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Kinematic Gait Analysis for School age Children in Capital Governorate at Kuwait

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Abstract: **Background:** pediatric gait evaluation is considered an important element of children's physical assessment and reflects their quality of life, health status and physical functions. **Purpose:** analyze kinematic gait parameters in normal school age children in Capital governorate at Kuwait and compare these findings with normal standard values **Methods:** Sixty normal healthy children from different schools at capital governorate in Kuwait were selected. Their ages were ranged from 6 to 12 years of both genders with normal Body mass index (BMI). They were assigned into three groups, group (A) 6 -8 years, group (B) 8 -10 years where group (C) 10 -12 years. All children underwent physical evaluations that were carried out for eligibility of selection. Then they scheduled for gait analysis using bioengineering BTS- FREEEMG 300 gait lab. The measured Kinematic gait parameters included temporal (stride time, stance time, swing time, stance phase, swing phase double support phase, velocity, and cadence), and spatial (stride length, step length, step width). **Results:** there were significant statistical difference between Kuwait children and normal standard values in some parameters as stride time for group A and group B, stance phase for group B, velocity for group A, B, and C, cadence for group C, step length for group A, B, and C and step width for group A and C. **Conclusion:** It can be concluded that kinematics gait analysis of Kuwait school age children at the capital governorate resembles and consistent with normal standard values ,except some values that differ significantly from the normal standard values.
Keywords: Kinematic Gait Analysis, Children, Kuwait.

1 Introduction

Gait is a complex pattern of movement which involves the whole body. It requires good coordination, intact muscles and normal body joints, it also requires intact sensory input for the control and the adaptation of the gait. .On the other hand locomotor behavior contributes to the ability of initiating and terminating locomotion for gait adaptation and overcoming any obstacles , it also contributes to change in speed and direction throughout gait [1] locomotion is a functional task which known to be recognized by loading and unloading periods of lower extremities, to move around direction throughout gait [1] locomotion is a functional task which known to be recognized by loading and unloading periods of lower extremities, to move around through complex interaction and coordination .It allows many of the activities of daily living, . It facilitates many social activities, and it is required in many occupations [2].

There are normal parameters within which human move to provide an efficient method of transport. It is interesting to realize that people are often easily recognized by their gait, yet normal gait is amazingly similar from one individual to another. When abnormalities in anatomy or pathology in function occur, gait modifications must follow for ambulation to occur [3].

Gait assessment in children is a part of the physical examination that can help in the screening for a variety of physical impairments and abnormalities. Clinical gait analysis is applied to evaluate gait abnormality by using several methods of assessment. These methods may include observation, videotaping, electromyography, kinetics, kinematics and energetic. Modern gait assessment is based on the integration of these methods to drive a complete analysis of the child [2]. The gait analysis reflects children health status and help in planning a proper physical therapy program plan [4].

Analysis of kinematic gait includes temporal, spatial and standing angles parameters. The temporal

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parameters are stride time, stance time, swing time, stance phase, swing phase double support phase, mean velocity, and cadence, while spatial parameters are stride length, step length, step width. Both temporal and spatial parameters represent functional aspect of the gait, while standing angles parameters are pelvic obliquity, pelvic tilt, pelvic rotation, hip abduction -adduction, hip flexion-extension, hip rotation, knee flexion -extension, ankle dorsi-planter flexion and foot progression. These parameters represent the joint kinematics. Evidence shows that a better understanding of normal development findings in children may be useful in interpreting the abnormal findings [5].

Based on our search there are no normative data for the gait parameters of typically developed children at Kuwait. This study may provide a valid reference dataset to determine the gait deviations.

The purpose of present study was to analyze the kinematic gait parameters, as well to assess the age differences in normal school children at Capital governorate in Kuwait with comparison to normal standard values.

2 Experimental Sections

2.1 Study Design: Descriptive Study.

2.2 Sample size calculation

Sample size for this study was calculated using the G*power program 3.1.9 (G power program version 3.1, Heinrich-Heine-University, Düsseldorf, Germany) for one tailed test, based on t tests - Means: Difference from constant (one sample case), Type I error (α) = 0.05, power (1-β error probability) = 0.80, Effect size d = 0.3266667. The appropriate minimum sample size for this study was 60 children.

2.3 Subjects

A total of sixty normal healthy children were selected from different schools at the capital governorate in Kuwait; their ages ranged from 6-12 years of both genders with normal body mass index (BMI) [6]. Participants were excluded if they had any cardiac or respiratory disorders, any musculoskeletal injuries, visual or auditory defects, a history of epilepsy or psychiatric disorders. All participated children had not shown any puberty signs and they didn't practice sport activity on daily bases.

After approval of the ethical committee of Faculty of Physical Therapy, Cairo University- No (P.T.REC/012/002298) Egypt, the procedures of the present study were explained thoroughly, and all the participants parents were asked to sign a written informed consent.

The participated normal children were divided into three groups, group (A) 6 -8 years, group (B) 8 -10 years where group (C) 10 -12 years, all children in three groups underwent gait analysis.

2.4 Measurement Instrument and Tools

-Weight-height scale:

It was used for measuring the body weight and height of each participated child in this study to calculate the body mass index [6].

-Universal Goniometer:

Large and medium Universal goniometers were used to measure hip flexion, extension, abduction, adduction, internal and external rotation, knee flexion and extension, ankle plantar and dorsiflexion to exclude range of motion (ROM) limitation in joints.

-Pelvimeter:

It was used to measure anterior superior iliac spine (ASIS) breadth, knees diameter around patella for both right and left knees and malleolus width. These measurements were needed as an entry data for gait analysis [7].

-Ruler:

Pelvic depth was measured by using two rulers in which the first ruler placed horizontally from the greater trochanter to the ASIS, and the second ruler is perpendicular over the first ruler at the level of ASIS of both right and left hips [7].

-Tape measurement:

It was used to determine the lower limbs length from ASIS to medial malleolus [7].

-Markers:

The 18 of two kind markers were used ,14 of the markers were applied with adhesive material to insure stable fixation of the marker and freedom of movement. They were placed by sticking them to the exposed bone marks**.** The other four markers were segmental markers with rubber built over the middle thigh and leg over both sides [7].

-Bioengineering bits freeemg 300 gait lab included the following:

a) Infrared video cameras

Twelve optoelectronic infrared video cameras were used to capture marker points from the three-dimensional coordinates, the system calculated the internal rotation centers as well outputting the changes in angle projected.

b) Walking surface and force platforms

A walking surface of 20-meter-long centered with modular platform for integration in terms of force platform was used. Two multi-axial force platforms were used to record the ground reaction force, center of mass and torsion moment. Integrated with kinematics, it calculated moment and powers within the joints.

c) Video recording with real time display

They recorded the child movement taken from different viewpoints.

d) Control screen

The 60” plasma monitor was used to monitor all the acquisition steps. It is generated by BTS EMGenius software for evaluation of movement’s cycle.

2.5 Procedures

1.Physical assessment: It was done for each participated child before gait analysis. It includes:
Measurements of ROM of hip flexion, extension, abduction adduction, internal rotation and external rotation, knee flexion and extension and ankle plantar flexion and dorsiflexion with straight and bent knee. Anthropometric measurement included ASIS breadth, pelvic depth, the knees diameter, malleolus width, pelvic and leg length.

2.Procedures for gait analysis: Participants had dressed in shorts and a sport top to expose anatomical landmarks after parents approved, as well they were asked to remain bare feet during the physical evaluation, calibration and gait analysis.

For data capture, markers were placed while the child in standing position. It was applied on specific points as followed; over the fifth metatarsal, over the lateral malleolus, over the lateral part of patella, over the greater trochanter, over superior iliac spine, over the sacrum, over the acromion process and over the spinous process of cervical vertebra. Segmental marker over the middle thigh and leg. The walking procedures were explained to the participated child that practice three walking trials before evaluation then the child walks two times for gait analysis. The data then were analyzed by BTS EMGenius software and compared with the normal standard values stored in the BTS EMGenius software.

2.6 Statistical Analysis

Data were screened, for normality assumption test and homogeneity of variance. Normality test of data using Shapiro-Wilk test was used, that reflect the data was normally distributed (P>0.05) after removal outliers that detected by box and whiskers plots. Additionally, Levene's test for testing the homogeneity of variance revealed that there was no significant difference (P>0.05). So, the data are normally distributed and parametric analysis is done. The statistical analysis was conducted by using statistical SPSS Package program version 25 for Windows (SPSS, Inc., Chicago, IL). Data are expressed as mean and standard deviation for age, BMI and kinematic parameters, number and percentage for gender. Analysis of variance (ANOVA-test) was used to compare among groups A, B, and C for kinematic parameters variables. Paired-t test was used to compare kinematic parameters versus normal values within group A (6-8 year), group B (8-10 year), and group C (10-12 year). All statistical analyses were significant at 0.05 level of probability ($P \leq 0.05$).

3 Results and Discussion

In the current study, a total of 60 school age children in capital governorate at Kuwait were assigned into 3 groups: group A included 18 children from 6 to 8 years, group B included 21 children from 8 to10 years, group C included 21 children from 10 to 12 years.

There were no significant differences in BMI (P=0.540; P>0.05) and gender (P=0.057; P>0.05) among groups A, B, and C as shown in Table 1.

Table 1: Demographic data of three age groups.

Items	Groups ($\bar{x}$ ±SD)		
	Group A (n=18)	Group B (n=21)	Group C (n=21)
Age (year)	7.07 ±0.53	8.82 ±0.32	11.40 ±0.52
BMI (kg/m^2)	18.20 ±1.91	18.60 ±2.16	19.60 ±2.14
Gender (Boys : Girls)	10 (55.60%) : 8 (44.40%)	15 (71.40%) : 6 (28.60%)	7 (33.30%) : 14 (66.70%)

After searching local database in Kuwait, there were no any research or data that analyzed kinematic gait parameters in Kuwait. It makes this study the foundation stone for analyzing the kinematic gait parameters and age-related differences in normal children. It represents first valid reference for normative database of Kuwait children.

The analysis of the temporal gait parameters of Kuwait children in three age groups and its comparison with normal standard values were presented in table (2)

Table 2: Comparison of temporal parameters for Kuwait children between three age groups and with normal standard values.

Temporal parameters	Groups	Kuwaiti values $\bar{x} \pm$ SD	Normal values	*P*-value
Stride time (s)	Group A	1.12 ±0.12	0.98 ±0.20	0.005*
	Group B	1.15 ±0.11	1.03 ±0.16	0.016*
	Group C	1.09 ±0.14	1.01 ±0.12	0.077
	P-value	0.413	0.585	
Stance time (s)	Group A	0.70 ±0.11	0.66 ±0.09	0.394
	Group B	0.71 ±0.10	0.68 ±0.09	0.358
	Group C	0.69 ±0.11	0.65 ±0.11	0.295
	P-value	0.853	0.760	
Swing time (s)	Group A	0.51 ±0.10	0.50 ±0.09	0.785
	Group B	0.54 ±0.09	0.52 ±0.09	0.466
	Group C	0.51 ±0.12	0.50 ±0.11	0.953
	P-value	0.548	0.861	
Stance phase (%)	Group A	62.34 ±11.68	58.24 ±1.25	0.119
	Group B	63.33 ±14.50	58.36 ±0.82	0.042*
	Group C	59.07 ±4.54	58.08 ±0.11	0.683
	P-value	0.433	0.554	
Swing phase (%)	Group A	43.70 ±12.70	41.20 ±2.51	0.371
	Group B	46.24 ±15.34	41.85 ±0.24	0.092
	Group C	40.33 ±4.27	42.14 ±0.11	0.483
	P-value	0.269	0.445	
Double support phase (%)	Group A	12.30 ±14.60	11.64 ±2.50	0.784
	Group B	8.60 ±3.39	12.21 ±1.24	0.104
	Group C	10.02 ±9.58	12.51 ±0.11	0.262
	P-value	0.517	0.219	
Velocity (m/s)	Group A	0.84 ±0.20	1.29 ±0.16	0.0001*
	Group B	0.88 ±0.28	1.32 ±0.11	0.0001*
	Group C	0.93 ±0.27	1.31 ±0.11	0.0001*
	P-value	0.595	0.704	
Cadence (steps/min)	Group A	122.53 ±9.02	124.43 ±7.11	0.428
	Group B	122.98 ±10.41	126.34 ±6.34	0.121
	Group C	123.39 ±5.64	129.71 ±0.11	0.005*
	P-value	0.953	0.012*	

$\bar{x}$ _are expressed as mean ± SD are expressed standard deviation.

P-value: probability value * significant (P<0.05) P-value>0.05: non-significant

The analysis of the spatial gait parameters of Kuwait children in three age groups and its comparison with normal standard values were presented in table (3)

Table 3: Comparison of spatial parameters for Kuwaiti children between three age groups and with comparison to the normal standard values.

Spatial parameters	Groups	Kuwaiti values $\bar{x} \pm$ SD	Normal value	*P*-value
Stride length (m)	Group A (n=18)	1.54 ±0.81	1.85 ±0.89	0.056
	Group B (n=21)	1.01 ±0.28	1.29 ±0.13	0.067
	Group C (n=21)	1.07 ±0.16	1.24 ±0.11	0.263
	P-value	0.002*	0.0001*	
Step length (m)	Group A (n=18)	0.64 ±0.30	0.86 ±0.39	0.001*
	Group B (n=21)	0.45 ±0.09	0.62 ±0.04	0.010*
	Group C (n=21)	0.41 ±0.09	0.61 ±0.04	0.002*
	P-value	0.001*	0.001*	
Step width (m)	Group A (n=18)	0.24 ±0.11	0.19 ±0.07	0.035*
	Group B (n=21)	0.19 ±0.05	0.15 ±0.05	0.059
	Group C (n=21)	0.19 ±0.05	0.14 ±0.04	0.015*
	P-value	0.039*	0.010*	

$\bar{x}$ _are expressed as mean ± SD are expressed standard deviation.

P-value: probability value * significant (P<0.05) P-value>0.05: non-significant.

Moreno et al 2010 [8] stated that walking pattern develops individually at age of seven years, while adolescents' gait will continue developing in certain temporal and spatial parameters; step, stride length, speed, cadence plus support and balance Thevenon et al,2015 [9] added that there were changes in gait after the age of seven till adulthood in spatial parameters (velocity, step length and stride length). Based on previous studies [8,9], the maturation of gait parameters still inapprehensible due to literature discrepancy. Hillman et al 2009 [10] and Lythgo et al. 2010 [11] reported that there is significant variation in gait parameters between children aged five to thirteen years and young adult ,also recommended further studies for gait parameters variation in teenagers. Lythgo et al 2010 [11] and Smith et al 2016 [12] agreed that gait symmetry is constant across age and unaffected by gait speed. Based on the previous studies the present study concerns the effect of age on gait variation, so recruiting the children into three groups according to their age.

This study targets children in Kuwait of both genders as supported by previous studies that stated the effect of gender was not of concern in gait analysis. It was found thatthe gait parameters were highly symmetric in both gender and there were no significant gender differences during gait analysis [8, 9, 12]. This finding excluded gender as being determinant factor for gait pattern variation in children before adolescences.

Regarding eligibility of subjects for this study, the sample was selected with ideal and normal body weight index in children to eliminate the effect of obesity on gait. This is supported by previous studies [4, 13, 14] that investigating the effect of weight and obesity on gait and found the significant differences between obese and normal weight young adult on gait kinematics. Also investigating interactions among obesity and age-related effects on the gait pattern and found that both age and obesity have a direct effect on gait alteration.

Dixon et al., 2014 [15] concluded that anthropometric data had significant effects on certain temporal gait parameters. Thevrnon et al. ,2015 [9] stated that during anthropometric measurement, examiner must consider length of the lower limbs instead of subject's full height which will reveal more reliable results. It's also stated that in literature, measurement of lower limb length has not been standardized, authors believed that the best way to measure the length of the lower limb is from anterior iliac spine to medial malleolus. This comes in agreement with Lythgo et al., 2010 [11] who use tape measurement to measure anterior iliac spine and medial malleolus, while Moreno Hernandez et al 2010 [8] measures distance between greater trochanter and the floor. Other studies use computed lower limb length from three-dimensional data however this may correlate but not exactly equal to the clinical measurement. Regarding the procedure for this study Davis protocol [7] was followed for determining anthropometric measurement. It measures lower limb length using tape measurement from anterior lilac spine till medial malleolus as this is the most used way in measuring leg length.

In light of numerous previous longitudinal and cross-sectional studies on gait analysis correlated to age that have been performed in Australia [11], Mexico [8], France [9], and United States [4]. Most of those studies used the GAITRite1 system to generate spatiotemporal data, which has shown good reliability in children. In this study authors used bioengineering Bts freeemg 300 gait lab. It is internationally scientific validated lab with high reliability [7, 16].

Concerning gait analysis with foot ware, it was stated that the best way of gait assessment while the child is barefoot [8]. Lythgo et al., 2010[11] and Dixon et al., 2014 [15] conducted gait analysis at different speed; the preferred speed, several self-selected speeds or an imposed speed. In this study, assessment of gait was carried out barefoot with normal self-selected speed as this is the most preferred way in assessing gait.

There is evidence that children show differences in gait standards based on race which makes finding local normative data of concern at worldwide [8]. This impact of the necessity on building local data base for every nation. This comes in agreement that the variations in gait analysis due to morphological features that justified the building up local data [9]. In this study of Kuwait school age children in the capital governorate, some parameters differ from normal standard values although there were some parameters consistent with normal values which confirm the need of creating and establishing normative data. Fang et al., 2018 [17] and kraan et al., 2017 [18] stated that gait analysis is critical for screening gait deviations and abnormalities in pediatric patients as well as it plays essential role in evaluating effectiveness of intervention. Voss et al., 2020 [19] stated that establishing a normative data as a reference for typically developed children and young adults is important and necessary for clinicians ,physical therapists and researchers to highlight typical gait maturation patterns and lead clinical practice in comparing motor outcomes in children with gait abnormalities Often, pediatric, orthopedics as well pediatrics neurosurgeons using gait analysis to detect gait deviation as a form of preoperative planning for surgical or medical intervention as it is well-document for the effectiveness of intervention in a functional improvement [12]. However, many clinicians have used gait analysis to understand the effects of orthotics, prosthetic usage, and/or limb reconstruction on gait deviation [20].

It is recommended that this study would be applied to other governorates rather than the capital governorate. Also, it is recommended that to apply this research with large number of participants with large sample size. it is also recommended to investigate the kinetic pediatric gait parameter.

4 Conclusions

It can be concluded that kinematic gait analysis of Kuwait school age children in the capital governorate resembles and consistent with normal standard values, except some values that differ significantly from the normal standard values in temporal parameters (stride time, stance phase, velocity and cadence) and spatial parameter (step length and step width). It was concluded that establishing normal local values for gait analysis created the foundation upon which clinicians could analyze various gait deviations.

The current study had some limitations; there were a total lockdown at Kuwait; plus, special restrictions for kids/ children's activities because of the international pandemic of COVID-19.

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Conflict of interest

The authors confirm that this article content has no conflict of interest.

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