COMPARATIVE GAIT ANALYSIS BETWEEN CHILDREN WITH AUTISM AND AGE MATCHED CONTROLS

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There are very few studies that have analyzed the gait of children with autism. The purpose of this study was to investigate gait of children with autism using temporal-spatial variables. Fifteen children with autism and fifteen age matched typically developing children walked 3 times on the GAITRite® system. Dependent variables were statistically analyzed using independent samples t-tests with Bonferroni adjustments. Results show a reduction in cadence, gait velocity, step length and an increase in step width for the children with autism. In conclusion, our results suggest that the children with autism have abnormal gait compared to age matched controls.

KEY WORDS: gait analysis, autism, GAITRite system.

INTRODUCTION: Research demonstrates various locomotor skills and gait problems associated autism due to a lack of postural control, stability, balance and coordination impairments (Minshew et al., 2004). Calhoun and associates (2011) report that hypotonia, muscle rigidity, akinesia, bradykinesia and postural control impairments, can led to instable and abnormal movements during daily activities. 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 children with autism, it is vital to be able to accurately evaluate individual autistic gait. Accurate gait analysis is of paramount importance as it leads to a comprehensive understanding of gait characteristics and problems. Furthermore, this understanding and gait data can provide a basis for the development of individual specific exercise treatment programs.

Autism affects gait patterns but only few studies have used quantitative methods. Vilensky et al., (1981) report shorter stride lengths, contrary to Calhoun et al., (2011) whom report no significant differences for stride length. Furthermore, Vernazza-Martin et al., (2005) report a shorter step length for the group with autism. With the inconstant data provided by these studies, the behavioral characteristics of children with autism have not been considered, especially when using motion analysis in a laboratory setting.

Collecting data from participants with autism can be very difficult as they may be hard to control participants in an unfamiliar testing environment (i.e. a laboratory setting) (Choi et al., 2011). If participants have to change their clothes and attach reflective markers, which is required by other motion capture systems, then due to their maladjustment and anxiety problematic behavior can emerge (Kim et al., 2011). To overcome these problems the portable GAITRite® system can be advantageous as it can be transported to where the participants 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 purpose of our study was to investigate gait patterns of children with autism using temporal-spatial variables.

METHODS: A total of 30 participants were recruited for this experiment. The control group consisted of fifteen typically developing age matched children, two females and thirteen males (M = 11.1 yrs, SD = 2.9 yrs). The group with autism consisted of fifteen children (M = 11.2 yrs; SD = 2.8 yrs), two females and thirteen males.

The GAITRite® system was installed in the local gymnasium where the children with autism practiced their exercise daily. After the participants gave their assent and the parental/guardians consent 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) by a qualified adapted physical educator. The leg length was defined as the distance from the greater trochanter to the lateral malleolus. After a few minutes of familiarization, involving walking along the walkway, the adapter physical educator suggested that the participants were ready. The participants started barefoot walking 8 m before they stepped onto the GAITRite® pressure mat and finished 8 m beyond. For each trial the participants were encouraged by the coach to maintain their most natural gait pattern and speed. The average of three trials for the top (right) foot was recorded for analysis.
The temporal-spatial variables were calculated by the GAITRite® software (version 3.2b). Figure 1 illustrates the temporal definitions for the right and left leg when they are in contact with the active sensor area. The step time (s) is defined as the time elapsed from the first foot contact to the first contact of the opposite foot. The gait cycle time is defined as time elapsed from the first contacts of two consecutive footprints of the same foot. The single leg support time (s) is defined as the time opposite foot is swinging to the next step and the double support time (s) is defined as the time when both feet are in contact with the ground. The stance time (s) is defined as the time between the first and last contact of the same footprint and the swing time (s) is defined as the time between the last contact of the current footprint and the first contact of the next footprint of the same foot. The ambulation time (s) is defined as the time from the first footprint heel's center of pressure to the last footprint toe’s center of pressure. The gait velocity (m/s) was calculated by dividing the recorded distance by the ambulation time. To calculate the normalized velocity (m/s/cm), the walking velocity (m/s) was divided by the average leg length (cm). The lower limb length was measured from the greater trochanter to the floor for both legs. The stride velocity (m/s) was calculated by dividing the stride length by the stride time. The step length (cm) was calculated from the distance of the center of pressure of the heel of the current footprint to the same of the previous footprint on the opposite foot. The stride length (cm) was calculated from the line of progression between the heel points of two consecutive footprints of the same foot (A-G). The step width (cm) was calculated as the distance between the progression line of one foot to the opposite foot (D-X). The toe out angle (deg) was calculated as the angle of the foot relative to the progression line (+a). The step/extremity ratio is calculated by dividing the step length by the leg length.
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-tests with Bonferroni adjustments were performed with a significance level of 0.05 applied. Significant differences between groups were further evaluated by using Cohen’s d (Cohen, 1988) effect sizes.

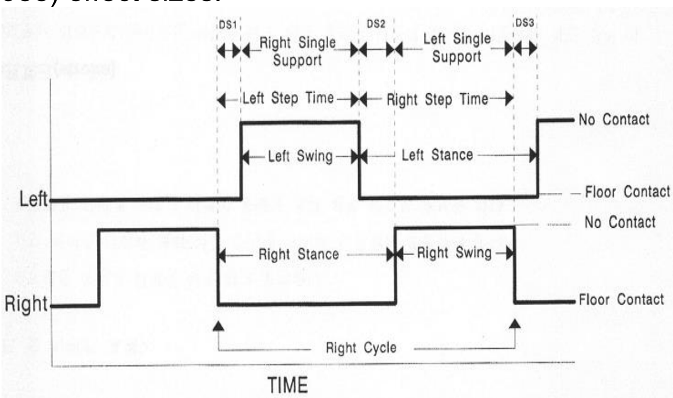

Figure 1: Temporal definitions. (GAITRite operating manual, 2001)

RESULTS: All the temporal and spatial variables are shown in Table 1. The cycle time, p = 0.042 (autism cv = 9.09, control cv =10.87), double support time, p = 0.004 (autism cv =

18.18, control cv =22.22), stance time, p = 0.01(autism cv = 9.84, control cv =18.87) were all significantly longer for the group with autism than the control group. The cadence, p = 0.048 (autism cv = 8.34, control cv =14.73) for the group with autism was lower than the control group. For the normalized velocity, p = 0.009 (autism cv = 12.96, control cv =24.51) and stride velocity, p = 0.038 (autism cv = 33.91, control cv =24.51) the experimental group was significantly slower. The step width, p = 0.008 (autism cv = 51.96, control cv =33.94) was significantly wider for the group with autism than the control group. The step/extremity ratio, p = 0.017 (autism cv = 12.20, control cv =10.99) was significantly lower for the group with autism than the control group.

Table 1
Temporal and spatial gait 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, $p<0.05$

DISCUSSION: The purpose of our study was to investigate gait patterns of children with autism using temporal-spatial and foot pressure variables. Among the temporal variables; cycle time, double support time, and stance time were significantly longer for the group with autism. Among the spatial variables; cadence was significantly lower for the group with autism in comparison with the control group. For the normalized velocity and stride velocity the group with autism was significantly slower than the control group. For the step width the group with autism was significantly wider than the control group. For the step/extremity ratio the group with autism was significantly lower than the control group.

Vernazza-Martin et al., (2005) compared the step length of nine young boys with autism (aged 4 to 6 years) with an age-matched control group consisting of six boys (aged 4 to 6 years). They showed that the boys with autism had a shorter step length. Vilensky et al., (1981) reported similar results for a control group of 15 boys (aged 3.3 to 10 years old, mean 6.1 years) and group with autism of 21 boys (aged 3.9 to 11.3 years old, mean 7.1 years). Contrarily Rinehart(Rinehart, Bruce et al., 2006) found increased step length variability, but no reduction in step length between ten boys with autism and ten aged matched control boys (age 6.8 to 14.4 years). In this study, there was no significant difference between the control and group with autism for their step length. However, for this study when the step length was normalized by their leg length, the group with autism was shorter than the control group (Table 1). One of the reasons for the discrepancies between each of the studies (Rinehart, Tonge, et al., 2006) was the differences in matching of controls, i.e. in this study, leg length was used, whereas Rinehart used age, sex and I.Q.

Vilensky et al., (1981) reported similar results to our study, as the stance time was statistically longer for the group with autism compared to the control group. Calhoun et al.,

(2011) reported the opposite results to our study, as they reported, cadence was higher for the group with autism than the control group aged between five to nine years old (mean age 6.3 yrs, mean height 121.0 cm, mean weight 29.3 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 group with autism than the control group. A suspected reason for the differences may be the age of the participants, as the participants in Calhoun's study (2011) averaged 6.3 years (5 to 9 years) and the participants in our study averaged 11.2 years (8 to 12 years). With the uncertainty of the effect of age, it may do well to investigate this as a confounding factor in gait of children with autism.

Gait cycle time and double support time have not been previously reported for children with autism. In this study, both gait cycle time and double support time were significantly longer for the group with autism than the control group. Also for the step width, the group with autism was significantly wider than the control group. It has been observed (Kirtley, 2005) that the gait of elderly is similar to children with autism as step width is wider, cycle time, double support time and stance time is longer.

In our 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 children with autism 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® system also provides footprint analysis which may help reveal underlying foot and gait problems, which are critical for the development of rehabilitation strategies. A clinician may be able to develop a treatment, based on the gait analysis, which can increase the ability of the child's locomotor skills (Kim et al., 2011), thus helping with their motor development.

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. Our results suggest that the children with autism have abnormal gait compared to age matched controls. Future studies may focus on the other factors such as cognitive functioning, age and fitness level as they may affect the gait of children with autism.

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