Reliability of TailGait Gait Analysis System for the Measurement of Gait Parameters of Normal Children between 7 and 11 years

Wongphaet P

Department of Rehabilitation Medicine, Samrong General Hospital, Samutprakarn, Thailand

ค่าความน่าเชื่อถือของการวัดค่าตัวแปรการเดินในเด็กปกติอายุ 7 ถึง 11 ปี ด้วยเครื่องวิเคราะห์การเดิน TailGait

ภาริส วงศ์แพทย์

แผนกเวชศาสตร์ฟื้นฟู โรงพยาบาลสำโรงการแพทย์ จังหวัดสมุทรปราการ

ABSTRACT

Objective: To study the test-retest reliability of temporal-spatial gait parameters' measurement in normal children between 7 to 11 years using the TailGait gait analysis system.
Study design: An observational correlation study.
Setting: A public primary school at Samrong, Samutprakarn, Thailand
Method: A convenient sample of 30 students from primary class 2nd,3rd, and 4th was selected and the students were invited to participate in the study. Each of the students put on the force sensing shoes, data logging belts and the distance measurement "tail" and then they successively walked two laps across the semi-outdoor basketball court at self-selected and comfortable speed. Correlation coefficient of the first and temporal-spatial gait parameters from the two trials were then calculated.
Results: The correlation coefficients of walking speed, cadence, and stride time between the two measurements were 0.83, 0.89, 0.88 respectively. The correlation coefficients of left stance time, right stance time, left swing time and right swing time between the two measurements were 0.84, 0.88, 0.83 and 0.84 respectively. Also, the correlation coefficients of stride length, left step length and right step length between the two measurements were 0.77, 0.89, and 0.72 respectively. Our results also showed that the correlation between each one of the above-mentioned gait parameters form and the two measurements was statistically significant at p <0.001.
Conclusion: The retest reliability of TailGait measurements of speed, cadence, stride time, and bilateral stance and swing time in normal children, 7-11 years old, was high but the retest reliability of stride length, left step length and right step length was moderate to high.

Keywords: TailGait, Gait analysis, normal children, reliability

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บทคัดย่อ

วัตถุประสงค์: เพื่อศึกษาค่าความน่าเชื่อถือของการวัดตัวแปรการเดินชนิด temporal และ spatial ของเด็กปกติอายุ 7 ถึง 11 ปี
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กลุ่มประชากร: เด็กนักเรียนชั้นประถมปีที่ สองถึงประถมปีที่สี่ จำนวนทั้งสิ้น สามสิบราย คัดเลือกเฉพาะที่ไม่มีโรคหรือภาวะที่ทำให้การเดินและการทรงตัวผิดปกติ
วิธีการศึกษา: ให้เด็กสวมใส่รองเท้าวัดแรงเหยียบ เข็มขัดพร้อมเครื่องบันทึกข้อมูล และไม้ติดล้อสำหรับวัดระยะการเดิน แล้วให้เดินด้วยความเร็วตามสบาย ข้ามสนามบาสเก็ตบอล ไป และกลับ อย่างละหนึ่งเที่ยว จากนั้นคำนวณหาค่าสัมประสิทธิ์สหสัมพันธ์ ระหว่างค่าที่ได้จากนำค่าตัวแปรการเดินที่ได้มาจากการ เดินทั้งสองรอบ
ผลการศึกษา: ค่าสัมประสิทธิสหสัมพันธ์ ระหว่างค่าความเร็วการเดิน ความถี่การก้าวขา คาบการเดิน ที่คำนวณจากการวัดค่าทั้งสองรอบ มีค่าเท่ากับ 0.83, 0.89 และ 0.88 ตามลำดับ ส่วนค่าสัมประสิทธิ์สหสัมพันธ์ ระหว่างค่า เวลาของระยะการเหยียบพื้นด้วยเท้าซ้ายและเท้าขวา ระยะเวลาการยกเท้าข้างซ้ายและ ข้างขวา ที่คำนวณจากการวัดค่าทั้งสองรอบมีค่าเท่ากับ 0.84, 0, 83, 0.88 และ 0.84 ตามลำดับ ค่าสัมประสิทธิสหสัมพันธ์ระหว่างค่าระยะการเดินหนึ่งวงรอบการเดิน (stride length) ระยะการก้าวขาซ้าย และ ระยะการก้าวขาขวา ที่คำนวณจากากรวัดค่าทั้งสองรอบ มีค่าเท่ากับ 0.77, 0.89 และ 0.72 ตามลำดับ ทั้งนี้พบว่าความสัมพันธ์ระหว่างตัวแปรการเดินจากาการวัดการเดินทั้งสองรอบที่กล่าวไปแล้วข้างต้นนี้ทุกรายการ มีความสัมพันธ์กันอย่างมีนัยสำคัญที่ค่า p<0.001

Correspondence to: Parit Wongphaet, M.D., Department of Rehabilitation Medicine, Samrong General Hospital, Samutprakarn 10270, Thailand. E-mail: spine.clinic@yahoo.com

สรุป: การวัดค่า ความเร็วการเดิน ความถี่การก้าวขา เวลาวงรอบการเดิน ค่าเวลาของการเหยียบ และยกเท้าทั้งสองข้าง ของเด็กปกติอายุ 7 ถึง 11 ปี ที่วัดด้วยเครื่อง วัดวิเคราะห์การเดิน TailGait มีความน่าเชื่อถือสูง ส่วนการวัดค่า ระยะการเดินหนึ่งวงรอบการเดิน ระยะการก้าวขาซ้าย และระยะการก้าวขาขวานั้นมีความน่าเชื่อถือปานกลางถึงสูง

คำสำคัญ: เทลเกต, วิเคราะห์การเดิน, เด็กปกติ, ความน่าเชื่อถือ

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Introduction

Temporal and spatial parameters of gait such as speed, stride length, cadence, ratio/absolute values of stance time, swing time, single support and double support time have been used to measure the quality of gait and balance ability in research and clinical practices.[1] It is generally assumed that single evaluation is a good representation of the typical performance of each person. For example, test-retest reliability of temporal-spatial gait parameters measured with a force sensitive mat system was found to be high in adults[2] and in children.[3] Such a force sensor embedded mat system for gait analysis is quick and easy to use but can be costly to purchase and maintain. The walking distance that can be measured is limited to the length of the force sensing mat size. The numerous force sensors inside the mat could break and would require repairs which may not be easily available to users in countries, located far away from the manufacturing company.

TailGait is a novel and wearable temporal-spatial gait analysis system. It consists of force sensing shoes, small and wearable data logging computer on waist belt, and a distance measuring roller connected to the posterior side of the subject's pelvis through a rigid and lightweight rod (as in Figure 1). Step length and stride length are calculated from the simultaneously collected trunk speed information from the distance roller and the step time information from the shoes. The system is light in weight and can be used on any dry, flat, non-slippery surface.

TailGait was used successfully to demonstrate the post therapy improvement in gait of children with cerebral palsy after therapy.[4] The findings confirmed that TailGait is sensitive enough to detect change. However, no study has been done so far to confirm the test-retest reliability of the system.

The objective of this study is to demonstrate the test-retest reliability of TailGait's temporal and spatial gait parameters in the primary school children.

Methods

A convenient sample of 30 students from primary school classes 2nd to 4th was selected and invited to participate in the gait analysis at the school's semi-outdoor basketball court. Only children with no history of neuro-musculoskeletal illness that affect walking and balancing abilities, such as cerebral palsy, scoliosis, foot deformities and active painful conditions, were included in this study. Body weight, height, sex and class of each participant were recorded.

The researchers helped the students to put on the force sensing shoes, and attached the data logging belt over the pelvis of the subjects at a height between iliac crest and greater trochanter of femur. The TailGait's distance measuring rod was attached to the posterior part of the belt. The children stood with feet close together at one end of the basketball court. On the verbal signal "Go!" from the researcher, the children started walking straight towards the opposite side of the court. No specific instruction was given regarding speed. The "Stop walking!" instruction was given when the children approached the opposite border of the court. No attempt was made to make the children stop walking at any specific point or when they has reached any specific distance of walking. Each child immediately turned around and did another measurement with the same method.

The data was transferred to a computer for analysis. The researcher marked the first 4 steps and last 4 steps of the analyses. Therefore, only the "steady state" gait parameters were studied.

Statistical analysis

Statistical analyses were performed using MS Excel and open source SOFA Statistics version 1.4.3 (Paton-Simpson & Associates Ltd, Auckland, New Zealand). Pearson's correlation coefficient between the parameters from the two recordings were calculated in order to demonstrate the test-retest reliability of gait parameters, such as, speed, cadence, step time, swing time, single support time, double support time, etc.

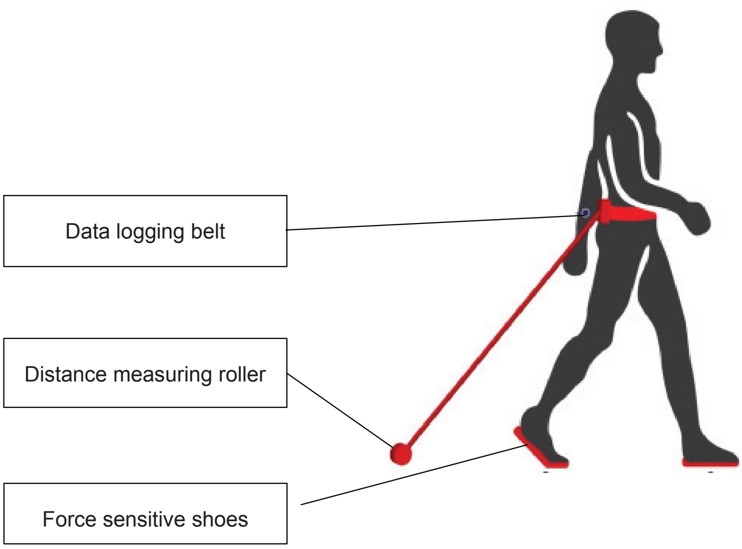

Figure 1. Demonstrating the components of "TailGait" gait analysis system which consist of force sensitive shoes , data logging belt , and distance measuring roller.

Mean and standard deviation (SD) values for each of the variables, such as speed, cadence, number of stride, duration and distance of the recording, and for each age group were also calculated separately.

Results

Total 30 children underwent the gait analysis. There were 17 boys and 13 girls with an average age of 8.99 years (SD=0.97). The height and weight of the children in each year-group is given in table 1. We did not make separate calculations for boys and girls because of the small sample size.

Collectively the "steady state" data of 30 children on 60 passes of gait analysis were used for analyses, which included 986 strides, 602.89 seconds, and 635.22 meters of walking. The total time needed for data collection of gait was three hours. The data on average duration and distance of walking, per subject, used for analyses was 10.05 seconds and 10.58 meters, respectively. The averages values for each age group are given in table 2.

The mean and standard deviation values of the gait parameters selected for this study, together with Pearson's correlation coefficient are calculated from the first and second gait analyses that were recorded, data are shown in table 3. The correlation coefficients of speed, cadence, stride time, bilateral stance time, bilateral swing time, were greater than 0.8 and were statistically significant at $p<0.001$.We found that the correlation coefficient of bilateral single support time, bilateral double support time, stride length, bilateral step length were also statistically significant at $p<0.001$, but their correlation coefficients were lower than those found using other parameters. They were between 0.59 and 0.80 as shown in table 3.

The correlation of the remaining gait parameters between the two recordings were found to be low to moderate. These parameters include distance, duration, number of strides, percentage of gait cycles spent on bilateral stance phase, swing phase, single support, and double support.

Discussion

The reliability of various gait speeds and cadences, analyzed in this study, is compatible with the findings of a prior study by Thorpe et al.[3] Thorpe et al. have demonstrated that the gait parameters of typically developing children range from poor to excellent, in which gait speed and cadence showed high test-retest reliability with ICC of 0.73 and 0.93, respectively, while stride length, percentage of stance time per gait cycle, percentage of swing time per gait cycle, percentage of single support time per gait cycle, and percentage of double support time per gait cycle were shown to be low to moderate.

In this study, we found that among the "time" parameters, the stride time, stance time and swing time showed high correlation coefficients, while single and double support time showed lower correlation coefficients. This may suggest that while the cycle of stance and swing of each leg may be constant, the temporal relationship between the phases of walking cycle of each leg can vary. Prior research has suggested that there may exist two "central stepping pattern generator" in the central nervous system, each one responsible for left and right side separately.[5,6] There must be coordination or "coupling" actions of these two centers order to keep a constant double support time.

It has been demonstrated that in adults the double support time is less variable than other parameters and the ICC of double support time in adult is well over 0.9.[7] Increased gait variability is correlated with immaturity of gait[7] or pathology.[8]

It is well known that the ratio of stance to swing time in a normal gait cycle is 60:40 and the ratio of single support and double support time in gait cycle is roughly 80:20.[1] In this study the "percentage of gait cycle" parameters show the lowest correlation coefficient among all gait parameters. The p-value of several of these parameters is not statistically significant. It seems that in 7- to 11-year-old children "time" parameters are highly reproducable. However, the "percentage of gait cycle" parameters are variable.

Table 1. Demographic data of participants

Age group	Number of subjects male:female	Height (cm)[1]	Body weight[1] (kg)	Body mass index[1] (kg/m^2)
7	1:0	119 (-)	19(-)	13.41(-)
8	1:4	128.2 (3.68)	27.6 (3.57)	16.81(2.36)
9	5:4	129.38 (7.25)	31.63 (12.36)	18.43(5.61)
10	9:0	134.44 (4.29)	35.56 (9.67)	19.21(4.99)
11	1:5	141.17 (5.86)	42.17 (7.9)	21.16(4.10)
average		132.83 (7.57)	33.9 (10.66)	18.77(4.66)

[1] Mean (SD)

Table 2. Basic gait parameters by age group

Age group	Duration[1] (sec)	Distance[1] (m)	Strides[1]	Speed[1] (km/hr)	Cadence[1] (steps/min)
7	10.49 (1.74)	9.02 (0.34)	13 (1.41)	3.12 (0.4)	80.5 (4.95)
8	10.53 (1.93)	10.56 (0.94)	16.9 (2.81)	3.68 (0.46)	102.8 (8.35)
9	9.17 (1.53)	10.12 (1.2)	15.72 (2.22)	4.04 (0.62)	110.28 (9.5)
10	9.25 (1.19)	10.9 (0.62)	16 (1.5)	4.3 (0.54)	111.33 (12.7)
11	12.09 (3.09)	11.1 (0.8)	18.33 (3.2)	3.44 (0.6)	97.83 (11.56)
Average	10.05 (2.19)	10.58 (1.02)	16.43 (2.57)	3.92 (0.66)	105.87 (12.65)

[1] Mean (SD)

Table 3. Average gait parameters and Pearson's correlation coefficient of the parameters obtained from both trials

	Parameters	Side	1st trial[1]	2nd trial[1]	Pearson's correlation coefficient (r)	*p* value
Basic						
	Speed (km/hr)		3.8 (0.66)	4.0 (0.66)	0.832	<0.001
	Cadence (step/min)		104.57 (12.75)	107.17 (12.63)	0.894	<0.001
	Distance (m)		10.6 (0.82)	10.56 (1.18)	0.408	=0.023
	Duration (sec)		10.37 (2.37)	9.73 (1.99)	0.761	<0.001
	Number of stride		16.73 (2.49)	16.13 (2.65)	0.562	=0.001
Time						
	Stride time (sec)		1.09 (0.14)	1.06 (0.09)	0.885	<0.001
	Stance (sec)	Left	0.66 (0.10)	0.63 (0.05)	0.845	<0.001
		Right	0.66 (0.04)	0.64 (0.04)	0.885	<0.001
	Swing(sec)	Left	0.43 (0.06)	0.43 (0.03)	0.832	<0.001
		Right	0.43 (0.03)	0.43 (0.12)	0.848	<0.001
	Single support (sec)	Left	0.41 (0.08)	0.42 (0.08)	0.72	<0.001
		Right	0.43 (0.05)	0.42 (0.05)	0.622	<0.001
	Double support (sec)	Left	0.10 (0.05)	0.09 (0.05)	0.8	<0.001
		Right	0.11 (0.03)	0.10 (0.02)	0.59	<0.001
Length						
	Stride length (m)		1.14 (0.12)	1.18 (0.10)	0.774	<0.001
	Step length (m)	Left	0.58 (0.06)	0.58 (0.06)	0.8	<0.001
	Step length (m)	Right	0.56 (0.06)	0.58 (0.06)	0.727	<0.001
Percent of gait cycle						
	Stance	Left	60.32 (1.81)	59.54 (1.79)	0.342	=0.060
		Right	60.27 (2.04)	59.71 (1.61)	0.694	<0.001
	Swing	Left	39.68 (1.81)	40.46 (1.79)	0.342	=0.060
		Right	39.73 (2.04)	40.29 (1.61)	0.694	<0.001
	Single support	Left	80.14 (3.58)	81.12 (3.77)	0.656	<0.001
		Right	78.55 (3.83)	80.36 (2.96)	0.544	=0.002
	Double support	Left	19.86 (3.58)	18.88 (3.77)	0.625	<0.001
		Right	21.45 (3.83)	19.64 (2.96)	0.544	= 0.002

[1] Mean (SD)

This author would propose that children at the age of 8–11 years are yet to develop a better coordination between left and right stepping pattern. This could be verified by further studies that involve a bigger sample size and compares the double support and single support ratios across age group 7-18 years.

The finding of this research confirms that TailGait is a reliable tool for gait analysis in 7- to 11-year-old children. Therefore, it is possible to use TailGait to monitor changes of the same subjects, before and after therapy.

The normative temporal and spatial parameters can vary between systems and labs because of the possibility of different definitions used. However, in order to compare gait parameter of any individual against a population norm, the normal reference value of TailGait gait parameters must be obtained through a study involving much more number of subjects.

In this study, only comfortable and self-selected speed of walking was analyzed. In future studies, different speeds of walking, slow and fast, should be analyzed as well.

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