GAIT ANALYSIS IN CHILDREN WITH AUTISM USING TEMPORAL-SPATIAL AND FOOT PRESSURE VARIABLES

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The purpose of this study was to investigate gait patterns of children with autism using temporal-spatial and foot pressure variables. A total of 30 children participated; 15 autistic children and 15 age matched controls. Group differences were tested using an independent t-test performed by SPSS. The cadence and step/extremity ratio was significantly lower for the experimental group than the control group. The step width was wider; while cycle time, double support time, stance time was longer for the experimental group. The active pressure area and maximum pressure in the hind foot were lower for the experimental group. There were reduced gait velocities and reduced pressure areas in the hind foot and mid foot.

KEY WORDS: autism, gait analysis, foot pressure, GAITRite system.

INTRODUCTION: Autism is associated with changes in motor development progress, hypotonia, muscle rigidity, akinesia, bradykinesia and postural control impairments and can lead to instable and abnormal movements during daily activities, such as walking (Calhoun, Longworth, & Chester, 2011). These abnormal walking patterns can lead to pain, fatigue, extra joint stresses, which can affect a child's functional capabilities and an overall reduction in quality of life (Calhoun et al., 2011). To develop an effective exercise treatment specific to autistic children, it is vital to be able to accurately evaluate individual autistic gait patterns. Previous studies have shown that autism affects gait patterns but only few studies have used quantitative methods (Vilensky, Damasio, & Maurer, 1981; Vernazza-Martin, Martin, Vernazza, Lepellec-Muller, Rufo, & Massion, 2005; Rinehart, Tonge, Bradshaw, Iansek, Enticott, & McGinley, 2006a). Hallet et al (1993) and Calhoun et al. (2011) are the only two comprehensive studies that have included three-dimensional kinematics and kinetics of gait in autism for adults and children, respectively. To our knowledge, collecting data with autism can be very problematic, as it is especially difficult to control subjects in unfamiliar environments (Choi, Kim, & Lim, 2011). If subjects have to change their clothes and attach reflective markers, required by other motion capture systems, then due to their maladjustment and anxiety problematic behaviour can emerge (Kim, Choi, & Lim, 2011). To overcome these problems the portable GAITRite system can be advantageous as it can be transported to where the subjects are in a familiar environment. The GAITRite system requires no reflective markers and tight clothing required like that of other passive and active motion capture systems. The GAITRite system reliability and validity has been tested and reported to be very high by McDonough et al. (2001) for both temporal-spatial variables and pressure distribution. The purpose of this study was to investigate gait patterns of children with autism using temporal-spatial and foot pressure variables.

METHODS: A total of 30 subjects were recruited for this experiment. There were two groups of 15, an autistic group (M = 11.2 y; SD = 2.8 y) and an age matched control group (M = 11.01 y, SD = 2.89 y). The dependent variables were measured and recorded by the GAITRite system (CIR Systems Inc. Peekskill, NY). The GAITRite system was installed in the local gymnasium where the autistic children practice their exercise daily. To evaluate the subjects' particular characteristics a meeting was setup with the parents of the subjects and the researchers. Here the researchers gathered the cognitive and physical characteristics through discussion with both the parents and their special physical needs certified coach. The following foot dimensions; foot length, foot width, shoe length, shoe width and leg length were measured by the Martin's joint measurement tool (Martin Co., Japan). The experiment then begun after the subjects became accustomed to walking over the walkway. The subjects started barefoot walking 5 m before they stepped onto the GAITRite pressure mat and finished 5 m beyond. Each trial the subjects were encouraged by the coach to maintain their most natural gait pattern and speed. For two subjects who didn't have a consistent gait pattern the coach held their hand lightly and walked beside them. The average of three trials for the right foot was calculated for analysis. The temporal-spatial and pressure distribution variables were calculated by the GAITRite software (version 3.2b). All dependent temporal-spatial and pressure distribution variables were entered into SPSS (version 18.0). To investigate the differences between the two groups means an independent t-test was performed with a significance level of 0.05 applied.

RESULTS: The mean and the standard deviations of the temporal-spatial and foot pressure variables are shown in the Tables 1 and 2 respectively.

Table 1
Temporal – spatial variables

Variables	Autism	Control
Step time (s)	0.49 (0.04)	0.46 (0.05)
Cycle time (s)	0.99 (0.09)	0.92 (0.10)*
Single support time (s)	0.39 (0.04)	0.39 (0.02)
Double support time (s)	0.22 (0.04)	0.18 (0.04)*
Swing time (s)	0.38 (0.04)	0.39 (0.03)
Stance time (s)	0.61 (0.06)	0.53 (0.10)*
Ambulation time (s)	2.47 (0.72)	2.14 (0.47)
Distance (cm)	291.54 (34.34)	292.62 (23.73)
Cadence (steps/min)	120.79 (10.07)	132.72 (19.55)*
Velocity (m/s)	1.25 (0.23)	1.43 (0.30)
Normalized velocity (m/s/cm)	1.62 (0.21)	2.04 (0.50)*
Stride velocity (m/s)	1.15 (0.39)	1.43 (0.30)*
Step length (cm)	62.64 (10.48)	64.01 (8.79)
Stride length (cm)	124.45 (22.96)	128.91 (17.94)
Step width (cm)	11.99 (6.23)	7.10 (2.41)*
Toe out angle (deg)	8.19 (11.39)	2.46 (5.16)
Step length/extremity ratio (cm/leg length)	0.82 (0.10)	0.91 (0.10)*

Mean (SD)
*Refers to significant differences between group, $p<0.05$

Table 2
Foot Pressure Variables

Variables		Autism	Control
	Hindfoot	23.39 (8.20)	32.87 (12.89)*
P*t (%)	Midfoot	24.68 (8.40)	21.54 (6.20)
	Forefoot	52.07 (10.57)	45.67 (12.74)
	Hindfoot	38.51 (5.54)	42.05 (2.86)*
Active area (cm^2)	Midfoot	26.78 (5.84)	24.81 (3.87)
	Forefoot	34.21 (4.76)	33.32 (2.83)
	Hindfoot	20.91 (7.39)	28.23 (10.97)*
Peak pressure (%)	Midfoot	25.53 (7.96)	24.58 (8.03)
	Forefoot	53.69 (8.27)	47.30 (11.83)

Mean (SD)

*Refers to significant differences between group, $p<0.05$

DISCUSSION: In this study, there was no significant difference between the control and experimental group's step length. However, when the step length was normalized by their leg length, the experimental group was shorter than the control group. One of the reasons for the discrepancies between each of the studies (Vernazza-Martin et al. 2005, Vilensky et al., 1981) were the differences in matching of controls, the use of normalizing by leg length and the different age of subjects. In this study, leg length was used whereas Rinehart used age, sex and I.Q. A more appropriate method would be a combination of matching the control used by Reinhart et al. (2006a) such as gender, age and I.Q. as well as matching the controls with leg length. Literature has demonstrated that if there is any pain or weakness in the hip, knee and ankle joints then step length shortens (Perry, 1992). It is especially noticeable if the control of plantar flexors and hip extensors are inefficient as the swing time is reduced, landing occurs quicker thus step length is shortened (Kirtley, 2005). Future study should examine the effect of exercise on plantar flexors and hip extensors. Vilensky et al. (1981) reported similar results to our study, as the stance time was statistically longer for autistic group compared to the control group. Calhoun et al. (2011) reported the opposite results to our study, as they reported, cadence was higher for autistic group than the control group aged between five to nine years old (6.3 y, 121.03 cm, 29.31 kg). In Calhoun et al. (2011) study, there was no statistical difference between the gait velocities. In our study, cadence, stride velocity and normalized velocity were lower for the experimental than the control group. A suspected reason for the differences may be the age of the subjects. With the uncertainty of the effect of age, it may do well to investigate this as a confounding factor in autistic gait. In this study, both gait cycle time and double support time were significantly longer for the experimental than the control group. Also for the step width, the experimental group was significantly wider than the control group. It has been observed (Kirtley, 2005) that the gait of elderly is similar to the autistic as step width is wider, cycle time, double support time and stance time is longer. Consistent with our study, other studies illustrate that pressure distribution is affected by gait velocity, when the velocity is reduced; the pressure in the hind foot is reduced (Andriacchi, Ogle, & Galante, 1977; Titianova, Mateev, & Tarkka, 2004). Similarly, Zhu et al. (1995) indirectly highlights the cause and effect of gait velocity by reporting the positive relationship between cadence and peak plantar pressure. Titianova et al. (2004) reports the time to maximum pressure occurs later for heavier subjects and in the mid foot the active area is wider, while the maximum pressure is higher in the hind foot. In this study, the control group subjects were heavier, the time to maximum plantar pressure was longer and the active area was wider for the mid foot, but the opposite was shown in the hind foot.

In this study, the novel GAITRite system was used instead of the standard 3 dimensional motion analysis system. Some of the main advantages of the GAITRite system are ease of its use in any gymnasium, the lack of preparation required, convenience of not having to change clothes and prepare markers either active or passive which is usually required for other motion analysis systems. These advantages are especially important when autistic children are the participants because when they are introduced into an unfamiliar environment and asked to change clothes in preparation for an experiment then many of them may refuse. The GAITRite analysis system also provides footprint analysis which may help reveal underlying foot and gait problems, which are critical for the development of rehabilitation strategies.

CONCLUSION: The main findings of this study describe a gait similar in characteristics to that of elderly gait i.e. a reduction in cadence, gait velocity, step length and an increase in step width. The plantar pressure reveals the lack of control of the plantar flexion and highlights the flat foot of autistic children. Any exercise treatment prescribed for autistic children should focus on improving the control and strength of the plantar flexors. Furthermore, it may do well to perform more studies focusing on the other factors such as cognitive functioning, age and fitness level that affect autistic children's gait.

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