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ORIGINAL REPORT

GAIT IN HEMIPLEGIA: EVALUATION OF CLINICAL FEATURES WITH THE WISCONSIN GAIT SCALE

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Objective: **To assess the ability of the Wisconsin Gait Scale to evaluate qualitative features of changes in hemiplegic gait in post-stroke patients.**
Design: **A prospective observational study.**
Subjects: **Ten healthy subjects and 56 hemiplegic outpatients, more than 12 months post-stroke, consecutively admitted in a rehabilitation centre.**
Methods: **Patients were videotaped while walking at a comfortable speed. Quantitative and clinical gait parameters were derived from videotaped walking tasks at admission and at the end of a period of rehabilitation training. Qualitative features were assessed using the Wisconsin Gait Scale. Functional status was rated through the modified Barthel Index.**
Results: **After training, the median Wisconsin Gait Scale score improved significantly (28 vs 26.5; $p = 0.003$). In particular, "weight shift to paretic side" and patterns during the swing phase of the affected leg were improved. Gait velocity (0.3 vs 0.4 m/sec; $p = 0.001$) and stride length (77 vs 85 cm; $p = 0.0002$) increased significantly, whereas number of steps (25 vs 23; $p = 0.004$), stride period (2.5 vs 2.3 sec; $p = 0.04$), and stance period (2.1 vs 2 sec; $p = 0.03$) of the unaffected side were reduced. The Barthel Index score increased (71 vs 78; $p = 0.005$).**
Conclusion: **The Wisconsin Gait Scale is a useful tool to rate qualitative gait alterations of post-stroke hemiplegic subjects and to assess changes over time during rehabilitation training. It may be used when a targeted and standardized characterization of hemiplegic gait is needed for tailoring rehabilitation and monitoring results.**

Key words: hemiplegia, stroke, gait, rehabilitation, qualitative gait analysis, outcome.

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INTRODUCTION

Cerebral vascular disease is a leading cause of gait impairment, resulting in long-term disability and handicap (1, 2). Walking recovery is a priority goal for most patients, since it widely determines patient's status with respect to activities of daily living and quality of life (3).

The gait of hemispheric stroke patients is characterized by several abnormal features (4, 5) such as asymmetry of stride time and length, reduced velocity, poor joint and posture control, muscle weakness, abnormal muscle tone, abnormal muscle activation patterns and altered energy expenditure, mostly affecting the paretic side (6–8). Several studies have investigated temporal and distance parameters of gait following stroke (1–13), but only a few are focused on clinical characterization of gait pattern. A detailed description of hemiplegic gait has been reported by Perry (14). Later, Rodriquez et al. (15) assessed efficacy of post-acute gait training program in hemiplegic patients, analysing both temporal and qualitative variables. For the visual quantification of hemiplegic gait quality the authors developed the Wisconsin Gait Scale (WGS), which was designed to identify hemiplegic gait deviations by examining weight-bearing joints and weight shift at each phase of gait. Hip, knee and ankle kinematics, inter-limb movement symmetry, balance/guardedness, assistive device use and selected gait parameters are examined and quantified. WGS proved to have high intra-rater and inter-rater reliability when administered by physiatrists with neuro-rehabilitative expertise (16, 17). Recently, Turani et al. (18) studied WGS testing in 35 patients from 2 to 40 weeks post-stroke, concluding that this visual scale is valuable for assessing gait deviations and monitoring gait performance gains in patients with hemiparesis. The WGS is a relatively new and unknown instrument, which is worth considering for clinical use.

The aim of this study was to evaluate the usefulness of WGS in monitoring changes in gait features in patients with hemiplegia and to verify its possible use in rehabilitation departments. Using videotaping, we evaluated patients before and after a 4-week physiotherapy training analysing WGS and gait temporal parameters. In addition, for exploring whether gait quality is related to functional improvement, the functional impact of gait modifications was assessed through the modified Barthel Index (BI) (19–22) and, more specifically, through its walking sub-score (9).

METHODS

Outpatients with hemiplegia following first stroke, consecutively admitted to a neuro-rehabilitation centre over a period of 15 months, were

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enrolled according to the following inclusion criteria: (*i*) supratentorial cerebral lesion, either ischaemia or intra-cerebral haemorrhage, assessed by computerized tomography or magnetic resonance imaging scans; (*ii*) stroke occurred at least 12 months previously; (*iii*) ability to walk 10 metres independently with or without a walking device; (*iv*) no neurological and/or orthopaedic co-morbidities impairing ambulation; (*v*) cognitive ability to understand training procedures and to follow the study instructions. All subjects signed an informed consent form, approved by the institutional ethics committee.

Gait trials were performed in a 20-metre wide laboratory, on a 50-cm wide and 10-metre long walking platform. A performance area was formed on the walking by positioning 2 marks, 2 m apart, in the same plane. Patients' gait was recorded by 2 VHS video-cameras (Panasonic Digital Video-camera DS35), using either close or distant recording techniques in both frontal and lateral planes. One video-camera was positioned in the frontal plane, 4 m from one end of the walking platform. The other was fixed on a trolley following the patient laterally, along his walking direction, at a constant distance approximately 2.5 m away from the patient. In the lateral plane, affected and non-affected sides were recorded.

Each patient was asked to walk 4 times along the platform, at a comfortable speed: twice while wearing their usual shoes and twice without. The use of orthoses or shoe insertions was not allowed; a cane was utilized necessary. Patients had a 5-minute rest between each trial.

Video-recordings were used for cinematic gait assessment. In order to consider gait stereotypical cadence, only steps in the middle 6 m of the platform were analysed for temporal and distance parameters. Select temporal-distance measures were obtained by manual calculations from the video-recordings, using frame to frame, slow motion techniques and chronometric measurements (23). The number of steps required to walk the 6-metre performance area, between the 2 marks, was calculated. Mean values of velocity (m/sec), cadence (number of steps/min), stride length (cm), stride period (sec), stance period and swing period of affected and unaffected sides (sec) were calculated, as well as stance/swing ratio and double support, as a percentage of total stride period. The symmetry ratio of stance and swing period was also calculated.

To provide baseline data for comparison with patients' results, 10 age-matched volunteer healthy subjects, 5 men and 5 women, were also assessed using the study protocol. They were recruited after a clinical examination that had excluded orthopaedic and neurological pathologies. Data from these subjects were compared with results published by other researchers (1, 9, 10) to determine the validity of our measurement technique.

To assess gait deviations and to monitor possible gait pattern modifications, WGS original testing (15) was used. It consists of 14 observable variables that measure clinically relevant components of gait. The variables assess the pattern of body movements in each gait phase.

The items of the scale are grouped in 4 phases: stance phase, toe-off, swing phase, and heel strike of the affected leg. Each item is scored from 1 (normal) to 3 (pathological), except for the first item (use of a hand-held gait aid) which is scored from 1 to 5, and for the 11th item (knee flexion from toe-off to mid-swing) scored from 1 to 4. The parameters are scored in comparison to the unaffected side or to gait parameters in healthy subjects. The best possible WGS total score is 14, and the worst possible is 45.

For WGS, only walking data without shoes were analysed because this was thought to be more clinically informative.

Patients were assessed before and after a 4-week standardized rehabilitation training. They received 60 min of physiotherapy daily, based on Bobath assumptions (24), 5 times a week. Training was individualized, with the goal of normalizing movement patterns and minimizing compensatory strategies (15). Intervention was designed to improve symmetry and inter-limb coordination during walking. Training emphasized normalization of lower extremity passive range of motion, balance skills in transitional movements, weight shift to the involved limb and progressive reduction in support from the uninvolved limb (15).

Videotaped gait trials were viewed blindly for pre-/post-training recording and assessed by one physiatrist with neuro-rehabilitative expertise, trained in WGS use.

The patients' functional level of independence was assessed by a neurologist through the modified BI. The BI was used to indicate the level of disability. It measures mobility and self-care on an ordinal scale from 0 to 100 (19) and is considered reliable, valid and sensitive (22).

The walking sub-score of the modified BI was used to rate walking performance according to a 3-point scale: walking with moderate help, with minimal help and independently (9).

Descriptive statistics for quantitative parameters, BI total score and its walking sub-score were calculated before and after physiotherapy. For WGS we computed medians and quartiles for both total score and the 14 sub-scores.

To compare pre-training and post-training gait assessment, we used non-parametric statistical analysis (Wilcoxon matched-pairs signed-rank test) for gait variables of WGS and an ANOVA for repeated measurements was applied to evaluate differences in quantitative walking parameters. To limit a mass effect due to multiple comparison, *post hoc* testing included a Fisher's Protected Least Significant method for probability values. A value of $p < 0.05$ was considered significant. Analysis was accomplished with the Stat View Statistical Package (SAS Institute, Inc., Cary, NC, USA).

RESULTS

Fifty-six patients following stroke, 37 men and 19 women, ranging in age from 42 to 87 years (mean age 68 (SD 10) years) were included in the study. The cerebral lesion was ischaemic in 44 patients and haemorrhagic in 12; it was localized in the left hemisphere in 23 patients; it was cortical in 23 patients and sub-cortical in 33. The mean time elapsed from stroke was 37 months (range 12–240). Thirteen patients used a walking aid.

Gait parameters' mean values, with and without shoes, before and after physiotherapy, are shown in Table I. Eighty-four percent of patients had an asymmetrical gait, with less time spent on the affected limb than on the unaffected limb during the single-limb support phase. Only 16% of patients were asymmetrical in the opposite direction.

In the pre-training, when patients walked with shoes, velocity, cadence and stride length were significantly greater, 13.5%, 7.2% and 6.4%, respectively, than without shoes ($p < 0.0001$). In the post-training, similar differences were revealed: velocity, cadence and stride length were greater by 14.6%, 8.2% and 5.7%, respectively ($p < 0.001$). The number of steps was significantly higher without than with shoes (before training + 10.6%, $p < 0.0005$; after training +10.7%, $p < 0.005$).

Time required to video-record patients was about 20–25 min and time to analyse video-tapes using WGS was about 15–20 min per patient.

The medians and interquartile ranges for WGS parameters and the variables for which statistically significant differences were noted are shown in Table II. At baseline all the WGS items were impaired: the most relevant alterations of gait patterns were a decreased weight shift to the affected side, hip hiking

Table I. *Gait parameters' mean values (standard deviations), before and after rehabilitation training*

	Patients with hemiplegia				
	With shoes (n = 56)		Without shoes (n = 56)		Healthy subjects
	Pre-training	Post-training	Pre-training	Post-training	(n = 10)
Velocity (m/sec)	0.3 (0.2)	0.4 (0.2)**	0.3 (0.2)	0.3 (0.2) ***	1.1 (0.2)
Step (n)	22.8 (7.5)	21.0 (7.5)***	25.6 (4.8)	23.6 (11.1)**	11.3 (0.2)
Cadence (steps/min)	53.9 (19.9)	53.5 (19.7)	50.0 (21.9)	49.1 (22.3)	90.0 (15)
Stride length (cm)	77.8 (25.7)	85.3 (28.8)**	72.8 (27.4)	80.4 (31)***	141.3 (29)
Stride period (sec)	2.5 (1)	2.3 (1) *	2.5 (1.1)	2.4 (1.1)	1.2 (0.2)
Stance period (sec)					
Affected side	1.9 (0.9)	1.8 (0.9)	1.9 (1)	1.8 (1)	0.8 (0.1)
Unaffected side	2.1 (1)	2.0 (1)*	2.1 (1.1)	2.0 (1.1)	0.8 (0.1)
Swing period (sec)					
Affected side	0.5 (0.2)	0.5 (0.1)	0.5 (0.2)	0.5 (0.1)	0.4 (0.1)
Unaffected side	0.3 (0.1)	0.3 (0.1)	0.3 (0.1)	0.3 (0.1)	0.4 (0.1)
Stance/swing ratio					
Affected side	3.7 (2.08)	3.6 (1.7)	3.6 (2.3)	3.7 (2.9)	20.6 (0.2)
Unaffected side	5.9 (3.2)	5.7 (3.1)	6.4 (3.5)	6.2 (3.9)	20.6 (0.2)
Double support (% stride)	59.0 (12.8)	58.8 (14.6)	58.2 (14.2)	56.8 (16)	34.8 (3)
Stance symmetry, ratio (affected/unaffected)	0.9 (0.1)	0.9 (0.1)	0.9 (0.1)	0.9 (0.1)	0.9 (0)
Swing symmetry, ratio (unaffected/affected)	0.7 (0.2)	0.7 (0.2)	0.6 (0.2)	0.6 (0.2)	1.0 (0)

Significant differences between pre-training and post-training scores (p derived from ANOVA test) *$p \le 0.5$; **$p \le 0.001$; *** $p \le 0.005$.
In healthy subjects, temporal parameters did not show differences with and without shoes.

at mid-swing during swing phase of the affected leg (pelvis is elevated during swing phase), a reduction in knee flexion from toe-off to mid-swing, a reduction in anterior pelvic rotation to help stance phase at terminal swing (posture is erect with pelvis in neutral rotation) and the initial foot contact with flat foot (foot lands with weight distributed over entire foot).

Median WGS total score significantly improved after physiotherapy (28 vs 26.5; $p < 0.005$). Improvement was higher in the swing parameters than in the stance parameters for the involved leg.

Table II. *Wisconsin Gait Scale results as median and interquartile range (IQR)*

	Pre-training		Post-training		
Gait variable	Median	IQR	Median	IQR	p
Stance phase affected leg					
Use of gait aid	2	2	2	1	ns
Stance time impaired side	2	1	2	1	ns
Step length unaffected side	2	1	2	1	ns
Weight shift to paretic side	2	1	2	0	0.005
Stance width	1	1	1	1	ns
Toe-off affected leg					
Guardedness	2	1	2	1	0.01
Hip extension	2	0	2	0.5	ns
Swing phase affected leg					
External rotation involved	2	1	2	1	0.01
Circumduction	2	0	2	1	0.005
Hip hiking	2	1	2	0	0.03
Knee flexion swing	2	1	2	1	0.01
Toe clearance	1	1	1	1	ns
Pelvic rotation	2	1	2	1	ns
Heel strike affected leg	2	0	2	0	ns
Total score	28	10	26.5	9	0.003

ns: not significant; IQR: interquartile range.
p derived from Wilcoxon test.

The mean total modified BI was 71.7 (SD 20). According to the walking sub-score of BI, 16 patients (28%) walked with moderate help, 29 patients (52%) walked with minimal help and 11 patients (20%) walked independently.

After physiotherapy, the total modified BI was significantly increased overall (71.7 (SD 20) pre-training vs 78.4 (SD 16) post-training; $p < 0.005$), whereas walking sub-scores did not change significantly (moderate help 23%; minimal help 54% and independently 23%).

DISCUSSION

A healthy subjects' gait is characterized by symmetry of temporal variables and by a higher walking velocity than that of patients with motor impairment. Walking data for the healthy subjects in our study are in accordance with reports in the literature (1, 9, 10), supporting our methodology overall.

The gait of patients with hemiplegia is characterized by asymmetry of timing in the single-limb support phase on the affected and unaffected limbs (10, 11, 25, 26). In the study sample, gait was characterized by low values for velocity (0.3 vs 1 m/sec), cadence (53 vs 90 steps/min) and stride length (79 vs 141 cm), which is in agreement with other studies (1–3, 10). The majority of patients had an asymmetrical gait and all the WGS items were impaired. Gait asymmetry involved particularly swing period and correlated variables, in agreement with other authors (12, 27). The swing period of the affected limb was increased, with a corresponding reduction in the unaffected limb. Reduction in weight shift to the affected side, revealed by WGS, was associated with an increase in stance period on the unaffected side. In the frontal plane, the patient was inclined away from the affected side, which is opposite to what is frequently observed in the antalgic gait. The period of double support was higher than in healthy subjects.

Higher velocity, cadence and stride length have been found in walking trials with shoes. This difference is probably related to the shoe's action of foot support during the swing period, with a reduction in foot drop or "steppage" and in foot supination control, with improved ankle and knee control.

The aim of a gait rehabilitation program in patients with stroke is generally to improve gait symmetry and velocity, since these 2 factors influence patients' chances of returning to their premorbid environments (2). In addition, a gait training program should correct some features such as reduced knee flexion of the affected leg during swing phase, reduced pelvic rotation at terminal swing and circumduction. These impaired patterns may depend on various pathological factors, such as abnormalities in motor control, motor impairment (28), presence of compensatory strategies and/or spasticity. Correcting these gait patterns may bring about an improvement in temporal parameters and may influence patients' perceptive and social status. For this reason, it would be useful to have a scale able to quantify gait qualitative patterns and to monitor changes in gait features during rehabilitative programs such as the WGS.

In the study sample, median WGS total score improved significantly after physiotherapy. All the WGS parameters improved, except for stance width. The main changes were a reduction in external rotation during the initial swing, a reduction in circumduction and in hip hiking at mid-swing, and an increase in knee flexion from toe off to mid swing, with consequent increase in weight shift to the affected side. All these factors may contribute to a greater gait velocity by means of increasing stride length. The limited ability of weight transferred to the affected leg results in a shorter stride length of the unaffected leg. A better stabilization of the affected hip through eccentric contraction of flexors in the mid-stance phase of the gait cycle allows the unaffected lower extremity to make a longer step, contributing to greater stride length of both extremities, which, in turn, increases gait velocity.

Improvement in gait parameters was associated with a statistically significant improvement in patients' functional level, supported by a modified BI score. The changes rated by WGS and temporal parameters were not detected by BI walking sub-score, which is too gross a scale for walking assessment because it does not measure quality of movement or allow for assessment of grades of improvement (15, 19). The WGS testing, instead, assesses the characteristics of hemiplegic gait deviations in detail.

As reported previously (18), WGS testing is a valuable scale, able to assess gait deviations in detail. It also appears to be a useful tool for better planning of single rehabilitation programs and for monitoring gains in gait performance. There is no doubt that computerized systems provide more reliable numerical data on gait temporal parameters. However, such systems are not easily available to all rehabilitation clinics and do not give details about patient's walk quality and how the body moves during the different phases of the gait cycle.

A possible limitation of this study is the ordinal nature of the WGS scale, which offers a form of quantitative information useful in scientific studies, but may be limited by low sensitivity to slight variations. It may present a cluster effect, in which most subjects tend to be grouped in the intermediate degrees of the scale. Nevertheless, the WGS, in comparison with the quantitative evaluation, was able to reveal a larger number of gait parameters that improved significantly. The data from this study suggest that, in addition to quantitative parameters such as gait velocity, gait quality should be also analysed. WGS, in addition, is able to do a more accurate qualitative evaluation than Barthel walking sub-score, which is too coarse for walking assessment. As the WGS gives a quantification of hemiplegic gait quality, it is sensitive in monitoring all the possible gait pattern modifications.

It is noticeable that methods used in this study to assess quantitative and qualitative walking variables proved to be effective and reliable, while they needed relatively simple, low-cost equipment (one video-camera and a video-recorder) available to any rehabilitation clinic and an acceptable amount of time of analysis.

As the WGS is a relatively new instrument for clinical use, further investigation is required to establish the real usefulness of this scale to monitor changes in gait features in rehabilitation clinics.

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