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KINEMATIC GAIT ANALYSIS IN HEMIPLEGIC PATIENTS

Neşe Özgirgin, Nesrin Bölükbaşi, Mehmet Beyazova and Sevim Orkun

From the Department of Physical Medicine and Rehabilitation, Gazi University, Medical Faculty, and Ankara Rehabilitation Centre, Ankara, Turkey

ABSTRACT. Temporal-distance variables of gait were investigated in 8 female and 23 male hemiplegic patients in order to assess the distribution of these variables according to functional ambulation category and to evaluate their validity. Video-recording technique was used for obtaining the temporal-distance values. Velocity, step-time, stride length and stride length in relation to lower extremity length proved to be valuable measures in the gait analysis, while cadence, step-time and step-time differential values seemed to be less important.

Key words: hemiplegia, gait, quantitative gait analysis.

Impairment in the ability to walk is one of the main functional problems in hemiplegic patients. The evaluation of hemiplegic gait is usually based upon subjective criteria, from the aspects of "what is abnormal" and "how much improvement has been gained" (11). As lack of standardization in the visual gait analysis methods may give uncertain results, kinetic and kinematic gait analysis methods have been developed. Kinetic analysis assesses the relationship between velocity and acceleration while kinematic analysis involves the angular evaluation of movements and temporal-distance (TD) measurements of gait (6). Holden & Brandstater have investigated in detail TD parameters in hemiplegic patients (3, 10, 11).

This study aimed to evaluate the TD parameters in hemiplegic patients and to define the distribution of these parameters according to functional ambulation category, and to investigate the relationships between the parameters in order to assess the validity and feasibility of each of them.

MATERIALS AND METHODS

Thirty-one hemiplegic patients, 8 females and 23 males, without any underlying physical reasons likely to interfere with ambulation were included in the study. Etiologic factors, determined by computerized tomography, were intracerebral haemorrhage in 9, cerebral infarction in 21, and intracerebral tumor in one patient. Patients were selected according to their ability to walk on level surfaces for at least 10 m with or without assistance. Use of ambulation aids was allowed while no type of orthoses was permitted.

Age, sex, duration and etiologic factors of disease, as well as hemiplegic side were recorded. Lower extremity motor functions were evaluated according to the Brunnstrom Functional Recovery Assessment (9). Lower extremity length was measured in the supine position between trochanter major and heels, bilaterally. Ambulatory assessments were made according to the Functional Ambulation Category (FAC) (10, 11). A walking platform 50 cm wide and 10 m long was drawn and a metric and centimetric scale was marked on it. The ambulation of the patients was recorded by video camera using both close and distant recording techniques in frontal and lateral planes. The video records were used for kinematic gait assessment. The steps in the first and last two meters of the walking platform were excluded during analysis so as not to destroy the stereotypical cadence of the gait. Steps in the middle 6 m of the platform were analyzed for temporal distance parameters using frame to frame and slow motion technique and also by chronometrical measurements. Velocity (m/s), cadence (number of steps/min), mean step length (for both extremities), mean stride length, mean stride length/lower extremity length (SL/LEL), mean step time for both extremities (mean step length/velocity) and mean step time differential were calculated.

RESULTS

Clinical features of the patients according to Functional Ambulation Category are presented in Table I. Temporal-distance measures according to Functional Ambulation Category are given in Table II. The patients were divided into two groups, the first consisting of FAC 1–3, and the second of FAC 4–5, in order to compare the mean values of temporal-distance measures between "fair" and "good" ambulants. Student's *t*-test was used for statistical evaluation. Results are shown in Table II.

Fig. 1 briefly demonstrates the overall evaluation of TD values for fair and good ambulants.

Correlation analysis was performed between velocity and the other TD variables in order to assess their validity with reference to velocity (Table III).

Table I. *Patient characteristics according to functional ambulation category*

	Functional Ambulation Category		
	1–3	4–5	TOTAL
Patients (n)	12	19	31
Age, yr, mean	55.4	48·7	51.2
Sex			
Male	8	15	23
Female	4	4	8
Months, poststroke	9.5	15.7	13.6
Lesion (cerebral)			
Infarction	7	13	20
Hemorrhage	4	6	10
Tumor	1	0	1
Side of paralysis			
Right	5	10	15
Left	7	9	16
*Stage of motor recovery**			
III	3	0	3
IV	9	4	13
V	0	10	10
VI	0	5	5

* According to Brunnstrom (8).

DISCUSSION

Temporal-distance measurement is a clinically feasible and quantitative approach for kinematic gait analysis (1–4, 6, 7, 10, 11, 15). However, objective and quantitative attainment of these values requires sophisticated techniques. Although time-consuming, the video recording system and evaluation by frame to frame and slow-motion techniques used in this study provide reliable and accurate data. Studies dealing with TD variables usually utilize derived values of step and stride length by dividing distance by total number of steps, whereas in this study every step length was meticulously measured by frame freezing, thus providing more reliable TD values. Statistical methods were utilized to select the most appropriate variables that can be used in a simpler but effective kinematic gait analysis.

Table II. *Statistical comparison of TD values between good and fair ambulators (Student's t-test)*

	All patients	FAC fair	FAC good	*p*
Step length (cm)				
Affected side	35.7	28.04	40.61	<0.001
Unaffected side	30.8	21.42	36.86	<0.01
Stride length (cm)	66.8	49.62	77.7	<0.001
Velocity (m/s)	0.42	0.29	0.49	<0.005
Cadence (steps/min)	79.6	80.75	78.91	>0.05
*SL: LEL ratio**	0.77	0.57	0.89	<0.005
Step time (s)				
Affected side	0.91	0.98	0.87	>0.05
Unaffected side	0.77	0.79	0.76	<0.05
Step time differential	0.29	0.39	0.22	<0.05

* Stride length/lower extremity length.

Velocity

That velocity is the best parameter reflecting the ambulatory performance among TD variables is a widely accepted fact (1–4, 6, 7, 10, 11, 15). Hemiplegic gait is fairly slow, to protect the paretic lower extremity, which consequently affects all other temporal distance variables of gait. Healthy people can reduce cadence and increase stride length and vice versa, and can walk with a constant velocity, but this is not the case with hemiplegics, since the velocities these patients choose require in general low energy in relation to their abilities and they do not have the ability to increase their velocity without excessively increasing the energy demand (11). The optimal velocity range in healthy people is known to be 1.2–1.5 m/s. A number of studies investigating gait velocity in hemiplegic patients have been carried out. Table IV shows the values obtained so far (1, 3, 5, 7, 8, 10, 12–16). In this study, overall mean velocity was found to be 0.42 m/s, where fair ambulants (FAC 1–3) display a velocity of 0.29 m/s and good ambulants (FAC 4–5) 0.49 m/s. Statistical evaluation yields a significant increase in velocity in favour of good ambulants ($p < 0.005$), which confirms that this variable is actually a valuable indicator of ambulation performance.

Cadence

Healthy people walk with a cadence of 100–120 steps/min. Cadence studied in hemiplegic patients has been found to be between 32.1–85.3 steps/min (3, 10, 11, 15). The mean cadence for all patients in this study was 79.6 steps/min, which was 80.75 and 78.92 in FAC 1–3 and FAC 4–5, respectively. No significant difference was observed between the two groups ($p > 0.05$). No correlation existed between velocity and cadence, either. Consequently, it can be concluded that cadence

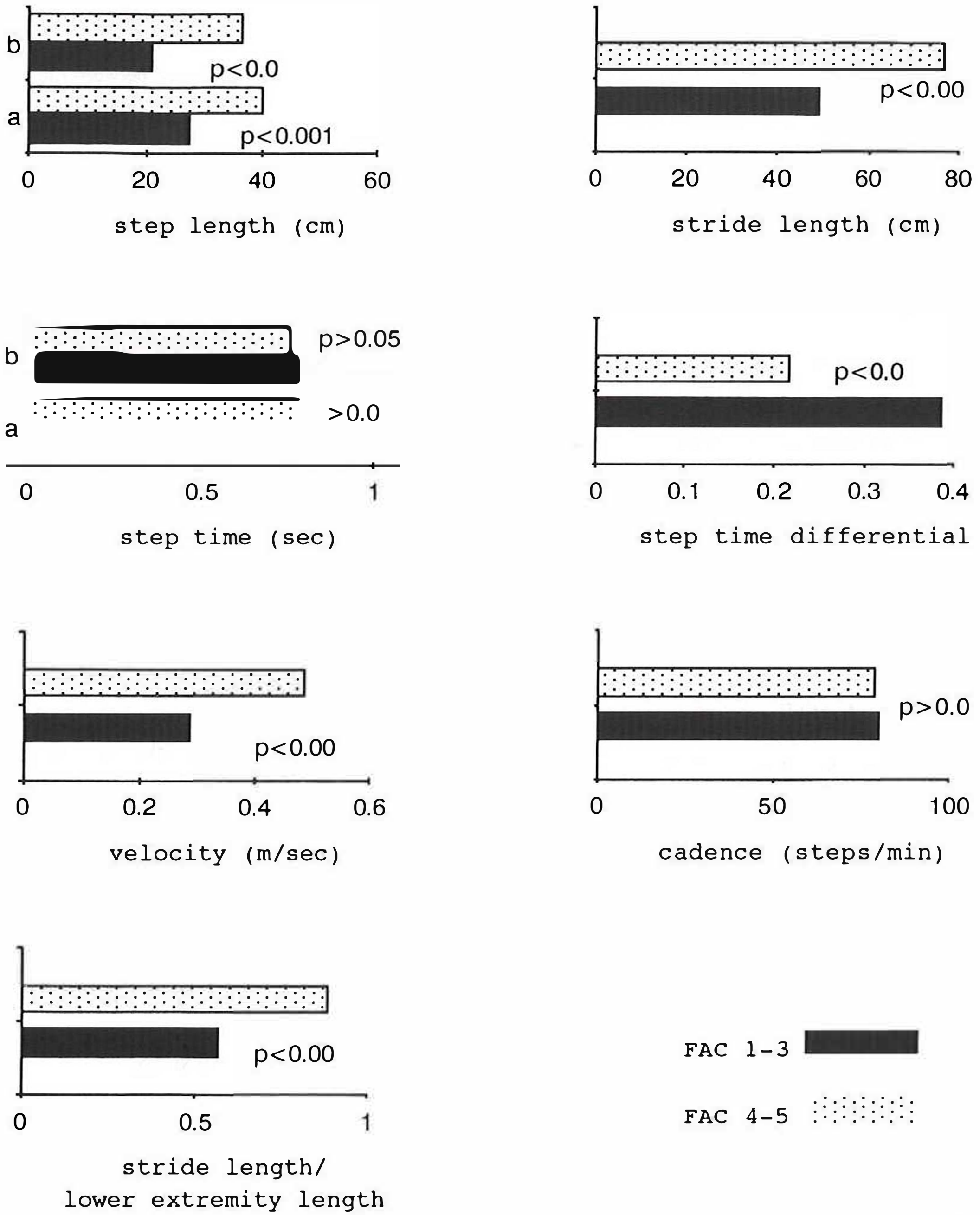

Fig. 1. Mean values of temporal-distance measurements in hemiplegic subjects grouped according to FAC (Functional Ambulation Category). *a* = affected side. *b* = unaffected side.

is a dispensible variable in evaluating ambulatory performance in hemiplegic patients.

Step length (affected and unaffected sides)

Hemiplegic gait is asymmetric, which leads to the need for measuring step length bilaterally. As mentioned above, we measured every step one by one and calculated mean step length value for each lower extremity (Table II). The values of step lengths for both affected and unaffected sides were found to be significantly higher ($p < 0.001$, $p < 0.01$). Step lengths

Table III. *Correlation between velocity and other TD values*

	r	p
Step length		
Affected side	0.802	<0.001
Unaffected side	0.707	<0.001
Stride length	0.823	<0.001
Cadence	0.18	>0.05
SL/LEL	0.839	<0.001
Step time		
Affected side	−0.507	<0.01
Unaffected side	−0.096	>0.05
Step time differential	−0.470	<0.01

of both lower extremities also correlated with velocity (r = 0.802, $p < 0.001$, r = 0.707, $p < 0.001$).

Stride length

This value has been reported to be in a range of 45–95 cm by Holden (10), 60 cm by Brandstater (3), 97 cm by Knutsson (12) and 47 cm by Ak (1). Our mean value is 66.8 cm. Statistical comparison of this variable between fair and good ambulators yields again a highly significant difference ($P < 0.001$). Correlation between velocity and stride length has been observed as well (Table III).

Stride length/lower extremity length

Holden has suggested that this variable demonstrates whether a subject is taking a stride length appropriate for his height and that the optimum ratio should be around 1.5 for normals (10. 11). A literature survey yields a range of 0.5–1.03 for hemiplegic patients (10, 11). This study yielded a ratio of 0.77. A significant statistical difference was observed between the groups of fair and good ambulants ($p < 0.005$). These ratios displayed a significant correlation with velocity (r = 0.839, $p < 0.001$).

Table IV. *Reported velocity values for hemiplegic patients*

Author	Velocity (m/s)
Mizzrahi (13)	0.25
Wall and Ashburn (16)	0.40
Brandstater (3)	0.31
Holden (10)	0.64
Knutsson and Richards (12)	0.62
Norton (14)	0.90
Corconan (5)	0.75
Roth (15)	0.43
Dettmann (7)	0.47
Ak (1)	0.25
Diamond (8)	0.83
Özgirgin	0.42

Step time (affected and unaffected sides)

These variables were not significantly different in the two groups according to FAC. Step time of the affected side correlated significantly with velocity, while this was not the case with the unaffected side. The time consumed in a paretic extremity is probably due mostly to circumduction which is decreased by the improvement in gait.

Step time differential

This variable should be equal to zero in a symmetric gait pattern (10, 11). Our findings reveal a significant difference in step time differential between the two groups ($p < 0.05$). A moderately negative correlation was attained between velocity and step time differential. This variable is a derived one obtained from step time for both lower extremities, therefore we suppose that it is not strictly necessary in a simple kinematic analysis involving TD parameters of gait.

In conclusion, to shorten the time necessary for TD gait evaluation, we believe that velocity, step and stride lengths, and stride length/lower extremity length are appropriate whereas cadence, step time and step time differential values contribute less to kinematic analysis of gait.

REFERENCES

1. Ak, A. N., Kutsal, Y. G. & Altıoklar, K.: Hemiplejik hastalarda yürüyüşün klinik olarak değerlendirmesi. Numune Hastanesi Tıp Dergisi, *304:* 57–66, 1990.
2. Bogataj, U., Gros, N., Malezic, M., Kelih, B., Kljajic, M. & Acimovic, R.: Restoration of gait during two to three weeks of therapy with multichannel electrical stimulation. Phys Ther *69:* 319–327, 1989.
3. Brandstater, M. E., Bruin, H., Gowland, C. & Clark, B. M.: Hemiplegic gait: Analysis of temporal variables. Arch Phys Med Rehabil *64:* 583–587, 1983.
4. Collen, F. M., Wade, D. T. & Bradshaw, C. M.: Mobility after stroke: reliability of measures of impairment and disability. Int Disabil Studies *12:* 6–9, 1990.
5. Corcoran, P. J. & Brengelmann, G. L.: Oxygen uptake in normal and handicapped subjects, in relation to speed of walking beside velocity-controlled cart. Arch Phys Med Rehabil *51:* 78–87, 1970.

6. Craik, R. L. & Oatis, C. A.: Gait assessment in the clinic. In: Measurement in Physical Therapy, Churchill Livingstone, New York, 1985, 169–206.
7. Dettmann, M. A., Linder, M. T. & Sepic, S. B.: Relationships among walking performance, postural stability and functional assessments of the hemiplegic patients. Am J Phys Med *66:* 77–90, 1987.
8. Diamond, M. F. & Ottenbacher, K. J.: Effect of a tone inhibiting dynamic ankle-foot orthosis on stride characteristics of an adult with hemiparesis. Phys Ther *70:* 423–430, 1990.
9. Hislop, J. H.: Movement therapy in hemiplegia: A neurophysiological approach (ed. Brunnstrom S.) Harper Row Publishers, New York, 1970.
10. Holden, M. K., Gill, K. M., Magliozzi, M. R., Nathan, J. & Piehl-Baker, L.: Clinical gait assessment in the neurologically impaired. Reliability and meaningfulness. Phys Ther *64:* 35–40, 1984.
11. Holden, M. K., Gill, K. M. & Magliozzi, M. R.: Gait assessment for neurologically impaired patients. Phys Ther *66:* 1530–1539, 1986.
12. Knutsson, E. & Richards, C.: Different types of disturbed motor control in gait of hemiparetic patients. Brain *102:* 405–430, 1979.
13. Mizrahi, J., Suzan, Z. & Heller, L., et al: Variation on time-distance parameters of the stride as related to clinical gait improvements in hemiplegics. Scand J Rehabil Med *14*: 133–140, 1982.
14. Norton, B. J., Bomze, H. A. & Sahrman, S. A.: Correlation between gait speed and spasticity at the knee. Phys Ther *55:* 355–359, 1975.
15. Roth, E. J., Merbitz, C. T., Grip, J. C., Bogolup, M., Mroczek, K., Dugan, S. & Donadio, K.: The time logger communicator gait monitor: recording temporal gait parameters using a portable computerized device. Int Disabil Studies *12:* 10–16, 1990.
16. Wall, J. C. & Ashburn A.: Assessment of gait disability in hemiplegics. Scand J Rehabil Med *11:* 95–103, 1979.

Address for offprints:

Nesrin Bölükbaşi, MD
Refik Belendir Sok.
63/14 06540
Yukarı Ayrancı Ankara
Türkiye