2014

An exploratory study of gait and balance in children with autism spectrum disorders

Krystal Mircovich
University of Richmond

An Exploratory Study of Gait and Balance in Children with Autism Spectrum Disorders

Krystal Mircovich

University of Richmond, Department of Psychology

May 2, 2014

Abstract

Research suggests that children with autism spectrum disorders (ASD) display movement impairments that are distinct from typically developing peers. Results from numerous studies suggest various and inconsistent findings. Therefore, movement differences in children with ASD should continue to be assessed. The current study examined the characteristics of gait and balance in children with ASD, between the ages of 7 and 11, by comparing behavioral observation and parent report. As two of the most frequent behaviors of movement and two of the main movements implicated in neurological disorders, an evaluation of how these behaviors differ in children with ASD will offer a better understanding of this spectrum of disorders to those who are affected, their families, and support services. Gait characteristics and balance abilities were examined in four children with ASD. Parent questionnaires were completed for each participant and compared to behavioral observations. Results supported previous research that suggests that children with ASD exhibit atypical gait patterns. Additionally, parent reports were consistent with behavioral observation. Implications are discussed in detail.

Table of Contents

An Exploratory Study of Gait and Balance in Children with Autism Spectrum Disorders

1. Introduction

Autism spectrum disorders (ASD) are a set of neurodevelopmental disorders that range on a spectrum of severity. Prior to recent changes to diagnostic criteria outlined in the Diagnostic and Statistical Manual of Mental Disorders (DSM), autism has been diagnosed based on the prevalence of three primary symptoms: impairments in verbal and/or nonverbal communication, impairments in social reciprocity or interaction, and presence of repetitive or restricted behaviors (American Psychiatric Association, 1994). According to the DSM-5, children who now display a prevalence of two symptoms, including impairments in social communication/interaction and repetitive or restricted behaviors, will be diagnosed with the broader term of autism spectrum disorders (American Psychiatric Association, 2013).

Despite these changes in the DSM-5, the symptoms required for a diagnosis of an ASD have minimally changed. Subsequently, the newest revision of the DSM fails to include recent evidence of deficits in movement. Specifically, research has shifted focus from socially defined symptoms, based on observation of behaviors, to other potential neurologically defined symptoms of autism. Along with social deficiencies in communication and a frequency of repetitive behaviors or interests, research suggests that children with autism also demonstrate differences in both gross and fine motor abilities, implying deficits in neurology. However, these motor symptoms are secondary to the more salient social and communication symptoms of ASD, and impairments in motor abilities have often been categorized as "associated symptoms" (Ming, Brimacombe, and Wagner, 2007) rather than core diagnostic symptoms in the DSM-5. Nonetheless, a prevalence and better understanding of deficits in general movement abilities could offer an additional indicator for early diagnosis (Ozonoff, Young, Goldring, Greiss-Hess,

Herrera, et al., 2008; Provost, Lopez, and Heimerl, 2007), enhance understanding of the effects

of motor difficulties on social symptoms (Leary and Hill, 1996; Robledo, Donnellan, and

Strandt-Conroy, 2012), initiate the development of new interventions and therapy (Hardy &

LaGasse, 2013; Sowa & Meulenbroek, 2012), and potentially modify diagnostic criteria

(Donnellan, Hill, and Leary, 2013).

    1.1. Motor impairments in school-aged children with ASD. Numerous studies have

reported motor impairments in children with ASD compared to typically developing children.

Researchers often use standardized tests of gross and fine motor development to assess motor

ability compared to typically developing and age-similar peers. According to data from several

recent studies, a majority of children with ASD demonstrated fine and gross motor deficits using

the Movement Assessment Battery for Children (M-ABC), an assessment that examines agility,

ball skills, and balance (Green, Charman, Pickles, Chandler, Loucas et al., 2008; Hilton, Wente,

LaVesser, Ito, Reed, and Herzberg, 2007; Miyahara, Tsuji, Hori, Nakanishi, Kageyama et al.,

1997). More specifically, results from the study conducted by Green and colleagues (2008) show

that 90 out of 101 children with ASD displayed movement difficulties. Miyahara and colleagues

(1997) reported that 22 out of 26 children with ASD were at last two standard deviations below

the mean score of the M-ABC. Likewise, Hilton and colleagues (2007) found that 65 percent of

children with ASD scored two standard deviations below the norm on the M-ABC.

    Similarly, Hilton, Zhang, Whilte, Klohr, and Constantino (2012) reported substantial

impairment in motor skills for children with ASD compared to unaffected siblings. For this

study, the Bruininks Oseretsky Test of Motor Proficiency, Second Edition (BOT2) was used to

measure motor ability, such as coordination, agility, and fine motor control. More specifically,

motor composite scores of 83% of these children with ASD were at least one standard deviation

below the general population mean compared to only 6% of unaffected siblings. Overall, findings from standardized testing of motor functioning reveal a prevalence of explicit differences between children with ASD and typically developing peers.

Additionally, Ming and collaborators (2007) reported a prevalence of motor impairments and deficits in motor development in children with ASD between the ages of 2 and 18, especially in the younger age group. Physical examinations by a pediatric neurologist suggested that children with ASD show the most prevalence in hypotonia and motor apraxia. More specifically, slightly over half of the 154 children with ASD displayed hypotonia, and 63% of children in the 2 to 6 year age range displayed hypotonia. Furthermore, 34% of all children with ASD exhibited motor apraxia, and 41% of children in the 2 to 6 year age range exhibited motor apraxia. Parent report and therapist records showed that only 19% of all children demonstrated toe walking throughout life. Finally, gross motor delay was only reported for 9% of all children with ASD.

1.2 Motor impairments in young children with ASD. It is clear that school-aged children with ASDs often display motor impairments. However, how early these motor impairments begin to appear in development is another question that researchers tend to debate. It is widely observed that early diagnosis and intervention has a positive effect on treatment and improved life outcomes for children with ASD. Thus, it has become increasingly vital to detect ASD early in life in order to benefit most from behavioral intervention. Unfortunately, biological factors have not been associated with an ASD and therefore, ASD is only diagnosed when behavioral symptoms first appear. By identifying early motor behavior and impairments in young children and infants, screening tools and indicators of ASD can be developed for early identification (Bryson, Zwaigenbaum, Brian, Roberts, Szatmari et al., 2007; Dawson, Osterling, Meltzoff, and Kuhl, 2000; Ozonoff et al., 2008; Teitelbaum, Teitelbaum, Nye, Fryman, and Maurer, 1998).

Research presents differing results concerning motor delay in young children and infants with ASD prior to diagnosis. Some researchers have evaluated home videos of children with ASD in the first years of life and infants who are at risk of developing an ASD (for example, infants who have an older sibling with an ASD) in order to assess indicators that could supplement early diagnosis of ASD. Results from the Teitelbaum and colleagues (1998) study, which examined home videos of 17 children with ASD as infants, suggest that disturbances of movement can be determined as early as the first 4 to 6 months of life. Specifically, motor milestone disturbances, including differences during development of lying, sitting, crawling, and walking, were noticed in a majority of the home videos.

Conversely, in a study that aimed to replicate the significant findings from the Teitelbaum and colleagues (1998) study, higher rates of movement abnormalities were not found in home videos of children with ASD in infancy (Ozonoff et al., 2008). However, Ozonoff and collaborators (2008) also examined early trajectories of motor development in children with ASD. Results showed marginally slower rates of development of supine lying (face down) and sitting for children with ASD. Additionally, children with ASD displayed significantly later ages for maturity of walking than typically developing controls. Overall, these studies, along with others, suggest opposing conclusions concerning motor delays significant to autism development and specific movement abnormalities in infancy.

Other researchers have aimed to identify movement differences in young children immediately following diagnosis with standardized tests for early development. Specifically, Provost and colleagues (2007) evaluated motor delay in young children with ASD (between 21 and 41 months) by using the Bayley Scales of Infant Development-2nd Edition (BSID II) and Peabody Developmental Motor Scales-2nd Edition (PDMS-2). These standardized tests assess

body control, coordination, fine motor abilities, dynamic movement, posture, and reflexes,

stationary body control, movement ability, object manipulation, grasping, and visual-motor

integration, respectively. Provost and colleagues (2007) reported that 12 out of 19 children with

ASD had significant delay in motor skills on the BSID II and would qualify for early

intervention services. Likewise, 13 out of 19 children with ASD scored significantly below the

mean on the PDMS-2 and would qualify for early intervention services. Overall, in this study, all

children with ASD showed some impairment in motor skills according to these standardized tests

for young children.

The first longitudinal study that analyzed the development of infants at high-risk of ASD

at 6, 12, and 24 months of age was conducted by Landa and Garrett-Mayer (2006). By using the

Mullen Scales of Early Learning (MSEL), which assesses gross and fine motor skills, visual

reception, receptive language, and expressive language, results showed that infants who

developed ASD by the age of 24 months performed significantly worse than infants who

developed a learning disability and infants who were unaffected in gross and fine motor ability.

At 6 months, all three groups of infants scored within the same range on the MSEL. However, by

14 months and even more so by 24 months, the infants who were diagnosed with ASD displayed

significant delay and difficulties with gross motor skills (Landa & Garrett-Mayer, 2006).

1.3 Differences in gait and balance. Although much literature reports general differences

in motor skills, this study specifically focused on identifying deficits in two main, coinciding

motor abilities: gait and balance. As acknowledged by Jansiewicz, Goldberg, Newschaffer,

Denckla, Landa et al. (2006) and Noterdaeme, Mildenberger, Minow, and Amorosa (2002),

widespread motor impairments of gait and balance have been identified in children with ASD.

For example, Jansiewicz and collaborators (2006) reported that boys with high-functioning

autism demonstrated impaired motor performance relative to age-matched controls according to the Physical and Neurological Exam for Subtle Signs (PANESS) test, which assesses stressed gaits, balance, repetitive timed movements, and patterned timed movements. Moreover, Noterdaeme and collaborators (2002) reported that children with ASD displayed significant differences in gross motor skills (stepping, running, stair climbing, and muscle tone) and balance (standing quietly on one leg, hopping on one leg, toe gait, and heel gait) than typically developing controls, based on a neurological examination.

Furthermore, Fournier, Hass, Naik, Lodha, and Cauraugh (2010) conducted a meta-analysis of 51 studies that examined motor coordination in individuals with ASD compared to typically developing individuals of all ages. Comparisons between these studies indicated that individuals with ASD display marked impairments in gait, balance, arm motor functions, and movement planning. Overall, Fournier and colleagues (2010) concluded that individuals with ASD show motor deficits in numerous domains, are less coordinated, and have fewer motor capabilities than typically developing individuals.

1.3.1. Gait differences. In particular, studies have demonstrated various gait patterns and differences between children with ASD and their typically developing peers. Unfortunately, results of gait disturbances have been inconsistent, and numerous brain regions have been associated with gait dysfunction in autism. Early research suggests similarities between the gait of a child with ASD and the gait of a patient with Parkinson's. For example, according to Vilensky, Damasio, and Maurer (1981), children with autism exhibit gaits that are reduced in stride length and increased in stance times compared to same-age controls. These gait disturbances, coded by observers who viewed participants walking from a video, suggest that

autism may be linked to dysfunction of motor systems that involve the basal ganglia, a part of the brain associated with voluntary motor control (Vilensky et al., 1981).

Similarly, Maurer and Damasio (1982) reported that children with ASD take shorter steps, spend more time in contact with the ground, and exhibit less angular motion at knee, hip, and ankle joints than typically developing children. These differences were consistent with those found by Vilensky and collaborators (1981) and are associated with the tendency to strike the ground with the sole of the foot more often than the heel. Additionally, Maurer and Damasio (1982) reported that children with ASD display abnormal postures when standing and walking, including a bowed head, flexed elbows, dropping hands, and diminished arm movement.

Years later, Hallett, Lebiedowska, Thomas, Stanhope, Denckla et al. (1993) conducted a study that contradicted these connections to parkinsonian gait. By clinical assessment, results showed that clumsiness, decreased ankle motion, and general gait irregularities were associated with ASD, suggesting deficits in the motor systems that involve the cerebellum, another part of the brain associated with motor control (Hallett et al., 1993). Additionally, Vernazza-Martin, Martin, Vernazza, Lepellac-Muller, Rufo, Massion et al. (2005) reported that children with ASD only differed from typically developing children in stride length, suggesting only one aspect of parkinsonian gait and more agreement with results from Hallett and colleagues (1993).

Rinehart, Tonge, Bradshaw, Iansek, Enticott, and McGinley (2006) further examined the potential of basal ganglia and/or cerebellum dysfunction in children with ASD by conducting observational gait analyses on children with ASD, children with Asperger's (high functioning autism), and typically developing children. Observations indicted that children with ASD exhibit significantly deficient performance for coordination, smoothness, consistency, and arm posture while walking than typically developing controls. Additionally, observations indicated that

children with Asperger's exhibit significantly deficient performance for coordination, smoothness, and head and trunk posture while walking than typically developing controls. Abnormalities in coordination, consistency, and smoothness of gait indicate cerebellum dysfunction, while abnormalities in arm, head, and trunk posturing indicate basal ganglia dysfunction. Rinehart and collaborators (2006) also suggest potential differences in the thalamus, a structure that is involved with both the cerebellum and basal ganglia.

Researchers have also aimed to identify early gait differences in infants. Esposito and Venuti (2008) examined the gait in toddlers with ASD after six months of independent walking and Esposito, Venuti, Apicella, and Muratori (2011) examined the unsupported gait in toddlers with ASD (when independent walking was reached). Both studies used the Walking Observation Scale, a scale developed to analyze foot, arm, and global movements of gait, in order to assess early motor deficits in ASD. Esposito and Venuti (2008) reported that children with ASD displayed more problems walking in a heel-to-toe pattern, more asymmetric arm postures when walking, and high frequencies of general movement abnormalities, specifically for the presence of "waddling walk." More specifically, children with ASD exhibited the largest differences from typically developing children in arm movement and position, suggesting a role of basal ganglia dysfunction in autism and the use of different arm positions to prevent deficits in balance.

Similarly, Esposito and colleagues (2011) reported that toddlers with ASD, who just began to walk without support, also displayed significant differences in foot movement and arms movement compared to typically developing toddlers. Specifically, toddlers with ASD exhibited differences in heel-toe pattern, tip-toe pattern, forearm/elbow position, arm rigidity, arm symmetry, and arm-and-hand flapping. Esposito and colleagues (2011) also examined dynamic and static symmetry with the Positional Pattern for Symmetry during Walking (PPSW) scale

between toddlers with ASD, toddlers with developmental delays of mixed etiology (DD), and typically developing (TD) toddlers. Results were consistent with the Teitelbaum and collaborators (1998) research and indicated that motor asymmetry in the first year of life is specific to autism, as it was not displayed in either the DD or TD control groups.

     1.3.2 Balance differences. Similar to these specific gait studies, other research has aimed to identify differences in balance and postural control, or the ability to maintain, achieve, and restore balance during postures (Pollock, Durward, Rowe, and Paul, 2000), between children with ASD and typically developing peers. Due to difficulties of objectively testing balance, many studies use the clinical Romberg test, or postural sway testing on force-measuring platforms, to decipher balance differences in children with autism (Diener & Dichgans, 1996; Kohen-Raz, Volkmar, and Cohen, 1992; Molloy, Dietrich, and Bhattacharya, 2003). During these tests, subjects are assessed in a number of conditions that measure sway trends and improvement of stability with visual feedback (for example, standing on a platform with eyes open versus standing on platform with eyes closed). The Romberg test assesses the possibility of deficits in various parts of the brain (particularly in the cerebellum) that correspond to specific types of postural instability and whether vestibular, somatosensory, and/or visual systems are deficient at maintaining posture and overall balance (Diener & Dichgans, 1996).

     Kohen-Raz and colleagues (1992) reported that children with ASD showed greater variability in posture, less stability, and greater difference between weight distribution on heel and toe parts than typically developing peers. Paradoxically, the children with ASD in this study displayed equal or sometimes better stability when vision or somatosensory input was blocked, suggesting improved balance when fewer stimuli are available. However, after replicating this study, Molloy and collaborators (2003) found that children with ASD showed less stability than

controls when visual cues were reduced, indicating that children with ASD mostly rely on visual stimuli to maintain balance. Therefore, when this system is inhibited (conditions where eyes are closed), postural sway and decreased balance greatly increased compared to controls (Molloy et al., 2003). Despite varying results, researchers propose that dysfunctions in the systems necessary for balance maintenance, or an inability to integrate information from these systems, could explain balance differences in children with autism (Molloy et al., 2003).

Minshew, Sung, Jones, and Furman (2007) also used dynamic posturography to test postural sway of individuals with ASD between the ages of 5 and 52 years to healthy control individuals. Participants experienced postural sway testing in six positions (as opposed to four in the previously mentioned studies), where eyes were either open or closed, participants viewed a fixed visual surround or a "sway-referenced" visual surround, and participants stood on a fixed platform or a sway-referenced platform. Results showed that individuals with ASD swayed more than control participants, specifically in conditions where a sway-referenced platform (a platform that moves based on weight distribution) was used. Additionally, individuals with ASD developed postural control significantly later than controls and rarely reached adult levels of mature balance (improved to age 12 maturity in postural control). These results support the Molloy et al. (2003) study and suggest that individuals with ASD rely on somatosensory input and the integration of all modality sensory integration (Minshew et al., 2003).

Overall, it is important to question the specific differences in gait and balance in children with ASD in order to understand the scope of the disorder and identify movements that are most associated with ASD.

1.4. Importance of understanding motor impairments. As is evident from the wealth of research suggesting movement deficits in children with ASD, motor impairments deserve

continued investigation. The following sections highlight the motivations to further explore

motor impairments in ASD. First and foremost, movement can be measured and is continuous. It

can therefore be analyzed and compared to standardized norms (Donnellan et al., 2013; Jeste,

2011). Additionally, understanding specific motor impairments could enhance knowledge of the

underlying brain mechanisms and neural circuits that are associated with ASD (Refer to *1.4.1:*

Fournier et al., 2010; Jeste, 2011; Nayate, Bradshaw, and Rinehart, 2005). As a critical aspect of

development, motor dysfunction could have an effect on the social symptoms that are most

salient in ASD (Refer to *1.4.2:* Jeste, 2011; Leary & Hill, 1996; Robledo et al., 2012). A

prevalence of motor deficits specific to ASDs could better characterize symptoms, enhance early

identification of autism, potentially modify diagnostic criteria (Refer to *1.4.3:* Donnellan et al.,

2013; Ozonoff et al., 2008; Provost et al., 2007), and support new interventions for those with

severe motor impairment (Refer to *1.4.4:* Hardy & LaGasse, 2013; Sowa & Meulenbroek, 2012).

     1.4.1. Brain mechanisms. There are varying views of the underlying mechanisms that are

responsible for motor impairments in ASDs. However, with awareness of how neurological

symptoms affect individuals with ASDs, the nature of differences experienced by those with an

ASD can be better understood (Donnellan et al., 2013). As indicated in the gait differences

(Refer to *1.3.1*) research, it is debated whether the cerebellum (Esposito et al., 2008; Hallett et

al., 2003), the basal ganglia (Maurer and Damasio, 1982; Vilensky et al., 1981), the thalamus

(Rinehart et al., 2006), or all three structures (Rinehart et al., 2006) are responsible for gait

disturbances in autism. However, because ASD occurs on a spectrum of severity, the brain

mechanisms involved in the motor impairments that are exclusive to particular individuals may

conflict. As Fournier and colleagues (2010) suggest in their synthesis and meta-analysis,

numerous brain structures have been reported as atypical. Abnormalities include increased size

of the brain, the caudate nucleus (part of the basal ganglia), and the cerebellum in individuals

with ASD. In general, most research indicates disruptions in the fronto-striatal circuits of the

brain (connecting the frontal lobe with the basal ganglia), the basal ganglia, and the cerebellum

in ASDs (Fournier et al., 2010; Nayate et al., 2005; Rinehart et al., 2006).

The roles of the fronto-striatal pathway, basal ganglia, and cerebellum are important to

assess in individuals with ASD in order to develop an understanding of motor impairments. Gait

and balance control is often implicated in well-known neurological conditions. By understanding

the differences of these brain structures and how they relate to gait and balance behavior in

various disorders, movement differences in ASD and the brain mechanisms involved can be

determined (Nayate et al., 2006).

In gait and balance, the cerebellum plays a crucial role in motor control, management of

continuous motion, integration of sensory inputs for balance and coordination of body

movements, stabilization of upright stance, motor learning, and trunk and limb position (Diener

& Dichgans, 1996; Nayate et al., 2005). Therefore individuals with cerebellar dysfunction tend

to display ataxic gait, or unbalanced and uncoordinated gait. Specific dysfunctions are veering

from side to side when walking, falling or lurching in various directions, difficulty coordinating

complex actions, swaying during stance, and using a wide base of support (Diener & Dichgans,

1996; Nayate et al., 2005). Similarly, the basal ganglia and the frontostriatal pathways play a

critical role in voluntary motor control and the postural changes necessary to initiate and

maintain movement. However, dysfunction of the basal ganglia does not purely impair

movement. Therefore, gait abnormalities reflect a combination of brain differences, including the

basal ganglia (Brown & Steiger, 1996; Nayate et al., 2005).

1.4.2. Motor impairment and social symptoms of ASD. Numerous researchers interested in motor differences in individuals with ASD suggest a link between motor impairments and more salient, social symptoms (social-communication deficits and restricted-repetitive behaviors and interests) of ASD (Bhat, Landa, and Galloway, 2011; Donnellan et al., 2013; Jansiewicz et al., 2006; Jeste, 2011; Leary & Hill, 1996; Robledo et al., 2012; Vernazza-Martin et al., 2005).

Leary and Hill (1996) first introduced the association between movement disturbances and core characteristics of ASD. Specifically, they questioned the impact that movement disturbances could have on behavior in autism. For example, disturbances affecting motor function, voluntary movements, and facility of activity could make it difficult for an individual with an ASD to interact and communicate in social settings. When it becomes difficult to involuntarily (or voluntarily) initiate, perform, switch, and continue an action or behavior, social communication is sacrificed for the sake of motor regulation (Leary & Hill, 1996). Overall, in order to socially interact, communicate, and participate in the environment, it is important to coordinate movements and regulate sensory inputs, functions that those with an ASD may lack.

Furthermore, motor impairments that occur early in life, and even in infancy, can trigger earlier onset of and more severe social symptoms in the future. When children have trouble managing gross and fine motor control and integrating movements in their environments, social play and communication is foregone (Jansiewicz et al., 2006; Vernazza-Martin et al., 2005). More specifically, coordination and agility in early childhood are critical to initiate and maintain social interactions. For example, children with movement disorders, such as cerebral palsy and developmental coordination disorders, display significant difficulties developing and maintaining peer relationships (Bhat et al., 2011). In terms of development, research suggests that toddlers at risk for ASD who experience motor delays at 18 months of age are highly more likely to be

diagnosed with an ASD at the age of three (Bhat et al., 2011). Additionally, better motor

performance in children with ASD at the age of two correlates with better future outcomes at the

age of four (Bhat et al., 2011); therefore, by understanding movement abnormalities and

targeting motor performance deficits at an early age, positive motor and social communication

development can be facilitated (Vernazza-Martin et al., 2005).

Particularly interesting research, conducted by Robledo and colleagues (2012),

demonstrated the clear links between motor impairments and social difficulties from the

perspectives of five individuals between the ages of 19 and 57 with ASD. In terms of motor

abilities, individuals described difficulties with controlling, executing, and combining two or

more movements or actions. For example, Barbara noted her challenges with coordination and

balance, her inability to control movement urges while excited or nervous, and her failure to

combine two actions (such as moving her feet and arms when learning to dance).

Many of the action challenges that the participants described corresponded to difficulties

with posture and proprioception. Anecdotally, Geneva commented on her difficulty with posture

and knowing where her body was in space, mentioning a time that she almost drowned in a pool

because she did not know which way was up. Additionally, Geneva recalls the extra conscious

thinking she needs to do in order to achieve relatively manageable functions. For instance,

Geneva notes her difficulty of walking and talking at the same time. She comments:

> Walking takes thinking. So if I am walking and you ask me a question I could trip or I
> could mess up the sentence and put the wrong word in… I can walk with my girl friend
> down the street and carry on a conversation as long as she is right there but I have to look
> down at the sidewalk. I have to keep track of where the sidewalk is and where any
> obstacles are and all that stuff and sometimes if I have to keep walking and I feel like I
> am going to blow any second I make sure the path is clear ahead of me and close my eyes
> and continue walking (Robledo et al., 2012, page 9).

Geneva's account demonstrates the difficulty of walking, a relatively simple task, and the excessive attention she must use to get from point A to point B. As is evident, Geneva does not display the characteristics of typical communication (looking down while walking during a conversation), which demonstrates the implications that motor disturbances have on social symptoms descriptive of ASD (Donnellan et al., 2013; Leary & Hill, 1996).

1.4.3. Early indicators and diagnostic criteria. As aforementioned, early diagnosis and intervention is known to have positive effects on life outcomes for children with ASD (Refer to *1.2)*. Therefore, detecting early indicators of ASD is important to prognosis. Because the core characteristics of ASD are social, symptoms are not typically observed until the ages of two or three. Thus, researchers are continually evaluating potential and non-social markers of early identification of ASD (Landa & Garrett-Mayer, 2006; Ozonoff et al., 2008; Provost et al., 2007; Teitelbaum et al., 1998).

Unfortunately, there is little research that examines the differences in movement between infants and toddlers at high-risk for or with ASD. The research that does exist presents inconsistent findings. For example, although Teitelbaum and colleagues (1998) spotted differences and/or delays in lying, crawling, sitting, and walking in infants with ASD, Ozonoff and collaborators (2008) reported that infants with ASD only showed marginally slower rates of development for supine lying and sitting. One finding that does seem to be consistent in infants and toddlers with ASD is motor asymmetry during early developmental stages (Teitelbaum et al., 1998) and initial unsupported walking (Esposito et al., 2011), as well as arm asymmetry after six months of walking (Esposito and Venuti, 2008). These studies suggest that motor asymmetry is a potential indicator of ASD in the first year of life.

Similar to identifying potential indicators for early diagnosis, many researchers suggest that a prevalence of motor deficits in ASD could affect future modifications to diagnostic criteria. In the most recent DSM-5, the core symptoms are defined as (a) deficits in social communication and interactions and (b) restricted, repetitive behavior or interests. Evidently, these symptoms do not involve differences in movement or gross motor development. Of course, in order for a symptom to be considered as a core characteristic of a disorder, it must be prevalent in all individuals with the disorder (Fournier et al., 2010); however, a prevalence of motor impairments, especially of specific motor impairments, in individuals with ASD has not been established.

Finally, some researchers stress that a better understanding of motor impairments and finding a prevalence of motor difficulties in individuals with ASD is not for the sole purpose of changing diagnostic criteria, although that could potentially happen. Rather, the motivation behind this research is to analyze difficulties that individuals with ASD may be struggling with that may not be evident to an outsider. For example, difficulties with complex movements, motor planning, or even walking could be restricting to numerous other aspects of functioning. By understanding the experiences of an individual with ASD and the associated symptoms of the disorder, appropriate care and support can be provided (Donnellan et al., 2013; Jeste, 2011).

1.4.4. New interventions and therapies. If motor impairments are prevalent in individuals with ASD and have an impact on the social symptoms that characterize the disorder, treatment should consider targeting motor performance and improving motor coordination (Fournier et al., 2010; Hardy & LaGasse, 2013; Sowa & Meulenbroek, 2012; Jeste, 2011).

Intervention for children with ASD is primarily behavioral or cognitive and rarely considers the effect of motor functioning on navigating the environment. Unfortunately,

intervention that targets movement differences in children with ASD is a new topic and has

rarely been researched. Hardy and LaGasse (2013) suggest that children with ASD who show

motor deficits in planning and coordination may benefit from auditory rhythmic cueing, or the

application of music to therapy for motor dysfunctions caused by neurologic disability. More

specifically, auditory rhythmic signals could support movement control for children with ASD

by influencing the timing of their actions, providing auditory feedback for balance control, and

enhancing reaction times and responses to the environment. Although this form of music therapy

has not been tested on children with ASD, it has shown to be effective for those with

neurological disabilities, such as for gait parameters in Parkinson's disease (Thaut, McIntosh,

Rice, Miller, Rathbun, and Brault, 1996) and gait kinematic parameters of stroke patients with

hemiparetic gait (Prassas, Thaut, McIntosh, and Rice, 1997).

Additionally, Sowa and Meulenbroek (2012) conducted a meta-analysis of 16 studies that

assessed the effects of physical exercise and exercise-based interventions on individuals with

ASD. Specifically, physical exercises included swimming, jogging, horseback riding, cycling

and weight training, and walking. Although the individual studies had small sample sizes, Sowa

and Meulenbroek (2012) concluded that, as a whole, individual exercise interventions were most

beneficial for children with ASD in terms of social skills and motor performance.

As aforementioned, further awareness of movement dysfunctions in children with ASD

could provide better insight on the effect of motor difficulties on social symptoms, early

indicators for diagnosis, modifications to diagnostic criteria, and the creation of new

interventions and therapies. Autism is a neurological disorder, and it is therefore logical that

children with ASD experience difficulties in other domains. Overall, it is important to attend to

neurological symptoms, such as differences in gross motor movement and development, in order

to fully understand the scope of autism, advance interventions that give those with an ASD proper care and support, and offer families identification skills necessary to receive early diagnosis and immediate intervention (Donnellan et al., 2013).

2. Current Study

This study aims to support and expand evidence that children with ASD demonstrate gait and balance difficulties. Previous research has examined motor differences by means of standardized testing, clinical examination, kinematic or kinetic gait analysis, and the Romberg test (Green et al., 2008; Hallett et al., 1993; Minshew et al., 2007). Although these assessments are reliable and have systematically compared differences between children with ASD and typically developing children, they fail to measure gait and balance in non-intrusive environments and may not capture actual gait and balance abilities. Furthermore, most research fails to examine the motor abilities and milestones of participants' developments at other times than when studies are conducted from parent report.

With exception to the use of the Walking Observation Scale in the studies conducted by Esposito and Venuti (2008) and Esposito and colleagues (2010), gait and balance abilities have rarely been determined based on behavioral observation. Additionally, with exception to studies that examined videos of infants with ASD, gait and balance observations have rarely been conducted in the natural environment. Finally, with exception to the study conducted by Ming and collaborators (2007), behavioral observations of movement have rarely been compared to parent report of child's motor abilities and development since birth.

Overall, this study aims to observe gait and balance patterns in children with ASD and compare results with parent reports. This study intends to answer three main research questions:

1. How do gait characteristics in children with ASD differ from typical gait patterns?

2. Do children with ASD display difficulties with balance?

3. How do these gait and balance characteristics compare with parent reports of child's

   motor abilities?

It was hypothesized that children with ASD will exhibit atypical gait patterns and difficulties

with balance and that parent reports will be consistent with behavioral observations of gait

characteristics and balance.

3. Measurement Development

Previous research rarely used behavioral observation methods to assess motor abilities

and impairments in children with ASD. Thus, the author developed gait and balance scales for

the method of the study. Additionally, a parent questionnaire was developed by the author in

order to compare observations with parent report.

3.1. Gait code development. The "Gait Observation Scale: Manual and Coding Protocol"

was developed by the author to (a) thoroughly describe the typical characteristics of gait, (b)

explain the corresponding Gait Coding Checklist, and (c) train observers to assess a child's gait

pattern in a natural environment. As defined in the manual, gait is the pattern of rhythmical and

alternating cycles of forward progression of the body by foot (Refer to Appendix – Part 2).

Normal gait appears as a smooth function of walking in a heel-to-toe forward pattern

where arms swing in alternation with opposite legs. The gait cycle is composed of the stance

phase (60% of cycle) and the swing phase (40% of cycle). The stance phase defines the time

between the foot's initial contact with the ground and the same foot's departure from the ground.

The swing phase defines the time between the foot's departure from the ground and the same

foot's contact with the ground. In order to determine features of abnormal gait, it is important to

understand the basic structure and functioning of the normal gait cycle (Malanga & DeLisa,

1998; Patrick, 1996).

      3.1.1. Gait Coding Checklist. All gait observations were coded using the Gait Coding

Checklist, designed by the author, which corresponds to the Gait Observation Scale (Refer to

Appendix – Part 2). As aforementioned, previous gait examinations were conducted in structured

laboratory settings and rarely assessed purely observational characteristics of gait. Therefore, this

checklist was developed in order to assess the presence of typical characteristics of gait in

children with ASD. A checklist format was used due to reliability of binary measurements (if a

behavior is absent or present) for behavioral observation (Krebs, Edelstein, and Fishman, 1985).

Additionally, the checklist focused on observing visibly evident components of gait, rather than

specific measurements, such as kinematics of gait (Krebs et al., 1985). This checklist consists of

three main sections that highlight (a) nine components of typical gait mechanics, (b) presence of

abnormal gait patterns, and (c) seven main characteristics of normal gait cycle. The six

sequences of gait cycle examined in this study were heelstrike, midstance, pushoff, acceleration,

midswing, and deceleration.

      In the first part of the Gait Coding Checklist, the main observer determined whether or

not each subject exhibited the nine components of typical gait mechanics (e.g., "heelstrike

contact is always made with the **heel**", "subject's toes are always **facing forward**"). These

components are representative of normal gait (Refer to Table 1: Patrick, 1996). If a subject

exhibited a component, the main observer checked the "yes" box following the statement. If the

subject did not exhibit a component, the main observer checked the "no" box following the

statement and continued to the check boxes below the component. These components defined

potential atypical gait patterns that the subject may have exhibited instead of the normal gait

component. These options were mutually exclusive, meaning that some, all, or none of the options may have applied to the subject. If there was a behavior demonstrated by the subject that was not listed as an alternative option, the main observer checked "Other" and wrote a description of the observed behavior.

In the second part of the Gait Coding Checklist, the main observer determined the presence of abnormal gait patterns in each subject. These abnormal gait patterns were added to the checklist because they are specific to certain neurological disorders and may have been observed in children with ASD. The abnormal gait patterns observed were circumduction gait, scissoring gait, slapping gait, stamping gait, and shuffling gait (Refer to Table 2). These patterns were coded based on if they were "Always," "Sometimes," or "Rarely" present.

In the third part of the Gait Coding Checklist, the main observer determined whether or not each subject exhibited the seven main characteristics of normal gait cycle (Refer to Table 3: e.g., "Reference leg is extended" and "Uses toes for pushoff"). These characteristics are supplemented with pictures at each phase and only target characteristics of the typical leg movements. Each characteristic replicates components from the first part of the checklist in order to insure internal validity of the coding measures. If the subject demonstrated a characteristic, the main observer checked the corresponding box. If the subject did not demonstrate a characteristic, the main observer did not check the corresponding box.

3.2. Balance code development. The "Balance Observation Manual" was developed by the author to (a) thoroughly describe postural control and balance definitions, (b) explain the corresponding Balance Coding Sheet, and (c) train observers to assess a child's balance abilities in a natural environment. As defined in the manual, static balance is the ability to maintain center of gravity, or the point where body weight is evenly distributed within its stationary base of

support (BOS: distance between two feet). However, the body is not always in a static (unmoving) position; therefore, the BOS and center of gravity frequently change. Dynamic balance is when movement changes the BOS, but postural control is achieved. Postural control refers to the ability to maintain, achieve, and restore balance during any movement. When the body moves and alters the BOS, it should detect change in stability and use muscles to preserve dynamic balance (Refer to Appendix – Part 3: Pollock et al., 2000; Winter, 1995).

   3.2.1. Balance Coding Sheet. All balance observations were coded using the Balance Coding Sheet, designed by the author, which corresponds to the Balance Observation Manual (Refer to Appendix – Part 3). As aforementioned, previous balance examinations were conducted in structured laboratory settings and rarely assessed purely observational characteristics of balance. For this coding sheet, a frequency count was used to tally observations of poor balance. Because it is difficult to observe balance abilities in a non-intrusive environment (for instance, without instructing a participant to stand on one leg to test good balance skills), observations consisted of poor balance counts. The seven poor balance observations were for trips, collisions with objects, collisions with people, collisions and falls, trips and falls, falls, and slips (described in detail in the Balance Observation Manual). When one of these poor balance observations occurred, the main observer tallied the action in the corresponding box on the Balance Coding Sheet. Each time an action was demonstrated, a tally was placed on the coding sheet.

   Additionally, the main observer took continuous notes of any other balance-related observations that were made during the observation on the Balance Coding Sheet. These observations were used to characterize other balance observations that did not correlate with the seven poor balance observations.

3.3. Parent Questionnaire development. The Parent Questionnaire was developed by the author in order to compare parent reports with behavioral observations of gait and balance. The questionnaire was based on the format of the Developmental Coordination Disorder Questionnaire (Wilson, Crawford, Green, Roberts, Aylott, and Kaplan, 2009), a 15-question form that probes a child's control during movement, fine motor/handwriting, and general coordination. Some questions were directly used from this questionnaire, specifically from the motor control and general coordination sections. Most questions were developed by the author and were based on research of typical motor skills, development, and milestones throughout early childhood and adolescence (Patrick, 1996; Woollacott, Assaiante, and Amblard, 1996).

3.3.1 Parent Questionnaire. The questionnaire consisted of four parts: (a) information about the child's diagnosis, therapy, and schooling, (b) child's current gross motor skills, (c) child's early motor milestones and development, and (d) other observed motor differences. The first part consisted of 6 questions concerning each participant's diagnosis, comorbid disorders, previous therapy, and schooling. The second part consisted of 17 questions on a Likert scale of five points (1 = not at all like my child, 2 = a bit like my child, 3 = moderately like my child, 4 = quite a bit like my child, 5 = extremely like my child). An example of a question from this section is, "Your child is *quick and competent* in tidying up, putting on shoes, dressing, etc." By comparing their child to children of similar age, parents circled a number based on how much the statement described their child. The third part consisted of 8 yes or no questions concerning early motor development and milestones. An example of a question from this section is, "Your child was able to *independently walk around 12-14 months of age.*" Parents circled one of three options: (a) Yes, (b) No, or (c) Don't Remember. The fourth part consisted of an open-ended

response, where parents could record other motor differences that they may have noticed throughout their children's lives.

    3.3.2. Parent Questionnaire scoring criteria. The second part of the questionnaire (section with 17 questions on a 5-point Likert scale) was scored on a scale range of 17 to 85. A higher total score signifies better motor performance and ability compared to similar aged peers. A lower total score signifies difficulty in motor performance and ability compared to similar aged peers. Based on total score computations established by Wilson and colleagues (2009), the total scores of the Parent Questionnaires in this study would fall on a range that indicates whether the child's score is an (a) indication of a movement impairment, (b) suspect of a movement impairment, or (c) probably not a movement impairment (Refer to Table 4 for score ranges). The third part of the questionnaire (section with 8 questions concerning motor milestones) was not a part of the total questionnaire score as the answers were used for additional descriptive data.

4. Method

    4.1. Participants. The participants for this study consisted of 4 children with autism spectrum disorders and their parents. As gait is typically not mature until the age of 7 (Patrick, 1996), all participants were between the ages of 7 and 11 years (Refer to Table 5 for participant descriptives). Participants were recruited from the RAIN (Richmond Autism Integration Network) after school and home school programs in Richmond, Virginia. The study received approval from the University of Richmond Institutional Review Board. Procedures, risks, and benefits were fully disclosed to participants and their parents/guardians prior to observations. Written informed consent was obtained for all participants.

4.2. Setting. The study took place at the RAIN program in Richmond, Virginia. The after school and home school programs offer children with autism the opportunity to participate in social and recreational activities with typically developing peers of similar ages. This site was selected as a result of (a) a relationship with the director of programs and volunteer coordinator and (b) permission of the executive director and founder of the program. All observations took place at this site, either inside or outside the building, and during recreational activities.

4.3. Criteria for Inclusion. Participants were selected for participation based on the following criteria: (a) the children were between 7 and 11 years of age at the start of the study, (b) the children were signed up at the RAIN after school or home school programs, and (c) the children were diagnosed as on the autism spectrum. According to parent reports, all children in the ASD group were clinically diagnosed as having an ASD.

4.4. Procedure. This study consisted of two parts: (a) observations of gait and balance behaviors in participants from the RAIN program between the ages of 7 and 11 and (b) a questionnaire completed by each participant's parent regarding his/her child's motor abilities and development since birth. All observations were conducted at the RAIN after school and home school programs in the participants' naturalistic environment by the author (main observer). Behaviors were naturally observed during typical free playtime without any interaction between the observer and participants. The two observed movement behaviors for this study were gait and balance.

4.4.1. Gait. For this study, the definition for gait is defined in the Gait Observation Scale: Manual and Coding Protocol as the pattern of rhythmical and alternating cycles of forward progression of the body by foot. Gait was coded based on behavioral observation with the Gait Coding Checklist (Refer to *3.1.* for gait code development).

All observations were recorded at the RAIN after school and home school programs. The main observer and trained observer did not interfere with the participants while recording. Observers observed the gait cycle of each participant for five minutes and recorded subsequent data on the Gait Coding Checklist. Observations were made after viewing the subject from the front, side, and behind (Refer to *3.1.1.* for information about the Gait Coding Checklist). When observations began, a five-minute timer was started. If at any point a participant was in a position where observation could not be taken (for example, if the participant was sitting), the timer continued. However, if the participant remained in the unobservable position for more than 30 seconds, the timer was stopped. When the participant's position again became observable, the time was started again from the previous time.

4.4.2 Balance. For this study, the definition for balance is defined in the Balance Observation Manual as the ability to maintain, achieve, and restore postural control of the body during any movement. Balance was coded based on behavioral observation with the Balance Coding Sheet (Refer to *3.2.* for balance code development).

All observations were recorded at the RAIN after school and home school programs. The main observer and trained observer did not interfere with the participants while recording. Observers observed the balance ability of each participant for five minutes and recorded subsequent data on the Balance Coding Sheet. Observers tallied the frequency with which a participant exhibited a trip, collision with an object, collision with a person, collisions and falls, trips and falls, falls and slips (Refer to *3.2.1.* for information about the Balance Coding Sheet). When observations began, a five-minute timer was started. If at any point a participant was in a position where observation could not be taken (for example, if the participant was sitting), the timer continued. However, if the participant remained in the unobservable position for more than

30 seconds, the timer was stopped. When the participant's position again became observable, the time was started again from the previous time.

      4.4.3. Parent Questionnaire. Each parent was administered a Parent Questionnaire in the distributed consent packets. These packets included a personal letter of intent from the author, a consent form for participation, and the Parent Questionnaire. Parents either filled out the consent form at the parent support group (held during the home school program) or filled it out and returned it to RAIN at their preferred time (Refer to *3.3.* for Parent Questionnaire development).

      4.5. Interobserver reliability. Gait and balance coding schemes were original and developed by the author. In order to ensure that these codes were reliable, interobserver agreement was calculated for each code. A third party observer was trained on gait and balance behaviors prior to observations. This third party observer first read the Gait Observation Scale and the Balance Observation Manual. The author then held two sessions where she and the third party observer reviewed all content in the manuals. Following this learning period, the main observer and the third party observer completed five open dual-observation sessions using predetermined videos of children and adolescents both with and without ASD. During these sessions, the main and third party observers identified gait and balance behaviors while openly discussing the code, as described in the manuals.

      Because the training and open dual-observation sessions were held in the fall of 2013, the author held a refresher-training course in January of 2014. This training refresher eliminated potential observer drift issues for the third party observer. The main and third party observers then completed two closed dual-observation sessions at the RAIN program of children with and without ASD. Observed behaviors were not discussed, and each observer coded behaviors based on the manuals. An interobserver agreement analysis was performed to determine consistency

among observers. The Kappa statistic was used; criterion for almost perfect agreement is 0.81 to 1.00 (Landis & Koch, 1977). After two closed dual-observation sessions, the interobserver reliability for the observers was found to be Kappa = 0.81 (p = .00). The third party observer, as well as the gait and balance codes, was deemed reliable.

The main observer coded gait and balance behaviors for all of the subjects, and the third party observer coded behaviors for 25% of these subjects. The 25% of data collected by both the main and third party observer represented the study's reliability data.

5. Results

Because this study was exploratory, there were only four participants. Each participant was diagnosed with an ASD at the time of observation. No control participants were used in this small pilot study (Refer to Table 5 for participant descriptives).

5.1. Gait results. Of the nine components in the first part of the Gait Coding Checklist, participants displayed an average of 5.25 typical characteristics (*SD* = .957). Percentage wise, participants displayed 58% of typical gait characteristics. More specifically, out of the three gait categories (stance phase, swing phase, and whole gait cycle), participants were more likely to display abnormal gait patterns in the three components of stance phase (*M* = 1.5, *SD* = .77) and the five components of the whole gait cycle (*M* = 2.25, *SD* = .957). None of the four participants displayed difficulty in the swing phase. The swing phase was characterized by one of the nine components: "The foot **completely clears** the ground and the knee is **flexed**."

5.1.1. Gait for Participant A. Participant A displayed a total of 6 out of the 9 typical gait characteristics. Specifically, in stance phase, Participant A showed 2 out of 3 atypical gait behaviors. Sometimes, Participant A made heelstrike contact with the ball of the foot (or the toes) instead of with the heel. Additionally, Participant A would occasionally flex his knee when

stepping with the toes. In the whole gait cycle, Participant A only showed difficulty with walking

in a heel-to-toe pattern, in which he would sometimes walk on his toes (specifically when

running). In general, Participant A exhibited relatively typical gait.

5.1.2. Gait for Participant B. Participant B displayed a total of 5 out of the 9 typical gait

characteristics. Specifically, in stance phase, Participant B displayed typical heelstrike contact,

but demonstrated unstable and uncoordinated upper body movement. In the whole gait cycle,

Participant B displayed 3 out of 5 atypical gait behaviors. In particular, he tended to lean his

trunk backward and stick his stomach forward. Additionally, both of Participant B's toes faced

outwards for approximately 50 percent of observation time. Finally, Participant B exhibited very

short steps, reduced arm swing, and bent arms at the elbow. In general, Participant B exhibited

relatively atypical gait.

5.1.3. Gait for Participant C. Participant C displayed a total of 4 out of the 9 typical gait

characteristics. Specifically, in stance phase, Participant C displayed 2 out of 3 atypical gait

behaviors. Although he stepped with the heel, he knees were slightly bent inwards throughout

gait. He also demonstrated unstable and uncoordinated upper body movement. In the whole gait

cycle, Participant C displayed 3 out of 5 atypical gait patterns. The toes of both of his feet always

faced inwards, therefore causing his trunk to sway in a left to right movement (waddling gait).

Additionally, Participant C showed very reduced arm swing, where his elbows were bent and his

forearms stayed close to his chest. In general, Participant C exhibited relatively atypical gait.

5.1.4. Gait for Participant D. Participant D displayed a total of 6 out of the 9 typical gait

characteristics. Specifically, in stance phase, Participant D only showed unstable upper body

movements, where it seemed like he was waddling or limping. In the whole gait cycle,

Participant D displayed 2 out of 5 atypical gait behaviors. His trunk and upper body were

unstable throughout the gait cycle and he displayed a slight right to left swaying movement. Additionally, Participant D exhibited short steps and very reduced forearm movement. In general, Participant D exhibited relatively typical gait, with atypical upper body movement.

5.1. Gait results (continued). In the second part of the Gait Coding Checklist, only Participant C showed a presence of an abnormal gait pattern. He displayed a scissoring gait for approximately 50 percent of behavioral observation. This gait pattern seemed to be caused by his inward facing toes and knees. Although his toes were always facing inwards his knees only crossed in a scissoring gait half of the time (Refer to Table 6 for complete overview of results).

In the third part of the Gait Coding Checklist, participants displayed an average of 5 out of the 7 typical characteristics (*SD* = 1.41). Because most of the participants exhibited atypical arm and trunk postures (characteristics that were not a part of the third part of the checklist), it is logical that the average for the third part of the checklist is higher than the average number of typical characteristics from the first part of the checklist.

5.2. Balance results. The five-minute balance observations were only completed for three participants due to a lack of movement activities at the RAIN program. Additionally, of the three participants for who balance observations were taken, none of the children exhibited any of the seven behaviors of poor balance. However, despite the lack of data for the balance measures, the main and third party observers recorded observed behaviors concerning the balance abilities of each participant.

5.3. Participant descriptions. During the 10 minutes of total observation for each participant, the main observer also recorded other observable actions and behaviors. These participant descriptions are explained below.

5.3.1. Participant A. Participant A was observed while playing tennis outside with a partner. He displayed good coordination, especially hand-eye coordination. Despite his dexterity, Participant A displayed excessive movement and would often cross his legs in excitement. He tended to walk on his toes, specifically when running. His ankles were also remarkably flexible. Sometimes, he would drag his feet on the ground when running. This participant was also observed by the third party observer, who also recorded his good hand-eye coordination and running on toes.

5.3.2. Participant B. Participant B was observed while running around outside and playing with bubbles. As aforementioned, Participant B displayed uncoordinated and clumsy upper body movements. He tended to lean his trunk backward and stick his stomach forward. When walking downstairs, Participant B hesitated with each step as if worried to fall. Finally, Participant B displayed poor spatial awareness and tended to enter others' personal space.

5.3.3. Participant C. Participant C was observed while running and playing outside with other children. He was slightly clumsy and demonstrated excessive upper body movement. Like Participant B, he often hesitated when walking down stairs and was not aware of his surroundings. As aforementioned, Participant C displayed a waddling gait that is most likely attributed to his clumsiness and trunk movement.

5.3.4. Participant D. Balance was not observed for Participant D. However, during gait observations, Participant D displayed slight waddling and unstable upper body movements.

5.4. Parent questionnaire results. Each participant's parents completed the Parent Questionnaire. The mean score for the four participants was 52.31 (SD = 13.55). Despite the fact that the questionnaire did not only assess gait and balance, parent reports were consistent with behavioral observation (Refer to Table 8 for summary of scores).

5.4.1. Participant A questionnaire results. The total Parent Questionnaire score for

Participant A was 69.06 out of 85. Similar to the gait and balance observations, parent report

suggests that Participant A displays good motor movement ability and probably does not have

significant motor impairments. More specifically, Participant A's parent only reported that he

had trouble with learning new motor skills at the same rate as other children and participates in

active games or sports less often than typically developing children. His parent also reported that

all described gross motor milestones were met at the developmentally typical age.

5.4.2. Participant B questionnaire results. The total Parent Questionnaire score for

Participant B was 37.19 out of 85. Similar to the gait and balance observations, parent report

suggests that Participant A displays poor motor movement ability and indicates significant motor

impairment. More specifically, Participant B's parent reported that numerous domains of

movement were atypical. For example, Participant B is described as clumsy and unstable in

upper body movement. He struggles with smooth, complex, and coordinated movements,

fatigues easily, avoids activities, games, or sports that involve frequent movement, and has

trouble standing still. He learns new motor skills at a slower rate than other children his age and

developed gross motor skills at a delayed rate from age-similar peers. In the second part of the

questionnaire, reports show that Participant B was delayed in independently standing,

independently walking, changing directions without losing balance, and walking up and down

stairs with two feet on each step. Finally, Participant B's parent reported that he had intermittent

exotropia as a child, which was corrected by surgery and had improved his gross motor abilities.

5.4.3. Participant C questionnaire results. The total Parent Questionnaire score for

Participant C was 56 out of 85. Similar to the gait and balance observations, parent report

suggests that Participant C displays poor-to-average motor movement ability and may be suspect

for significant motor impairment. More specifically, Participant C's parent reported that he had trouble with learning new motor skills at the same rate as other children, participates in active games or sports less often than typically developing children, and prefers engaging in activities that require sitting. His parent also reported that all described gross motor milestones were met at the developmentally typical age. However, his parent noted that Participant C struggles with using slides and rollerblades.

5.4.4. Participant D questionnaire results. The total Parent Questionnaire score for Participant D was 47 out of 85. Unlike the gait observations, which illustrated that Participant D had relatively typical gait and some problems with upper body movement and stability, parent report suggests that Participant D displays poor motor movement ability and is suspect for significant motor impairment. More specifically, Participant D's parent reported that he had trouble with learning new motor skills at the same rate as other children, prefers engaging in activities that require sitting, falls or trips when walking, running, or playing sports, and fatigues easily. His parent also reported that he developed gross motor skills at a delayed rate from age-similar peers. His parent was not able to recount 7 out of the 8 motor milestones in the questionnaire, but reported that Participant D was not able to climb on jungle gyms and ladders around the age of 3.

6. Discussion

Overall, the hypotheses of this study were supported by the results. Children with ASD exhibited atypical gait patterns and some showed difficulty with balance. Additionally, parent reports were consistent with behavioral observations of gait and balance.

6.1. Gait. Participants exhibited 5.25 of the 9 main gait components and 5 out of the 7 typical characteristics of the gait cycle. These results suggest that children with ASD display gait

patterns that are atypical. All gait impairments were demonstrated in stance phase and throughout the whole gait cycle (Refer to Table 7 for specific gait impairments).

A majority of differences were seen in upper body and arm movement. More specifically, 3 of the 4 participants (B, C, and D) displayed atypical arm postures (restricted, rigid, reduced arm swing; arms bent at the elbow), which supports findings from numerous previous studies (Esposito and Venuti, 2008; Esposito et al., 2011; Maurer and Damasio, 1982; Rinehart et al., 2006). Similarly, 3 of the 4 participants (B, C, and D) displayed atypical trunk postures (Rinehart et al., 2006). Specifically Participant B displayed a backward lean. Participants C and D displayed right to left upper body movement, or a waddling gait, which was documented in previous research (Esposito and Venuti, 2008).

Additionally, 3 of the 4 participants displayed a variety of differences in leg movement and position during the gait cycle. Specifically, 2 of the 4 participants (B and C) demonstrated abnormal toe position. Rather than toes always facing forward, the toes of both of Participant B's feet faced slightly outward; in contrast, the toes of both of Participant C's feet faced inwards. Additionally, 2 of the 4 participants (B and D) exhibited short steps, although symmetrical in length. Despite the lack of definite measurements, this finding supports research that has related the gait of children with ASD to patients with Parkinson's (Maurer and Damasio, 1982; Vernazza-Martin et al., 2005; Vilensky et al., 1981). Only Participant A displayed abnormal heelstrike and heel-to-toe patterns.

As aforementioned, none of the participants displayed difficulty in the swing phase. Additionally, none of the participants displayed differences in symmetry in stride length. Although Participants B and D exhibited short steps, those steps were symmetrical in length.

6.2. Balance. Despite the lack of data recorded during balance coding, observations made by the observers provided some important evidence of balance difficulties in children with ASD. For example, two of the 4 participants (B and C) were described as looking clumsy and uncoordinated when playing with others. These two participants also portrayed hesitation when walking down steps and a lack of awareness of surroundings. These descriptions support findings from a breadth of research (Hallett et al., 1993; Hilton et al., 2012; Jansiewicz et al., 2006; Provost et al., 2007; Rinehart et al., 2006).

Additionally, because balance and gait often relate, the excessive upper body movement seen in 3 of the 4 participants (B, C and D) also corresponds to differences in postural control and balance. These participants were described as exhibiting abnormal upper body movement and postures throughout gait and during play. These findings are consistent with studies that suggest that children with ASD have poor postural stability compared to typically developing children (Kohen-Raz et al., 1992; Minshew et al., 2007; Molloy et al., 2003; Provost et al., 2007). Overall, balance and postural control were assessed somewhat subjectively and without specific measurements; therefore, analysis may not be consistent among all children with ASD.

6.3. Parent Questionnaire. Parent Questionnaires were completed for each participant. As documented in the results, 3 of the 4 parents (of Participants A, B, and C) reported consistent information with behavioral observation. Participant A, who displayed few gait and balance impairments during observation, scored in the range of "Probably not a motor impairment." Participant B, who displayed numerous impairments in gait and balance during observation, scored in the range of "Indication of a motor impairment." Participant C, who displayed numerous impairments in gait and balance during observation, scored in the range of "Suspect of a motor impairment." Participant D, who displayed few gait and balance impairments during

observation, scored in the range of "Suspect of a motor impairment" and was not as consistent as other participants (Refer to Table 8 for summary of scores).

Specific questions in the Parent Questionnaire seemed to elicit similar results for a majority of participants. In particular, all four parents reported that their child did not learn new motor skills (such as rollerblading and swimming) as easily as same-age peers and required more time or practice than other children to achieve the same skill level. Similarly, 3 out of 4 parents (of Participants B, C, and D) reported that their child prefers to engage in activities that require sitting rather than standing, walking, and/or running. The parent of Participant A reported that his child "moderately" preferred engaging in activities that require sitting. Additionally, 3 of the 4 parents (of Participants B, C, and D) reported that their child did not develop gross motor skills at the same time as other age-similar peers, suggesting a delay in gross motor development (Refer to Table 9 for a complete review of Parent Questionnaire reports).

Overall, it is evident that parents of children with ASD are aware of and can identify their children's gross motor difficulties. However, this small sample and specific population of children with ASD could have been a factor in this positive parent attention. For example, 3 of the 4 participants (B, C, and D) are home-schooled, suggesting that much time is spent at home with parents who can constantly observe their children's motor abilities. Most of the parents seemed in tune to their children's abilities and were financially stable without a steady income. This continuous parent support and interaction may be unique to this small sample of children.

6.4. Limitations. There are several limitations to this small pilot study. First and foremost, the study lacks a control group. Although this study was originally intended to include both children with ASD and typically developing peers, time restraints and low participation rates in the newly developed RAIN home school and after school programs made this difficult. A

majority of the children who attended the RAIN programs were diagnosed with an ASD, and therefore, there were only two children that signed up who did not have an ASD. Because one of these two potential control participants was diagnosed with ADHD, she was dropped from the study. Additionally, statistical analysis could not be completed with only one control participant, so the control group was dropped from the study. Because of the lack of a control group, observer bias could have occurred, where the observers may have reported more abnormal gait and balance differences because all of the participants had an ASD. Additionally, an analysis of differences could not be computed, and therefore, all data was descriptive.

Besides the lack of a control group, there were only four children with ASD that participated in the study. Again, due to time restrictions and a limited number of children signed up at the RAIN programs, it was difficult to recruit participants who were consistent members at RAIN. Despite the low participation rate, participants were of various pre-adolescent ages and displayed a wide range of motor abilities.

Although a Kappa of 0.81 was achieved between the main observer and third party trained observer for the gait and balance codes, these codes were developed by the author and have not been tested for reliability on a large scale. Additionally, the Parent Questionnaire was not tested in terms of reliability or validity and was not standardized based on norms. Because the questionnaire was based off of the DCDQ'07, it was deemed appropriate for use in this study. However, for use in the future, this questionnaire should be assessed prior to administration.

Finally, the Balance Coding Sheet did not seem to be an accurate assessment of balance ability. None of the children exhibited any of the balance disturbances (falls, trips, slips, collisions, etc.) in the five minutes that they were observed, suggesting rarity of these behaviors. Although studies that examine balance abilities based on observational measures, such as degree

of coordination, smoothness, and consistency in gait and balance, have been conducted (Rinehart et al., 2006), they may display more subjective results. These methods were therefore not employed in this study. However, it was evident that a frequency count of balance disturbances may also not be an exact measure of balance ability.

6.5. Future directions. In the future, this study should be replicated to include a control group as well as a larger sample of participants. When both children with ASD and typically developing peers are assessed on gait characteristics and balance abilities, statistical analysis and comparisons can be made between the two groups of children in order to evaluate the differences in motor abilities.

6.6. Review of implications. As mentioned in Section *1.4.*, there are numerous implications to understanding motor impairments in children with ASD. By gaining a better understanding of motor impairments in children with ASD and the specific impairments experienced in various motor domains, brain mechanisms that are affected can be identified, the relationship between movement difficulties and social/communication difficulties can be clarified, and the development of services to address motor impairments can be introduced to provide better outcomes for children with ASD.

The impairments that were observed in the majority of participants were excessive or abnormal upper body movements, rigid or restricted arm postures, clumsiness, and lack of coordination. In previous research, these impairments have been linked to dysfunction of the basal ganglia (Upper body and arm posture: Esposito and Venuti, 2008; Esposito et al., 2011; Maurer & Damasio, 1982) and the cerebellum (Clumsiness and coordination: Hallett et al., 1993; Kohen-Raz et al., 1992; Minshew et al., 2007; Molloy et al., 2003; Rinehart et al., 2006),

supporting beliefs that these brain mechanisms are involved in and potentially responsible for motor impairments in children with ASD.

Additionally, because children with ASD display atypical gait and balance difficulty, it may follow that they are more impaired in social communication and interaction. However, none of the observed participants displayed severe social impairments; all four children had language abilities and played with the other children. Because the program's mission is to enhance social abilities in children with ASD by creating an environment that encourages social interactions, it is logical that the children at the program had developed better social communication abilities. Despite the social abilities displayed by participants, it is important to identify and clarify the relationship between motor impairments and social communication differences in children with ASD (Donnellan et al., 2013; Leary & Hill, 1996; Robledo et al., 2012).

Finally, as motor impairments are continually defined, services, programs, and treatments that address motor difficulties could provide an enhanced developmental outcome for children with ASD. All children who are at risk for or diagnosed with an ASD should receive a full evaluation that includes motor ability and movement development assessments. There is a need to clarify the nature of motor impairments in children with ASD, so that proper care and support can be offered and providers can better understand the behaviors exhibited by individuals with ASD (Donnellan et al., 2012; Sowa & Meulenbroek, 2012).

6.7. Study overview. Overall, this study examined the gait characteristics and balance abilities in four children with ASD and compared results with parent reports of each child's motor skills and development. Results suggest motor impairments in children with ASD and parental awareness of these differences. Further research should replicate this study in order to analyze these motor differences between children with ASD and typically developing peers.

Appendix – Part 1

I. Table 1 – Part 1 of Gait Coding Checklist - Nine components of typical gait mechanics

Stance Phase	1. Heelstrike contact is always made with the **heel.** 2. At heelstrike contact, the knee is **extended.** 3. At midstance, body weight is **aligned over the reference limb** where knee is **extended** and the subject is **stable.**
Swing Phase	4. During swing phase, the foot **completely clears** the ground and the knee is **flexed.**
Whole Gait Cycle	5. The subject always walks in a **heel-to-toe pattern.** 6. Subject's toes are always **facing forward.** 7. The **trunk** is **upright and stable** throughout stance and swing phases. 8. The **arms swing freely and alternate with the leg swing** (when right leg is forward, left arm is forward and vice versa). 9. The subject takes **symmetrical steps in stride length.**

II. Table 2 – Part 2 of Gait Coding Checklist – Five potential abnormal gait patterns

Circumduction Gait	Subject **hikes hip and corresponding leg makes half circle to come forward.**
Scissoring Gait	Subject's **legs cross directly over the other** with each step.
Slapping Gait	Subject's **whole foot comes in contact with ground** at initial contact **with a slapping sound.**
Stamping Gait	Subject's foot is lifted from the ground by taking a **high step and strikes the ground with a flat-footed stamp.**
Shuffling Gait	Subject's **flat foot slides across the ground with each step.**

III. Table 3 – Part 3 of Gait Coding Checklist – Seven characteristics of gait cycle

Stance Phase	• Initial contact is always made with heel • Reference leg is extended • All weight on reference leg • Uses toes for pushoff
Swing Phase	• Foot completely leaves ground • Swing leg flexes at knee and moves forward
Whole Gait Cycle	• Toes face forward

IV. Table 4 – Scoring Criteria for Parent Questionnaire

Age Group	Indication of Motor Impairment	Suspect of Motor Impairment	Probably not Motor Impairment
7 years 0 months to 9 years 11 months	17 – 39	40 – 60	61 – 85
10 years 0 months to 12 years	17 – 43	44 – 64	65 – 85

V. Table 5 – Participant Descriptives

Participant ID	A	B	C	D	Mean (SD)
Age at Assessment	7	9	10	11	9.25 (1.708)
Age of Diagnosis	6	5	2	4	4.25 (1.708)
Gender	Male	Male	Male	Male	--
Other Diagnoses	N/A	ADD/ADHD	N/A	PDD-NOS; SID; SA	--
Occupational Therapy	Yes	Yes	Yes	Yes	--

ADD/ADHD = Attention Deficit Disorder/Attention Deficit Hyperactivity Disorder
PDD-NOS = Pervasive Developmental Disorder, Not Otherwise Specified
SID = Sensory Integration Disorder
SA = Speech Apraxia

VI. Table 6 – Gait Coding Checklist Results for Behavioral Observation

Participant ID	A	B	C	D	Mean (SD)
Gait Coding Checklist – Part 1					
Total Typical Gait Characteristics (of 9)	6	5	4	6	**5.25 (.957)**
Percent of Atypical <u>Stance Phase</u>	67%	33%	67%	33%	**50% (19.63)**
Percent of Atypical <u>Swing Phase</u>	0	0	0	0	**0**
Percent of Atypical <u>Whole Gait Cycle</u>	20%	60%	60%	40%	**45% (19.15)**
Gait Coding Checklist – Part 2					
Presence of Abnormal Gait Pattern	No	No	Sometimes (Scissoring gait)	No	--
Gait Coding Checklist – Part 3					
Total Typical Gait Characteristics (of 7)	4	5	4	7	**5 (1.41)**

VII. Table 7 – Specific Gait Impairments – Part 1 of Gait Coding Checklist

Characteristic	Participant Impaired	Alternative
Heelstrike with heel	A	Ball of foot
Knee extended at heelstrike	A; C	Knee flexed[A]; Knees bend inwards[C]
Body weight aligned over reference limb; knee extended; upper body stable	B; C; D	Excessive upper body movement[AC]; unstable upper body[D]
Foot completely clears ground and knee is flexed	None	N/A
Heel-to-toe pattern	A	Half of time on toes
Toes always facing forward	B; C	Slightly outward[B]; both feet inwards[C]
Trunk is upright and stable	B; C; D	Leans backward[B]; waddling gait[CD]
Arms swing freely and alternate with leg swing	B; C; D	Restricted[B]; elbows bent and arms up against body[C]; reduced forearm movement[D]
Symmetrical steps in stride length	None	N/A

VIII. Table 8 – Parent Questionnaire Results

Participant ID	A	B	C	D	Mean (SD)
Total Parent Questionnaire Scores	69.06	37.19	56	47	**52.31(13.55)**
Parent Questionnaire Score Range	**PN**	**IND**	**SUS**	**SUS**	**--**

IND = Indication of Motor Impairment
SUS = Suspect of Motor Impairment
PN = Probably Not Motor Impairment

IX. Table 9 – Specific Difficulties According to Parent Questionnaire

Parent Questionnaire Item	Participant Impaired (1 = Not at all like my child or 2 = A bit like my child)	Potential Impairment (3 = Moderately like my child)
Quick/Competent	B	--
Never described as clumsy	B	D
Does not fatigue easily	B, D	A
Moves effortlessly	B	D
Prefers activities that require standing, walking, running	**B, C, D**	**A**
Rarely collides with objects/peers	None	D
No trouble standing still	B	C, D
Good balance	None	B, D
Rarely falls or trips	D	--
Controlled body movements	B	--
Frequently participates in active sports/activities	A, C	B
Learns new motor skills at same rate as others	**A, B, C, D**	--
Runs as fast and similar to others	B, C	D
Effectively completes planned motor activities	B	C
Easily avoids obstacles in play environments	None	D
Developed gross motor skills at same time as others	**B, C, D**	--
Developed gross motor skills at same time as siblings	D	C

Appendix – Part 2

Gait Observation Scale:
Manual and Coding Protocol

Krystal Mircovich
Senior Honors Thesis
University of Richmond
September 2013-April 2014

PART I – INTRODUCTION

This Gait Observation Manual will train observers to measure children's gait patterns while participating in social, play, and structured settings. The code described in this manual is used to determine if the observed subject exhibits behaviors of normal gait. If the subject does not exhibit normal gait behaviors, the code will determine if the subject instead exhibits behaviors of abnormal gait. Understanding this coding manual will allow the observer to distinguish whether or not the subject being observed demonstrates a normal gait.

Observation Guidelines:

1. Observers will record observations at the RAIN afterschool program.
2. Observers will not interfere with the subjects while recording.
3. Observers will record and code 5 minutes of gait cycle observations for each subject.
4. Observations will be made after viewing the subject from the front, side, and behind.
5. Observations will be recorded using the Gait Cycle Checklist. The observer will check off the "Yes" or "No" check boxes for each of the nine main characteristics of normal gait. If the observer checks "No" (meaning that the subject does not exhibit the described action of normal gait), then the observer will check off any of the subsequent boxes (if the subject demonstrates those behaviors instead).
6. If the subject exhibits a behavior that would fall in the same characteristic category, but is not listed to check off, the observer will fill in this behavior on the "Other" line.
7. When observations begin, a 5-minute timer will be started. If at any point, a subject is in a position where observation cannot be taken (e.g., the subject sits), the timer will continue. However, if the subject remains in the unobservable position for more than 30 seconds, the timer will stop. When the subject's position again becomes observable, the timer will start again from the previous time.

What is Gait?

Gait is the pattern of rhythmical and alternating cycles of forward progression of the body by foot. Normal gait presents a smooth function of walking in a heel-to-toe forward pattern where arms swing in alternation with opposite legs. The gait cycle is composed of stance and swing phases. The stance phase is when the reference leg (white) is in contact with the ground. The swing phase is when the reference leg is not in contact with the ground and is instead swinging forward to begin the stance phase again. Below is a diagram of the stance and swing phases of gait that depicts a normal gait cycle.

| Heelstrike | Midstance | Pushoff | Acceleration | Midswing | Deceleration |

Stance Phase | Swing Phase
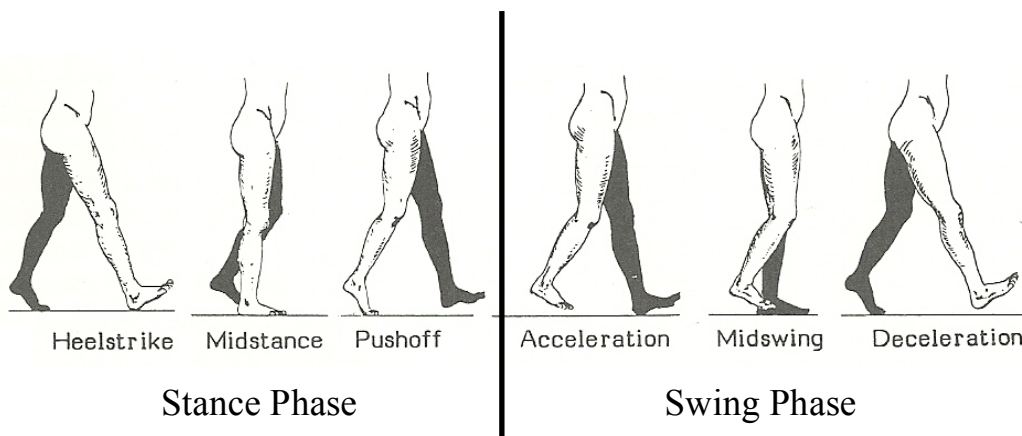
How to Complete the Gait Coding Checklist:

In order to code gait patterns in children with autism and typically developing peers, it is important to understand how to fill out the corresponding Gait Coding Checklist.

Complete the following steps in order to complete the stance phase, swing phase, and whole gait cycle sections of the checklist.
- First, observe the nine characteristics that define a typical gait pattern. These characteristics are underlined and described in this manual and underlined in the checklist. These nine characteristics are also written below. On the following pages, the bolded terms for each statement are defined.

1. Heelstrike contact with the ground is always made with the **heel**.
2. At heelstrike contact, the knee is **extended**.
3. At midstance, body weight is **aligned over the reference limb** where knee is **extended** and the subject is **stable**.
4. During swing phase, the foot **completely clears** the ground and the knee is **flexed**.
5. The subject always walks in a **heel-to-toe pattern**.
6. Subject's toes are always **facing forward.**
7. The **trunk** is **upright and stable** throughout stance and swing phases.
8. The **arms swing freely and alternate with the leg swing** (when right leg is forward, left arm is forward and vice versa).
9. The subject takes **symmetrical steps in stride length.**

- If the subject demonstrates these characteristics, check the YES box following the statement.
- If the subject does not demonstrate these characteristics, check the NO box following the statement, and then continue to the check boxes *below* the typical gait characteristics.
    - These characteristics define potential atypical gait patterns that the subject may exhibit if he/she does not exhibit the underlined typical gait pattern.
    - These options are mutually exclusive, meaning that some, all, or none of these options may apply to the subject.
    - If there is a behavior that the subject demonstrates that is not an alternative option to the typical gait pattern, write a description of the gait on the "Other" option.

Complete the following steps to complete the other gait observations section of the checklist.
- Check off the "**ALWAYS**" box if the subject demonstrates the statement more than 90 percent of coding time.
- Check off the "**SOMETIMES**" box if the subject demonstrates the statement between 40 and 60 percent of coding time.
- Check off the "**RARELY**" box if the subject demonstrates the statement less than 10 percent of coding time.

PART II – Definitions: STANCE PHASE

When coding an adolescent's gait, it is important to understand (1) the four parts of normal stance phase and (2) what to look for when coding gait.
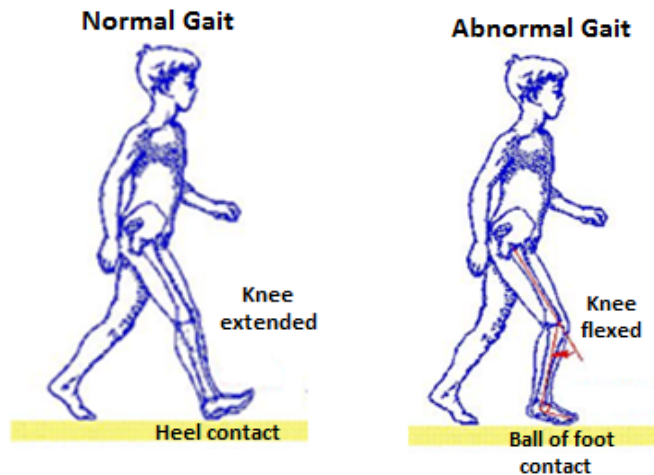
Stance Phase
Stance phase is when the reference limb (white) is in contact with ground.
- It begins when the reference limb contacts the ground and ends when the reference limb goes into swing phase (Part III).
- The diagram below depicts the three main parts of stance phase: heelstrike, midstance, and pushoff.
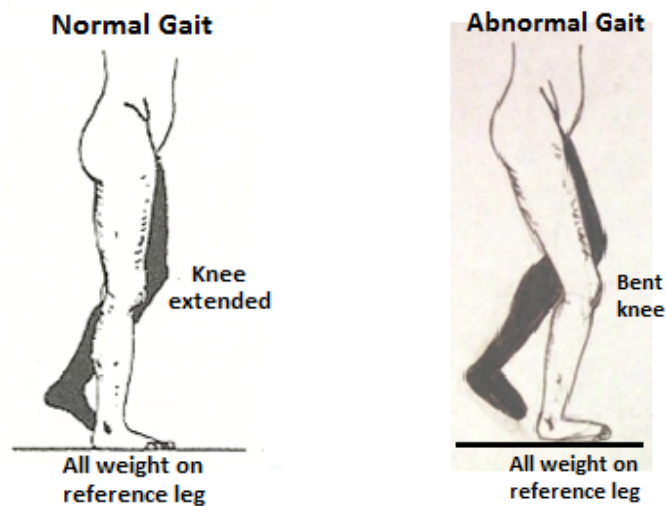

Heelstrike   Midstance   Pushoff
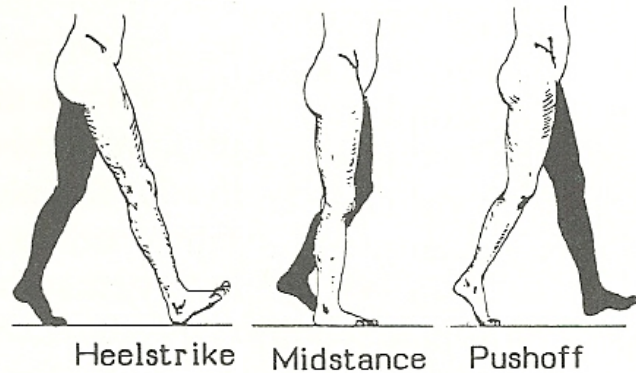
1. Heelstrike contact is always made with the **heel.** The heel is the back part of the foot that lies below the ankle.
   IF NOT – (the subject might display the following atypical behaviors)
   a. Initial contact is made with the **ball of the foot.** The ball of the foot is the padded part of the foot sole that is between the toes and the arch of the foot.
   b. Initial contact is made with a **flat foot.** Stepping with a flat foot is when the whole sole of the foot comes in contact with the ground at initial contact.

2. At heelstrike contact, the knee is **extended.** An extended knee is when the leg is straightened at the knee.
   IF NOT – (the subject might display the following atypical behaviors)
   a. At initial contact, the knee is **flexed.** A flexed knee is when the leg is bent at the knee.

Normal Gait   Abnormal Gait

Knee extended   Knee flexed

Heel contact   Ball of foot contact

3. At midstance, body weight is **aligned over the reference limb** where knee is **extended and the subject is stable.** When subject is in the middle of stance phase, the reference leg supports whole body weight. The subject's upper body is straight and directly in line with the reference leg. The subject is stable, meaning he/she is unlikely to fall or change upper body position while weight is all on reference limb. Leg is straightened at the knee.

IF NOT – (the subject might display the following atypical behaviors**)**

   a. Weight is **aligned over reference limb,** but subject is **not stable.** The reference leg supports whole body weight, but the subject's upper body is not straight and/or directly in line with the reference limb. The subject is not stable, meaning that he/she is likely to fall, stumble, or change upper body position while weight is all on reference limb.

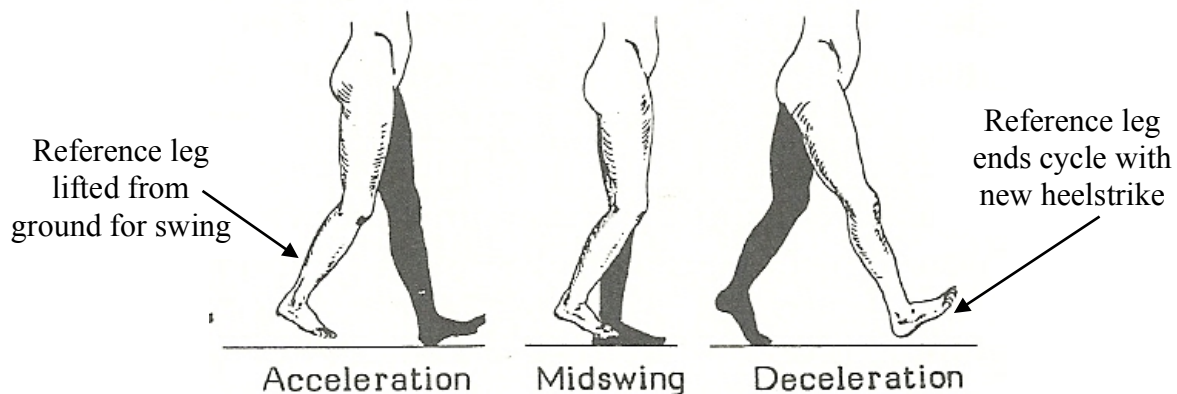   b. Knee is **flexed.** A flexed knee is when the leg is bent at the knee.

Normal Gait

Knee extended

All weight on reference leg

Abnormal Gait

Bent knee

All weight on reference leg

PART III – Definitions: SWING PHASE

When coding an adolescent's gait, it is important to understand (1) the three parts of normal swing phase and (2) what to look for when coding gait. The above guidelines for completing the checklist also apply to swing phase.

Swing Phase
Swing phase is when the reference limb (white) is not in contact with ground because it is swinging to take a new step.
- It begins when the reference limb leaves the ground and ends just before the heel contacts the ground again.

Reference leg lifted from ground for swing

Reference leg ends cycle with new heelstrike

Acceleration   Midswing   Deceleration

4. During swing phase, the foot **completely clears** the ground and the knee is **flexed**.

Completely clears means that the foot is lifted from the ground to about the height of the top of the standing limb's foot. No part of the foot is in contact with the ground while swinging. The leg is bent at the knee as it swings to take a step and the leg moves the subject in a directly straightforward direction.

IF NOT – (the subject might display the following atypical behaviors**)**
   a. During swing phase, **toes drag** on the ground. When the toes drag, only the heel of the foot clears ground when taking a step. The toes are not lifted and instead slide across the ground to take a step.
   b. During swing phase, the knee is **extended.**

PART IV – WHOLE GAIT CYCLE

When coding an adolescent's whole gait cycle, it is important to understand (1) the typical gait procedures and (2) what to look for when coding abnormal gait.

5. The subject always walks in a **heel-to-toe pattern**.

A heel-to-toe pattern includes making initial contact with the heel and pushing off with the toe.

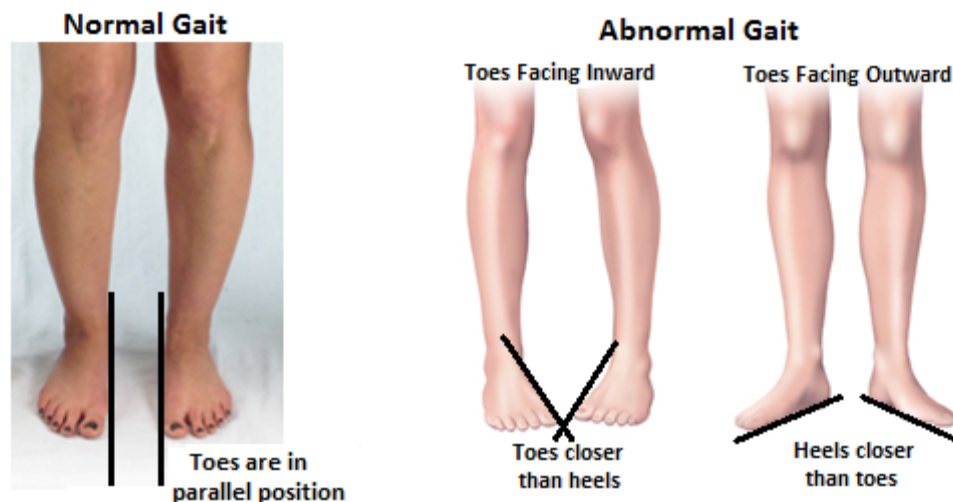>**IF NOT – (**the subject might display the following atypical behaviors**)**
> a. Subject walks on his/her **toes (toe walking).** Initial contact is made with toes or ball of foot and the heel rarely contacts the ground. The toes/ball of foot remains the primary contact with the ground throughout the whole gait cycle. Subject may exhibit a "bounce in step" as they lift and lower heel during cycle.
> b. Subject walks on his/her **heels (heel walking).** Initial contact is made with heel and the toes rarely contact the ground. The heel remains the primary contact with the ground throughout the whole gait cycle.

6. Subject's toes are always **facing forward.**

Toes facing forward means that the big toes of the subject's feet are parallel to each other throughout the entire gait cycle.

IF NOT – (the subject might display the following atypical behaviors**)**
> a. The toes of at least one foot **faces outward.** The subject's toes are facing away from the center of the body. The subject's heels are closer together than the subject's toes.
> b. The toes of at least one foot **faces inward.** The subject's toes are facing toward the center of the body. The subject's toes are closer together than the subject's heels.
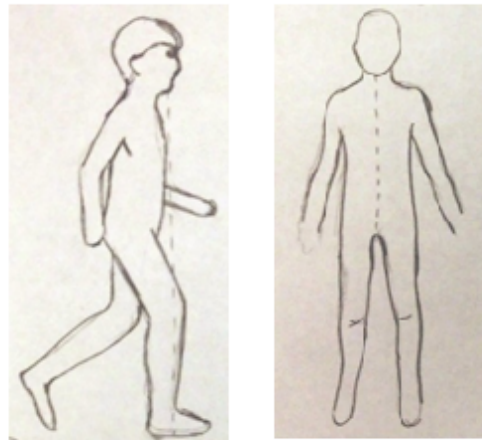

Normal Gait

Toes are in parallel position

Abnormal Gait

Toes Facing Inward

Toes closer than heels

Toes Facing Outward

Heels closer than toes

7. The **trunk** is **upright and stable** throughout stance and swing phases.

The trunk (torso) of the body is the main part of the body that excludes the head, arms, and legs. The subject's trunk is upright meaning that the chin is in line with the center of the body and the subject's body is in vertical position. The trunk remains stable meaning that it is unlikely to change its upright position throughout the cycle.

> **IF NOT – (**the subject might display the following atypical behaviors**)**
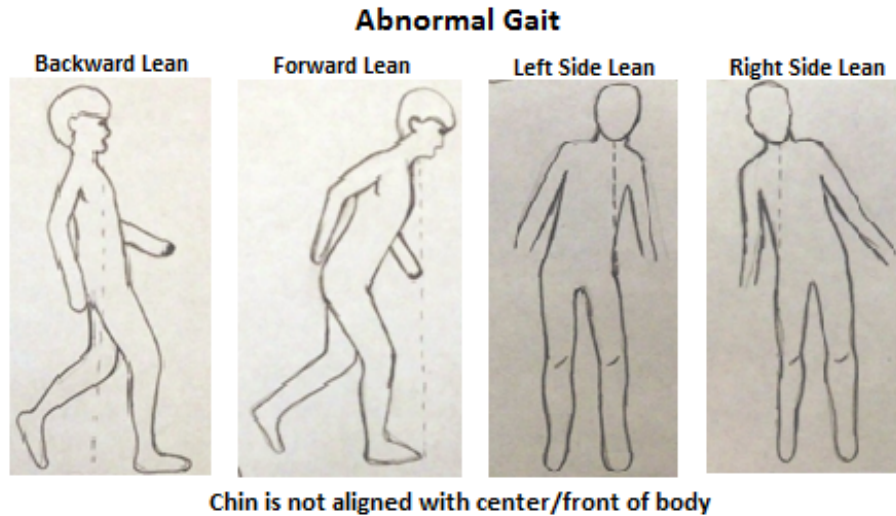> a. The trunk **leans to the left.** The trunk is not vertical and subject's body bends to the left at the hip. When walking, chin is in line with or further away from the left hip.
> b. The trunk **leans to the right.** The trunk is not vertical and subject's body bends to the right at the hip. When walking, chin is in line with or further away from the right hip.
> c. The trunk **leans forward.** The trunk is not vertical and subject's body bends forward at the hip. When walking, chin is in line with or further away from the stepping limb's toes.
> d. The trunk **leans backward.** The trunk is not vertical and subject's body bends backward at the hip. When walking, chin is in line with or further away from the subject's back.
> e. The trunk **rocks in a backward-forward movement.** The subject's trunk moves from a forward position (chin is in line with or further away from the stepping limb's toes) to a backward position (chin is in line with or further away from the subject's back) in a consistent and/or continuous pattern.
> f. The trunk **sways in a left to right movement (waddling gait).** The subject's trunk moves from a left leaning to a right-leaning position in a consistent and/or continuous pattern.

Normal Gait

Body is vertical and chin is in
line with body center/front

Abnormal Gait

| Backward Lean | Forward Lean | Left Side Lean | Right Side Lean |

Chin is not aligned with center/front of body

8. The **arms swing freely and alternate with the leg swing** (when right leg is forward, left arm is forward and vice versa).

Subject's arm swing looks like a natural motion where each arm swings with the motion of the opposite leg. When the arms swing freely they are not restricted and are involuntarily powered by speed of gait rather than voluntarily by the subject.

> **IF NOT – (**the subject might display the following atypical behaviors**)**
> a. The arms **DO NOT swing freely and DO NOT alternate with swing leg.** The subject seems to voluntarily move his/her arms and they therefore do not alternate with the swinging legs. The subject's arm swing does not look natural and each arm does not always swing in motion with the opposite leg.
> b. The arms are always **at the sides of the subject and do not move.** Arms of the subject do not move during gait.
> c. The arms show **reduced arm swing.** Subject does not exhibit adequate arm swing relative to speed and stride length. There may be a reduction of arm swing velocity and/or range of motion.

9. The subject takes **symmetrical steps in stride length.**

Each step that the subject takes is similar in stride length than previous steps. Stride length is the distance from the standing limb to heelstrike of the reference limb (swinging limb).

> **IF NOT – (**the subject might display the following atypical behaviors**)**
> a. The subject takes **steps that vary in stride length** (some steps are long while others are short – no rhythm). The subject's steps are different with each step that he/she takes. The distance from the standing limb to heelstrike of the reference limb is asymmetrical.

PART V – OTHER GAIT OBSERVATIONS

When coding an adolescent's gait, it is important to look for gait occurrences that may or may not be consistent during coding time. Check the "**ALWAYS**" box if the subject demonstrates the statement more than 90 percent of coding time. Check the "**SOMETIMES**" box if the subject demonstrates the statement between 40 and 60 percent of coding time. Check the "**RARELY**" box if the subject demonstrates the statement less than 10 percent of coding time.

1. Subject **hikes hip and corresponding leg makes a half circle to come forward** (circumduction gait).

    Subject's leg does not bend at the knee and remains stiff throughout gait cycle. With each step, the subject's legs are rotated away from the body and then towards it, forming a semicircle. The subject's hip generally "hikes" meaning that it is lifted above the height of the standing limb's hip. **Main focus on knee and hip.**

2. Subject's **legs cross directly over the other** with each step (scissoring gait).

    The subject's legs, hips, and knees bend at various degrees and the subject seems to crouch during the gait cycle. The subject's knees and thighs may often hit or cross over each other. Therefore, this is referred to as a scissoring gait. **Main focus on knees, feet, and hips.**

3. Subject's **whole foot comes in contact with ground** at initial contact **with a slapping sound** (slapping gait).

    Subject does not exhibit normal heelstrike. When the foot comes in contact with the ground, the *heel* hits the ground first but the rest of the *foot immediately "slaps"* the ground with a slapping sound. Ankle may be weak and therefore the subject lifts the leg high to clear foot from ground. **Main focus on ankle.**

4. Subject exhibits a **stamping gait,** where the foot is lifted from the ground by taking **a high step and strikes the ground with a flat-footed stamp.**

    Subject does not exhibit normal swing phase and heelstrike. The foot and knee of the swinging leg is lifted above the knee of the standing limb. Swing leg then stamps on the ground at a fast speed and lands in a *flat-footed* position. Subject's trunk tends to be in a crouched or leaning forward position. **Main focus on flat foot.**

5. Subject exhibits a **shuffling gait,** where **flat foot slides across the ground with each step.**

    The subject's feet never leave ground and the whole sole of the foot remains in contact with the ground. The subject takes short, quick steps. Knees and upper body may be flexed throughout the whole cycle during this type of walk. **Main focus on feet.**

Appendix – Part 3

Balance Observation Manual

Krystal Mircovich
Senior Honors Thesis
University of Richmond
September 2013-April 2014

PART 1 – INTRODUCTION

This Balance Observation Manual will train observers to measure balance ability of children while participating in social, play, and structured settings. The code described in this manual is used to determine if the observed subject displays behaviors of balance relative to peers. Understanding this coding manual will allow the observer to distinguish whether or not the subject being observed demonstrates balance abilities.

Observation Guidelines:

1. Observers will record observations at the RAIN afterschool program.
2. Observers will not interfere with the subjects while recording.
3. Observers will code balance observations for 5 minutes for each subject.
4. Observations will be recorded using the Balance Coding Sheet. The observer will tally the frequency with which the observed subject exhibits the defined term: trips, collisions with objects, collisions with people, collisions and falls, trips and falls, slips
5. If the observer notices other balance differences that cannot be labeled as one of the five main balance characteristics, the observer should describe the behavior in the "Other Observations" section.
6. When observations begin, a 5-minute timer will be started. If at any point, a subject is in a position where observation cannot be taken (e.g., the subject sits), the timer will continue. However, if the subject remains in the unobservable position for more than 30 seconds, the timer will stop. When the subject's position again becomes observable, the timer will start again from the previous time.

What is Balance?

In order to understand the definition for balance, it is first important to understand definitions associated with balance.

- An individual's **center of gravity** (also known as a line of gravity) is the point of the body where all weight is evenly distributed on both sides of the line.
- An individual's **base of support (BOS)** is the distance between the individual's two feet.

In the following diagram, the line of gravity lies in the middle of the figure, and therefore, weight is even on both sides of this line. Additionally, the BOS is the distance between the figure's feet.
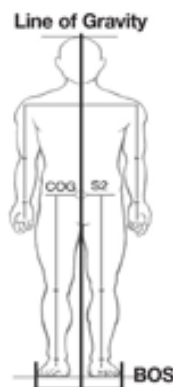
- **Static balance** is the ability to maintain center of gravity within its stationary BOS. In other words, when an individual evenly distributes his/her weight depending on the distance between feet, he/she exhibits static balance.

Of course, the body is not always in a static (not moving and stationary) position. Therefore, the BOS and center of gravity often change.

- An individual exhibits **dynamic balance** when movement changes the base of support, but the individual achieves postural control.
- **Postural control** refers to the ability to maintain, achieve, and restore balance during any movement.

Therefore when the body moves and changes the BOS, it should naturally sense a change in stability and therefore use muscles to preserve dynamic balance (Pollock et al. 2000).

How do Individuals Maintain Balance?

An individual's ability to maintain balance is identified in three main situations.

- First, an individual maintains balance by **maintaining static postures**, such as sitting and standing.
- Second, an individual maintains balance by **achieving voluntary movements**, such as carrying out movements between postures.
- Third, an individual **restores** balance by **reacting to external disturbances**, such as a trip, slip, or push (Pollock et al. 2000).

The following diagram outlines these three main functions requiring postural control and strategies to maintain postural control.
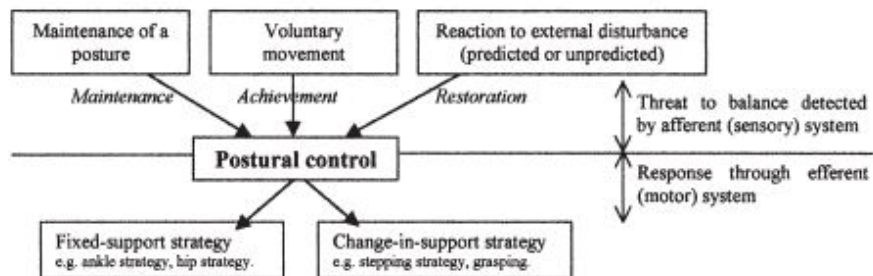
PART II –BALANCE OBSERVATIONS

When coding an adolescent's balance ability, it is important to understand the characteristics of balance. When a subject exhibits one of the following actions, the observer should tally the action in the Balance Coding Sheet in the corresponding box. Each time an action is demonstrated, a tally should be placed on the coding sheet.

Descriptions of Poor Balance Observations

1. **Trips** – A trip is when the observed subject stumbles and uses arms to regain balance, but does not descend (fall) to the ground.
   a. The trip could be a consequence of stumbling on an object, change in surface, or nothing.
   b. *Only tally a trip if the trip does not directly precede a fall. Therefore, if the subject falls immediately after tripping, ONLY tally the fall.*

2. **Collisions with objects** – A collision with an object occurs when the subject runs into, bumps, and/or comes into contact with an object.
   a. The subject exhibits uncontrollable body movements (*cannot voluntarily control his/her motions*).
      i. The subject <u>did not</u> collide with the object intentionally or in order to complete a goal (e.g., as a last resort to stop forward movement).
   b. Collision may be due to an unbalanced body and/or lack of postural control.
   c. Objects include desks, tables, playground equipment, wall, and/or boundaries.

3. **Collisions with people** – A collision with another person is when the subject runs into, bumps, and/or comes into contact with another person.
   a. The other person must be in stable position and did not cause the collision.
   b. The subject exhibits uncontrollable body movements (*cannot voluntarily control his/her motions*).
      i. The subject <u>did not</u> collide with the object in order to complete a goal (e.g., as a last resort to stop forward movement).
   c. Collision may be due to an unbalanced body and/or lack of postural control.

4. **Collisions and Falls** – A collision with another person or object the directly leads the subject to descend to the ground. The fall can either be in a forward or backward process where the subject either lands on hands, knees, or stomach OR the subject lands on buttocks or hands respectively.
   a. Collisions with people or objects are defined in Numbers 2 and 3 above.

5. **Trips and Falls** – A trip (as defined in Number 1 above) directly leads the subject to descend to the ground. The fall occurs in a forward process and the subject lands on his/her hands, knees, and/or stomach. The subject's stomach is facing the ground.
   a. The trip could be a consequence of stumbling on an object, change in surface, or nothing.

b. The subject may stumble (almost fall) before falling to the ground. *In cases where trips precede a fall, do not tally the Trips and do not tally the Falls: ONLY tally Trips and Falls.*

6. **Falls** – A fall is when the observed subject descends to the ground in a forward process and lands on his/her hands, knees, and/or stomach. The subject's stomach is facing the ground.
     a. The fall is typically a consequence of nothing. However, a direct fall may occur due to a change in surface or an object (ex. toy on the ground).
     b. The subject makes *no attempt* to regain balance (a trip and stumble method) and instantly falls.
     c. If the subject stumbles (almost falls) before falling to the ground, this means that a trip precedes the fall. *In cases where trips precede the fall, do not tally the Falls, and ONLY tally the Trips and Falls.*

7. **Slips** – A slip is when the observed subject descends to the ground in a backward process and lands on his/her buttocks and/or hands. The subject's back is facing the ground.
     a. The slip could be a consequence of interaction with an object on the ground, change in surface, or nothing.

Frequency Count Overview

1. If the subject **trips,** but does not fall → Mark as a **TRIP**

2. If the subject **collides** with an **object**, but does not fall → Mark as a **COLLISION WITH OBJECT**

3. If the subject **collides** with a **person**, but does not fall → Mark as **COLLISION WITH PERSON**

4. If the subject **collides** with an **object** or **person** and then **falls** → Mark as **COLLISION AND FALL**

5. If the subject **trips** and then **falls** → Mark as **TRIP AND FALL**

6. If the subject **falls forward** without stumbling to regain balance → Mark as **FALL**

7. If the subject **falls backward** → Mark as **SLIP**

References

American Psychiatric Association. (1994). *Diagnostic and Statistical Manual of Mental Disorders, 4th Edition*. American Psychiatric Press, Washington, DC.

American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders, 5th Edition*. American Psychiatric Press, Washington, DC.

Bhat, A.N., Landa, R.J., and Galloway, J.C. (2011). Current perspectives on motor functioning in infants, children, and adults with autism spectrum disorders. *Physical Therapy, 91,* 1116-1129.

Bryson, S.E., Zwaigenbaum, L., Brian, J., Roberts, W., Szatmari, P., Rombough, V., et al. (2007). A prospective case series of high-risk infants who developed autism. *Journal of Autism and Developmental Disorders, 37,* 12-24.

Brown, P. and Steiger, M.J. (1996). Basal ganglia gait disorders. In A.M. Bronstein, T. Brandt, and M.H. Woollacott (Eds.), *Clinical Disorders of Balance, Posture, and Gait* (pp. 156-167). London: Arnold.

Dawson, G., Osterling, J., Meltzoff, A.N., and Kuhl, P. (2000). Case study of the development of an infant with autism from birth to two years of age. *Journal of Applied Developmental Psychology, 21(3),* 299-313.

Diener, H-C. and Dichgans, J. (1996). Cerebellar and spinocerebellar gait disorders. In A.M. Bronstein, T. Brandt, and M.H. Woollacott (Eds.), *Clinical Disorders of Balance, Posture, and Gait* (pp. 147-155). London: Arnold.

Donnellan, A. M., Hill, D. A., and Leary, M. R. (2013). Rethinking autism: Implications of sensory and movement differences for understanding and support. *Frontiers in Integrative Neuroscience, 6,* 1-11.

Esposito, G. and Venuti, P. (2008). Analysis of toddlers' gait after six months of independent

walking to identify autism: A preliminary study. *Perceptual and Motor Skills, 106,* 259-

269.

Esposito, G., Venuti, P., Apicella, F., and Muratori, F. (2011). Analysis of unsupported gait in

toddlers with autism. *Brain and Development, 33,* 367-373.

Fournier, K.A., Hass, C.J., Naik, S.K., Lodha, N., Cauraugh, J.H. (2010). Motor coordination in

autism spectrum disorders: A synthesis and meta-analysis. *Journal of Autism and*

Developmental Disorders, 40, 1227-1240.

Green, D., Charman, T., Pickles, A., Chandler, S., Loucas, T., Simonoff, E., et al. (2009).

Impairment in movement skills of children with autism spectrum disorders.

Developmental Medicine and Child Neurology, 51, 311-316. DOI: 10.1111/j.1469-

8749.2008.03242.x

Hardy, M. W. and LaGasse, A. B. (2013). Rhythm, movement, and autism: Using rhythmic

rehabilitation research as a model for autism. *Frontiers in Integrative Neuroscience, 7,* 1-

9.

Hallett, M., Lebiedowska, M. K., Thomas, S. L., Stanhope, S. J., Denckla, M. B., and Rumsey, J.

(1993). Locomotion of autistic adults. *Archives of Neurology, 50,* 1304-1308.

Hilton, C. L., Wente, L., LaVesser, P., Ito, M., Reed, C., Herzberg, G. (2007). Relationship

between motor skill impairment and severity in children with Asperger syndrome.

Research in Autism Spectrum Disorders, 1, 339-349.

Hilton, C. L., Zhang, Y., Whilte, M. R., Klohr, C. L., and Constantino, J. (2012). Motor

impairment in sibling pairs concordant and discordant for autism spectrum disorders.

Autism, 16(4), 430-441.

Jansiewicz, E. M., Goldberg, M. C., Newschaffer, C. J., Denckla, M. B., Landa, R., and

    Mostofsky, S. H. (2006). Motor signs distinguish children with high functioning autism

    and Asperger's syndrome from controls. *Journal of Autism and Developmental*

    Disorders, 36, 613-621.

Jeste, S.S. (2011). The neurology of autism spectrum disorders. *Current Opinion in Neurology,*

    24(2), 132-139.

Kohen-Raz, R., Volkmar, F. R., and Cohen, D. J. (1992). Postural control in children with

    autism. *Journal of Autism and Developmental Disorders, 22(3),* 419-432.

Krebs, D.E., Edelstein, J.E., Fishman, S. (1985). Reliability of observational kinematic gait

    analysis. *Physical Therapy, 65,* 1027-1033.

Landa, R. and Garrett-Mayer, E. (2006). Development in infants with autism spectrum disorders:

    A prospective study. *Journal of Child Psychology and Psychiatry, 47(6),* 629-638.

Landis, J.R. and Koch, G.G. (1977). The measurement of observer agreement for categorical

    data. *Biometrics, 33(1),* 159-174.

Leary, M.R. and Hill, D.A. (1996). Moving on: Autism and movement disturbance. *Mental*

    Retardation, 34(1), 39-53.

Malanga, G., and DeLisa, J.A. (1998). Clinical observation. In *Gait analysis in the science of*

    rehabilitation. Washington, D.C.: Dept. of Veterans Affairs, Veterans Health

    Administration, Rehabilitation Research and Development Service, Scientific and

    Technical Publications Section.

Maurer, R.G. and Damasio, A.R. (1982). Childhood autism from the point of view of behavioral

    neurology. *Journal of Autism and Developmental Disorders, 12(2),* 195-205.

Ming, X., Brimacombe, M., Wagner, G.C. (2007). Prevalence of motor impairment in autism spectrum disorder. *Brain and Development, 29,* 565-570.

Minshew, N.J., Sung, K., Jones, B.L., and Furman, J.M. (2004). Underdevelopment of the postural control system in autism. *Neurology, 63,* 2056-2061.

Miyahara M., Tsujii, M., Hori, M., Nakanishi, K., Kageyama, H., and Sugiyama, T. (1997). Brief report: Motor incoordination in children with Asperger syndrome and learning disabilities. *Journal of Autism and Developmental Disorders, 27(5),* 595-603.

Molloy, C. A., Dietrich, K. N., and Bhattacharya, A. (2003). Postural stability in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 33(6),* 643-652.

Nayate, A., Bradshaw, J.L., Rinehart, N.J. (2005). Autism and Asperger's disorder: Are they movement disorders involving the cerebellum and/or basal ganglia? *Brain Research Bulletin, 67,* 327-334.

Noterdaeme, M., Mildenberger, K., Minow, F., Amorosa, H. (2002). Evaluation of neuromotor deficits in children with autism and children with a specific speech and language disorder. *European Child and Adolescent Psychiatry, 11,* 219-225.

Ozonoff, S., Young, G. S., Goldring, S. Greiss-Hess, L., Herrera, A. M., Steele, J., et al. (2008). Gross motor development, movement abnormalities, and early identification of autism. *Journal of Autism and Developmental Disorders, 38,* 644-656.

Patrick, J.H. (1996). Orthopaedic assessment of gait disorders. In A.M. Bronstein, T. Brandt, and M.H. Woollacott (Eds.), *Clinical Disorders of Balance, Posture, and Gait* (pp. 64-78). London: Arnold.

Pollock, A. S., Durward, B. R., Rowe, P. J., and Paul, J. P. (2000). What is balance? *Clinical Rehabilitation, 14,* 402-406.

Prassas, S., Thaut, M., McIntosh, G., and Rice, R. (1997). Effect of auditory rhythmic cuing on gait kinematic parameters of stroke patients. *Gait and Posture, 6(3),* 218-223.

Provost, B., Lopez, B. R., and Heimerl, S. (2007). A comparison of motor delays in young children: Autism spectrum disorder, developmental delay, and developmental concerns. *Journal of Autism and Developmental Disorders, 37,* 321-328.

Robledo, J., Donnellan, A.M., Strandt-Conroy, K. (2012). An exploration of sensory and movement differences from the perspective of individuals with autism. *Frontiers in Integrative Neuroscience, 6,* 1-13.

Sowa, M. and Meulenbroek, R., (2012). Effects of physical exercise on autism spectrum disorders: A meta-analysis. *Research in Autism Spectrum Disorders, 6,* 46-57.

Thaut, M.H., McIntosh, G.C., Rice, R.R., Miller, R.A., Rathbun, J., and Brault, J.M. (1996). Rhythmic auditory stimulation in gait training for Parkinson's disease patients. *Movement Disorders, 11(2),* 193-200.

Teitelbaum, P., Teitelbaum, O., Nye, J., Fryman, J., and Maurer, R.G. (1998). Movement analysis in infancy may be useful for early diagnosis of autism. *Proceedings of the National Academy of Sciences, 95,* 13982-13987.

Vernazza-Martin, S., Martin, N., Vernazza, A., Lepellac-Muller, A., Rufo, M., Massion, J., et al. (2005). Goal directed locomotion and balance control in autistic children. *Journal of Autism and Developmental Disorders, 35(1),* 91-102.

Vilensky, J. A., Damasio, A. R., and Maurer, R. G. (1981). Gait disturbances in patients with autistic behavior. *Archives of Neurology, 38,* 646-649.

Wilson, B.N., Crawford, S.G., Green, D., Roberts, G., Aylott, A., and Kaplan, B. (2009).

>   Psychometric properties of the revised developmental coordination disorder

>   questionnaire. *Physical and Occupational Therapy in Pediatrics, 29(2),* 182-202.

Winter, D.A. (1995). Human balance and posture control during standing and walking. *Gait and*

>   *Posture, 3,* 193-214.

Woollacott, M.H., Assaiante, C., and Amblard, B. (1996). Development of balance and gait

>   control. In A.M. Bronstein, T. Brandt, and M.H. Woollacott (Eds.), *Clinical Disorders of*

>   *Balance, Posture, and Gait* (pp. 41-63). London: Arnold.