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Three-Dimensional Gait Analysis for Spatiotemporal Parameters in Spastic Diplegic Cerebral Palsied Children

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Abstract: ***Background****: Abnormal gait is a common problem in children with CP, Increasing the knowledge concerning the difference in gait parameters between children with spastic diplegic CP and age-matched normal children can be helpful for both therapists and researchers in proper treatment planning. Purposes: To investigate the abnormality in the gait patterns by 3D gait analysis of the spatiotemporal parameters in spastic diplegic children.*

Materials and methods: *twenty children of both sexes participated in this study were assigned into two groups ten spastic diplegic cerebral palsied patients as study group and ten age matched normal children as control group. Spatio-temporal parameters were assessed for all subjects by Three-dimensional gait analysis including Step length, Stride length, step width, cadence, speed, stride time and step time*

Results: *There was a significant decrease in mean values of stride length and step length and walking speed in the study group and there was a significant increase in mean values of stride time , step time and step width but there was non- significant difference in cadence between both groups*

Conclusion *The 3D gait analysis provides an objective evidence of changes in spatiotemporal gait parameters between children with spastic diplegia and normal children which will help the persons involved in the care of CP children.*

Key words: *Gait, CP, spatiotemporal parameters.*

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I. Introduction

Cerebral palsy (CP) is a group of long-lasting and non-progressive conditions caused by static injury to the developing brain and considered as the most common childhood motor disability[1,2,3]. There is delayed onset of abnormal gait pattern because the injury disrupts the brain's ability to govern motion, conserve posture and balance leading to limitations in activities and societal participation [2,4,5].

Other than the motor defects they have in common, patients may possibly struggle with extra manifestation of brain malfunction, comprising mental retardation, epilepsy, sensory defects (e.g. auditory or visual defeat) learning disabilities, and emotional difficulties; however, these difficulties are not diagnosed as CP [6].

Spastic diplegia, is the foremost CP form and currently reached almost half of the total CP patients [7]. This rising implied by premature babies who are now alive in greater percentage than before [8]. Spastic diplegia is manifested by motor incoordination, mainly in the lower extremities, that affects several functional skills, including walking which is the most observed. The major concern of CP children parents is the ability to walk, therefore, the primary focus in most therapeutic interventions emphasis on improving or maintaining this ability [9,10,11].

The lesions associated with spastic diplegia might produce some or all of the next symptoms: (1) higher muscle tone, or a velocity dependent resistance to passive muscle stretch in synergists (2) absence of active motor control (3) poor equilibrium and (4) imbalance of muscle forces across lower extremity joints [9].

Spastic diplegic children generally walk freely, but most have an easily detected gait disorder that might include sagittal plane deviations as toe walking, flexed-stiff knee joints, flexed hip joints and forward tilted pelvis with lumbar lordosis [12]. Moreover, they have a plano-valgus feet deformity. Anatomically this associates with externally rotated foot in relation to the shank while dorsiflexed during clinical exam [7].

To measure and study the walk patterns of spastic diplegic children in order to understand and treat gait abnormalities, the gait analysis laboratories is the best method. Gait can be objectively evaluated in a modern three-dimensional (3D) gait laboratory session [13]. Gait analysis lap accounts for kinematic and kinetic measures testing and analysis to deliver descriptive data of the events through studying the pressure under the foot and the path of the center of gravity [14].

Spatiotemporal parameters (STPs) are useful measurement for any assessment as they afford vital information about time and position related to gait, and they could be collected in a clinical session by simple measuring devices. The commonest spatiotemporal parameters used are walking speed, stride length, step length, and cadence [15].

Objective data are missing considering gait deviations distribution and limiting function in CP children. Objective records are required to increase awareness of the most common gait problems in children looking for therapy and helping researchers and therapists focusing their labors in the areas having major influence on quality of care.

II. Subjects and Methods

Subjects:

Ten spastic diplegic cerebral palsied patients were participated in this study. Their age ranged from six to ten years, and ten age matched normal children, all processes were clarified to all subjects and their parent(s), Parental consent form was obtained prior to each child's participation in the study.

The inclusive criteria:

The patients were included based on the following criteria

- Level 3, 2, 1 GMFCS.
- Spasticity is ranged from 1+ to 2 according to modified Ashowrth scale MAS.
- Able to walk independently.
- Able to respond well to instruction

Exclusion criteria

The patients were excluded according to the following criteria

- Underwent any bony surgeries in the last 12 months.
- Any previous fracture
- Hip dislocation
- Mental retardation
- Visual impairment
- Any involuntary movement
- Recent Botox injection in lower limbs (last 12 weeks)

Design of study:

Ten spastic diplegic cerebral palsied children were assigned to the study group and ten age matched normal children were assigned as a control group.

Spatio-temporal parameters were assessed for all subjects by Three-dimensional motion including Step length, Stride length, step width, cadence, speed, stride time as well as step time

Assessment Materials

Three-dimensional motion capture using an eight-camera Vicon movement analyzing system (Oxford Metrics Ltd., Oxford, UK). Recording ground reaction forces were done at a rate of 1200 Hz by one AMTI force plate (OR6-5-1000; Advanced Mechanical Technology, Inc., Newton, MA) camouflaged within a eight meters pathway were used to collect kinematic data of reflective markers at 100 Hz **Fig. (1)**.

Figure (1): Eight-camera Vicon motion analysis system for 3 D gait analysis.

Assessment Procedure:

Each patient underwent 3D gait analysis and physical examination. After static calibration of gait lab, anthropometric measurements were applied including; mass, height, leg length, knee and ankle circumferences. Later, sixteen reflective markers Reflective markers (14mm spheres) were placed by gait lab expertise by consensus on the next anatomical landmarks based on the requirements of the lower body Plug-in-Gait model; the anterior superior iliac spine, posterior superior iliac spine, lateral thigh, lateral femoral epicondyle, lateral shank, lateral malleolus, second metatarsal head, and calcaneus **Fig. (2)**.

Figure (2): Placement of the reflective marks

Each child was asked to walk freely two to three times before measurement to be familiar with the lab environment. Each child was asked to stand on the force plate with feet apart and arms extended and abducted 90∘to start markers' calibration **Fig. (3)**.

Figure (3): Position of the child on the force plate for calibration

Later, each child started to perform six trials as their usual speed, to detect their favorite usual speed. For minimizing speed variability effects on biomechanical factors, all trial calculated in the data analysis are compulsory to fall within 5% of detected usual speed [16]. Ground reaction forces and kinematics were recorded simultaneously as children paced barefoot all the 8-m walkway. Trials with entire foot made contact with the force-plate with no targeting were included in the analysis.

Parameters:

Spatial-temporal parameters of gait cycle including; cadence, speed, step length, stride length, step width, step time and stride time were collected.

Data processing:

Gait data were computed using Nexus 2.1 software. Data later exported to Polygon 4.2 software to be further processed **Fig. (4)**.

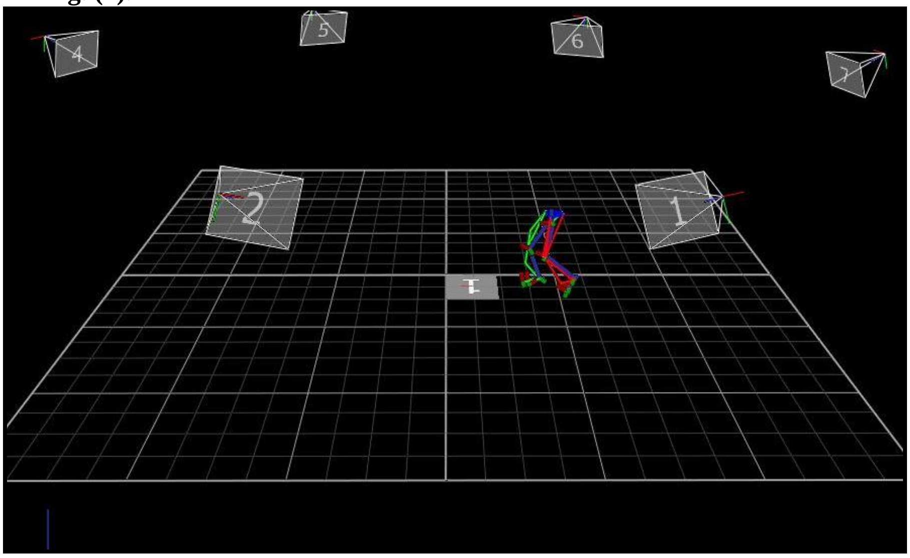

Figure (4): Data processing

Statistical analysis:

The average of the parameters for six trials parameters were taken for every child. Unpaired t-test will be used to compare gait parameters between groups.

III. Results

The study aimed to examine gait patterns abnormality by measuring spatiotemporal parameters in spastic diplegic children. First, data were collected from both groups and then studied. Analytic and descriptive statistics were used.

Subjects General Characteristics:

Twenty children of both sexes participated in this study, ten cerebral palsied children with spatic diplegia and ten age –matched normal children and were assigned into two groups, a control group (A) and study group (B).

- **Group (A):**

Ten age matched normal children (7 males and 3 females) participated. Data in table (1) and Fig. (6) represented their mean age (7.7±1.41) years, their mean weigh (29.3±3.86) kg, their mean height (131.4±4.83) cm.

- **Group (B):**

Ten children (7 males and 3 females) with spatic diplegic cerebral palsy participated. Data in table (1) and Fig. (5) represented their mean age (7.4±1.50) years, their mean weight (28.8±4.41) kg, their mean height (133.3±3.83) cm.

No significant differences for age between both groups were shown in unpaired test (P value of 0.65), weight (P value of 0.79), height (P value of 0. 25) were shown in Table (1).

Table (1): Subjects general characteristics in groups.

Items	Group(A)	Group(B)	Comparison	
	Mean±SD	Mean±SD	t-value	P-value
Age (years)	7.7±1.41	7.4±1.50	0.46	0.65
Weight (Kg)	29.3±3.86	28.8±4.41	0.27	0.79
Height (cm)	131.4±4.83	133.3±3.83	-1.18	0.25

SD: standard deviation, P: probability.

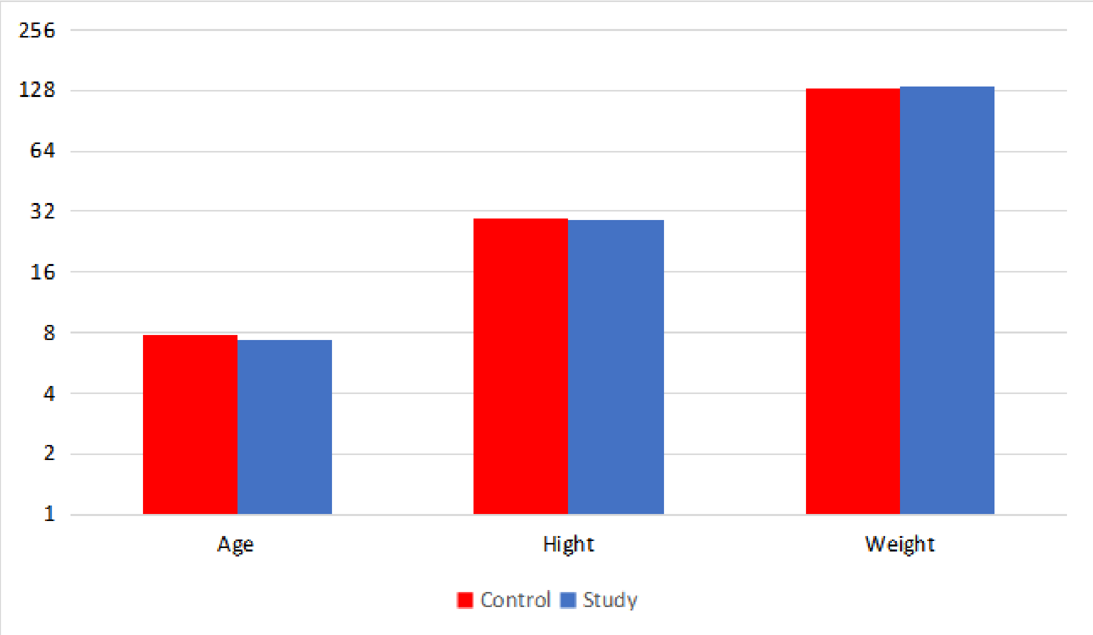

Figure (5): Mean values of age, height and weight in both groups.

Stride length and step length:

There was a significant decrease in mean values of stride length and step length between both groups as the mean values of the right stride length and step length for group (A) were (1.44±0.03) meter and (0.71±0.01) respectively, and for group(B) were (0.67±.15) and (0.33±0.10) meter respectively, where the P-values were (0.0001) and (0.0001) respectively. The mean values of the left stride length and step length for the control group (A) were (1.44±0.02) respectively, and (0.70±0.02) meter and for the study group (B) were (0.67±.15) and (0.35±0.11) meter where the P-values were (0.0001) and (0.0001) respectively. As demonstrated in Table (2) and illustrated in Fig. (6).

Table (2): Comparison of stride length and step length mean values between the control group (GA) and study group (GB).

Item Group	Stride length Mean ±SD		Step length mean ±SD	
	RT	LT	RT	LT
Control group G(A)	1.44±0.03	1.44±0.02	0.71±0.01	0.70±0.02
Study Group G (B)	0.67±.15	0.67±0.15	0.33±0.10	0.35±0.11
t value	15.77	15.89	11.68	10.03
P –value	0.0001 *	0.0001 *	0.0001 *	0.0001 *

* *Significant at ≤ 0.05, SD: standard deviation..*

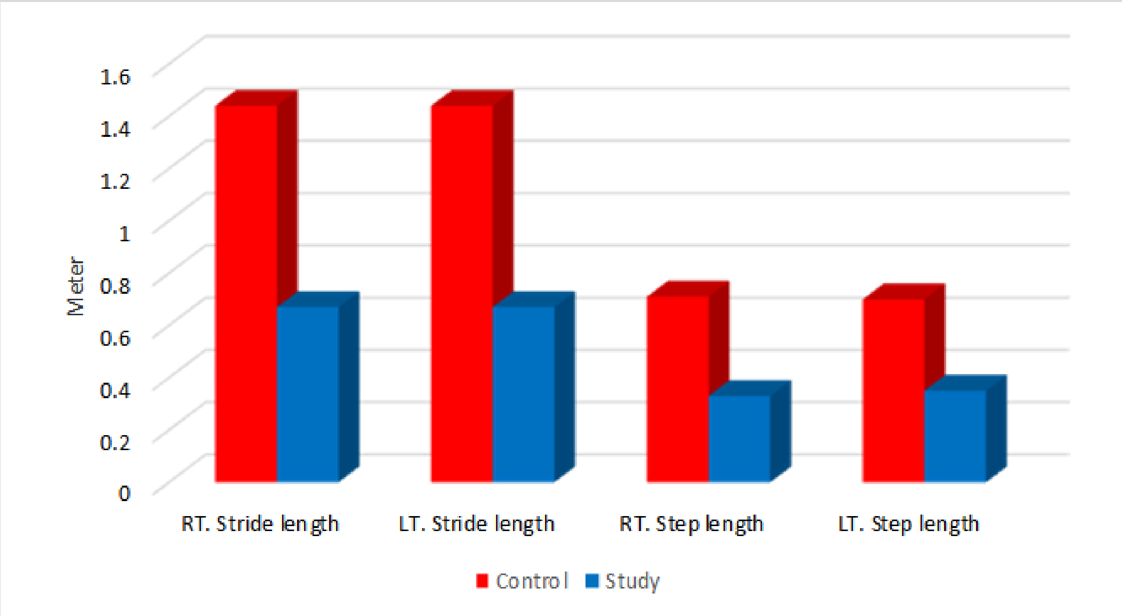

Figure (6): Mean values of right and left stride length and step length in both groups.

Stride time and step time:

A significant increase in stride time and step time mean values between both groups was seen as the mean values of the right stride time and step time for group (A) were (0.97±0.04) and (0.51±0.03) seconds and for group (B) were (1.29±0.21) and (0.67±0.11) seconds where the P-values were (0.001) and (0.001) in turn. The mean values for the left stride time and step time for the control group (A) were (0.98±0.04) seconds and (0.51±0.02) seconds and for the study group(B) were (1.26±0.26) and (0.66±0.13) seconds, where the P-values were (0.003) and (0.002) respectively as demonstrated in Table (3) and illustrated in Fig. (7).

Table (3): Comparison of stride time and step time mean values between the control group (GA) and study group (GB).

Item / Group	Stride time Mean ±SD		Step time mean ±SD	
	RT	**LT**	**RT**	**LT**
Control group	0.97±0.04	0.98±0.04	0.51±0.03	0.51±0.02
Study Group	1.29±0.21	1.26±0.26	0.67±0.11	0.66±0.13
t value	-4.60	-3.388-	-4.69	-3.631-
P –value	0.001*	0.003*	0.001*	.002*

* *Significant at ≤ 0.05, SD: standard deviation.*

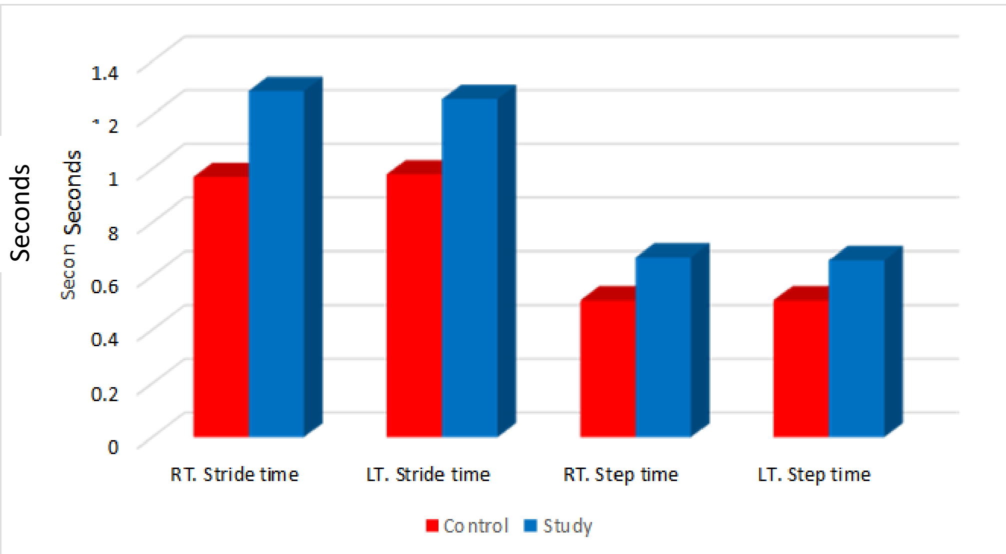

Figure (7): Mean values of right and left stride time and step time in both groups.

Step width, walking speed and cadence:

There was a significant increase in mean values step width between both groups as the mean value of the step width for group (A) was (0.07±.01) meter and for group(B) was (0.13±.0.07) meter where the P-value was (0.01) as demonstrated in Table (4) and Fig. (8). There was a significant decrease in mean values walking speed between the control group and the study group as the mean value of the walking speed for group (A) was (1.62± 0.145) meter/second and for group(B) was (0.79±0.23) meter/second and where the P-value was (0.0001). As demonstrated in Table (4) and Fig. (9).Regarding the cadence there was a non- significant difference between the control group and the study group as the mean value of the cadence for the control group (A) was (113.6±2.76) steps /min and for the study group(B) was (109.6±5.79) steps /min and where the P-value was (0.07), as demonstrated in Table (4) and Fig (10).

Table (4): Comparison of step width, Cadence and walking speed mean values between the control group (GA) and study group (GB).

Item / Group	Step width (meter) mean ±SD	Walking speed (meter/second) mean ±SD	Cadence (steps /min) mean ±SD
Control group	0.07±.01	1.62± 0.145	113.6±2.76
Study Group	0.13±.0.07	0.79±0.23	109.6±5.79
t value	-2.81	9.29	1.97
P -value	0.01*	.0001*	0.07

** Significant at ≤ 0.05, SD: standard deviation.*

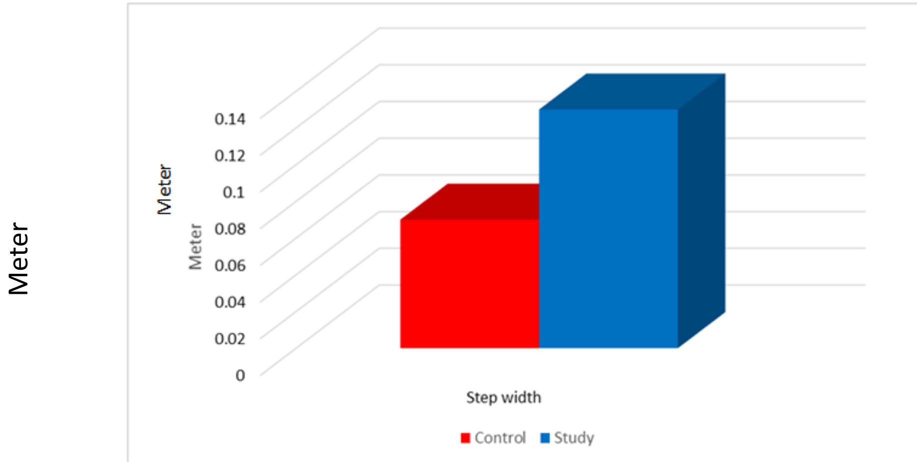

Figure (8): Mean values of step width in both groups.

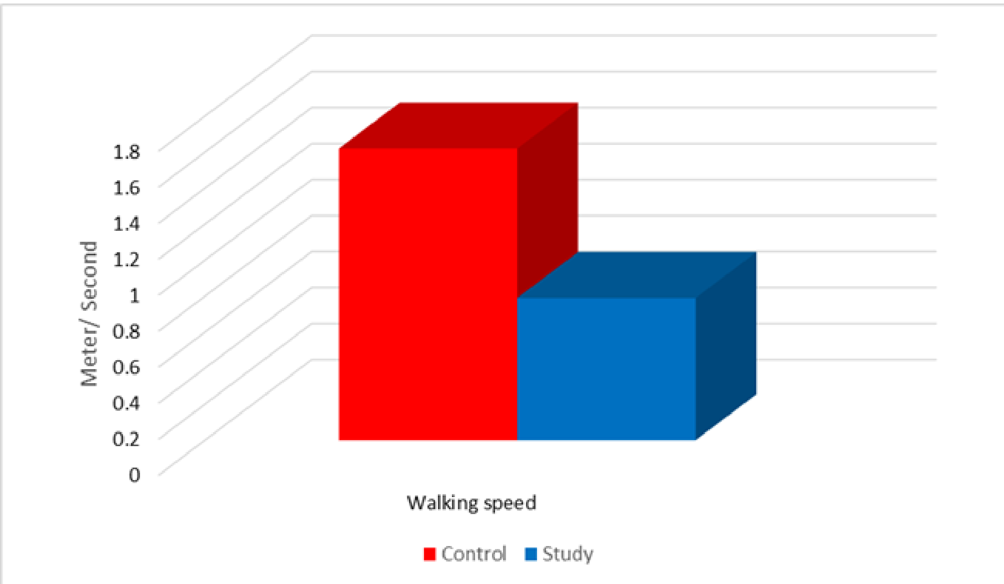

Figure (9): Mean values of walking speed in both groups.

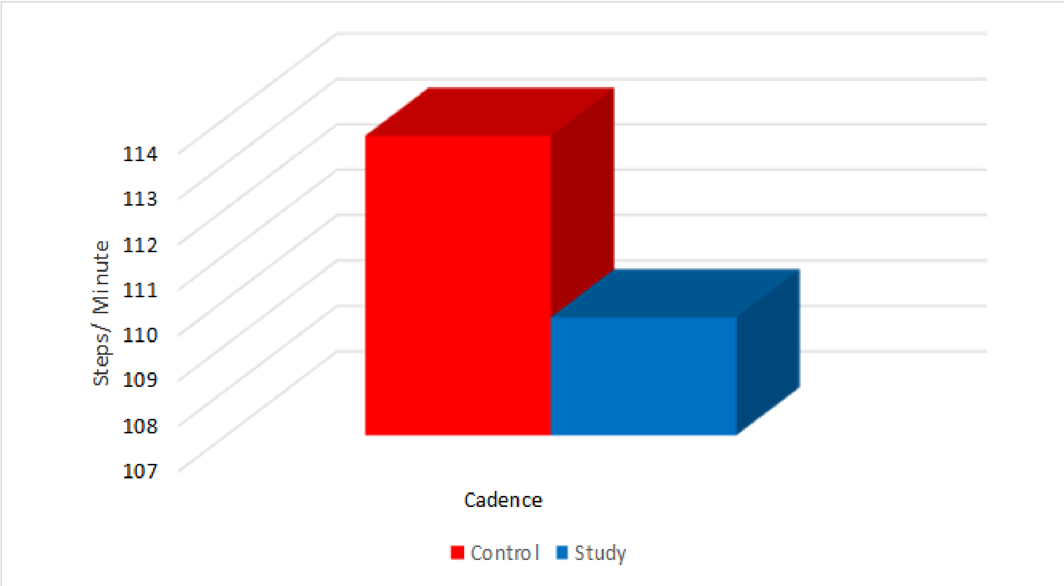

Figure (10): Mean values of the cadence in both groups.

IV. Discussion

The study was conducted for investigating the variances in spatiotemporal gait parameters measured by 3D motion analysis among spastic diplegic CP children and normal age matched children.
In this study, no statistically significant differences were seen in the mean values of age, weight and height among normal and children with spastic diplegic CP.
Our results revealed a significant decrease of stride length and step length, while there was a significantly increased step width.
The significant decrease of both step length and stride length could be explained by presence of spasticity and motor weakness of the lower limbs. This is consistent with ***Johnson et al.*** [17] who reported that gait abnormality is a common problem in cerebral palsy children due to muscle weakness and reduced voluntary motor control, resulting in a slower walking speed and shorter-stride length.
This is also consistent with ***Kim & Son*** [18] who found that decreased stride length, and increased step width of the CP children than normally developed children.
The increasing of step width could be attributed to poor balance so CP children might walk with a broader base of support to maintain the center of gravity within the base of support.
This come in consistent with ***Klebe et al.*** [19] who stated that spatio-temporal parameters of the children with cerebral palsy are different from normality; regarding walking speed; step width and the changes of these parameters indicate the need to provide stability in subjects characterized by balance-related gait features.
The findings of the current study revealed lower speed and increased step time and stride time of gait of the cerebral palsied children than normal children and this could be attributed to decreased stride length and decreased gait cycle time. This agree with the findings drawn by ***Bourgeois et al*** [20]**.** In addition, this agree with ***Piccinini et al*** [21]**.** Who found lower velocity of progression and larger step width in spastic diplegic patient when compared to control group.
Our results also, are consistent with ***Wang et al***. [22] who found significant increase of the stride time and step width, but significant reduction in the speed of the gait.
Unlike our results with non-significant change in the cadence, the results of ***Wang et al***. [22] which revealed significant reduce in the cadence of the spastic diplegic children which may be attributed to their selection for level III of gross motor function classification that is more involved than level I and II.
This standardized and objective gait analysis helping in detecting and interpreting gait abnormalities in CP children to help the personnel involved in CP children care.

V. Conclusion

The 3D gait analysis provides an objective indication of changes in spatiotemporal gait parameters between spastic diplegiac children and normal children which will help the personnel involved in CP children care.

References

[1]. Bax M, Goldstein M, Rosenbaum P, Leviton A, Paneth N, Dan B, et al. Executive committee for the definition of cerebral palsy. Proposed definition and classification of cerebral palsy. *Dev Med Child Neurol., 47, 2005, 571–6.*

[2]. Blasco P. Pathology of cerebral palsy. In: Sussman M (Ed.), *The diplegic child. (Rosemont: American Academy of Orthopaedic Surgeons; 1992) 3–20.*

[3]. Facts about Cerebral Palsy, Centers for Disease Control and Prevention [online] (July 13, 2015). Cited 2016 Apr 3. *Available at: http://www.cdc.gov/ncbddd/cp/facts.html*

[4]. Cerebral Palsy: Hope through Research, National Institute of Neurological Disorders and Stroke [online] *(March 15, 2016).Cited 2016 Apr 3. Available at: http://www.ninds.nih.gov/disorders/cerebral_palsy/detail_cerebral_palsy.htm?css=print*

[5]. A. Bonnefoy-Mazure, Y. Sagawa Jr., P. Lascombes , G. De Coulon , S. Armand. Identification of gait patterns in individuals with cerebral palsy using multiple correspondence analysis. *Developmental Disabilities, 34, 2013, 2684–2693.*

[6]. Russman, B. S., Tilton, A., & Gormley, M. E. Cerebral palsy: A rational approach to a treatment protocol, and the role of botulinum toxin in treatment. *Muscle & Nerve Muscle Nerve, 20(S6),* 1997*, 181-193.*

[7]. Rosen MG, Dickinson JC. The incidence of cerebral palsy. *Am J Obstet Gynecol, 167, 1992, 417-23.*

[8]. Wilson-Costello D, Friedman H, Minich N, et al. Improved survival rates with increased neurodevelopmental disability for extremely low birth weight infants in the 1990s. *Pediatrics, 2005, 115(4), 997–1003.*

[9]. Gage, J. R. Gait analysis in cerebral palsy. *Clinics in Developmenta Medicine, 121, 1991, London: Mac Keith Press*

[10]. Wan J, Sims D, Harckham F, et al. A prospective study of inhibitive casting as an adjunct to physiotherapy for cerebral-palsied children. *Dev Med Child Neurol., 28, 1986, 480-488.*

[11]. Binder ti, Eng GD. Rehabilitation management of children with spastic diplegic cerebral palsy. *Arch Phys Med Rehabil. 70, 1989, 482-489.*

[12]. Rodda, J. M., Graham, H. K., Carson, L., Galea, M. P., & Wolfe, R. Sagittal gait patterns in spastic diplegia. *J Bone Joint Surg (Br), 86(2), 2004, 251-258.*

[13]. Gaston, M., Rutz, E., Dreher, T., & Brunner, R. Transverse plane rotation of the foot and transverse hip and pelvic kinematics in diplegic cerebral palsy. *Gait & Posture, 34(2), 2011, 218-221.*

[14]. Davis, R. B.Clinical Gait Analysis. *IEEE Engineering in Medicine and Biology magazine, 1988,35-40.*

[15]. Roberts M, Mongeon D and Prince F. Biomechanical parameters for gait analysis: a systematic review of healthy human gait. *Phys Ther Rehabil., 2017; 4:6.*

[16]. Queen RM., Gross MT., Liu HY. Repeatability of lower extremity kinetics and kinematics for standardized and self-selected running speeds. *Gait and Posture, 23(3), 2006, 282-287.*

[17]. Johnson DC, Damiano DL, Abel MF: The evolution of gait in childhood and adolescent cerebral palsy. *J Pediatr Orthop, 17, 1997, 392–396.*

[18]. Kim CJ and Son S M: Comparison of Spatiotemporal Gait Parametersbetween Children with Normal Development and Children with Diplegic Cerebral Palsy. *J. Phys. Ther. Sci. 26, 2014, 1317–1319*

[19]. Klebe S, Stolze H, Kopper F, Lorenz D, Wenzelburger R, Volkmann J, Porschke H, Deuschl G. Gait analysis of sporadic and hereditary spastic paraplegia. *J Neurol, 251(5), 2004, 571-8.*

[20]. Bourgeois A. B, Mariani B., Aminian K., Zambelli P.Y., Newmanc C.J: Spatio-temporal gait analysis in children with cerebral palsy using, foot-worn inertial sensors. *Gait & Posture, 39, 2014, 436–442.*

[21]. Piccinini L, Cimolin V, D'Angelo M G, Turconi A C: 3D gait analysis in patients with hereditary spasticparaparesis and spastic diplegia: A kinematic, kineticand EMG comparison. *Journal of the European Paediatric Neurology 15, 2011, 138-145.*

[22]. Wang T-M, Huang H-P, Li J-D, Hong S-W, Lo W-C, Lu T-W: Leg and Joint Stiffness in Children with Spastic Diplegic Cerebral Palsy during Level Walking. *PLoS ONE, 10(12), 2015, e0143967.*

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