closer distances, the control group threw with a more immature trunk pattern and when they threw to longer distances they used a more mature pattern. This change in throwing pattern is verified by no significant differences between distances 3.04m, 4.56m and 6.08m, indicating that once the control individuals threw to longer distances their mature trunk pattern was consistent (Table 5).

Table 3. *Throwing Success for Control and LE-ASD Throws*

Distances	Control	Experimental
1.52m	3.00 (100%)	2.33 (55.60%)
3.04m	3.00 (100%)	2.00 (55.56%)
4.56m	3.00 (100%)	1.89 (51.85%)
6.08m	3.00 (100%)	1.00 (29.63%)

Table 4. *Qualitative Analysis on Stepping and Trunk Motion for Control and LE-ASD Throwing Motion (*indicates significance)*

Stepping Action	Control	Experimental
1.52m	1.50*	1.00*
3.04m	1.61*	1.14*
4.56m	1.82*	1.13*
6.08m	1.70*	1.08*
Trunk Action	Control	Experimental
1.52m	1.21	1.00
3.04m	1.64*	1.05*
4.56m	1.93*	1.00*
6.08m	2.00*	1.04*

Table 5. *Chi-Square Analysis and p Values between Distances*

Stepping Action	Control Chi-Square	Control *p* Value	Experimental Chi-Square	Experimental *p* Value
1.52m & 3.04m	$X^2(1)=0.003$	$p > 0.05$	$X^2(1)=2.257$	$p > 0.05$
1.52m & 4.56m	$X^2(1)=1.763$	$p > 0.05$	$X^2(1)=2.165$	$p > 0.05$
1.52 m & 6.08m	$X^2(1)=1.148$	$p > 0.05$	$X^2(1)=2.080$	$p > 0.05$
3.04m & 4.56m	$X^2(1)=0.617$	$p > 0.05$	$X^2(1)=0.002$	$p > 0.05$
3.04m & 6.08m	$X^2(1)=0.278$	$p > 0.05$	$X^2(1)=0.007$	$p > 0.05$
4.56m & 6.08m	$X^2(1)=0.167$	$p > 0.05$	$X^2(1)=0.002$	$p > 0.05$
Trunk Action	Control Chi-Square	Control *p* Value	Experimental Chi-Square	Experimental *p* Value
1.52m & 3.04m	$X^2(1)=4.800$	$p < 0.05$	$X^2(1)=1.105$	$p > 0.05$
1.52m & 4.56m	$X^2(1)=17.143$	$p < 0.05$	$X^2(1)=0.000$	$p = 0$
1.52 m & 6.08m	$X^2(1)=15.152$	$p < 0.05$	$X^2(1)=1.020$	$p > 0.05$
3.04m & 4.56m	$X^2(1)=4.444$	$p < 0.05$	$X^2(1)=1.020$	$p > 0.05$
3.04m & 6.08m	$X^2(1)=3.360$	$p < 0.05$	$X^2(1)=0.003$	$p > 0.05$
4.56m & 6.08m	$X^2(1)=0.137$	$p < 0.05$	$X^2(1)=0.981$	$p > 0.05$

Discussion & Conclusions

Throwing patterns assessed in this study were meant to determine if LE-ASD adults were able to throw a ball similarly to adults that have no neurodevelopmental disorders. Throwing ability was rated from pre-mature to mature according to the utilized rubric. Since the experimental group scored a ~1 for both trunk and stepping action, they are rated in the premature category for the motor skills required to sending objects away from the body.[20] Based on the trunk and stepping assessments in throwing, the adults with LE-ASD scored in the same category that children around the ages of 3-4 score.[20] Developmentally, this could possibly show a delay or deficit in these adults throwing motor skills compared to the adults without LE-ASD.

In terms of stepping action the groups were drastically different. In the LE-ASD group most of the participants did not move their feet from the original starting position. In throwing motions, taking a step helps to get the ball further by increasing the time from push-off on the ground, which leads to increased velocity of wrist and therefore the ball .[21,22] In contrast, the control group took either a step on the same side of the throwing hand or a step with the opposite foot of the throwing arm 55.25% of the time. In both cases the homolateral or contralateral step helped complete the pass to the target and was observed mostly in the longer distances. In the shorter distance throws, both experimental and control groups did not move from their initial foot position and relied more on shoulder and elbow extension to complete the throw to the target. Neither the control nor the experimental group used a long contralateral step to complete their throw, which is seen in highly mature throwing patterns.[20] However, this may not have been observed because it usually occurs when higher ball velocity need to be met to get the ball to targets at longer distances, and we did not have a long distance target.[21]

In regards to trunk movement the experimental group had zero trunk action with no flexion or extension or rotation of the trunk during the follow through of the throw, unless there was slight flexion due to high velocity elbow extension. Trunk rotation has been shown by Escamilla et al.[23] to transfer angular momentum to the throwing arm and therefore increase ball velocity for reaching further targets. They did not utilize any trunk rotation in order to get the ball to the target, instead they use elbow and shoulder extension as the only source of power. The only trunk movement observed was due to high shoulder and elbow extension velocities during the follow through, which resulted in slight flexion of the trunk. However, this flexion does not have any part in the projection of the ball. The lack of trunk movement could be due to a loss of core strength or muscle tone in the body, also know as hypotonia, which Ming et al.[6] noted in 38% of the children in their study from ages 7-18. Another reason for the lack of trunk movement could be that individuals with LE-ASD Crossing the midline refers to one hand or arm crossing over to the opposite side of the body to perform some sort of motor task. Zoia et al.[24] has speculated that children with developmental coordination disorders, such as autism, have trouble crossing the midline due to the advanced need for postural adjustments and increased planning and motor coordination demands. Therefore, they will not follow through across their midline or utilize hip rotation because this will result in a midline cross. In comparison, the control group either had a more mature trunk rotation in order to follow through on throwing medium/long distances or differentiated rotation. Differentiated rotation refers to when the individual twists away from the where the target is and begins forward rotation with the pelvis while the upper spine is still twisting the opposite direction during the longer distance throwing.[20] Both trunk patterns helped the control groups put the ball in a high, curved trajectory and reach the target. Without any trunk rotation the experimental group had a lower, downward ball trajectory, which resulted in a decreased success to the longer distances since there was no follow through or aim of the ball. Typically the unsuccessful throws landed around 1.52-3.04m and were uncatchable.

The LE-ASD group had a similar throwing pattern across all four distances. There was no movement from their initial leg position and there was no trunk movement accompanied by a follow through. In this study, throwing was broken up into the preparatory phase, the throwing phase and the follow through phase (Figures 2,3). During the preparatory phase of the throw, the experimental group had no trunk rotation for wind up and no external rotation of the arm. The only preparation was moving the ball from receiving in an elbow extended position, to flexing their elbow straight up. During the actual throw the only movement besides ticks associated with each individual was elbow extension. This motion created the downward, less powerful trajectory of the ball. There was enough power out of the elbow extension to get the ball to the closer targets, but even when instructed to throw the ball to the target farther away, there was no change in the preparatory phase or throwing phase. The LE-ASD group showed no follow through phase and no cross of the midline during the follow through phase. Conversely, the control adults displayed a follow through phase and had a follow through that crossed the midline when throwing the ball longer distances. Regardless of distance, the LE-ASD adults had no change in their throwing motion and were missing the step, rotation of the trunk and extension followed by flexion of the trunk, which propels the ball into a rounded trajectory towards a target.

The control group had significantly no differences in stepping action across all four distances and always displayed a mature stepping pattern. However, trunk action did not significantly change until after the first distance. For the final three distances the control group had no significant difference in trunk pattern and began to display a more mature trunk-throwing pattern. This exhibits the control groups' ability to adapt to a given task, in this case throwing the ball to a farther target.

Overall the LE-ASD group had a linear, immature throwing pattern that did not allow them to adapt to a specific task of throwing the ball further away from them. Distance did not stimulate a difference in the way they threw the ball. Compared to the control group, which developed a more mature throwing motion as distance increased, the LE-ASD group had no alteration in their throwing patterns. Within the experimental group there was no significant variation when it came to stepping and trunk action. The only trunk action observed was when there was too much power created by elbow extension causing the individual to flex at the hips. Otherwise, before the preparatory phase and after the follow through phase the LE-ASD individuals were in the nearly the same overall body position. Within the experimental group there was significantly little variation within the throwing motion and the individuals were consistent regardless of throw distance. Based upon the age of our participants and the lack of development in throwing motion it is possible that this represents a true deficit as opposed to a delay in motor development.

The limitations of this study are the factors during testing that could not be controlled for. For example, lights hanging from the ceiling got in the way of throwing properly to the longer distances. Therefore, even the control subjects were forced to change their throwing pattern in order to avoid the lights. Also cameras, lab tables, lab equipment, computers, extra researchers and parents were in the room during testing. All of these variables could have been distractions that changed the throwing pattern of the LE-ASD individuals. Also the markers placed on LE-ASD individuals caused some distraction during testing and markers that fell off during testing had to be estimated as to where they were during data analysis. We were also not able to control whether the noted differences in throwing motion are from the disorder or from a lack of opportunity in physical education (PE) classes as children. We could not control for throwing experience since these individuals could have had different therapies, or PE classes while developing.

After assessing the LE-ASD throwing patterns there are a few clinical ramifications. First, it is important to work with and instruct motions such as throwing to LE-ASD individuals as if they are children around the age of 3-4. It is also important to work with LE-ASD individuals before they reach maturity on core strength and stability. With core strength, patients will be able to perform ADLs that include motion away from the body in the arms or throwing patterns in a much more mature matter. This improved strength will help to stabilize their trunks and allow rotations to produce more power from their arms while throwing a ball. In addition to training core strength, therapies should focus on training LE-ASD patients to cross the midline. Many ADLs involve crossing the midline, for example, reaching for a toothbrush with your dominant hand that is located on your non-dominant side. If individuals with LE-ASD could be trained to cross their midline, their ability to perform ADLs, as well as their quality of life could increase. It is also important to include mirroring, or demonstrating a skill, into therapy. Individuals with this disorder have a much easier time mirroring a motion than they do performing it with no instruction at all. If mirroring were introduced into therapies where throwing motions were involved, there may be a maturation of throwing patterns from that alone.

There are also some adaptive physical education (PE) ramifications that could potentially help teachers dealing with LE-ASD individuals teach throwing patterns. Adaptive PE teachers could implement a core-strengthening program in order to help with blocked trunk rotation. They could also try to break the throwing motion apart into the preparatory, throwing and following through phases and emphasize work on each individual phase (Figures 2, 3). This would include teaching elbow flexion and shoulder external rotation for the preparatory phase, trunk rotation during the throwing phase and midline crossing during the follow through phase. By breaking apart the throw and mirroring for individuals with LE-ASD, it is possible that adaptive PE teachers may be able to teach non-linear throwing patterns in this population. These teachers could also focus on throwing distances greater than or equal to 6.08m since this distance had the largest amount of controls throwing in a mature pattern. This shows that closer distances may result in an immature throwing pattern regardless of the LE-ASD individuals throwing abilities since some of the controls did not adapt to a mature throwing pattern until longer distances.

In the future more research should be done to determine the efficacy of core strength, midline crossing and mirroring therapies in rehabilitating individuals with LE-ASD to improve their ability to live more independently. There should also be further research into whether or not throwing a ball translates into every day tasks and what tasks specifically would be affected by teaching an individual with LE-ASD how to throw a ball properly. Lastly, there should be more research in the movement of adults with LE-ASD since most research is focused on children. These adults have a long life expectancy and it is important to be able to improve their quality of life through research.

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