Vertical Ground Reaction Force Gait Patterns During Walking in Children with Autism Spectrum Disorders

Article *in* International Journal of Engineering · May 2018

DOI: 10.5829/ije.2018.31.05b.04

4 authors:

Che Zawiyah Che Hasan
Politeknik Ungku Omar

Rozita Jailani
Universiti Teknologi MARA

Noorita Tahir
Universiti Teknologi MARA

Hisham Mohamad Desa
UNIVERSITI KUALA LUMPUR, British Malaysian Institute, Gombak, Selangor, MALA…

IJE TRANSACTIONS B: Applications Vol. 31, No. 5, (May 2018) 705-711

International Journal of Engineering

Journal Homepage: www.ije.ir

Vertical Ground Reaction Force Gait Patterns During Walking in Children with Autism Spectrum Disorders

C. Z. C. Hasan*[a,b], R. Jailani[a], N. M. Tahir[a], H. M. Desa[a]

[a] *Faculty of Electrical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia*
[b] *Department of Electrical Engineering, Politeknik Sultan Idris Shah, Sungai Lang, Sungai Air Tawar, Selangor, Malaysia*

PAPER INFO

Paper history:
Received 05 August 2016
Received in revised form 16 February 2018
Accepted 16 February 2018

Keywords:
Autism Spectrum Disorder
Gait Analysis
Gait Pattern
Ground Reaction Force
Vertical Ground Reaction Force

ABSTRACT

The characteristics of vertical ground reaction force (VGRF) gait patterns in children with autism spectrum disorders (ASD) are poorly understood. The purpose of this study was to identify VGRF gait features that discriminate between children with ASD and the peer control group. The VGRF data were obtained from 30 children with ASD and 30 normal healthy children aged 4 to 12 years. A three-dimensional motion analysis system with eight cameras and two force plates were used to collect VGRF data while subjects performed self-selected speed of barefoot walking. Parameterization techniques were applied to VGRF waveforms to extract the VGRF gait features. Mean significant differences between the two groups were tested using independent samples t-test and Mann-Whitney U test. Significant group differences were found for four VGRF gait features. Results indicated that children with ASD exhibited a significant reduction of the second peak of VGRF, earlier relative time to the occurrence of the second peak of VGRF, lower push-off rate, and higher peak ratio of the two VGRF peaks during normal speed of walking. These prominent differences showed that children with ASD had difficulties in supporting their body weight during terminal stance phase and these conditions affect the gait instability. The findings of this study develop further understanding of VGRF gait patterns that significantly differentiate between children with ASD and the peer control groups.

***doi**: 10.5829/ije.2018.31.05b.04*

1. INTRODUCTION[1]

Walking is the process of moving the body naturally forward from one location to another. This complicated dynamic phenomenon involves the movement of limbs in a repetitive sequence while at the same time maintaining stance stability [1, 2]. Every human has a unique style of walking that can be assessed systematically using instrumented gait analysis [3]. The technology of gait analysis has been widely used to quantify and measure the mechanics of human walking, to identify abnormalities from normal movement patterns and to provide appropriate corrective procedures to improve motion [4, 5].

In order to address these challenges, gait analysis is utilized to investigate the three-dimensional (3D) ground reaction forces (GRF) generated during the contact of foot with the ground. Relatively, this could be used to indicate the causes of the movement abnormalities pattern and the relation with underlying muscle function [6]. In routine gait analysis, force plates are employed to measure the 3D GRF components in medial-lateral, anterior-posterior and vertical direction. These GRF components provide a comprehensive interpretation of how the body weight drops and moves across the supporting foot during walking [1]. All of the three force components, the vertical GRF (VGRF) is the highest in magnitude during gait cycle and this force component has been previously assessed in identifying specific movement characteristics. The VGRF has been successfully applied to discriminate normal and pathological gait patterns of various conditions such as children with cerebral palsy [7], Parkinson disease patients [8], lower limb fractures patients [9], individuals with hip arthroplasty [10] and pregnant

*Corresponding Author Email: *zawiyah.hasan@gmail.com* (C. Z. C. Hasan)

Please cite this article as: C. Z. C. Hasan, R. Jailani, N. M. Tahir, H. M. Desa, Vertical Ground Reaction Force Gait Patterns During Walking in Children with Autism Spectrum Disorders, International Journal of Engineering (IJE), IJE TRANSACTIONS B: Applications Vol. 31, No. 5, (May 2018) 705-711

women [11]. VGRF features were also used to relate gait stability in the virtual reality environments [12], and to assist in the decision-making for recovery balance control in control schemes [13].

Previous studies have reported that children with ASD demonstrated a wide range of gait abnormalities particularly in temporal spatial measurements [14], joint kinematics and joint kinetics [15, 16]. A more recent study showed that children with ASD exhibited asymmetries in several kinematic and kinetic gait features [17]. However, there is a paucity of research investigating the GRF components specifically VGRF gait patterns in children with ASD. So far, the only published literature that has investigated the GRF gait patterns in children with ASD is done by Ambrosini et al. [18]. This study has demonstrated an important association between VGRF gait patterns and ASD gait. Children with ASD were found to relatively reduce second peak of VGRF during the terminal stance when compared to normative data. Our recent published study has comprehensively analysed the 3D GRF gait patterns in children with ASD and suggested the significant variations in the anterior-posterior and VGRF gait patterns [19].

Further assessment of VGRF gait patterns in children with ASD may provide beneficial information to clinicians and facilitate appropriate treatment and rehabilitation programmes. Therefore, the purpose of this study was to identify relevant VGRF gait features that would characterise the autistic gait patterns in children with ASD. The relevant descriptive gait features are essential for the design of machine learning-based on classification techniques to support diagnosis of ASD gait [20, 21]. To aid in identification of differences in movement patterns, gait features of VGRF were extracted by parameterization techniques and the significant features were statistically selected using appropriate statistical approaches.

2. METHODOLOGY

2. 1. Data Collection A total of 60 children aged 4 to 12 years volunteered to participate in the study and were divided into two groups. Thirty children had been clinically diagnosed with ASD (23 males and 7 females; mean age 8.63 years; mean height 1.29 m; mean body weight 31.21 kg; mean body mass index (BMI) 18.12 kg/m^2) and thirty normal healthy children for the control group (15 males and 15 females; mean age 9.52 years; mean height 1.27 m; mean body weight 28.03 kg; mean body mass index 16.81 kg/m^2).

The children with ASD were recruited from the National Autism Society of Malaysia (NASOM) centre in Klang, Selangor, Malaysia and local community by approaching the parents via social media network. All ASD subjects were diagnosed with mild category and were able to follow verbal instructions. The ASD subjects were attended by their parents or caretakers at all time during the experiment session. The normal healthy children were recruited from the families of faculty members and nearby neighbourhood. All subjects were able to walk independently without any assistive devices and had no medical history of lower extremity injuries or musculoskeletal disorders. The parent or guardian of the subject signed an informed consent form and all children provided verbal assent before the experiment was conducted. The study design was approved by the Research Ethics Committee of the Universiti Teknologi MARA, Shah Alam.

Gait analysis was performed at the Human Motion Gait Analysis laboratory at UiTM, Shah Alam using an eight-camera (Vicon T-series) 3D motion capture system (Vicon Motion Systems Ltd., Oxford, United Kingdom) and two force plates (Advanced Mechanical Technology Inc., MA, USA). The 3D motion capture system was used to capture kinematic data at 100 Hz and the force plates which were embedded in the middle of a 6.5-metre walkway were used to measure the 3D GRF data at 1000 Hz. The force plates were also used to detect foot contact and foot off events of each limb of the subjects during walking trials.

Thirty-five spherical retro-reflective markers were placed bilaterally on the specific anatomical landmarks of the subjects using the Plug-in Gait model (Vicon) based on the Newington-Helen Hayes gait model [22, 23]. After static calibration, subjects were instructed to perform a straight barefoot walking along the walkway at their self-determined comfortable walking speed. Subjects were allowed to perform several practice trials for familiarization with the environment and the experimental settings before the real walking trial began. Both force plates were calibrated at the beginning of each trial.

2. 2. Data Processing Trials were excluded if the subjects purposely extended or shortened their normal stride in order to ensure foot contact with the force plates. Only valid trials with single foot contact on each force plate and with complete temporal spatial, kinematic and kinetic data sets were selected for further processing.

Force plate data were filtered using a second order low-pass Butterworth filter with 30 Hz cut-off frequency to remove noise [24]. Trajectories data were smoothed using the built-in Woltring generalized cross-validatory spline algorithm to minimize trajectory noise [25]. The foot contact and foot off events during force plate contact were traced using a 20 Newton threshold. The gait data were extracted into the ASCII text format for data analysis. All data processing were computed using the Vicon Nexus software (version 1.8.5, Vicon, Oxford, UK).

A single gait cycle from a valid trial was selected to represent each subject for detailed analysis [26, 27]. The VGRF data from left limb stance were analysed as the children with ASD were found to have a normal interlimb movement during walking [28]. The VGRF data were then normalized in order to eliminate the variations among the subjects with different height, body mass and duration of stance phase [29, 30]. The magnitude of the VGRF was normalized to the percentage of subject's body weight, while the time component was normalized to the percentage of stance phase duration [31, 32]. The stance phase begins when the foot is in contact with the ground and ends by the toe-off of the same limb, which corresponds to 0% and 100%, respectively. Normalization of gait data was computed in Microsoft Excel version 2013 (Microsoft Corp., USA).

2. 3. Feature Extraction VGRF which follows the *z*-axis is the force component with the largest magnitude during gait [7, 33]. Figure 1 shows a typical M-shape graph of VGRF for a control female subject with a normal walking gait of the entire stance duration. The normal pattern of VGRF has two peaks separated by a valley. This graph also shows the six characteristic points that were studied.

Parameterization techniques were applied to the graph to extract the instantaneous values of amplitude and its relative time of occurrences [15, 33, 34]. The values of the two peaks (Fz1 and Fz3) and the valley (Fz2) and its relative time of occurrences (Tz1, Tz2, and Tz3) were determined as the gait features. Fz1 is the first peak of VGRF that occurs at the beginning of mid-stance in response to the weight-accepting event during loading response. Fz3 is the second peak of VGRF that occurs in terminal stance in response to the push-off phase of the gait cycle. Fz2 is the minimum value of VGRF between Fz1 and Fz3 and usually occurs during mid-stance. Additional features examined in this study were derived from the distinct points.

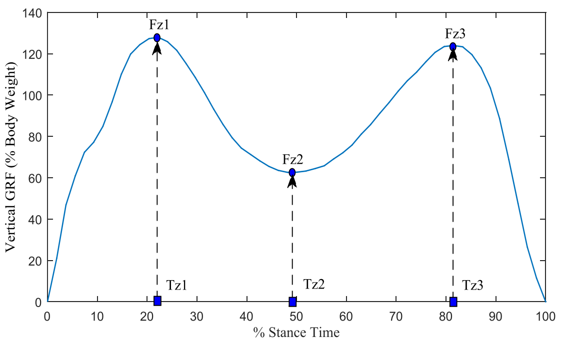

Figure 1. Selected vertical ground reaction force for a subject with a normal gait as a function of the percentage of the stance time

The features are loading rate (Fz1/Tz1), push-off rate (Fz3/(100 – Tz3)), and peak ratio (Fz1/Fz3) [11, 12, 33]. Other analyzed features were walking speed and stance time which represent the temporal gait components.

2. 4. Statistical Analysis After extracting the VGRF gait features, the next process is to select significant features that would possibly differentiate between the two groups of children. By conducting this feature selection, the original high dimensional gait features could be reduced into lower dimensional and only significant gait features were selected for further analysis [35, 36]. The process of significant features selection was depicted graphically in Figure 2.

Selection of significant features was performed using Statistical Package for the Social Sciences (SPSS), version 21.0 (IBM, New York, USA). All extracted features were explored for normal distribution between both groups using the Shapiro-Wilk (SW) test [37]. The data are significantly normally distributed if the statistical outcome of the SW test is greater than or equal to 0.05 ($p \geq 0.05$).

The independent samples t-tests were used to compare the mean differences between the two groups for features that were normally distributed or parametric. For features that were non-parametric, the Mann-Whitney U tests were applied to examine the differences [37, 38]. The significant (*p*-value) difference between the two groups was defined as $p < 0.05$. The magnitude of the difference was measured using the Pearson's *r* [38, 39].

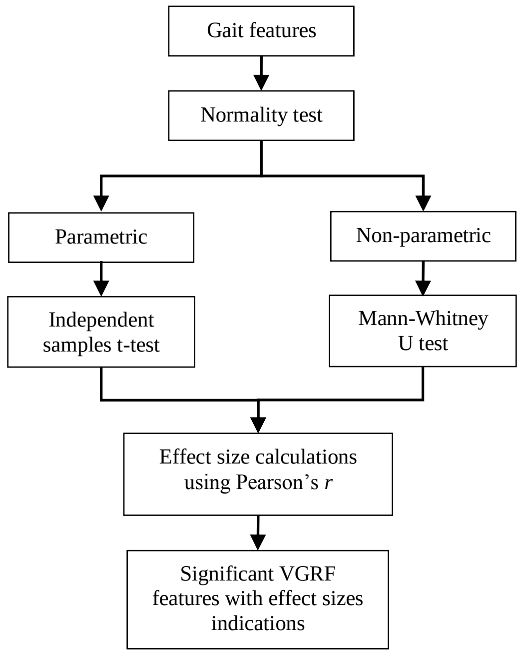

Figure 2. Process diagram of selecting significant VGRF gait features using parametric and non-parametric tests

3. RESULTS AND DISCUSSION

The demographic characteristics of the ASD and control groups are presented in Table 1. Results showed that both groups were comparable in age, height, body mass, and BMI. For the extracted gait features, the Shapiro-Wilk's tests show that Fz3, Tz2, push-off rate, walking speed, and stance time were parametric; therefore, were tested using the independent samples t-test. The other six features are non-parametric and were tested using the Mann-Whitney U test.

Table 2 summarizes the means, standard deviations and p-values for the examined features. Additionally, Table 2 also provides the effect size values for these features that were used to represent the magnitude of the difference. Four significant differences were observed in the VGRF gait features between the two groups of children. The *p*-values of the significant features are bolded in the table. Children with ASD demonstrate a significant reduction of the second peak of VGRF (Fz3) (103.124 % BW versus 109.447 % BW, $p < 0.01$) and a significantly lower push-off rate (4.277 versus 4.967, $p < 0.05$) as compared to control group. Meanwhile, the relative time to the second peak of VGRF (Tz3) occurs significantly earlier for the children with ASD (73.808 % St versus 77.434 % St) in contrast to the normal healthy children. However, the peak ratio of Fz1 and Fz3 is significantly higher in the children with ASD (1.124 versus 1.034, $p < 0.01$) as compared to the control group. The effect sizes of the four significant VGRF gait features represent medium effect, indicating the importance of the findings and the magnitude of the differences of the VGRF gait features between the ASD and control groups. There were no significant differences in the other VGRF gait features between the two groups. Both groups exhibit approximately similar walking speed and stance time during their normal walking.

TABLE 1. Group characteristics

Characteristics	**ASD**	**Control**	***p*-value**
Number of subjects	30	30	N/A
Gender (Male : Female)	23 : 7	15 : 15	N/A
Age (years)	8.63 (2.16)	9.52 (1.96)	0.102
Height (m)	1.29 (0.14)	1.27 (0.13)	0.649
Body mass (kg)	31.21 (14.20)	28.03 (10.57)	0.469
Body Mass Index (BMI)	18.12 (5.09)	16.81 (3.31)	0.712

Data are given either as total number and mean (standard deviation)

TABLE 2. Differences in the VGRF gait features for children with ASD and control children. Effect sizes of the differences were calculated using the Pearson's *r*

Feature	**ASD**		**Control**		***p*-Value**	**Effect size, *r***	**Size**
	Mean	**SD**	**Mean**	**SD**			
Fz1 (% BW)	115.780	18.216	112.959	15.256	0.595	0.069[b]	Small
Fz2 (% BW)	78.198	14.406	77.874	7.734	0.209	0.162[b]	Small-medium
Fz3 (% BW)	103.124	7.644	109.447	6.882	**0.001**	0.404[a]	Medium-large
Tz1 (% St)	23.854	6.369	22.794	2.756	0.304	0.133[b]	Small
Tz2 (% St)	46.893	9.337	45.191	5.375	0.391	0.126[a]	Small
Tz3 (% St)	73.808	9.142	77.434	3.720	**0.048**	0.255[b]	Medium
Loading rate (BW/s)	5.317	2.094	5.049	1.086	0.894	0.017[b]	Very small
Push-off rate (BW/s)	4.277	1.168	4.967	0.800	**0.010**	0.331[a]	Medium
Peak ratio	1.124	0.163	1.034	0.145	**0.012**	0.323[b]	Medium
Walking speed (m/s)	1.012	0.296	1.080	0.139	0.264	0.174[a]	Small-medium
Stance time (s)	0.620	0.123	0.595	0.075	0.359	0.133[a]	Small

Significant differences between groups, $p < 0.05$. SD: standard deviation. BW: body weight. St: stance

[a] Parametric tests. [b] Non-parametric tests. Effect size using Pearson's *r*

To the authors' knowledge, this is the first study to investigate the VGRF gait patterns in children with ASD and to contrast these data with the control group. The major findings of the present study indicate that the children with ASD demonstrated some aspects of gait deviations in the VGRF during their normal self-selected speed of barefoot walking which provided a new dimension to the analysis of gait specifically in children with ASD.

Present study suggests that the gait patterns of the children with ASD are characterized by a significant decrease in push-off rate and a higher peak ratio of the two VGRF peaks. These results were possibly due to the significant reduction of the second peak of VGRF in terminal stance in response to the push-off phase of the gait cycle. These new findings are in agreement with our earlier published study [19], which further established the observation made by Ambrosini et al. [18] that has reported a decrease in the second peak of VGRF in most of their ASD subjects.

The reduction of second peak of VGRF exhibited by children with ASD were identical to the gait patterns observed in children with cerebral palsy (CP). Williams et al. [7] have found that 87% of the CP children in their study have exhibited some degree of reduced second peak of VGRF. The study has also suggested that the CP children were unable to sufficiently support their own body weight in late stance phase and this condition reflects the gait instability. Another study that has been carried out by White et al. [31] has also reported a significantly reduction in second peak of VGRF for both limbs in the CP children and stated that the feature is one of the most reliable parameters to be used with confidence in clinical assessments.

The effect sizes of the significant features as shown in Table 2 also describe the importance of the findings and the strength of the difference for each feature between the groups. It was shown that the four significant gait features from VGRF had potential to effectively distinguish the ASD gait pattern from the healthy control groups.

4. CONCLUSION

This study has found several novel significant gait features in VGRF gait patterns that significantly differentiate between children with ASD and the normal healthy control groups. The children with ASD experience a significant reduction of the second peak of VGRF, earlier relative time to the occurrence of the second peak of VGRF, lower push-off rate, and higher peak ratio of the two VGRF peaks during their normal speed of walking. These findings conclude that children with ASD have movement impairments in the VGRF gait patterns which could remark difficulties in supporting their body weight during terminal stance, thus signifying the gait instability. These significant characteristics together with other movement pattern alterations may further be considered as potential biomarkers to permit earlier diagnosis of ASD gait impairments and to assist in the development of appropriate rehabilitation treatments for ASD children needing therapies.

5. ACKNOWLEDGMENTS

The authors wish to thank the Ministry of Higher Education (MOHE) Malaysia for the funds received through the Niche Research Grant Scheme (NRGS), project file: 600-RMI/NRGS 5/3 (8/2013) and (9/2013), the Human Motion Gait Analysis Laboratory, Institute of Research Management and Innovation Unit (IRMI) Premier Laboratory, Universiti Teknologi MARA, Shah Alam, Selangor. The authors also would like to thank the National Autism Society of Malaysia (NASOM), all volunteered subjects and their families for the realization of this study. This study was pursued during the study leave of the main author under the 2014 Federal Training Scheme (SHLP) awarded by the MOHE Malaysia.

6. REFERENCES

1. Perry, J. and Davids, J.R., "Gait analysis: Normal and pathological function", ***Journal of Pediatric Orthopaedics***, Vol. 12, No. 6, (1992), 815-822.
2. Safartoobi, M., Dardel, M., Ghasemi, M. and MOHAMMADI, D.H., "Stabilization and walking control for a simple passive walker using computed torque method", ***International Journal of Engineering, Transactions B: Applications***, Vol. 27, No. 11, (2014), 1777-1786.
3. Whittle, M.W., Gait analysis, in The soft tissues. 1993, Elsevier.187-199.
4. Davis, R.B., "Clinical gait analysis", ***IEEE Engineering in Medicine and Biology Magazine***, Vol. 7, No. 3, (1988), 35-40.
5. Chester, V.L., Biden, E.N. and Tingley, M., "Gait analysis", ***Biomedical Instrumentation & Technology***, Vol. 39, No. 1, (2005), 64-74.
6. van der Krogt, M.M., Sloot, L.H., Buizer, A.I. and Harlaar, J., "Kinetic comparison of walking on a treadmill versus over ground in children with cerebral palsy", ***Journal of Biomechanics***, Vol. 48, No. 13, (2015), 3586-3592.
7. Williams, S., Gibbs, S., Meadows, C. and Abboud, R., "Classification of the reduced vertical component of the ground reaction force in late stance in cerebral palsy gait", ***Gait & Posture***, Vol. 34, No. 3, (2011), 370-373.
8. Manap, H.H. and Tahir, N.M., "Detection of parkinson gait pattern based on vertical ground reaction force", in Control System, Computing and Engineering (ICCSCE), 2013 IEEE International Conference on, IEEE., (2013), 631-636.

9. Muniz, A. and Nadal, J., "Application of principal component analysis in vertical ground reaction force to discriminate normal and abnormal gait", ***Gait & Posture***, Vol. 29, No. 1, (2009), 31-35.

10. McCrory, J.L., White, S.C. and Lifeso, R.M., "Vertical ground reaction forces: Objective measures of gait following hip arthroplasty", ***Gait & Posture***, Vol. 14, No. 2, (2001), 104-109.

11. McCrory, J.L., Chambers, A.J., Daftary, A. and Redfern, M.S., "Ground reaction forces during gait in pregnant fallers and non-fallers", ***Gait & Posture***, Vol. 34, No. 4, (2011), 524-528.

12. Hollman, J.H., Brey, R.H., Bang, T.J. and Kaufman, K.R., "Does walking in a virtual environment induce unstable gait?: An examination of vertical ground reaction forces", ***Gait & Posture***, Vol. 26, No. 2, (2007), 289-294.

13. Miripour, F.B., Bagheri, A. and Khoskbijari, A., "Receding horizon based control of disturbed upright balance with consideration of foot tilting (research note)", ***International Journal of Engineering, Transactions A: Basics***, Vol. 26, No. 10, (2013), 1243-1254.

14. Weiss, M.J., Moran, M.F., Parker, M.E. and Foley, J.T., "Gait analysis of teenagers and young adults diagnosed with autism and severe verbal communication disorders", ***Frontiers in Integrative Neuroscience***, Vol. 7, No. 10, (2013), 33-40.

15. Calhoun, M., Longworth, M. and Chester, V.L., "Gait patterns in children with autism", ***Clinical Biomechanics***, Vol. 26, No. 2, (2011), 200-206.

16. Dufek, J.S., Eggleston, J.D., Harry, J.R. and Hickman, R.A., "A comparative evaluation of gait between children with autism and typically developing matched controls", ***Medical Sciences***, Vol. 5, No. 1, (2017), 1-11.

17. Eggleston, J.D., Harry, J.R., Hickman, R.A. and Dufek, J.S., "Analysis of gait symmetry during over-ground walking in children with autism spectrum disorder", ***Gait & Posture***, Vol. 55, (2017), 162-166.

18. Ambrosia, D., Courchesne, E. and Kaufman, K., "Motion analysis of patients with infantile austism", ***Gait & Posture***, Vol. 7, No. 2, (1998), 188-205.

19. Hasan, C.Z.C., Jailani, R., Tahir, N.M. and Ilias, S., "The analysis of three-dimensional ground reaction forces during gait in children with autism spectrum disorders", ***Research in Developmental Disabilities***, Vol. 66, No., (2017), 55-63.

20. Kumar, S. and Sahoo, G., "A random forest classifier based on genetic algorithm for cardiovascular diseases diagnosis (research note)", ***International Journal of Engineering-Transactions B: Applications***, Vol. 30, No. 11, (2017), 1723-1729.

21. Hasan, C.Z.C., Jailani, R., Tahir, N.M. and Sahak, R., "Autism spectrum disorders gait identification using ground reaction forces", ***TELKOMNIKA (Telecommunication Computing Electronics and Control)***, Vol. 15, No. 2, (2017), 903-911.

22. Kadaba, M.P., Ramakrishnan, H. and Wootten, M., "Measurement of lower extremity kinematics during level walking", ***Journal of Orthopaedic Research***, Vol. 8, No. 3, (1990), 383-392.

23. Davis III, R.B., Ounpuu, S., Tyburski, D. and Gage, J.R., "A gait analysis data collection and reduction technique", ***Human Movement Science***, Vol. 10, No. 5, (1991), 575-587.

24. Thompson, M., Lee, S., Seegmiller, J. and McGowan, C., "Kinematic and kinetic comparison of barefoot and shod running in mid/forefoot and rearfoot strike runners", ***Gait & Posture***, Vol. 41, No. 4, (2015), 957-959.

25. Woltring, H.J., "A fortran package for generalized, cross-validatory spline smoothing and differentiation", ***Advances in Engineering Software (1978)***, Vol. 8, No. 2, (1986), 104-113.

26. Massaad, A., Assi, A., Skalli, W. and Ghanem, I., "Repeatability and validation of gait deviation index in children: Typically developing and cerebral palsy", ***Gait & Posture***, Vol. 39, No. 1, (2014), 354-358.

27. Dixon, P., Bowtell, M. and Stebbins, J., "The use of regression and normalisation for the comparison of spatio-temporal gait data in children", ***Gait & Posture***, Vol. 40, No. 4, (2014), 521-525.

28. Chester, V.L. and Calhoun, M., "Gait symmetry in children with autism", ***Autism Research and Treatment***, Vol. 2012, (2012), 1-5.

29. Baker, R., "Gait analysis methods in rehabilitation", ***Journal of Neuroengineering and Rehabilitation***, Vol. 3, No. 1, (2006), 1-10.

30. Stansfield, B., Hillman, S., Hazlewood, M., Lawson, A., Mann, A., Loudon, I. and Robb, J., "Normalisation of gait data in children", ***Gait & posture***, Vol. 17, No. 1, (2003), 81-87.

31. White, R., Agouris, I., Selbie, R. and Kirkpatrick, M., "The variability of force platform data in normal and cerebral palsy gait", ***Clinical Biomechanics***, Vol. 14, No. 3, (1999), 185-192.

32. Molloy, M., Salazar-Torres, J., Kerr, C., McDowell, B.C. and Cosgrove, A.P., "The effects of industry standard averaging and filtering techniques in kinematic gait analysis", ***Gait & Posture***, Vol. 28, No. 4, (2008), 559-562.

33. Su, B., Song, R., Guo, L. and Yen, C., "Characterizing gait asymmetry via frequency sub-band components of the ground reaction force", ***Biomedical Signal Processing and Control***, Vol. 18, No., (2015), 56-60.

34. Greer, N.L., Hamill, J. and Campbell, K.R., "Dynamics of children's gait", ***Human Movement Science***, Vol. 8, No. 5, (1989), 465-480.

35. Alaqtash, M., Sarkodie-Gyan, T., Yu, H., Fuentes, O., Brower, R. and Abdelgawad, A., "Automatic classification of pathological gait patterns using ground reaction forces and machine learning algorithms", in Engineering in Medicine and Biology Society, EMBC, 2011 Annual International Conference of the IEEE, (2011), 453-457.

36. Allison, K., Wrigley, T.V., Vicenzino, B., Bennell, K.L., Grimaldi, A. and Hodges, P.W., "Kinematics and kinetics during walking in individuals with gluteal tendinopathy", ***Clinical Biomechanics***, Vol. 32, (2016), 56-63.

37. Mayers, A., "Introduction to statistics and spss in psychology, Pearson Higher Ed, (2013).

38. Pallant, J., "Spss survival manual, McGraw-Hill Education (UK), (2013).

39. Field, A., "Discovering statistics using spss, Sage publications, (2009).

Vertical Ground Reaction Force Gait Patterns During Walking in Children with Autism Spectrum Disorders

C. Z. C. Hasan[a,b], R. Jailani[a], N. M. Tahir[a], H. M. Desa[a]

[a] *Faculty of Electrical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia*
[b] *Department of Electrical Engineering, Politeknik Sultan Idris Shah, Sungai Lang, Sungai Air Tawar, Selangor, Malaysia*

PAPER INFO

Paper history:
Received 05 August 2016
Received in revised form 16 February 2018
Accepted 16 February 2018

Keywords:
Autism Spectrum Disorder
Gait Analysis
Gait Pattern
Ground Reaction Force
Vertical Ground Reaction Force

چکیده

ویژگی نیروی واکنش عمودی از زمین و یا بیماری قلبی نوزادان درک ناقصی داشته که هدف این مقاله تشخیص نوزادان بیمارASD با مقایسه با گروه کنترل است. داده های بدست آمده از ۳۰ نوزاد مبتلا . ۳۰ نوزاد سالم در سنین ٤ الی ۱۲ سال مقایسه گردید. جهت جمع آوری داده ها با ۸ دوربین و ۲ صفحه نیرو برای بررسی حرکت سه بعدی با پاه برهنه راه رفتن مورد بررسی قرار گرفت. با روش تعیین پارامترها حرکت موجی بررسی می شود. میانگین اختلاف بین دو گروه بروش آزمون های تی و یو بطور مستقل بررسی خواهند شد. اختلاف فاحشی برا ی چهار ویژه گیVGRF مشخص گردید.نتایج نشان میدهد که نوزادان مبتلا بهASD کاهش قابل ملاحظه ای در ظاهر شدن زود رس پیک دوم بطور ضعیف VGRF مشاهده گردید. همچنین نسبت بیشتری با دو پیک VGRF در طول راه رفتن با سرعت عادی داشته است. اختلاف مشهودی بین نوزادان سالم و نوزادان مبتلا بهASD برای نگهداری وزن بدن در طول مسیر پیاده روی و ناپایداری آنها ملاحظه گردید. نتایج مطالعات منجر به درک VGRF گردید. اختلاف قابل ملاحظه ای بین گروه نوزاذان مبتلا به ASD با گروه سالم مشاهده گردید.

***doi**: 10.5829/ije.2018.31.05b.04*