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Methods and Professionals Involved in Evaluating Postural Control in the Autism Spectrum Disorder Population: A Systematic Review

Christina Melora
The Graduate Center, City University of New York

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METHODS AND PROFESSIONALS INVOLVED IN EVALUATING POSTURAL CONTROL IN THE AUTISM SPECTRUM DISORDER POPULATION: A SYSTEMATIC REVIEW

by

CHRISTINA MELORA

A capstone research project submitted to the Graduate Faculty in Audiology in partial fulfillment of the requirements for the degree of Doctor of Audiology, The City University of New York

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CHRISTINA MELORA

This manuscript has been read and accepted for the Graduate Faculty in Audiology in satisfaction of the capstone research requirement for the degree of the Au.D.

DATE

Barbara E. Weinstein, Ph.D.
Faculty Mentor

DATE

John Preece, Ph.D.
Executive Officer
Abstract

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CHRISTINA MELORA

Advisor: Barbara E. Weinstein, Ph.D.

The objective of this systematic review was to determine the methods in which postural
stability and control are being quantified in persons with Autism Spectrum Disorder (ASD), with
what instrumentation and which healthcare professionals are included in this process. It is well
studied that persons with Autism Spectrum Disorder (ASD), which now include those with
Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS) and Asperger Disorder,
often suffer from vestibular modulation abnormalities (Rogers & Ozonoff, 2005; American
Psychiatric Association, 2013.) These individuals may present with either an under- or over-
responsiveness to vestibular inputs resulting in a variety of repetitive behaviors or deviations in
gait and postural control (Ben-Sasson et al., 2009). In total, 14 studies were analyzed. The review
revealed that instrumentation used to study postural control and ASD included: 1) industry-
standard static forceplates, 2) electromagnetic motion trackers, 3) the Nintendo Wii balance Board
and 3) computerized dynamic posturography. Background of all authors involved was identified
in order to determine which professionals are involved in assessing balance in the ASD population.
Of the 57 authors, 54 backgrounds were able to be identified and were found to be one of the following: psychologist, medical doctor, kinesiologist, biotechnology specialists, occupational therapist, engineer, optometrist, neuroscientist, physicist, statistician, or biologist. With audiologists being balance experts whom are also familiar with the above-named instrumentation, it is essential that they too participate in this area of research.
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Introduction

AUTISM SPECTRUM DISORDER

It is well studied that persons with Autism Spectrum Disorder (ASD), which now include those with Pervasive Developmental Disorder- Not Otherwise Specified (PDD-NOS) and Asperger Disorder, often suffer from vestibular modulation abnormalities (Rogers & Ozonoff, 2005; American Psychiatric Association, 2013.) These individuals may present with either an under- or over-responsiveness to vestibular inputs resulting in a variety of repetitive behaviors or deviations in gait and postural control (Ben-Sasson et al., 2009). Dysfunction in modulating this sensory input has long been studied, including not only vestibular stimulation, but also taste, touch and smell, have been described (Kern et al., 2006).

ASD is defined as group of developmental disabilities that may cause significant social, communication and behavioral challenges (American Psychiatric Association, 2013). The use of “spectrum” in this diagnosis characterizes the range of presentations seen within one disorder, with causes believed to be both genetic and environmental. The diagnostic criteria put forth by the Diagnostic and Statistical Manual of Mental Disorders, Fifth Addition (DSM-V) includes five major criteria. To meet the diagnosis criteria, an individual must first show “persistent deficits in social communication and social interaction across multiple contexts”, including deficits in social-emotional reciprocity and use of non-verbal communication in social interactions (American Psychiatric Association, 2013). Poor pragmatic skills are often evident, such as lack of eye contact and appropriate body language, resulting in failure to engage in typical back and forth conversation. The second major criterion is “restricted repetitive patterns of behavior, interests, or activities” due to hypo and hyper reactions to sensory input. This may include any of the
following, but is not limited to: repetitive speech such as intonational noise making and squealing or repetitive motor movements such as rocking, flapping, clapping and teeth grinding. Also included is a markedly abnormal posture, including toe walking. The DSM-V states “the child’s symptoms must be present in early developmental period and cause clinically significant impairments in social, occupational or other important areas of current functioning”. Ultimately, these types of behaviors noted in a child are separate and distinct from issues such as low IQ or global delays. (American Psychiatric Association, 2013).

A severity scale is used to classify individuals along the spectrum with ASD based on their level of functioning. There are three severity levels, ranging from Level 1 to Level 3, indicating degree of support needed (American Psychiatric Association, 2013). Children with Level 1 ASD display noticeable deficits without any support, however, minimal support is needed. Children with Level 3 ASD display severe deficits even with very substantial support, and engage in little-to-no speech and/or social interactions (American Psychiatric Association, 2013). Although social and communication deficits are typically highlighted in ASD, global sensory defensiveness and sensory integration deficits are often present. Aversion to other stimuli such as light, touch or odors are not uncommon in this population (Kern et al.,2006). It has been well documented that individuals with Autism Spectrum Disorder (ASD) have a disturbance in sensory integration and modulation, including vestibular, visual and somatosensory inputs (Kanner & Ritvo, 1968; Bejerot & Humble, 2013; Doumas, McKenna, & Murphy, 2016).

ASD affects 1 in 68 children, and is significantly more common in males than in females. (The Centers for Disease Control (CDC) & Prevention, 2015). More recently, a government survey of parents in the United States conducted through the CDC’s National Center for Health Statistics suggested that as many as 1 in 45 individuals between the ages of 3 and 17 are affected by ASD.
The average age of diagnosis of ASD and PDD-NOS is approximately 4 years, with a diagnosis of Asperger Disorder noted to be later at an average of 6 years of age (Christensen, 2016).

Hand flapping, spinning, jumping and rocking are several hallmark repetitive behaviors in children with autism is caused by under- or over-responsiveness to vestibular input (American Psychiatric Association, 2013). Kanner and Ritvo (1968) described the dynamic nature sensory modulation in persons with Autism with their “Perceptual Inconsistency Theory”. This theory provides an explanation for how processing of sensory information may change from one moment or day to the next. It is not only sensory modulation, but also sensory integration, that may have an effect on these behaviors. It is has been commonly studied that repetitive behaviors and sensory processing are correlated with one another (Rogers & Ozonoff, 2005). Researchers have thus found that restricted, repetitive behaviors are related to poor postural stability and that even, perhaps, postural stability is affected by IQ (Travers et al., 2013; Minshew et al., 2004; Radonovich, Fournier & Hass, 2013).

THE VESTIBULAR SYSTEM

The vestibular system includes both peripheral and central components: the bony labyrinth structure of the inner ear, the vestibulocochlear nerve and various areas of the cortex. This system is responsible for maintaining balance, which is defined as a “complex process involving coordinated activities of multiple sensory, motor and biomechanical components. (Jacobson & Shepard, 2008).

Three sensory inputs to the system that are critical in effectively coordinating balance are visual, vestibular and somatosensory. The most peripheral portion of the vestibular system, located in the inner ear, is comprised of a membranous labrynth structure. Each ear includes three fluid-
filled semi-circular canals (SCC), the cupula and two otolithic organs, namely the utricle and the saccule.

The SCCs are filled with endolymph and are responsible for regulating rotational, angular movements, while the otolith organs regulate linear movements, such as vertical and horizontal (Jacobson & Shepard, 2008). There are three SCCs within each ear: the horizontal, anterior and posterior canals, each responsible for detecting particular movements of the head. The fluid in an individual’s horizontal SCC shifts in response to rotational movements around the vertical plane, while latter two canals are responsible for rotations around the frontal and sagittal planes (Jacobson & Shepard, 2008). The end of each SCC is relatively enlarged, which are the ampulla (Jacobson & Shepard, 2008). Filling the ampulla is the crista, which serves as barrier from the vestibule. Within this structure are sensory cells, the kinocilia and stereocilia three to five microns in diameter (Jacobson & Shepard, 2008). The endolymph makes contact with these sensory cells, which are very sensitive to movements. Deflection of the stereocilia toward the kinocilia causes the cell’s membrane potential to depolarize, leading to excitation. The deflection of the stereocilia away from the kinocilia causes the cell’s membrane potential to hyperpolarize, leading to inhibition. A head turn to the right or left leads to excitatory potentials ipsilateral to that side (Jacobson & Shepard, 2008).

The two otolithic organs, the saccule and the utricle, contain sensory cells that sit on the maculae called otoconia. The otoconia are responsible for linear acceleration such as up-and-down or side-to-side movements of the head. Like stereocilia, motion of otoconia cells toward the kinocilia result in excitation, and visa versa (Jacobson & Shepard, 2008).

It is in the internal auditory canal (IAC) that the central portion of the vestibular system begins. The vestibular nerve cells receiving input to the brain are located in Scarpa’s ganglia,
where the vestibular nerve meets the cerebellopontine angle (CPA). The vestibular nerve divides into the superior and inferior ipsilateral pathways, stimulating the horizontal/anterior SCCs and the posterior SCC, respectively. The superior vestibular nerve extends into the medial vestibular nuclei, nodulus and flocculus, and the inferior vestibular nerve extends to the medial, lateral and inferior nuclei. (Jacobson & Shepard, 2008).

Working with the vestibular system, the visual and somatosensory systems are critical in effectively coordinating balance with inputs allowing individuals to accurately determine center of gravity and activate muscles to remain standing in a stable, upright position (Jacobson & Shepard, 2008). Visual input provides the knowledge of one’s surroundings, and is one of the most important forms of afferent feedbacks one can receive (Jacobson & Shepard, 2008). When an individual is able to keep their eyes open during a balancing task, they are able to focus on a fixed point as support. Somatosensory inputs are processed by sensing the stability of our feet on the support surface. When a surface is stable, it is typically easy for one to stand in a stable fashion without utilizing any additional input. Vestibular inputs compute accelerations of the head, in and from all directions, relative to space; with vision available, vestibular inputs control the eyes, gaze, and in turn our head, in order to stabilize images on the fovea (Jacobson & Shepard, 2008).

Postural stability is achieved when “the center of mass of the body is maintained within the base of support or stability boundary” and “by maintaining the body’s spatial position and orientation within specific limits of the stability boundary” (Bagchee et al., 1998). When evaluating one’s stability of balance, each of these senses may be made available or unavailable to either favor or disrupt use. For example, in a balancing task, a patient may be asked to stand upright on a stable surface with their eyes open. In this example, both visual and somatosensory inputs are being favored since the individual was able to keep their eyes open, and were standing
on a stationary surface. However, if the patient was asked to close their eyes and stand on a less stable surface, such as a piece of foam, both visual and somatosensory senses would be considered to be disrupted. In a case of the latter example, when both of these senses are disrupted or not available, it has been found that vestibular input then becomes much more essential in maintaining a stable posture (Jacobson & Shepard, 2008). The importance of one input over another shifts depending upon environmental changes, and relies on rapid sensory integration processing (Doumus, McKenna & Murphy, 2015).

METHODS OF ASSESSING POSTURAL CONTROL

As Nash (2014) outlines, there are two main categories of postural control assessments: performance tests and posture-evoked response tests (Jacobson & Shepard, 2008). Each of these methods utilizes different types of data to explain different aspects of an individual’s postural control. While performance tests give information on postural stability and movement strategies, which are relevant to activities of daily living, posture-evoked response tests provide diagnostic-specific information such as latency, strength and pattern of responses when one’s balance is disturbed. Performance tests are highly dependent upon patient motivation, while posture-evoked measures are unaffected (Jacobson & Shepard, 2008). Many studies have combined each of these approaches in their battery of tests to measure postural stability in the ASD population.

The simplest way of examining postural control with no equipment needed is the Romberg Test (Hain, 2016). First described in the 1850’s, the Romberg Test was initially used to detect neurosyphilis which would often affect the spinal cord and reduce vestibular feedback. While advanced-stage neurosyphilis is no longer a prevalent issue in today’s society, the Romberg test is still used as a gross measure of balance and postural stability (Hain, 2016). Popularly today, this
test is used by physician’s to evaluate function of the cerebellum when and to determine change over time, potentially during rehabilitation (Hain, 2016; Jacobson & Shepard, 2008). For this test, one is instructed to stand still with their feet together in both the vision-allowed and vision-denied conditions. Sway under each condition is monitored, typically for 30 seconds; if the vision-denied condition caused a “substantial increase” in sway, or resulted in a fall, then a peripheral pathology was determined to be present. This is attributed to the fact that somatosensory input serves as the primary information needed for balance function while vision is secondary (Jacobson & Shepard, 2008). Various versions of the Romberg test have been performed, such as the “modified Romberg” utilizing a piece of foam to destabilize the surface (Hain, 2016). Furthermore, if individuals are able to successfully complete these task, The Tandem Romberg is employed. For this test, the patient is instructed to “stand with the feet in a straight line with the heel touching the toes of the other foot”, which is again recorded for 30 seconds. Going one step further, a patient may be asked to stand on one foot while being timed.

**POSTURAL CONTROL IN PERSONS WITH AUTISM SPECTRUM DISORDER**

As discussed above, sensory integration is essential in maintaining a constant, stable posture and adequate center of gravity. Clumsiness has been noted for activities of daily living in persons with autism, and some have speculated this is due to poor sensory integration, and therefore, poor postural stability. As reported by Bejerot & Humble (2013) there is a significant link between visuo-spatial deficits discussed above, and poor motor coordination (2013). Dewey & colleagues (2007) as well as Ghaziuddin and colleagues (1994) estimated that 60-80% of individuals with ASD are classified as having poor motor coordination. This “clumsiness” is strongly associated with peer victimization, as poor motor function interferes with typical socialization (Bejerot & Humble, 2013). In view of this, vestibular function, in particular postural
stability is deemed an important area of study. Nickle et al., (2013) reported that very early signs of postural stability weakness during infancy are evident. Nickel et al. (2013) found that infants with a diagnosis of ASD later in life, demonstrated greater difficulty sitting unsupported at 6 months of age, when compared to typically developing children (Nickel et al., 2013).

Early on in this area of study, Kohen-Raz, Volkman and Cohen (1992) studied a group of 91 children with autism, 18 children with mental retardation and 166 typically developing (TD) children. They examined each group’s ability to maintain postural control. They found that children with autism had more difficulty in maintaining postural control than both TD and mentally retarded children (Kohen-Raz, Volkman & Cohen, 1992). Similar results have since been found and replicated thoroughly throughout the literature (Molloy, Dietrich and Bhattacharya, 2003; Minshew et al., 2004).

Molloy, Dietrich and Bhattacharya (2003) evaluated the postural stability in eight males between the ages of 5-12 ASD, as compared with age-, race- and gender-matched typically developing children. Results suggested that persons with ASD demonstrated greater difficulty maintaining postural control, and presented with an “overreliance” of visual afferent input in order to maintain balance, as compared with typically developing children. That is, they demonstrated significantly greater difficulty maintaining postural when presented with less afferent inputs (Molloy, Dietrich and Bhattacharya, 2003). Similar results were found the following year in a group of 79 ASD children, when compared with 61 TD children (Minshew et al., 2004). Interestingly, different results were found in an older ASD population, where increase in afferent inputs did not improve postural stability, which was suggested by the authors that perhaps postural stability has a maturational component for development (Travers, Powell, Klinger & Klinger, 2013).
Research Questions

Audiologists are defined and trained as both hearing and balance specialists (ASHA, 2004) yet there appear to be a dearth of studies on ASD and the conducted by audiologists. It is important to determine if the methods in which balance are evaluated in the ASD population are within the scope of practice of audiologists. If so, it is critical to ensure that these professionals are currently partaking in this conversation. Understanding balance dysfunction in this population will allow audiologists to channel their balance expertise in order to improve the quality of life of children with ASD.

In the literature, postural control in persons with autism has been studied and systematically reviewed, including related motor impairments and sensory integration issues; however, the methods and by which professionals it has been investigated by has not been analyzed. In this systematic review, the following research questions are explored:

1. What are the methods of studying postural control in persons with Autism Spectrum Disorder?

2. Which groups of professionals are involved in research of evaluating postural control in persons with autism spectrum disorder?
Methods

Four electronic databases were searched, Google Scholar, Pub Med, Medline and CUNY OneSearch, using a combination of any of the following search terms: autism, ASD, Aspergers, pervasive developmental disorder, PDD, balance, posture, postural control, stability, vestibular, sensory, integration, postural sway and equilibrium. Only studies from peer-reviewed scholarly journals were included, from 1992-2017. Studies were included with participants who were both males and females, and between the ages of 5 and 52. Eighteen abstracts in total were reviewed, and ultimately 16 were included in the systematic review. The studies included were experimental in nature and were an independent measures/between group design. Of 16 studies with both an experimental and control group, 16 matched participants for age, 8 matched for gender, and 7 matched for IQ. Studies were analyzed to determine 1) method of evaluating postural control and 2) professionals evaluating postural control. In all studies included, individuals with ASD were given the diagnosis by a psychologist or psychiatrist, following guidelines from the DSM (edition of the DSM dependent upon year of the study).

In order to determine the professionals involved in this area of study, the background of each author was researched to determine their subject of expertise, and when applicable, their specialty within their field of study. Fifty-seven authors who contributed to the 16 studies included in this review were identified. Information was obtained through the following sources: university websites, LinkedIn and Wikipedia. Ultimately, area of expertise was identified in 53 of these authors.
Results


*Static Posturography*

Static Posturography techniques were utilized in 15 of the 16 studies included in this systematic review.

*Industry-Standard Static Forceplates*

Industry-standard static forceplates instrumentation was employed using static posturography techniques in a total of eight of the studies analyzed in this review (Molloy, Dietrich & Bhattacharya, 2003; Ghanouni et al., 2017; Kohen-Raz, Volkman & Cohen, 1992; Memari et al., 2013; Memari et al., 2014; Fournier et al., 2010; Gepner et al., 1995; Gepner & Mestre, 2002; Chang, et al., 2010; Greffou et al, 2011).

Force platforms now used in diagnostic testing of balance and posture have allowed professionals to quantify measures of sway, rather than subjective observations used previously (Jacobson & Shepard, 2008). These measures may be displayed in either a numeric and graphical manner (Valis et al., 2012). The type of testing examines the center of foot pressure for measures such as sway, stability, symmetry and gait initiation (Jacobson & Shepard, 2008; Valis et al., 2012; Fournier at al., 2010). Early on in this work of building upon the Romberg test, Black et al. used a fixed force plate interfaced with a microprocessor that would detect oscillations of a standing
subject (1982). Specifically, he used a Model 9261A piezoelectric force plate (1982) from Kistler (Figure 1). The microprocessor was responsible for amplifying recorded forces which were projected onto the surface, received by vertical-force sensors analyzing movement every .1 seconds (Black et al., 1982). Subjects may be asked to stand on such a platform under various conditions, for example, with or without vision and/or a stable or unstable surface, which is referred to as a sensory organization test (SOT) (Jacobson & Shepard, 2008).

This technology was first used with the ASD population to evaluate postural stability in 1992 (Kohen-Raz, Volkman & Cohen). A group of investigators studied a group of 91 children with Autism, 18 children with mental retardation and 166 TD children using a SOT. This study indeed found less postural stability in the ASD population, and furthermore, noted maturational differences in the mentally retarded and TD groups, but not in the ASD group (Kohen-Raz, Volkman & Cohen, 1992). In 2003, postural stability was again evaluated using a SOT, comparing a group of children with ASD and TD children (Molloy, Dietrich & Bhattacharya). Each subject was asked to “stand as quietly as possible with arms at their sides for 30 seconds” under four combinations of the following conditions: eyes open or eyes closed, while either standing on the solid force platform or standing on a piece of foam. Each of the above tasks varied in amount and type of afferent feedback made available to the participant. Under each condition for each participant, the average sway area (SA) of two trials was accepted for analysis, and plotted on stabilograms (Figure 2) (Molloy, Dietrich & Bhattacharya, 2003). Results suggested that persons
with ASD demonstrated greater difficulty maintaining postural control in the “modified somatosensory” condition, that is, while standing on the piece of foam. Furthermore, regardless of the modified vs unmodified somatosensory condition, the ASD group presented with an “over-reliance” of visual afferent input in order to maintain balance, as compared with typically developing children. That is, they demonstrated significantly greater difficulty maintaining postural control with their eyes closed despite all other conditions (Molloy, Dietrich & Bhattacharya, 2003). Sway area using static force plates were used in several other studies, revealing similar results of increased sway area and postural instability in the ASD population (Memari et al., 2013; Memari et al., 2014).

In one study, the effects of visual versus auditory tasks on postural control were examined (Memari et al., 2014). While standing quietly on a force plate, participants were asked to perform a cognitive task that was either visual or auditory in nature. The experimental ASD group presents with increased postural sway as compared with the control TD across each condition. Interestingly, it was more difficult for ASD children to maintain postural control while performing a visual task than auditory, suggesting an over dependence of visual afferent input in order to maintain postural control (Memari et al., 2014).

Most recently, postural stability was studied to examine the effects of social visual stimuli versus non-social visual stimuli in participants with ASD as compared with TD individuals...
(Ghanouni et al., 2017). For each trial, the children were instructed to stand quietly for 20 seconds on the force plate measuring postural sway while looking at different images on the wall. Social-visual afferent stimuli included images of faces, while non-social stimuli included images of a random object, for example, a drum. The average of two trials was accepted for analysis. Postural sway was overall significantly larger for ASD than TD children for all trials. Furthermore, ASD children were more greatly affected by social stimuli, especially those with a greater-rated severity of autism. Ultimately, it was found that postural stability of children with ASD was affected by social vs. non-social stimuli, while TD children were not significantly affected (Ghanouni et al., 2017).

Gait initiation requires dynamic postural control and may also be evaluated using a static footplate system (Fournier et al., 2010). As it had been well documented that children with ASD present with a larger sway area, a group of investigators were interested in how this may affect locomotion. Gait initiation is defined as “a functional task requiring voluntary destabilization of the whole body’s center of mass and transition from a large to small base of support”; furthermore, it “requires the integration of multiple sensory and motor pathways so that the central nervous system can coordinate the anticipatory/postural and intentional movement components” (Fournier et al., 2010). The first part of this study was similar to the above, whereas children were asked to stand quietly and “as still as possible” for 20 seconds on a static force platform while sway area was recorded. Similar results were found, whereas the ASD group produced a significantly larger sway area than did the TD group. Participants were then asked to initiate their gait for 4 meters. Dynamic postural stability was calculated by looking at center of mass and center of pressure to determine participant’s ability to remain stabilized when shifting away from the base of support (Fournier et al., 2010). As hypothesized, children with ASD in this study were confirmed to have
less dynamic postural stability, which would theoretically affect activities of daily living that require more coordinated movements, such as playing sports (Fournier et al., 2010).

**Static Forceplates & Virtual reality**

This instrumentation was employed using static posturography techniques in two of the studies included in this review (Gepner et al., 2005; Gepner & Mestre, 2002).

In 1995, Gepner and colleagues first used a virtual reality setup to evaluate postural instability during visual motion in a group of young children with an ASD diagnosis. They advocated for this method of study as they believed it required limited active participation minimized potential confounding variables by taking advantage of reflex-like movements. Participants were standing on a force platform while visual stimuli were projected onto a screen located approximately 4 meters away. The room was completely dark as to not give “any visual cues from providing a reference gram for the stable environment around the stimulus”.

Participants were instructed to stare at the center of the stimulus with gaze at eye level. The stimulus was a radial gradient which appeared to be a tunnel with depth. Data was analyzed to determine overall postural instability in the following eight conditions: eyes closed, eyes open in the static display, and eyes open with 6 different speeds of visual stimuli (Gepner et al., 1995). Participants were found to have a hypo-reactivity to the visual stimuli, but were generally more unstable. A second study employing this same technique was conducted several years later to determine if similar findings would be found in the Asperger syndrome population; at this point in time, Asperger Syndrome and Autism were classified under two different diagnoses in the DSM-IV (Gepner & Mestre, 2002). This replication and extension of their previous study revealed that while participants with Asperger syndrome had poorer postural stability than TD
children, autistic individuals presented with less postural control than both the Asperger and TD groups (Gepner et al., 2005; Gepner & Mestre, 2002).

*Electromagnetic Motion Tracker- Flock of Birds*

This instrumentation was used utilizing static posturography techniques in two of the studies analyzed in this review (Chang et al., 2010; Greffou et al., 2011). This system evaluates postural stability based on motion of the head or torso, with sensors located on a set of goggles, helmet or placed on the lower back (Chang et al., 2010; Greffou et al., 2011). Flock of Birds (FOB) technology was first used in 2010 by Chang and colleagues. Participants were asked to stand still with their hands in their pockets for 70 seconds while either staring at a blank screen, or while completing a cognitive task of searching for target Arabic numerals. They were positioned halfway between the target and extended range transmitter (ERT), with approximately half a meter on each side, as pictured below. In order to minimize head movement, the height of targets were at eye level, and this case, sensors were positioned on a helmet worn by the participant, as pictured in Figure 3. As expected, the ASD group presented with heightened postural activity as compared with the TD group; however, both groups showed decreased activity during the cognitive search task (Chang, et al., 2010).
Flock of Birds & Virtual Reality

One of the studies included in this review combined FOB technology and virtual reality to assess postural activity in persons with ASD (Greffou, et al., 2011). Greffou and colleagues described their methods as a “fully immersive virtual reality approach .. in a sway-inducing virtual reality tunnel” (2011). Two different age groups were included in this study for both the experimental and control groups (12-15 and 16-33 years old) in order to examine the effect of development on postural reactivity and stability.

Participants were instructed to stand in an 8 x 8 x 8 feet room that is apart of the CAVE system (Figure 4), placing them in the middle of a virtual environment of a three-dimensional spinning tunnel. Rather than the magnetic motion sensors placed on a helmet, participants wore a set of stereoscopic goggles with such sensors; therefore, postural activity is still being measured at the level of the head. Participants were instructed to stand as still as possible while staring at a red dot, placed at eye level in the CAVE. Static conditions were used as a control, while dynamic served as the experimental visual environments. In the static condition, the tunnel did not rotate; both vision allowed and vision denied conditions were included. In the dynamic conditions, the tunnel rotated at three various frequencies with vision allowed. Once again, it was found that postural hypo-reactivity to visual information was present in the ASD group when compared with the TD group (Greffou, et al., 2011).

**Nintendo Wii Balance Board**

This instrumentation was utilized in conjunction with static posturography techniques in two of the studies analyzed in this review (Travers et al., 2012; Stins et al., 2015). The advent of gold-standard force plate technology such as NeuroCom’s Smart Equitest, has been proven to provide critical information regarding balance and postural control, and when available, is often included in vestibular diagnostic batteries (Stewart et al., 1999; Ek-Kashlan et al., 1998; Yardley et al., 1998; Sargent et al., 1997). However, accessibility of this instrumentation to balance professionals is often limited due to inability to purchase or transport. In view of this, Nintendo’s Wii Balance Board (WBB) has been tested and validated as a tool which may be used to obtain quantitative information regarding force distribution and oscillations of sway (Clark et al., 2009). This video game controller has not only been utilized as a tool for vestibular rehabilitation, but also as a device to collect state-of-the-art quality data for research purposes in participants of all ages (Clark et al., 2009; Young, Ferguson & Brault, 2011; Chang et al, 2013).

Interestingly, a group of researchers used the WBB to evaluate postural stability in the ASD population (Travers et al., 2012). Postural stability was quantified in terms of balance time, amount of drift, amount of postural waver, and symmetry. Balance time was defined as “the length of time a person is able to hold a posture”, drift as “the time-related tilting of the body that may occur when trying to maintain balance in static postures”, waver as “the variability in balance that is not accounted for by systematic drift over time”, and symmetry as the degree to which the left and right sides of the body are exerting equal pressure during a posture” (Travers et al, 2012). Participants, which included 26 individuals with ASD and 26 TD individuals were given a sensory organization test including the following conditions: standing on two feet vision allowed, standing on two feet vision denied, standing on one foot vision allowed, and standing on one foot vision
denied. Results for balance times revealed no significant differences between groups when asked to stand still for 45s on two feet in both vision conditions, however, TD participants were able to balance longer on one leg than ASD participants. In terms of postural drift, the ASD group presented with a significantly larger degree. Differences in waver and symmetry between groups were not found to be statistically significant, however, ASD participants tended to stand less symmetrically during all two-legged standing trials (Travers et al., 2012).

Three years following, a group of investigators again used the WBB with this population (Stins et al., 2015). Participants were asked to stand on the WBB to measure center of pressure under the following four conditions while standing as still as possible: eyes open, eyes closed, performing a cognitive task with eyes open and performing a cognitive task with eyes closed. The cognitive task had participants concentrate on a list of words, memorize as many as possible and recall them at the end of each trial. Results were analyzed to determine deviation of sway area, the distance between postural exertions in each direction, and the summed length of postural exertions. As previously found, the ASD group presented with a significantly larger reliance on vision in maintaining postural control as compared with the TD group (Kohen-Raz, Volkman & Cohen, 1992; Stins et al., 2015).

**Computerized Dynamic Posturography**

One of the 16 studies of this systematic review utilized Computerized Dynamic Posturography (CDP), which is defined as “a quantitative method for assessing upright and in-place balance function under a variety of tasks that effectively simulate the conditions encountered in daily life (Minshew et al., 2004; Jacobson & Shepard, 2008). This type of testing evaluates sensory, motor and biomechanical components of balance, and how to use them in both
isolation and integration (Jacobson & Shepard, 2008). Clinically, this test is used to track compensation of balance following vestibular rehabilitation exercises (Hain, 2016).

An SOT is typically completed when using this platform posturography technology. While secured in a harness, the patient is asked to maintain balance through a series of progressively more difficult tasks, as outlined in Table 1 (Jacobson & Shepard, 2008; Hain, 2017).

<table>
<thead>
<tr>
<th>Condition</th>
<th>Vision</th>
<th>Surface</th>
<th>Visual Surround</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Eyes Open</td>
<td>Stable</td>
<td>Stable</td>
</tr>
<tr>
<td>2</td>
<td>Eyes Closed</td>
<td>Stable</td>
<td>Stable</td>
</tr>
<tr>
<td>3</td>
<td>Eyes Open</td>
<td>Stable</td>
<td>Sway-Referenced</td>
</tr>
<tr>
<td>4</td>
<td>Eyes Open</td>
<td>Sway-Referenced</td>
<td>Stable</td>
</tr>
<tr>
<td>5</td>
<td>Eyes Closed</td>
<td>Sway-Referenced</td>
<td>Stable</td>
</tr>
<tr>
<td>6</td>
<td>Eyes Open</td>
<td>Sway-Referenced</td>
<td>Sway-Referenced</td>
</tr>
</tbody>
</table>


Clinically, patients are asked to stand upright and as still as possible during the above conditions three times, with trials lasting 20 seconds (Jacobson & Shepard, 2008). In a 2004 study, participants were asked to complete one to two trials for the first three conditions, and two to three trials for the final three conditions (Minshew, et al.). From the average of these 15-second-long trials, an equilibrium score was calculated depending on the amount of anterior-posterior sway; a score of 100 indicated no sway, and 0, a fall. Results of this test were compared between a group of individuals with ASD and a TD control group. Expectedly, the ASD group presents with postural instability as compared with the TD control group, which was exacerbated by disrupting somatosensory input. Once again, over-reliance of visual information to improve stability reinforces that the ASD population has issues with sensory integration.
RESEARCH QUESTION #2. Which Groups Of Professionals Are Involved In Research In Postural Control In Persons With Autism Spectrum Disorder

The backgrounds of 53 of the 57 authors were identified. Each of these 53 authors fell into one of the ten following areas of expertise: psychologist (25), medical doctor (13), kinesiologist (3), biotechnology specialists (3), occupational therapist (2) engineer (2), optometrist (1), neuroscientist (1), physicist (1), statistician (1), or biologist (1). Four of the authors’ expertise was not able to be identified.

Table 2. Areas of Expertise of each lead and co-author in alphabetical order.

<table>
<thead>
<tr>
<th>AUTHOR</th>
<th>EXPERTISE</th>
<th>RESEARCH STUDY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beek, Peter</td>
<td>Psychologist-Cognitive</td>
<td>Attentional and sensory contributions to postural sway in children with autism spectrum disorder (2015)</td>
</tr>
<tr>
<td>Bertone, Armando</td>
<td>Psychologist- Neuro</td>
<td>Postural hypo-reactivity in autism is contingent on development and visual environment: a fully immersive virtual reality study (2012)</td>
</tr>
<tr>
<td>Collinsworth, Amy</td>
<td>Biotechnology Specialist (Imaging)</td>
<td>Postural orientation and equilibrium processes associated with increased postural sway in autism spectrum disorder (ASD) (2016)</td>
</tr>
<tr>
<td>Name</td>
<td>Profession</td>
<td>Research</td>
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<tr>
<td>Conroy, Kaitlin</td>
<td>Psychologist</td>
<td>Postural orientation and equilibrium processes associated with increased postural sway in autism spectrum disorder (ASD) (2016)</td>
</tr>
<tr>
<td>Emck, Claudia</td>
<td>Biologist</td>
<td>Attentional and sensory contributions to postural sway in children with autism spectrum disorder (2015)</td>
</tr>
<tr>
<td>Faubert, Jocelyn</td>
<td>Physicist</td>
<td>Postural hypo-reactivity in autism is contingent on development and visual environment: a fully immersive virtual reality study (2012)</td>
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<tr>
<td>Furman, Joseph</td>
<td>Medical Doctor- Neurologist</td>
<td>Underdevelopment of the postural control system in autism (2004)</td>
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<tr>
<td>Name</td>
<td>Discipline</td>
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<tr>
<td>Greffou, Selma</td>
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<td>Hahler, Eva-Maria</td>
<td>Psychologist</td>
<td>Postural hypo-reactivity in autism is contingent on development and visual environment: a fully immersive virtual reality study (2012)</td>
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<tr>
<td>Hallac, Rami</td>
<td>Biotechnology Specialist (Imaging)</td>
<td>Postural orientation and equilibrium processes associated with increased postural sway in autism spectrum disorder (ASD) (2016)</td>
</tr>
<tr>
<td>Hanssens, Jean-Marie</td>
<td>Optometrist</td>
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<tr>
<td>Jones, Bobby</td>
<td>Statistician</td>
<td>Underdevelopment of the postural control system in autism (2004)</td>
</tr>
<tr>
<td>Kane, Alex</td>
<td>Medical Doctor- Pediatric Surgeon</td>
<td>postural orientation and equilibrium processes associated with increased postural sway in autism spectrum disorder (ASD) (2016)</td>
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23
<table>
<thead>
<tr>
<th>Name</th>
<th>Profession</th>
<th>Publications</th>
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<tr>
<td>Mestre, Daniel</td>
<td>Psychologist</td>
<td>Responses in Individuals with Autism Spectrum Disorder (2017)</td>
</tr>
<tr>
<td>Minshew, Nancy</td>
<td>Medical Doctor - Psychiatrist</td>
<td>Underdevelopment of the postural control system in autism (2004)</td>
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<tr>
<td>Mosconi, Matthew</td>
<td>Psychologist- Clinical</td>
<td>Postural orientation and equilibrium processes associated with increased postural sway in autism spectrum disorder (ASD) (2016)</td>
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<tr>
<td>Mottron, Laurent</td>
<td>Neuroscientist</td>
<td>Postural hypo-reactivity in autism is contingent on development and visual environment: a fully immersive virtual reality study (2012)</td>
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<tr>
<td>Stins, John</td>
<td>Psychologist</td>
<td>Attentional and sensory contributions to postural sway in children with autism spectrum disorder (2015)</td>
</tr>
<tr>
<td>Sung, KiBum</td>
<td>Medical Doctor</td>
<td>Underdevelopment of the postural control system in autism (2004)</td>
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<tr>
<td>Name</td>
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<td>Sweeney, John</td>
<td>Psychologist-Clinical</td>
<td>Postural orientation and equilibrium processes associated with increased postural sway in autism spectrum disorder (ASD) (2016)</td>
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<tr>
<td>Tillman, Mark</td>
<td>Engineer</td>
<td>Decreased static and dynamic postural control in children with autism spectrum disorders (2010)</td>
</tr>
<tr>
<td>Travers, Brittany</td>
<td>Psychologist</td>
<td>Motor difficulties in autism spectrum disorder: linking symptom severity and postural stability (2013)</td>
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<tr>
<td>Volkmar, Fred</td>
<td>Psychiatrist</td>
<td>Postural control in children with autism (1992)</td>
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<tr>
<td>Wang, Zheng</td>
<td>Psychologist</td>
<td>Postural orientation and equilibrium processes associated with increased postural sway in autism spectrum disorder (ASD) (2016)</td>
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<tr>
<td>White, Stormi</td>
<td>Psychologist- Clinical</td>
<td>Postural orientation and equilibrium processes associated with increased postural sway in autism spectrum disorder (ASD) (2016)</td>
</tr>
<tr>
<td>Ziaee, Vahid</td>
<td>Medical Doctor- Pediatrician</td>
<td>Postural sway patterns in children with autism spectrum disorder compared with typically developing children (2013)</td>
</tr>
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</table>
Discussion

It is well-documented that persons with ASD present with vestibular abnormalities that includes their inability to maintain postural control as well as the TD population (Rogers & Ozonoff, 2005; American Psychiatric Association, 2013). This study aimed to determine the methods in which postural control is studied in the ASD population, as well as the professionals involved in such research. The literature was systematically reviewed to answer the aforementioned questions.

There were two primary techniques in studying postural control in the ASD population, namely static and dynamic posturography. Static posturography was used in 15 of the 16 studies conducted, while CDP was utilized in one. Of the studies utilizing static posturography, there were five types of instrumentation setups used: forceplates alone, forceplates combined with virtual reality, electromagnetic motion trackers, electromagnetic motion trackers, electromagnetic motion trackers combined with virtual reality, and the Wii Balance Board. In order to assess postural control using CDP, investigators utilized a moving platform.

Areas of expertise of 57 authors was investigated, and was able to be identified in 53. There were ten areas of expertise noted: psychology, medicine, kinesiology, biotechnology, occupational therapy, engineering, optometry, neuroscience, physics, statistics and biology. A majority of the researchers in this area were either psychologists or medical doctors. Audiologists were never included.
IMPLICATIONS

It is known that adequate static balance and postural control is essential for proper motor control. As explained by Emck & colleagues (2009), “motor performance and self-perceived motor competence have a great impact on the psychosocial development of children in general” (Emck et al., 2009). In their review, they concluded that children on the autism spectrum demonstrate poor gross motor performance and present with self-perceived motor incompetence. It is clear that individuals not only have these difficulties, but are also self-aware of such. It has been revealed that individuals who live a more active lifestyle present with decreased postural sway, as compared with those who are not (Cheldavi et al., 2014). Poor postural stability and in turn, motor control, may result in isolating behaviors in common social situations of childhood. Individuals who are self-aware of poor coordination may avoid or not be able to partake in activities such as sports and riding a bicycle, which also serve as important to health and wellness. A vicious cycle of anxiety to participate, and therefore, less practice in these tasks may persist (Emck et al., 2009). This fact, paired with the unusual eating habits of ASD individuals may also contribute to higher obesity rates in this population (Curtin et al., 2010).

It is critical that psycho-social support must be provided to individuals presenting with motor control difficulties. These children must learn to cope with this issue that may be a barrier in everyday social situations. In order for children to participate in play at school and at home, they must be able to jump, run and throw. If they are not able to complete tasks such as these, it is known that problems with peer relationships, negative social feedback, poor self-esteem, depression and behavioral issues can ensue (Emck, 2009). Furthermore, vestibular dysfunction may affect oculomotor abilities (Berger, 2002). Difficulty with eye movements may possible impact learning, short-term memory, attention and image retention (Berger, 2002).
Aside from helping individuals emotionally deal with their vestibular weaknesses, assistance must be given to strengthen these areas of dysfunction. In order to determine the appropriate therapy, a therapist must first understand if motor difficulties are contributable to poor motor coordination, learning issues, or both. If potential candidates for therapy, this should be routinely offered to individuals with reported subjective and objective balance and coordination issues.

Cheldavi and colleagues (2014) investigated the effect of an eight-week balance training program in children with ASD. It was revealed that postural control can be improved with interventions with progressive sensory alterations. For each session that occurred three times per week lasting 45 minutes, participants were asked to stand as quietly as possible on a force platform. Individuals were either standing on a thick or thin piece of foam with eyes opened or eyes closed. This type of therapy would not only benefit their objective balance, but their subjective self-perception of poor motor coordination by decreasing anxiety and facing their shortcomings (Cheldavi, et al., 2014).

Berger (2002), a music therapist, reported that her interventions combining movement and music have great potential in treating these patients. She first explained the benefit of using trampoline jumping in her therapy; a continuous disturbance in the vestibular system which jump-starts an adaptive process. Berger (2002) found that “when providing piano music in pulses synchronized with the jumping child, and reinforcing the movement with supportive pulsed lyrics parallelling the humper’s speed, rhythmic momentum of the jumper is sustained quite comfortably. This exercise also aids in the ultimate internalization of rhythm, setting new homeostatic references of adaptive motor pacing” (Berger, p 64-65, 2002).
Audiologists were not involved in any of the studies analyzed in this review. As hearing and balance specialists, their training can extend in the clinic beyond their typical role in order to help a population in need of their expertise. Not only can audiology professionals diagnose vestibular impairments, but may help strengthen these impairments as well. The American Speech-Language-Hearing Association (ASHA) defines the Scope of Practice for audiologists. They declare that audiologists are responsible for providing both diagnostic and rehabilitative services for auditory, vestibular, and related impairments (ASHA, 2004). Particularly, they consult and provide vestibular and balance rehabilitation therapy to persons with both vestibular and balance impairments (ASHA, 2004). Most importantly, audiologists may serve as counselors to individuals having these difficulties. With the association between hearing loss and balance disorders, it is even more critical that audiologists be prepared for these types of clinical cases. This means being included in all big-picture conversations happening within the scope of practice. It is critical that vestibular therapists within audiology teams be involved in the conversation of postural stability in persons with ASD in order to extend assistance to a greater number of individuals. By collaborating with psychologists, physicians, occupational therapists and other related fields, new interventions may be discovered to improve their quality of life to provide more potential opportunities.

Finally, in view of the association between hearing loss and vestibular pathologies an important consideration of rehabilitation programs is hearing status and optimizing audibility to help reduce listening effort and fatigue during rehabilitation. If one’s hearing status is not adequate, vestibular rehabilitation efforts may be affected. Ensuring that patients are adequately amplified, if necessary, is essential. By increased ease of communication to reduce listening effort, cognitive load during therapy can be focused on the task at hand. Future research in this
area should not only include audiologists, but expand on current studies utilizing devices such as FM system during therapy sessions to improve patient outcomes.

LIMITATIONS

Nearly all of the studies in this review employed static posturography techniques in order to assess postural control. While this type of testing correlates with daily life and functional capabilities, it is influenced by patient motivation, focus, cooperation and effort (Jacobson & Shepard, 2008). This may present as problematic when testing a population that often present with comorbidities such as schizophrenia and communication, learning, attentional and behavioral issues (Dvir & Frazier, 2011; Noterdaeme et al., 2001). For evaluating this population, it may be deemed more appropriate to utilize CDP testing, as this type of testing is not under one’s conscious control. Extraneous variables such as fatigue, poor motivation and anxiety are able to easily identified in this type of testing, as these variables typically vary from one recording to the next (Jacobson & Shepard, 2008). Of note, however, CDP instrumentation is often expensive and difficult to transport, resulting in limited utilization across many clinics. In view of this, future research must take special care in eliminating possible extraneous variables such as fatigue and critically analyze results with this in mind.

CONCLUSION

Ultimately, persons with ASD present with a proportionately large number of vestibular abnormalities, one specifically being postural instability. The methods in which these paradigms are explored, through static and dynamic posturography, fall within the audiology scope of practice. There is a clear absence of collaboration between professionals, with a large majority of
investigators being psychologists or medical doctors. A comprehensive approach must be taken in future research to examine postural control in persons with ASD in order to develop effective therapies that can be more routinely performed in a wider variety of settings.
References


