Gait Symmetrical Indexes and Their Relationships to Muscle Tone, Lower Extremity Function, and Postural Balance in Mild to Moderate Stroke

Sunee Bovonsunthonchai MS, PT*, Vimonwan Hiengkaew PhD*,
Roongtiwa Vachalathiti PhD, PT*, Mantana Vongsirinavarat PhD, PT*

** Faculty of Physical Therapy, Mahidol University, Salaya, Nakhon Pathom, Thailand*

Objective: *To investigate asymmetrical gait characteristics and degree of associations between gait symmetrical indexes and clinical measures in a stroke population.*

Material and Method: *Thirty patients with stroke participated in the present study. Clinical measures included muscle tone of affected hip adductors (HA), hip extensors (HE), knee extensors (KE), ankle plantarflexors (AP) and ankle invertors (AI), lower extremity function and postural balance. Symmetrical indexes of gait biomechanics included braking peak force (Y1), propulsive peak force (Y2), first peak vertical force (Z1) and second peak vertical force (Z2), step length, single support time (SST), step time, stance time and swing time were determined.*

Results: *The symmetrical index of force was significantly related with muscle tone and lower extremity function. Temporo-spatial variables significantly related to muscle tone and lower extremity function, but not to postural balance.*

Conclusion: *Muscle tone and lower extremity function were important for walking efficiency as the presented relationships with symmetrical gait characteristic in patients with a stroke.*

Keywords: *Stroke, Gait symmetrical index, Muscle tone, Lower extremity function*

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After a stroke, changes in muscle tone, lower extremity function, and postural balance have been frequently observed and these changes deteriorate gait performance in stroke populations. It has been reported that increased ankle plantarflexors muscle tone can significantly affect gait at both stance and swing phases[1]. Simultaneous activation of the quadriceps with the gluteus maximus causes a mass extension pattern during the stance phase[2]. The mass flexion pattern causes synergistic contraction of the hip flexors, knee flexors and ankle dorsiflexors during the swing phase[2]. This primitive motor control produces the primitive patterned limb movement and inhibits normal progression during walking[3]. Walking necessitates lower limb motor function over the whole gait cycle; thus, lower limb function is a factor expected to be related with stroke gait performance. In addition, postural balance is one of the critical factors playing an important attribution to gait difficulties and falls in stroke[4].

Asymmetrical gait characteristics usually appear in post stroke patients. It has been reported that patients with a stoke show asymmetrical gait in temporo-spatial variables, such as step length[5-9], stance time[5,7], swing time[7,10], single support time[5,9]; in kinematic, for example hip[9], knee[9] and ankle[9,11] range of motions; and in kinetic parameters, for instance propulsive and braking impulses[6,12], average vertical force[7], center of pressure[8] and center of mass[8]. These asymmetries were related to motor function[5,6] and gait speed[5,11,13] disturbances. However, relationships of the peak forces and asymmetrical gait pattern have not yet been stated. Vertical force plays a role in walking for maintaining the body in vertical axis. Braking and propulsive forces are the other two forces that assist the body to move forward. Thus, these variables may help the authors to get more information about force related symmetrical gait characteristic.

In stroke rehabilitation, increased muscle tone, reduced lower limb motor functions, poor postural

Correspondence to:
Hiengkaew V, Faculty of Physical Therapy, Mahidol University, 999 Phuttamonthon 4 Rd, Salaya, Phuttamonthon, Nakhon Patom 73170, Thailand.
Phone: 0-2441-5450, Fax: 0-2441-5454
E-mail: ptvhk@mahidol.ac.th

control and balance are generally corrected to enhance more symmetrical gait characteristics. Furthermore, improvement in symmetrical gait characteristics is one of the ideal objectives in functional rehabilitation for individuals with a stroke[5,7]. It is important to understand which crucial changes in gait recovery of stroke population are. Thus, the purpose of the present study was to investigate asymmetrical gait characteristics and to determine the degree of associations between gait symmetrical indexes, motor functions, and postural balance in stroke population.

Material and Method

Participants

Thirty patients with a stroke (25 males, 5 females) participated in the present study. The inclusion criteria were first stroke caused by cerebrovascular disease, not from brain tumor and trauma, independent walking at least 10 meters without using any assistive devices, intact sensation, no other neurological problems such as Parkinsonism or Alzheimer disease and no problems of cognitive status and communication. Participants who received medical treatment for spasticity and/or had musculoskeletal or cardiopulmonary complication interfering with walking were excluded from the present study. Cognitive status was screened by Thai Mental State Examination (TMSE)[14]. Characteristic of subjects is demonstrated in Table 1.

Procedures

The present study was performed in the Human Motion Laboratory, Faculty of Physical Therapy, Mahidol University, Thailand; and was approved by the Ethical Committee, Faculty of Medicine Siriraj Hospital, Mahidol University, Thailand. The age, body weight, height, time since stroke, type of stroke, and affected side were recorded. Participants were assessed for muscle tone of the affected side by the Modified Ashworth Scale (MAS)[15] in hip adductors (HA), hip extensors (HE), knee extensors (KE), ankle plantarflexors (AP) and ankle invertors (AI). Then, the lower extremity function was assessed by the Fugl-Meyer Assessment (FMA)[16] and the postural balance was assessed by the Berg Balance Scale (BBS)[17,18]. For the following items of the BBS, sitting to standing, transferring, turning to look behind, turning 360 degrees, standing unsupported with one foot in front and standing on one leg, participants separately performed these items in the affected and the un-affected sides. Therefore, each participant had two output data of the BBS score, score for the affected side and for the un-affected side.

After finishing all clinical measurements, spherical markers were attached on both feet of the subjects at the second metatarsal, lateral malleolous, and calcaneous. Prior to gait data collection, participants practiced 10-meters walk on the walkway with one force platform (OR6-7) (AMTI, Advanced Mechanical Technology Inc.) embedded in the middle until they could place their affected or un-affected foot on the force platform. Gait data were collected both motion and force at 100 Hz by Vicon™ Motion Analysis System, version 612 and at 1,000 Hz by force platform. Participants had walking data collected for the affected and un-affected sides with their preferred comfortable and preferred fast speeds. Force and temporo-spatial parameters were braking peak force (Y1), propulsive peak force (Y2), first peak vertical force (Z1), second peak vertical force (Z2), step length, single support time (SST), step time, stance time, and swing time.

Table 1. Subject characteristics

Characteristics	Number of subjects	Mean ± SD
Type of stroke		
Hemorrhage	12	-
Ischemic	18	-
Affected side		
Left	22	-
Right	8	-
Age (years)	30	53.3 ± 8.77
Body weight (kilograms)	30	68.1 ± 14.0
Height (centimeters)	30	166.0 ± 7.40
Time since stroke (months)	30	32.3 ± 19.6
Thai Mental State Examination (scores)	30	27.9 ± 1.84

Data deductions and analyses

Muscle tone, lower extremity function and postural balance were described as minimum and maximum scores. In addition, frequency of each score for the HA, HE, KE, AP and AI muscle tones was presented; and the score of lower extremity function, postural control and balance were demonstrated as mean and standard deviation.

Two output of gait data (affected and un-affected), Y1, Y2, Z1, Z2 step length, SST, step time, stance time, and swing time were used for calculation of the symmetrical index[19].

$$\text{Symmetrical index of X (\%)} = \frac{(X_{affected} - X_{un\text{-}affected})}{1/2\,(X_{affected} + X_{un\text{-}affected})} \times 100$$

; Where X, may refer to any gait variable

The negative symmetrical index value represented the lesser value of the affected side than the un-affected side, whereas the positive value represented the greater value of the affected side than the un-affected side. For the ideal symmetrical gait condition, the symmetrical index should be zero, presenting perfectly symmetrical gait pattern. The greater symmetrical index value, the greater asymmetrical gait characteristic was. Without concerning the asymmetrical occurred whether the affected or un-affected sides, absolute value of symmetrical index was used to determine relationships with clinical measures by Spearman and Pearson correlations. The significant level was set at $p < 0.05$.

Sample size calculation

Sample size for correlation of clinical measures and symmetrical indexes came from pilot study (n = 10 subjects), showing the correlation of $r = 0.5\text{-}0.9$ at $\alpha = 0.05$ and attained 46 to 99% power. Thus, there was a 54 to 1% chance committed a type II error. To find a number of subjects needed for 80% power, a subject sample size ranging from 5 to 22 was recruited[20]. Consequently, the number of subjects at 30 was set in the present study.

Results

Clinical measures

As shown in Table 2, there was normal tone or slightly increased tone in most of the patients. The lower extremity function was in the moderate to high levels (24.3 $\pm$ 5.18, range 16-33). Furthermore, patients with stroke demonstrated quite good postural balance for the affected (49.5 $\pm$ 3.69, range 40-55) and the un-affected side (51.7 $\pm$ 3.26, range 45-56).

Gait symmetrical index characteristic

In patients with a stroke, symmetrical indexes with positive and negative signs are separately shown in Table 3. All of the parameters demonstrate both positive and negative signs except for the index of stance time and swing time, which reveal only negative and positive signs, respectively. The results showed, either at comfortable or fast gait speed, patients with stroke presented asymmetry and inconsistent pattern for the Y1, Y2, Z1, Z2, step length, SST, and step time while demonstrated asymmetry and consistent pattern for stance time and swing time.

Correlations between gait symmetrical indexes and clinical measures

As shown in Table 4, significant relationships between gait symmetrical indexes and muscle tone were found between Z1 and muscle tone in HA ($r_s = 0.41$), HE ($r_s = 0.40$), KE ($r_s = 0.42$) at comfortable gait speed. In addition, Z1 was significantly correlated to muscle

Table 2. Muscle tone of hip adductors (HA), hip extensors (HE), knee extensors (KE), ankle plantarflexors (AP), and ankle invertors (AI) in the affected side, lower extremity function, and postural balance using the affected and un-affected sides in patients with stroke (n = 30)

Clinical measures	Number of subjects on each Modified Ashworth Scale						Min-Max
	0	1	1.5	2	3	4	
Muscle tone in the affected side							
HA	10	12	7	1	0	0	0-2
HE	10	10	8	2	0	0	0-2
KE	13	7	8	2	0	0	0-2
AP	4	6	14	5	1	0	0-3
AI	3	8	14	4	1	0	0-3
			Means $\pm$ SD				Min-Max
Lower extremity function:			24.3 $\pm$ 5.18				16-33
Postural balance:							
Affected side			49.5 $\pm$ 3.69				40-55
Un-affected side			51.7 $\pm$ 3.26				45-56

tone in HE (r_s = -0.43) and in KE (r_s = -0.47) at fast gait speed. For the symmetrical index of step length, it was found to relate with muscle tone in AP (r_s = 0.40) at fast gait speed. Significant relationships were demonstrated between symmetrical index of SST and muscle tone in HA (r_s = 0.42), HE (r_s = 0.43), KE (r_s = 0.49), AP (r_s = 0.52), and AI (r_s = 0.57) at fast gait speed. In addition, the significant relationship between SST and muscle tone in KE (r_s = 0.37), AP (r_s = 0.40) and AI (r_s = 0.41) were found at the comfortable gait speed. Significant relationships of symmetrical index of step time and muscle tone in HA (r_s = 0.37), HE (r_s = 0.37), KE (r_s = 0.50) and AI (r_s = 0.41) at comfortable gait speed were demonstrated. Furthermore, symmetrical indexes of step time were found to relate with muscle tone in KE (r_s = 0.46) and AI (r_s = 0.40) at fast gait speed. At both comfortable and fast gait speeds, significant relationships were found between symmetrical index of stance time and muscle tone, for KE (r_s = 0.45, for comfortable speed, r_s = 0.40, for fast speed) and AI (r_s = 0.43, for comfortable speed, r_s = 0.45, for fast speed). Symmetrical index of swing time were significantly related with all muscle tones (HA, r_s = 0.36, for comfortable speed, r_s = 0.37, for fast speed; HE, r_s = 0.38, for comfortable speed, r_s = 0.42, for fast speed; KE, r_s = 0.43, for comfortable speed, r_s = 0.43, for fast speed; AP, r_s = 0.37, for comfortable speed, r_s = 0.44, for fast speed; and AI, r_s = 0.48, for comfortable speed, r_s = 0.53, for fast speed).

As shown in Table 4, there were significant relationships between lower extremity function and Y2, at both comfortable and fast gait speeds [comfortable gait speed: Y2 (r_p = -0.48), SST (r_p = -0.67), step time (r_p = -0.49), stance time (r_p = -0.63), and swing time (r_p = -0.68); fast gait speed: Y2 (r_p = -0.41), SST (r_p = -0.68), step time (r_p = -0.48), stance time (r_p = -0.66), and swing time (r_p = -0.68)]. Significant relationship between symmetrical index of step length and lower extremity function at comfortable gait speed was found (r_p = -0.44). No relationship was found between symmetrical index of any gait variables and postural balance.

Discussion

Among several relationships that were exhibited in the present results, it was expected to observe positive relationships of gait symmetrical

Table 3. Symmetrical indexes of braking peak force (Y1), propulsive peak force (Y2), first peak vertical force (Z1), second peak vertical force (Z2), step length, single support time (SST), step time, stance time, and swing time at the preferred comfortable (COM) and fast (FAST) gait speeds in the stroke. Number of participants (n) and percentage of participant (%) showing negative and positive values of symmetrical index are demonstrated (n = 30)

Gait variables	Speed	Symmetrical indexes (%)	
		Negative sign Means ± SD (n, %)	Positive sign Means ± SD (n, %)
Y1	COM	-27.1 ± 22.2 (14, 47)	32.9 ± 22.0 (16, 53)
	FAST	-22.9 ± 24.8 (14, 47)	44.2 ± 27.8 (16, 53)
Y2	COM	-74.9 ± 46.9 (24, 80)	34.6 ± 33.0 (6, 20)
	FAST	-62.6 ± 44.2 (25, 83)	23.8 ± 18.1 (5, 17)
Z1	COM	-3.0 ± 1.5 (8, 27)	7.0 ± 4.2 (22, 73)
	FAST	-8.1 ± 5.4 (10, 33)	8.5 ± 6.5 (20, 67)
Z2	COM	-3.6 ± 3.5 (18, 60)	2.8 ± 1.8 (12, 40)
	FAST	-7.2 ± 5.3 (20, 67)	3.8 ± 2.2 (10, 33)
Step length	COM	-14.4 ± 18.1 (2, 7)	17.3 ± 18.2 (28, 93)
	FAST	-7.4 ± 11.5 (9, 30)	18.0 ± 21.2 (21, 70)
SST	COM	-26.7 ± 14.3 (27, 90)	11.2 ± 12.7 (3, 10)
	FAST	-24.2 ± 13.9 (27, 90)	13.71 ± 16.1 (3, 10)
Step time	COM	-5.2 ± 3.5 (3, 10)	24.2 ± 15.5 (27, 90)
	FAST	-9.1 ± 6.2 (2, 7)	23.0 ± 15.8 (28, 93)
Stance time	COM	-10.6 ± 6.5 (30, 100)	-
	FAST	-12.8 ± 7.9 (30, 100)	-
Swing time	COM	-	22.9 ± 13.9 (30, 100)
	FAST	-	24.8 ± 15.9 (30, 100)

Table 4. Correlations between clinical measures and gait symmetrical indexes at preferred comfortable and fast gait speed in patients with stroke (n = 30)

Clinical measures		Speeds	Gait symmetrical indexes								
			Y1	Y2	Z1	Z2	Step length	SST	Step time	Stance time	Swing time
Muscletone (r_s)	HA	COM	-0.16	0.14	0.41*	-0.02	0.16	0.33	0.37*	0.33	0.36*
		FAST	-0.12	0.19	-0.36	-0.17	0.22	0.42*	0.34	0.28	0.37*
	HE	COM	-0.02	0.16	0.40*	0.64	0.18	0.34	0.37*	0.34	0.38*
		FAST	-0.08	0.24	-0.43*	-0.20	0.19	0.43*	0.33	0.34	0.42*
	KE	COM	-0.04	0.21	0.42*	0.64	0.11	0.37*	0.50+	0.45*	0.43*
		FAST	0.10	0.29	-0.47+	-0.13	0.12	0.49+	0.46*	0.40*	0.43*
	AP	COM	-0.02	0.22	0.34	0.01	0.32	0.40*	0.33	0.30	0.37*
		FAST	0.01	0.30	-0.28	-0.06	0.40*	0.52+	0.32	0.34	0.44*
	AI	COM	-0.07	0.19	0.43*	-0.16	0.32	0.41*	0.41*	0.43*	0.48+
		FAST	-0.07	0.35	-0.29	-0.12	0.34	0.57+	0.40*	0.45*	0.53+
Lower extremity		COM	0.08	-0.48+	-0.20	-0.20	-0.44*	-0.67+	-0.49+	-0.63+	-0.68+
Function (r_p)		FAST	0.07	-0.41*	0.28	-0.01	0.35	-0.68+	-0.48+	-0.66+	-0.68+
Postural balance(r_p)	Affected	COM	0.07	-0.31	-0.06	-0.20	-0.05	-0.24	-0.25	-0.32	-0.34
		FAST	-0.15	-0.23	0.33	0.06	-0.05	-0.31	-0.28	-0.30	-0.27
	Un-affected	COM	0.03	-0.09	0.02	-0.22	-0.02	-0.27	-0.15	-0.35	-0.34
		FAST	-0.13	-0.08	0.25	-0.02	-0.07	-0.34	-0.18	-0.23	-0.20

r_s = Spearman rank correlation coefficient; r_p = Pearson correlation coefficient
* = Significant level at $p < 0.05$; + = Significant level at $p < 0.01$
Y1 = Braking peak force; Y2 = Propulsive peak force; Z1 = First peak vertical force; Z2 = Second peak vertical force
SST = single support time; HA = hip adductors; HE = hip extensors; KE = knee extensors; AP = ankle plantarflexors; AI = ankle invertors

indexes and muscle tones. It was indicated that increased asymmetrical gait pattern might result from increased muscle tone in patients with stroke. However, relationships between symmetrical index of Z1 and muscle tone in HE and KE at fast speed were found in negatively. This indicated that increased muscle tone in HE and KE might assist more symmetrical pattern of the vertical force during the fast walking speed. It might result from the functional role of these two muscles in preventing body collapse and in maintaining body in upright position. Thus, the difference of the affected and un-affected performances may reduce. Moreover, gait symmetrical indexes were expected to show negative relationships with lower extremity function and postural balance. It was indicated that good lower extremity function and postural balance may reduce asymmetrical gait pattern. Although postural balance was classified into the score of affected and un-affected for challenging patients with stroke to perform, no correlation was shown between gait symmetrical index and postural balance neither affected nor un-affected performances. An explanation was that most of the participants had quite good postural balance in the affected and the un-affected side, therefore, the relationship with the changed score of gait symmetrical index was not observed.

For the remaining gait symmetrical variables (Y1, Y2, Z1, Z2, step length, SST, and step time), patients with a stroke demonstrated inconsistent asymmetrical gait characteristic as observed from the patients were performing function on both affected and un-affected sides. Some patients with a stroke showed predominance in the affected side, the others showed the un-affected side predominantly in Y1, Y2, Z1, Z2, step length, SST, and step time. The variations in Y1, Y2, Z1, Z2, step length, SST, and step time may be due to difference in gait pattern; for example, using various compensatory strategies for walking. From observation during gait data collection, a few participants walked nearly typical gait pattern. Most participants showed hip hiking and circumduction gait patterns during the swing phase. In addition, lack of ankle dorsiflexion with foot inversion was always presented during the initial contact and midswing.

Without consideration of asymmetrical pattern direction appearing in neither the affected nor the un-affected sides, relationships of absolute value of gait symmetrical indexes and clinical measures existed. Interestingly, new findings of the present study express significant relationship between symmetrical index of Y2 and lower extremity motor function and between symmetrical index of Z1 and muscle tone, suggesting that both lower extremity function and muscle tone may play the role for generating reaction force during walking.

In addition, temporo-spatial variables significantly related to muscle tone and lower extremity function, but not to postural balance. To the authors' knowledge, there is little evidence of the study in spatial asymmetry and gait performance. Similar to previous study(5), a weak correlation was found between step length asymmetry and lower extremity function. The present study further found a relationship of symmetrical index of step length and muscle tone in AP at fast speed.

The temporal variables (SST, step time, stance time, and swing time) were found to be related with muscle tone and lower extremity function. Lower limb motor functions have been reported to relate with stance time(21), swing time(21,22) and SST(5) asymmetries. From the current results, moderately strong relationships were found between lower extremity function and symmetrical index of SST step time, stance time and swing time. Therefore, lower extremity function may necessarily limit gait symmetrical characteristic in the aspect of temporal parameter.

The present study revealed that the stroke showed a consistent pattern of asymmetrical gait pattern as indicated by uneven stance and swing times between the affected and un-affected sides. Similar to a previous study(7), all patients with a stroke had less stance time on the affected side than the un-affected side. In addition, they demonstrated a greater swing time on the affected side than the un-affected side. During walking, the affected side is a stance limb while the un-affected is a swing one. Thus, the increased stance time in the affected side is suggested to enhance an increase in swing time in the un-affected side, leading to a decrease asymmetrical stance and swing time.

Significant positive relationship between symmetrical index of stance time and muscle tone, in the KE and AI of the affected side, was shown at either comfortable or fast gait speed. The KE and AI are important muscle groups during the stance phase of the gait cycle(23). Spasticity of the KE impaired movement pattern(24,25). Equinovarus foot placement is often associated with subsequent knee hyperextension during stance(23). Increased KE muscle tone induces knee hyperextension(26) and increased AI muscle tone makes improper foot placement(23), these cause inappropriate knee and foot function for weight bearing during stance phase[23], possibly leading to short stance time in a gait cycle period of the affected side. It was suggested to decrease muscle tone in KE and AI of the affected side in order to assist an increase stance time of the affected side.

The positive association between symmetrical index of swing time and muscle tone in HA, HE, KE, AP, and AI of the affected side was shown at comfortable and fast gait speeds. Individuals with a stroke have been reported to demonstrate difficulty in releasing lower limb extensor muscles[23,27]. Therefore, they show compensatory strategies in walking; for instance, hip hiking and circumduction[28]. This has been reported to relate with increased swing time in the affected side[10]. The present study also found that symmetrical index of swing time was significantly correlated to the affected muscle tone of HA. Increased HA muscle tone results in narrow base of support, causing scissoring gait[29]. In general, HA assists iliopsoas to flex the hip during the initial to mid swing period[30]. Therefore, increased HA muscle tone may result in improper hip flexion function, leading to using compensatory movements for swinging. The present findings suggested the need to reduce affected tone of HA, HE, KE, AP and AI for decreasing swing time in the affected side.

Conclusion

In conclusion, current evidence confirms that patients with stroke walk with different patterns show inefficient asymmetrical pattern with uneven affected and un-affected performance. Consistent asymmetrical gait characteristic can be observed by the stance time and swing time, and suggest it be used in detecting gait recovery. Therefore, to improve gait symmetrical characteristics in patients with stroke, it is suggested to reduce muscle tone and increase their lower extremity function of the affected side. In one gait cycle, it should be noted that patients with a stroke demonstrate decreased stance time but increased swing time of the affected side when compared to the un-affected side. Hence, the intervention effective for improving symmetrical gait characteristics in patients with stroke will be further investigated.

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Potential conflicts of interest

None.

References

1. Lamontagne A, Malouin F, Richards CL. Contribution of passive stiffness to ankle plantarflexor moment during gait after stroke. Arch Phys Med Rehabil 2000; 81: 351-8.
2. De Quervain IA, Simon SR, Leurgans S, Pease WS, McAllister D. Gait pattern in the early recovery period after stroke. J Bone Joint Surg Am 1996; 78: 1506-14.
3. Perry J. Pathological mechanisms. In: Willoughby CD, editor. Gait analysis: normal and pathological function. New York: SLACK; 1992: 171-82.
4. Harris JE, Eng JJ, Marigold DS, Tokuno CD, Louis CL. Relationship of balance and mobility to fall incidence in people with chronic stroke. Phys Ther 2005; 85: 150-8.
5. Hsu AL, Tang PF, Jan MH. Analysis of impairments influencing gait velocity and asymmetry of hemiplegic patients after mild to moderate stroke. Arch Phys Med Rehabil 2003; 84: 1185-93.
6. Balasubramanian CK, Bowden MG, Neptune RR, Kautz SA. Relationship between step length asymmetry and walking performance in subjects with chronic hemiparesis. Arch Phys Med Rehabil 2007; 88: 43-9.
7. Kim CM, Eng JJ. Symmetry in vertical ground reaction force is accompanied by symmetry in temporal but not distance variables of gait in persons with stroke. Gait Posture 2003; 18: 23-8.
8. Hesse S, Reiter F, Jahnke M, Dawson M, Sarkodie-Gyan T, Mauritz KH. Asymmetry of gait initiation in hemiparetic stroke subjects. Arch Phys Med Rehabil 1997; 78: 719-24.
9. Oken O, Yavuzer G. Spatio-temporal and kinematic asymmetry ratio in subgroups of patients with stroke. Eur J Phys Rehabil Med 2008; 44: 127-32.
10. Chen G, Patten C, Kothari DH, Zajac FE. Gait differences between individuals with post-stroke hemiparesis and non-disabled controls at matched speeds. Gait Posture 2005; 22: 51-6.
11. Lin PY, Yang YR, Cheng SJ, Wang RY. The relation between ankle impairments and gait velocity and symmetry in people with stroke. Arch Phys Med Rehabil 2006; 87: 562-8.
12. Bensoussan L, Mesure S, Viton JM, Delarque A. Kinematic and kinetic asymmetries in hemiplegic patients' gait initiation patterns. J Rehabil Med 2006; 38: 287-94.
13. Wall JC, Turnbull GI. Gait asymmetries in residual hemiplegia. Arch Phys Med Rehabil 1986; 67: 550-3.

14. Train the Brain Forum (Thailand). Thai Mental Status Exam (TMSE). Siriraj Hosp Gaz 1993; 45: 359-74.
15. Gregson JM, Leathley M, Moore AP, Sharma AK, Smith TL, Watkins CL. Reliability of the Tone Assessment Scale and the modified Ashworth scale as clinical tools for assessing poststroke spasticity. Arch Phys Med Rehabil 1999; 80: 1013-6.
16. Fugl-Meyer AR, Jaasko L, Leyman I, Olsson S, Steglind S. The post-stroke hemiplegic patient. 1. a method for evaluation of physical performance. Scand J Rehabil Med 1975; 7: 13-31.
17. Smith PS, Hembree JA, Thompson ME. Berg Balance Scale and Functional Reach: determining the best clinical tool for individuals post acute stroke. Clin Rehabil 2004; 18: 811-8.
18. Stevenson TJ. Detecting change in patients with stroke using the Berg Balance Scale. Aust J Physiother 2001; 47: 29-38.
19. Sadeghi H, Allard P, Prince F, Labelle H. Symmetry and limb dominance in able-bodied gait: a review. Gait Posture 2000; 12: 34-45.
20. Portney LG, Watkins MP. Power and sample size. In: Mehalik C, editor. Foundations of clinical research: applications to practice. 2nd ed. New Jersey: Prentice Hall Health; 2000: 705-30.
21. Dawes H, Enzinger C, Johansen-Berg H, Bogdanovic M, Guy C, Collett J, et al. Walking performance and its recovery in chronic stroke in relation to extent of lesion overlap with the descending motor tract. Exp Brain Res 2008; 186: 325-33.
22. Patterson KK, Parafianowicz I, Danells CJ, Closson V, Verrier MC, Staines WR, et al. Gait asymmetry in community-ambulating stroke survivors. Arch Phys Med Rehabil 2008; 89: 304-10.
23. Higginson JS, Zajac FE, Neptune RR, Kautz SA, Burgar CG, Delp SL. Effect of equinus foot placement and intrinsic muscle response on knee extension during stance. Gait Posture 2006; 23: 32-6.
24. Knutsson E, Richards C. Different types of disturbed motor control in gait of hemiparetic patients. Brain 1979; 102: 405-30.
25. Olney SJ, Richards CL. Hemiparetic gait following stroke Part I: characteristics. Gait Posture 1996; 4: 136-48.
26. Yelnik A, Albert T, Bonan I, Laffont I. A clinical guide to assess the role of lower limb extensor overactivity in hemiplegic gait disorders. Stroke 1999; 30: 580-5.
27. Sommerfeld DK, Eek EU, Svensson AK, Holmqvist LW, von Arbin MH. Spasticity after stroke: its occurrence and association with motor impairments and activity limitations. Stroke 2004; 35: 134-9.
28. Kerrigan DC, Frates EP, Rogan S, Riley PO. Hip hiking and circumduction: quantitative definitions. Am J Phys Med Rehabil 2000; 79: 247-52.
29. Giuliani CA. Adult hemiplegic gait. In: Smidt GL, editor. Gait in rehabilitation. New York: Churchill Livingstone; 1990: 253-66.
30. Whittle MW. Normal gait. In: Whittle MW, editor. Gait analysis: an introduction. 4th ed. Edinburgh: Butterworth-Heinemann; 2007: 47-100.

ดัชนีความสมมาตรของการเดิน และความสัมพันธ์ต่อความตึงตัวกล้ามเนื้อการควบคุมการทำงานของขา และการรักษาสมดุลในผู้ป่วยโรคหลอดเลือดสมอง

สุนีย์ บวรสุนทรชัย, วิมลวรรณ เหียงแก้ว, รุ่งทิวา วัจฉละฐิติ, มัณฑนา วงศ์ศิรินวรัตน์

***ภูมิหลัง**: ความผิดปกติที่เกิดขึ้นภายหลังจากเป็นโรคหลอดเลือดสมองส่งผลให้ผู้ป่วยไม่สามารถเคลื่อนไหวได้เหมือนเดิม ลักษณะการเดินที่ผิดปกติไปสังเกตได้จากความเร็วที่ลดลง และความไม่สมมาตรของการเดินที่ควบคุมจากขาสองข้าง การศึกษาถึงความสัมพันธ์ระหว่างตัววัดทางคลินิกต่อคุณลักษณะการเดินต่อจึงมีความสำคัญในการฟื้นฟูผู้ป่วยในทางคลินิก*

***จุดประสงค์**: เพื่อตรวจสอบคุณลักษณะการเดิน และระดับความสัมพันธ์ระหว่างดัชนีความสมมาตรของการเดินและตัววัดทางคลินิกในกลุ่มประชากรผู้ป่วยโรคหลอดเลือดสมอง*

***วัสดุและวิธีการ**: ผู้ป่วยโรคหลอดเลือดสมองจำนวน 30 คน เข้าร่วมในการศึกษานี้ตัววัดทางคลินิก ประกอบด้วยความตึงตัวกล้ามเนื้อด้านที่เป็นอัมพาตของกล้ามเนื้อ กางตะโพก, เหยียดตะโพก, เหยียดเข่า, กระดกข้อเท้าลง, และหมุนข้อเท้าเข้าด้านใน, การควบคุมการทำงานของขา และการรักษาสมดุลดัชนีความสมมาตรของการเดินในตัวแปรทางชีวกลศาสตร์ ประกอบด้วย แรงสูงสุดในการชะลอตัว และส่งตัวแรงสูงสุดในแนวดิ่งอันแรก และอันที่สอง, ระยะก้าว, เวลาที่เท้าสองข้างสัมผัสพื้น, เวลาก้าว และเวลาที่ใช้ในการยืนและก้าวในหนึ่งวงจรการเดิน*

***ผลการศึกษา**: ดัชนีความสมมาตรการเดินของแรงมีความสัมพันธ์อย่างมีนัยสำคัญทางสถิติกับความตึงตัวของกล้ามเนื้อ และการควบคุมการทำงานของขา นอกจากนี้ยังพบความสัมพันธ์อย่างมีนัยสำคัญทางสถิติระหว่างตัวแปรด้านเวลาและระยะทางของการเดินต่อความตึงตัวของกล้ามเนื้อ และการควบคุมการทำงานของขา แต่ไม่พบความสัมพันธ์ต่อการรักษาสมดุล*

***สรุป**: ความตึงตัวของกล้ามเนื้อและการควบคุมการทำงานของขามีความสำคัญต่อประสิทธิภาพในการเดิน ดังเห็นได้จากความสัมพันธ์กับความสมมาตรของการเดินในผู้ป่วยโรคหลอดเลือดสมอง*