Jurnal Teknologi

Full Paper

GENDER DIFFERENCES IN GAIT FEATURES OF HEALTHY CHILDREN

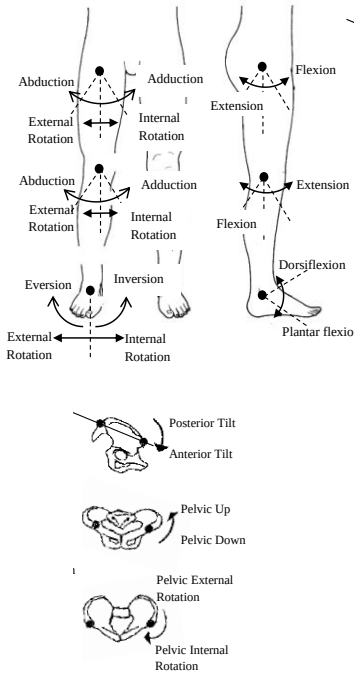
Nur Khalidah Zakaria*, R. Jailani, NM Tahir

Faculty of Electrical Engineering, Universiti Teknologi MARA, 40450, Shah Alam, Selangor, Malaysia

Article history
Received
19 June 2015
Received in revised form
26 June 2015
Accepted
10 July 2015

*Corresponding author
zkhalidah@gmail.com

Graphical abstract



Abstract

As a part of on-going research gait studies among children, this paper presents an analysis of spatiotemporal, kinematic angles at lower limb and kinetic forces of walking gait among children. Total of 20 healthy children which is 11 boys and 9 girls aged between 6 to 12 years old were participated in this study. Five spatiotemporal parameters and four selected kinematic angles at hip, knee, ankle and pelvic as well as kinetic ground reaction forces were obtained using Vicon® Nexus Plug-in-Gait at Human Motion and Gait Analysis Laboratory, UiTM Shah Alam. Each parameter will be analyzed to investigate the differences of walking gait in children for both genders. For kinematic parameters, this study will be analyzed for any differences at anatomical planes, which are sagittal, frontal and transverse planes. The result shows that there are significant differences between boys and girls at kinematic angles features at hip, knee and ankle. Additionally, the differences ranges of motion for both genders exist at all three anatomical planes.

Keywords: Gait; gender; anatomical planes

Abstrak

Sebagai sebahagian daripada kajian penyelidikan dalam gaya berjalan di kalangan kanak-kanak, kertas kerja ini membentangkan analisis menggunakan parameter seperti spatiotemporal, sudut kinematik pada bahagian bawah anggota badan dan daya kinetik ketika berjalan di kalangan kanak-kanak. Seramai 20 kanak-kanak yang sihat yang terdiri daripada 11 orang kanak-kanak lelaki dan 9 orang kanak-kanak perempuan berusia antara 6 hingga 12 tahun telah mengambil bahagian dalam kajian ini. Lima spatiotemporal parameter, empat sudut kinematik iaitu pinggul, lutut, pergelangan kaki dan pelvik serta daya kinetik *ground reaction forces* telah diperolehi dengan menggunakan software Vicon® Nexus Plug-in-Gait di Human Motion and Gait Analysis Laboratory, UiTM Shah Alam. Setiap parameter akan dianalisis untuk mengkaji perbezaan gaya berjalan pada kanak-kanak untuk kedua-dua jantina. Bagi parameter kinematik, perbezaan kajian ini akan dianalisis daripada paksi badan manusia, iaitu *sagittal*, *frontal* dan *transverse*. Hasil kajian menunjukkan bahawa terdapat perbezaan yang signifikan di antara kanak-kanak lelaki dan perempuan di sudut kinematik pada bahagian pinggul, lutut dan buku lali. Selain itu, perbezaan antara gerakan untuk kedua-dua jantina wujud di ketiga-tiga paksi badan manusia.

Kata kunci: Gaya berjalan; jantina: paksi anatomi

1.0 INTRODUCTION

Over the years, there has been an explosive growth of research interest in the studies of locomotion especially in human. Research in bipedal walking have gained it attention in broad area such as in medical diagnostic, rehabilitation and in sport training in order to improve the athlete performance [1-3]. In gait analysis, there were several features that can be extracted from human walking. Spatiotemporal, kinematic, kinetic and electromyography (EMG) often used as the gait features in gait analysis [4]. Spatiotemporal is the basic measurement in gait analysis where most of the measurement is in time and distance in walking. Kinematic measurement is a description of motion in a form of joint angles while kinetics measurement is study of forces, moments, masses and accelerations of subjects. The difference between them is kinematics only describe the movement without any reference to the force acting on it. However, kinetics studies about force without involved any detailed in the motion of the subjects [5].

Researchers and practitioners used gait analysis as diagnostic tools in examining the abnormalities in movement [2, 6, 7]. Usually the comparison between two or more groups of study was performed in evaluating the gait analysis. The advantage of gait analysis is in detecting the abnormalities. Additionally, it is able to differentiate the gait features in many studies [8, 9].

Study in cerebral palsy (CP) children has been conducted by Malone et al. to compare deviations in walking gait in typically developing (TP) children and cerebral palsy children while walking over the level ground (LG) and uneven ground (UG). The result found that CP has reduced flexibility of ankle movement and formed overly trunk movement in the transverse and sagittal planes for balancing their gait especially at UG [10]. Study in autism children by Chester et al. found that autistic children performed smaller range of motion at ankle [11]. This result was similar with other compare study in autism [12].

Differences in walking gait exist in genders. Previous study used subjects aged 50 to 96 years old shows that female performed greater hip angular motion and significant lower at hip angular motion especially at frontal and sagittal planes respectively [13]. Other study that compare gait differences in gender average aged at 24 years old conclude that females produced significantly greater at ankle joint motion and vertical ground reaction force as compared to males [14]. Unlike conclusion from B. Nigg et al., they found only small deviations between genders in kinematic and kinetic features. The study hence concluded that the result is not strong to verified that there is differences in walking gait between genders [15].

Based on [13] and [14], aged also contributed in gait changes as concluded by study that found relations between age and genders where maturing process affect the walking gait [16]. Differ from other study; D. Verniba et al. had investigated the effect of visual targeting at force plate during measuring gait. His study examined the differences between natural and targeting walking trials from spatiotemporal, kinematic and kinetic measurements. Result shows that force plate targeting has no consequence on gait measures in healthy subjects [17].

During walking experiment, subjects normally asked to walk at their comfortable speed. This method will preserve the normality in walking gait [15]. However, M. H. Schwartz had done a research that varies the walking speed in order to inspect the walking gait characteristic. The result has clearly discussed that speed significantly effect on gait features especially in kinematics features at sagittal, frontal and transverse planes [18]. Therefore, changes in gait pattern may lead to difference in the other gait features including spatiotemporal and kinetic measurement [17].

J. Romkes and K. Schweizer had conducted a study on immediate effects of unilateral restricted ankle motion in healthy subjects. In this study, subjects need to walk with two conditions which are with non-restricted self-selected speed and with unilateral restricted ankle motion. In free walking, the study concludes that there were no significant differences between both left and right leg existed [19].

The aim of this study is to compare the differences between genders in Malaysian children aged from 6 to 12 years old in spatiotemporal, kinematic angles and kinetic ground reaction forces. To our knowledge, there are a small numbers of researches in walking gait especially in children that based on genders. This paper was organized in the following manners: Section 2.0 will discuss the experimental and methodology adopted for this study. Section 3.0 will present the results and discussions obtained from the study, and Section 4.0 is the conclusion for this study.

2.0 EXPERIMENTAL

In this section, the procedures for data collection will be described and the methods for the analysis will be explained. Spatiotemporal parameters, kinematic angles and kinetic forces data at lower limb have been collected using Vicon® Nexus Plug-in-Gait and all data collection have been carried out at Human Motion and Gait Analysis Laboratory, Universiti Teknologi MARA (UiTM) Shah Alam.

20 healthy children consist of 11 boys and 9 girls were participated in this study. All parent need to confirmed that their children does not have any diseases that could contribute to the additional effect on their body balance before signing the consent form. Additionally, all subjects must be able to walk freely without any cane or mechanical aid device during walking. This is can eliminate the influence of aid device on the reading while performing the experiment.

In this study, Vicon® Nexus Plug-in-Gait is used to compute the three types of gait parameter namely basic, kinematic and kinetic. Eight infrared cameras at

sampling rate of 100 Hz are used to trace the reflective markers during experiment. Subjects' measurements were collected at early experiment setup. Basic subject physiological data such as age (year), weight (kg) and height (cm) will be measured before the experiment.

35 reflective markers are adhered to the subjects' skin for the gait data collection. Subjects will be asked to walk freely on walkway with two embedded force plate at their comfortable pace. One of the requirements is that, only one foot allowed to touch the force plate at one time. The walking task is carried out few times until the experiment requirements are met. Next, the data form the Vicon® Nexus was extracted for further analysis.

Five basic spatiotemporal parameters, twelve gait kinematic angles obtained from hip, knee, ankle and pelvic and ground reaction force at vertical and horizontal forces was gathered to perform the analysis for gender comparison in children. For kinematic angles, the anatomical planes were used as reference axis in defining the movement during walking. The anatomical planes are divided into three axis namely sagittal, frontal and transverse planes. Two vertical axes in anatomical plane is sagittal plane where the body is divides into left and right side and frontal plane which divide the body into front and back side. Transverse plane is the horizontal axis in human body where body is divides into upper and lower section of body.

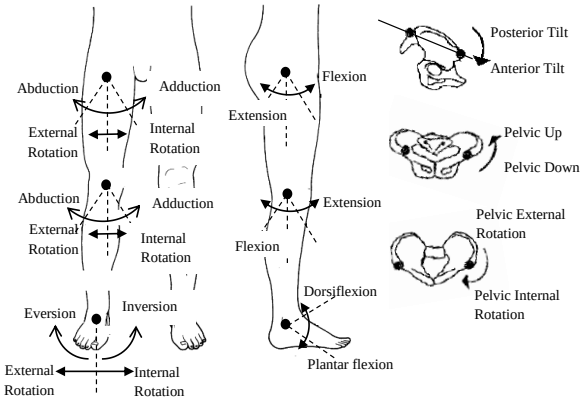


Figure 1 Defining movement in anatomical planes

Figure 1 shows directions for hip, knee, ankle and pelvic in anatomical planes. The figure shows how the body movement is defined on sagittal, frontal and transverse planes. In sagittal plane, the angles obtained consist of hip flexion and extension, knee flexion and extension, ankle dorsiflexion and plantar flexion and pelvic anterior and posterior tilt. In frontal plane, there are angles of hip adduction and abduction, knee adduction and abduction, ankle inversion and eversion and pelvic obliquity up and down. Lastly in transverse plane, angles exists are hip internal and external rotation, knee internal and external rotation, ankle internal and external rotation and pelvic internal and external rotation.

Each of the movement have the opposite movement and works in pairs. Angles of flexion, dorsiflexion and anterior tilt are the positive angles in sagittal plane. Meanwhile in frontal plane, angles of adduction, inversion and obliquity up are the positive angles. Additionally, angles of internal rotation were the positive angles while there rest of the angles were the negative angles at anatomical planes.

The raw data were pre- and post-processed with the Vicon software to extract the gait features data from walking trials. All joint angles were normalized from time based into 100% gait cycle. A complete one gait cycle is determined with the two occurrences of the same foot strikes. All the data was inspected for any outliers using statistical analysis. The outliers was then removed before proceed to another analysis. An independent t-test with 95% of confidence interval was used to examine the gender differences in gait features for spatiotemporal, kinematics and kinetics parameters.

The comparison between genders in all parameters was analyzed using statistical analysis and separated between boys and girls. The comparison between boys and girls walking gait features are observed. Spatiotemporal, kinematic angles of hip, knee, ankle and pelvic and kinetic forces will be analyzed in details. Result obtained from this study will be discussed in detail in next section.

3.0 RESULTS AND DISCUSSION

This section presents results obtained from the data collection carried out for this study. 20 healthy children consist of 11 boys and 9 girls were participated in this study. Both genders have almost similar mean of age which is 8.181 years for boys and 8.222 years old for girls. However, girls have greater in mean of height and mean of weight which is 128 cm and 29.23 kg respectively, meanwhile the mean of height and mean of weight for boys is 122.973 cm and 24.755 kg respectively. The statistical mean comparisons; t-test was used to analyse and compared the differences between two groups for each parameters. The result was presented and tabulated in table and figure below.

Figure 2 shows parameters of spatiotemporal gait features for both groups. Based on result plotted, girls have only greater stride time while boys performed greater stride length, step time, cadence and walking speed with all parameters significant value more than 0.2. Additionally, from the observation during the data collection and tabulated graph in Figure 2, it is show that boys walk faster compared to girls since the walking speed for complete one gait cycle is shorter than girls. Based on the results, it is shown that there is no significant value occurs in contributing for the differences of genders in walking gait for children in temporal spatial parameters.

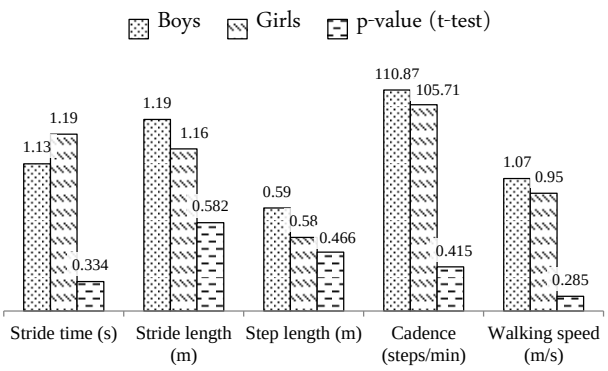


Figure 2 Bar chart of spatiotemporal parameters

Table 1 shows results from kinematic angles of hip, knee, ankle and pelvic for both groups at sagittal, frontal and transverse planes. From the result, both genders do not produced full knee extension, posterior pelvic tilt and pelvic down obliquity. It is observed that only boys do not produced full hip adduction, ankle inversion and hip internal rotation. Based on the observation, mostly boys tend to have greater range of motion at three anatomical planes as compared to girls. Additionally, girls have greater range of motion only at extension and adduction of hip, adduction and external rotation of knee, plantar flexion and inversion of ankle and external rotation of pelvic.

Table 1 Kinematic parameters

Anatomical planes	Gait features	Mean values		t-test (p-value)
		Boys	Girls	
Sagittal	Hip angle	21.529	14.128	0.281
	Max hip flexion*	40.989	26.893	**0.001**
	Max hip extension	-9.933	-12.734	0.477
	Knee angle	26.748	21.766	0.465
	Max knee flexion*	66.020	58.251	**0.002**
	Max knee extension	NA	NA	NA
	Ankle angle	17.384	11.140	0.158
	Max ankle dorsiflexion	37.034	30.338	0.342
	Max ankle plantar flexion	-8.067	-9.640	0.871
	Pelvic angle	11.428	9.020	0.131
	Max anterior pelvic tilt	14.374	9.737	0.189
	Max posterior pelvic tilt	NA	NA	NA
Frontal	Hip angle*	-7.602	-3.228	**0.015**
	Max hip adduction	NA	2.983	NA
	Max hip abduction	-15.663	-14.356	0.652
	Knee angle*	-2.427	2.849	**0.007**
	Max knee adduction	5.026	10.080	0.205
	Max knee abduction	-17.064	-8.030	0.144
	Ankle angle*	-7.565	-1.449	**0.000**
	Max ankle inversion	NA	1.530	NA
	Max ankle eversion	-15.354	-6.264	0.077
	Pelvic angle	-0.313	0.591	0.373
	Max pelvic up obliquity	4.864	4.340	0.764
	Max pelvic down obliquity	NA	NA	NA
Transverse	Hip angle*	-22.216	-10.568	**0.000**
	Max hip internal rotation	NA	4.656	NA
	Max hip external rotation	-31.841	-21.609	0.207
	Knee angle*	1.309	-9.555	**0.001**
	Max knee internal rotation	16.162	3.853	0.140
	Max knee external rotation	-12.001	-24.556	0.087
	Ankle angle	14.332	13.820	0.906
	Max ankle internal rotation	34.460	32.850	0.802
	Max ankle external rotation	-13.102	-11.203	0.815
	Pelvic angle	2.374	1.009	0.626
	Max pelvic internal rotation	13.750	11.313	0.500
	Max pelvic external rotation	-9.651	-12.482	0.278

*Significant value (p<0.05)

Based on kinematic mean angles, there are significant differences at frontal plane and transverse plane for both groups. For frontal plane, it is show significant differences at hip, knee and ankle angle with p is equal to 0.015, 0.007 and 0.000 respectively. While at transverse plane, the significant difference occurs at hip and knee angle with p is equal to 0.000 and 0.001 respectively. Looking at range of motion analysis for each plane, the significant differences only occurs at sagittal plane. Based on the result, there is significant value for both groups at hip flexion and knee flexion with the p is equal to 0.001 and 0.002 respectively.

Table 2 Kinetic parameters

Gait features	Mean values		t-test (p-value)
	Boys	Girls	
Mean GRF Fy	0.208	0.206	0.977
Max GRF Fy	2.090	1.723	0.158
Min GRF Fy	-1.683	-1.391	0.199
Mean GRF Fz	6.025	6.350	0.276
Max GRF Fz	10.434	9.946	0.246
Min GRF Fz*	0.463	0.800	**0.053**

*Significant value (p<0.05)

Table 2 shows parameters of kinetic gait features for both groups. Based on result tabulated above, boys have greater mean ground reaction force (GRF) at all vertical forces (Fy) component and only one at horizontal force (Fz) component which is maximum GRF Fz. Additionally, girls performed greater GRF at Fz and minimum GRF at Fz. Based on the p value obtained from the analysis, there is significant difference occurs at minimum GRF Fz with the p is equal to 0.053. However the p-value is more than significant value which is less than 0.05.

Result in Figure 1 and Table 1 shows consistency with M. H. Schwartz et al.. Based on our findings, boys produced greater for most kinematic angle features and this was supported from previous research where walking speed had significantly effect on other gait measurement such as kinematics parameters [18]. There is significant difference between genders at hip and knee flexion where boys performed greater for both range of motions. This findings were supported with study in [13], where study found significant difference at sagittal plane. However, S.-u. Ko et al. focused on healthy older subjects in their study. From result, girls showed greater range of motion at hip internal rotation and hip adduction. The result was similar from previous research [20]. Additionally, boys have greater anterior pelvic tilt compare to girls and this finding had contras result from previous study by S. H. Cho et al. [21]. The difference in these findings may be due to age different between subjects for both studies. It is found that subjects age will affect the kinematic walking gait parameters where walking style will change when age increase.

4.0 CONCLUSION

The difference between gender on basic spatiotemporal, kinematic angles and kinetics of the lower limb body were explored using 3D motion analysis system using statistical analysis. From this study, gait features from spatiotemporal, kinematic angles and kinetics can provide information in differentiate between genders based on the result obtained. Result from analysis shows that kinematic angles had significant difference in differentiate between genders as compared to spatiotemporal features and kinetic features. For mean angles in kinematics features, the difference between genders can be observed at angles of hip, knee and ankle at frontal plane and angles of hip and knee at transverse plane with significant value less than 0.02. Whereas the significant difference between genders on range of motion can be observed at maximum of hip and knee flexion at sagittal plane with significant values less than 0.02. The result may be varies from others study due to different factors such as in age and physical body structure.

Acknowledgement

An acknowledgement is accorded to the Ministry of Education, Malaysia for the funds received through the Niche Research Grant Scheme (NRGS), Project file: 600-RMI/NRGS 5/3 (9/2013) and to the Research Management Institute (RMI), Universiti Teknologi MARA (UiTM) Shah Alam.

References

[1] M. J. Weiss, M. F. Moran, M. E. Parker, and J. T. Foley, 2013."Gait Analysis Of Teenagers And Young Adults Diagnosed With Autism And Severe Verbal Communication Disorders," *Frontiers In Integrative Neuroscience*. 7:1-10,.

[2] D. A. Winter, A. E. Patla, J. S. Frank, and S. E. Walt, 2007."Biomechanical Walking Pattern Changes In The Fit And Healthy Elderly," *Physical Therapy*.70: 340-347.

[3] R. Bartlett, Introduction To Sports Biomechanics: Analysing Human Movement Patterns: Routledge,.

[4] C. L. Vaughan, B. L. Davis, and J. C. O'connor,1992. Dynamics Of Human Gait: Human Kinetics Publishers Champaign, Illinois,.

[5] M. W. Whittle, 2003.Gait Analysis: An Introduction,.

[6] I. Stancic, T. G. Supuk, and M. Bonkovic, 2012."New Kinematic Parameters for Quantifying Irregularities in the Human and Humanoid Robot Gait," *International Journal of Advanced Robotic Systems*. 9:1-9.

[7] N. Rohila, B. Kumar, and N. Chauhan, 2010."Abnormal Gait Recognition," *International Journal on Computer Science and Engineering*.2: 1544-1551.

[8] R. Senden, B. Grimm, I. Heyligers, H. Savelberg, and K. Meijer,2009."Acceleration-Based Gait Test For Healthy Subjects: Reliability And Reference Data," *Gait & Posture*. 30: 192-196.

[9] B. S. Cığalı, E. Uluçam, and C. Bozer, 2011."3D Motion Analysis of Hip, Knee and Ankle Joints of Children Aged Between 7-11 Years During Gait," *Balkan Medical Journal*. 28, :197-201.

[10] A. Malone, D. Kiernan, H. French, V. Saunders, and T. O'Brien, 2015."Do Children With Cerebral Palsy Change Their Gait When Walking Over Uneven Ground?," *Gait & Posture*. 41: 716-721.

[11] V. L. Chester and M. Calhoun, 2012."Gait Symmetry in Children with Autism," *Autism Research And Treatment*. 2012.

[12] M. Calhoun, M. Longworth, and V. L. Chester, 2011."Gait Patterns In Children With Autism," *Clinical Biomechanics*. 26: 200-206.

[13] S.-u. Ko, M. I. Tolea, J. M. Hausdorff, and L. Ferrucci, 2011."Sex-Specific Differences In Gait Patterns Of Healthy Older Adults: Results from the Baltimore Longitudinal Study of Aging," *Journal of Biomechanics*. 44: 1974-1979.

[14] M.-C. Chiu and M.-J. Wang, 2007."The Effect Of Gait Speed And Gender On Perceived Exertion, Muscle Activity, Joint Motion Of Lower Extremity, Ground Reaction Force And Heart Rate During Normal Walking," *Gait & Posture*. 25: 385-392.

[15] B. Nigg, V. Fisher, and J. Ronsky, 1994."Gait Characteristics As A Function Of Age And Gender," *Gait & Posture*.2: 213-220.

[16] M. L. Callisaya, L. Blizzard, M. D. Schmidt, J. L. McGinley, and V. K. Srikanth. 2008. Sex modifies the relationship between age and gait: a population-based study of older adults," *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*. 63: 165-170,

[17] D. Verniba, M. E. Vergara, and W. H. Gage, 2015."Force Plate Targeting Has No Effect On Spatiotemporal Gait

Measures and Their Variability In Young And Healthy Population. *Gait & Posture*.
[18] M. H. Schwartz, A. Rozumalski, and J. P. Trost, 2008."The Effect Of Walking Speed On The Gait Of Typically Developing Children. *Journal of Biomechanics.* 41: 1639-1650.
[19] J. Romkes and K. Schweizer, 2015."Immediate Effects Of Unilateral Restricted Ankle Motion On Gait Kinematics In Healthy Subjects. *Gait & Posture*. 41: 835-840.
[20] E. S. Chumanov, C. Wall-Scheffler, and B. C. Heiderscheit, 2008. Gender Differences In Walking And Running On Level And Inclined Surfaces. *Clinical Biomechanics.* 23: 1260-1268.
[21] S. Cho, J. Park, and O. Kwon. 2004. Gender Differences In Three Dimensional Gait Analysis Data From 98 Healthy Korean Adults," *Clinical Biomechanics.* 19: 145-152.