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Original research article

Analysis of consistency between temporospatial gait parameters and gait assessment with the use of Wisconsin Gait Scale in post-stroke patients

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ABSTRACT

Introduction: Due to the increasing incidence and social effects of stroke there is a growing interest in finding methods enabling gait analysis in this group of patients. Observational techniques are predominantly applied in clinical practice; on the other hand advanced quantitative methods allow in-depth multidimensional gait assessment. The present study was designed to assess the consistency between temporospatial gait parameters acquired through 3-dimensional gait analysis and the results of gait assessment with the use of observational WGS in post stroke hemiparetic patients.

Material and method: The study was performed in a group of 30 post-stroke patients, over 6 months from the onset of ischaemic stroke, who were able to walk unassisted. Gait assessment based on WGS was performed by an experienced physiotherapist, with the use of video recordings. Assessment of temporospatial parameters was based on gait analysis performed with BTS Smart system.

Results: The findings show moderate correlation between WGS based gait assessment and gait velocity ($r = -0.39$; $p = 0.0316$). Similar relationship was identified between gait cycle duration and score in WGS for both unaffected ($r = -0.36$; $p = 0.0477$) and affected side ($r = -0.37$; $p = 0.0426$). Higher correlation level was demonstrated for stance phase on the unaffected side and gait assessment based on WGS ($r = 0.58$; $p = 0.0009$).

Conclusions: Gait assessments with the use of temporospatial parameters and with observational WGS were found to produce moderate and good consistent results. WSG is a useful, simple tool for assessing gait in post stroke hemiparetic patients.

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1. Introduction

Current epidemiological data show that annually 16.9 million people throughout the world are affected by stroke. Between 1990 and 2010 the number of stroke survivors nearly doubled and currently has reached 33 million. According to epidemiological forecasts by 2030 the number will increase to 77 million, which is particularly important given the fact that each year a considerable number of stroke survivors are left with permanent impairments, including locomotor disabilities. Due to the increasing incidence and social effects of stroke there is a growing interest in finding methods enabling gait analysis in this group of patients. Gait assessment performed at the early and at the chronic stage after stroke onset is a sensitive measure of progress in treatment, makes it possible to accurately identify the level of functional capacities and provides ground for determining therapeutic goals [1–3].

A number of methods are used to perform gait assessment in patients after stroke. These include observational techniques, predominantly applied in clinical practice, and objective quantitative methods based on complex systems of instruments. The advanced, computer-aided 3-dimensional gait analysis enables thorough and comprehensive gait assessment based on temporospatial, kinematic, kinetic and electromyographic parameters. Yet, it is rather time consuming, requires costly sophisticated equipment, and due to this it frequently is unattainable. Conversely, methods of observational gait analysis may be applied easily and quickly, hence they are accessible to all members of rehabilitation team. Another advantage related to this group of method is the fact that they do not require large financial investment [4–6].

Advanced quantitative methods of 3-dimensional gait analysis include those based on optoelectronic computing systems comprising infrared radiation emitting cameras which capture motion of passive or active markers attached to selected anatomical points on the patient's body. Data from all the cameras are transferred to the computer which reconstructs the trajectory of the marker movements and calculates the changes in angles between segments of the patient's body. The systems enable simultaneous recording of kinetic parameters. Additionally such systems are equipped with digital cameras recording gait in the frontal and sagittal planes. Apart from temporospatial, kinetic and kinematic gait assessment the systems record bioelectrical activity of muscles and provide a large variety of evidence [7–10]. Such data, however, are frequently too complicated for clinicians to interpret and to link with neurological deficits in patents after stroke. Consequently, methods routinely applied by the community of therapists are based on clinical tests and scales. Some of these, e.g. 10 or 20-metre walk test, assess gait velocity; some assess gait efficiency, e.g. 2, 6, 12-minute walk test, or independent mobility and risk of falling, e.g. Get Up&Go Test. There are also scales assessing deficits in gait pattern; one of these is Wisconsin Gait Scale (WGS). In order to ensure detailed analysis of changes in gait pattern in subjects with post-stroke hemiparesis and to evaluate effects of rehabilitation it is necessary to ensure access to scales with high specificity and accuracy. Numerous authors report that WGS is an efficient scale of observational gait analysis; it is reliable, accurate, easy to use and consequently it is an effective tool to assess progress of patients with post-stroke hemiparesis in gait reeducation [5,6,11–15].

The present study was designed to assess the consistency between temporospatial gait parameters acquired through 3-dimensional gait analysis and the results of gait assessment with the use of observational WGS in post-stroke hemiparetic patients.

2. Material and methods

2.1. *Participants*

The study was performed in a group of 30 patients, at a chronic stage after stroke, over 6 months from the onset of ischaemic stroke. The subjects were recruited among patients receiving treatment at the Clinical Rehabilitation Ward, Province Hospital No. 2 in Rzeszów, Poland. Ischaemic stroke was confirmed by CT and MR examinations. Inclusion criteria: single stroke, ability to walk unassisted. Exclusion criteria: cognitive function deficits impairing the ability to understand and follow instructions (Mini Mental Scale over 24), unstable medical condition, contractures and orthopaedic disorders of lower limbs. All the subjects were informed in detail about the purpose and procedure of the study, before its start, and they agreed in writing to participate. The study protocol was approved by the Bioethics Commission of the Medical Faculty. The group's characteristics are shown in Table 1.

2.2. *Measurements*

The patients' gait was assessed with Wisconsin Gait Scale, and temporospatial gait parameters were examined in Gait Laboratory with the use of BTS Smart system. Markers were distributed in accordance with Davis protocol. During the trial the subjects walked with self-selected speed, and were allowed to use aids such as canes, elbow crutches and tripods. The following were analyzed: gait velocity, step width, cadence, duration of swing phase and duration of stance phase of affected and unaffected limb, gait cycle length, swing velocity and gait cycle velocity. 3D gait recording was performed simultaneously with two video cameras distributed in such a way as to obtain images recorded in both frontal plane and sagittal plane. The video camera filming the view of the frontal plane was located in the middle of the delineated distance, 2 metres away from the route walked by the subject. The camera filming the view of the sagittal plane was placed in

Table 1 – Baseline characteristics of individuals with stroke.

	Group (n = 30)
Age [years], mean (SD)	61.9 (11.4)
Sex [women/men]	11/19
Paretic limb [right/left]	16/14
Time from stroke month, mean [range]	36.0 [8–120]

SD – standard deviation.

line with the route walked. The recording was made for 6 walks, with the minimum of 3 complete gait cycles. The films available for rating and gait assessment provided right and left side, as well as back and front view of the patient. The subjects were instructed to walk the defined distance at self-selected (comfortable) speed, with the support of orthopaedic aids used on a daily basis. Interpretation of the recording and gait assessment based on WGS were performed by an experienced physiotherapist, who had been trained in gait disorders affecting post-stroke hemiparetic patients and had knowledge of assessment criteria used in WGS.

WGS assesses fourteen observable gait parameters, divided into four subscales related to the specific gait phases: stance phase, toe off phase, swing phase and heel strike phase of the affected leg; it also takes into account the use of orthopaedic aids while walking as well as kinematic parameters of hip, knee, and ankle joint and pelvis. Scores assigned to all the items of the scale are in the range from 1 to 3, except for the first item which is graded from 1 to 5, and the eleventh item graded from 1 to 4. The scores are in the range from 13.35 to 42 points. Higher scores reflect greater gait impairments [11,13]. The scale was translated into Polish with permission of the author.

2.3. *Statistical analysis*

Statistical analyses were computed with the use of Statistica 10.0 (StatSoft, Poland). Parameters of the measured characteristics distribution were assessed with Shapiro–Wilk test. The correlations between Wisconsin scale and temporospatial parameters were assessed by computing Spearman's rank correlation coefficient and *p*-value, i.e. the result of the test for the significance of correlation coefficient. Statistical significance was assumed for $p < 0.05$. The distribution of the final value of Wisconsin scale was presented in the form of descriptive statistics: arithmetic mean, median, standard deviation, minimum and maximum value.

3. Results

Table 2 presents detailed information related to the distribution of values for each of the 14 items constituting Wisconsin Scale. The last column shows the mean value representing average level of gait impairment. The items of the scale are arranged in the order starting with those where the assessment was most negative. It has been shown that the item of WGS with the worst assessment was hip extension of affected limb (Mean = 2.23), and the item with the best assessment was the use of hand held gait aid (Mean = 0.78).

The mean score in WGS based gait assessment was 26.4 ± 5.4 points (Me = 26.9). The lowest score in WGS, representing the best condition, was 15.4 points and the highest 34.9 points. Distribution of Wisconsin scale measures is presented in Fig. 1 where distribution is shown in three-point intervals.

Comparative analysis of the scores in Wisconsin Scale and the temporospatial parameters showed statistically significant relationships. Interestingly, these correlations are more distinctive for the values of temporospatial parameters on the unaffected side (Table 3). The findings show moderate correlation between WGS based gait assessment and gait velocity ($r = -0.39$; $p = 0.0316$). Similar relationship was identified between gait cycle duration and score in WGS for both unaffected ($r = -0.36$; $p = 0.0477$) and affected side ($r = -0.37$; $p = 0.0426$). Higher correlation level was demonstrated for stance phase on the unaffected side and WGS based gait assessment ($r = 0.58$; $p = 0.0009$) (Fig. 2). Statistically significant high correlation, yet with opposite orientation, was also shown for the swing phase on the unaffected side and score in WGS ($r = -0.58$; $p = 0.0009$). Likewise, duration of swing phase on the unaffected side significantly correlated with WGS based gait assessment ($r = -0.41$; $p = 0.0259$) (Fig. 3). For the affected side the statistically significant relations were associated with gait cycle velocity, swing phase velocity and WGS score ($r = -0.37$; $p = 0.0419$, $r = -0.40$; $p = 0.0279$) (Table 3).

Table 2 – Distribution of Wisconsin scale measures in the study group.

Items of Wisconsin scale	Assessment of gait impairment level[1)]										Mean
	1		2		3		4		5		
Hip extension of affected side (7)	3	6%	17	34%	10	20%	×	×	×	×	2.23
Stance width (5)	8	16%	10	20%	12	24%	×	×	×	×	2.13
Stance time on impaired side (2)	5	10%	18	36%	7	14%	×	×	×	×	2.07
Weight shift to the affected side (4)	5	10%	18	36%	7	14%	×	×	×	×	2.07
Pelvic rotation at terminal swing (13)	5	10%	18	36%	7	14%	×	×	×	×	2.07
Initial foot contact (14)	7	14%	14	28%	9	18%	×	×	×	×	2.07
Toe clearance (12)	9	18%	11	22%	10	20%	×	×	×	×	2.03
Hip hiking at mid swing (10)	6	12%	20	40%	4	8%	×	×	×	×	1.93
Guardedness (6)	8	16%	18	36%	4	8%	×	×	×	×	1.87
External rotation during initial swing (8)	8	16%	18	36%	4	8%	×	×	×	×	1.87
Knee flexion from toe off to mid swing (11)	3	6%	11	22%	15	30%	1	2%	×	×	1.85[2)]
Circumduction at mid swing (9)	12	24%	12	24%	6	12%	×	×	×	×	1.80
Step length of unaffected side (3)	15	30%	13	26%	2	4%	×	×	×	×	1.57
Use of hand held gait aid (1)	26	52%	0	0%	3	6%	1	2%	0	0%	0.78[2)]

1) Gait impairment is assessed on a 3-pint scale, except for item 1 9 (scale 1–5 points) and item 11 (scale 1–4 points).
2) Due to the different range of values, the means were multiplied by 3/5 and 3/4, respectively.

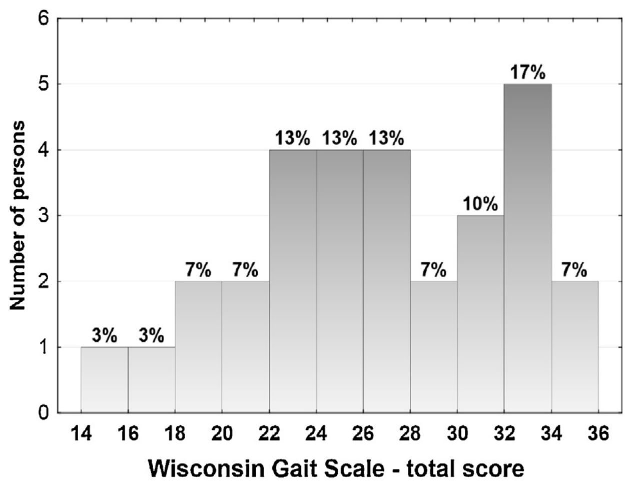

Fig. 1 – Distribution of Wisconsin scale measures in three-point intervals.

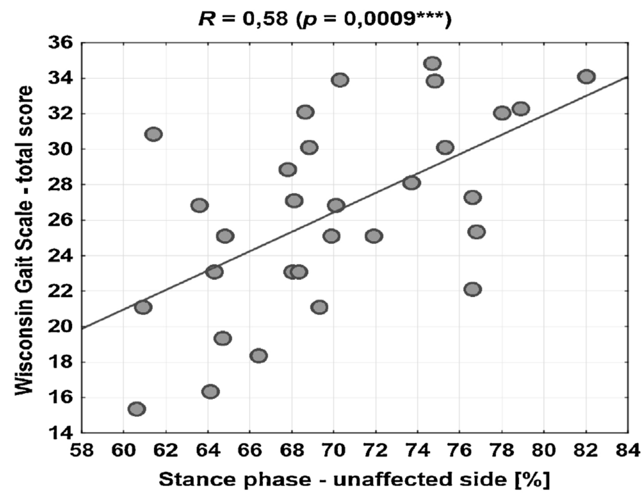

Fig. 2 – Correlation of Wisconsin Gait Scale with stance phase – unaffected side.

4. Discussion

Examination of patients after stroke, in one of the main parts, is designed to assess both functional and quantitative aspects of gait. This results from the fact that gait assessment makes it possible to accurately plan the goals, select adequate methods of therapy and monitor effects of rehabilitation. Gait assessment can also be used as a predictor of the patient's functional performance in the future [16,17]. Gait can be examined with the use of methods involving observation, including gait scales or walk tests as well as quantitative methods describing gait patterns taking into account temporal, spatial, kinematic and kinetic results obtained during the examination. The inspiration for investigating this matter came from the question whether such descriptive method as Wisconsin scale corresponds with temporal and spatial gait parameters identified during 3-dimensional examination. In the literature there is scarcity of reports focusing on assessment of correspondence between observational gait scales and objective data, in particular acquired from 3-dimensional gait analysis [18,19].

Undoubtedly, advanced, computer-aided, 3-dimensional gait analysis constitutes the golden standard in this field since it provides reliable numerical data representing temporal, spatial and kinematic gait parameters thereby enabling comprehensive assessment of any asymmetries in gait pattern in post-stroke hemiparetic patients. Yet, it is not commonly available in clinical practice due to certain limitations: optoelectronic computer systems are quite expensive, and rather demanding as far as specific technical knowledge, time and tooling are concerned [5,7,20,21]. As a result, the tools

Table 3 – Correlation of Wisconsin Gait Scale with temporospatial parameters.

Parameters	Wisconsin Gait Scale – total score
Cadence (step/min)	$r = -0.31$ ($p = 0.0919$)
Step width [m]	$r = -0.06$ (0.7378)
Velocity [m/s]	$r = -0.39$ (0.0316)
Stance phase – affected side [%]	$r = -0.03$ (0.8709)
Stance phase – unaffected side [%]	$r = 0.58$ (0.0009)
Swing phase – affected side [%]	$r = 0.03$ (0.8709)
Swing phase – unaffected side [%]	$r = -0.58$ (0.0009)
Stride length – affected side [m]	$r = -0.37$ (0.0426)
Stride length – unaffected side [m]	$r = -0.36$ (0.0477)
Stance phase – affected side [s]	$r = 0.11$ (0.5537)
Stance phase – unaffected side [s]	$r = 0.23$ (0.2170)
Swing phase – affected side [s]	$r = 0.26$ (0.1720)
Swing phase – unaffected side [s]	$r = -0.41$ (0.0259)
Stride time – affected side [s]	$r = 0.20$ (0.2918)
Stride time – unaffected side [s]	$r = 0.24$ (0.1971)
Stride velocity – affected side [m/s]	$r = -0.37$ (0.0419)
Stride velocity – unaffected side [m/s]	$r = -0.21$ (0.2661)
Swing velocity – affected side [m/s]	$r = -0.40$ (0.0279)
Swing velocity – unaffected side [m/s]	$r = -0.11$ (0.5488)

r – Spearman rank correlation coefficient, p – test probability values.

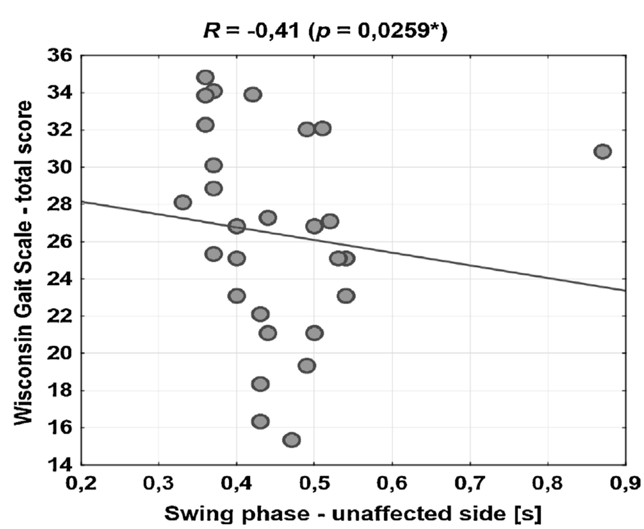

Fig. 3 – Correlation of Wisconsin Gait Scale with swing phase – unaffected side.

most popular with the community of therapists are based on scales and tests which are simple, time-effective and inexpensive. Therefore, observational gait analysis continues to be most commonly used to assess gait. It involves visual assessment of joints mobility and temporospatial gait parameters, and it can be aided with video recording with the use of cameras, which makes it possible to replay the image many times and to stop it at any moment [12,16]. There are a number of scales assessing various aspects of gait in patients after stroke. Some of these assess biomechanical gait parameters, others focus on temporospatial parameters, and some of them enable combined assessment of both types of parameters. One of the observational scales enabling multifactorial analysis of gait faction in patients with post-stroke hemiplegia is WGS. The specific components of the scale focus on assessment of temporospatial (subscale one), as well as kinematic parameters of gait (subscale two, three and four) [5,11–15,22].

The purpose of the present study was to answer the question whether or not the easy-to-use, inexpensive and observation-based Wisconsin Gait Scale enables gait assessment which is consistent with findings acquired through advanced, complicated 3-dimensional gait analysis in patients with post-stroke hemiparesis. The findings show moderate and good correlations between selected temporospatial parameters and gait assessment based on WGS (the highest correlation coefficient was $r = -0.58$, $p < 0.05$).

Consistency of findings acquired with 3-dimensional gait analysis and observational gait analysis was also investigated by Taş et al. The study was performed in a group of 33 individuals with clinical and radiological diagnosis of bilateral knee osteoarthritis. Video recording was made for the needs of 3-dimensional gait analysis; subsequently the recordings were subjected to two observational analyses, to assess 11 kinematic and 5 temporospatial parameters. The authors reported moderate positive consistency in terms of the observed temporospatial parameters ($r = 0.52$–0.69, $p < 0.05$). The highest internal agreement and repeatability related to step width, step length, cadence and gait velocity. These researchers emphasize the necessity to continue research with patients diagnosed with various medical conditions [18]. Accuracy and reliability of observational gait analysis related to push-off phase in patients after stroke were investigated by McGinley et al. The group qualified to participate consisted of 11 patients with post-stroke hemiplegia. Ankle push-off strength was assessed with a computerized gait analysis system, and the patients' gait was videotaped at the same time. Subsequently two observational gait analyses were performed using these video recordings. The findings showed high correlation between the observational and instrumental assessment of push-off phase in subjects after stroke ($r = 0.84$). The authors demonstrated that a physiotherapist using video recording is able to accurately and reliably assess gait in post-stroke patients by applying observational method alone. They also suggest that further research is needed to evaluate accuracy and reliability of evidence acquired through observational gait analysis [19]. Gor-Garcia-Foged and colleagues report that due to the lack of well-defined standard criteria for assessing the accuracy of the scales, a number of different scales are applied while three-dimensional gait analysis, which could be recognized as a standard reference criterion for qualitative gait assessment, was used only in two studies. The authors also report that, when compared to 3-dimensional gait analysis, the only scale showing good results was Gait Assessment and Intervention Tool (G.A.I.T.), yet these related only to two items of the scale. Because of this the researchers suggest that further studies should take this into account and should compare all observational gait assessment scales with objective evidence provided by instrumental gait analysis systems [4].

The present study assessed relationships between three-dimensional gait analysis and the results of gait assessment based on the observational WGS and showed that the observed correlations between temporospatial gait parameters and WGS scores present logical trends – where the higher values of temporospatial parameters reflect better gait function, there is negative correlation since Wisconsin Scale has the opposite design, which means that higher scores correspond with greater gait impairments. Therefore it can be concluded that although this simple, inexpensive observational method, which is also sensitive to changes in patient's physical condition, cannot fully substitute 3-dimensional gait analysis, in a situation when the costly objective methods of gait assessment are unavailable for various reasons, WGS may constitute an adequate tool to evaluate the effects of rehabilitation in patients after stroke.

The results of the present study suggest moderate and good level of correlation between temporospatial parameters and the global score on WGS scale, which encourages further, more detailed analysis, to be carried out separately for the specific components in order to compare consistency of temporospatial parameters acquired during 3-dimensional gait analysis with temporospatial traits assessed in part one of WGS, as well as 3-dimensional kinematic parameters with the kinematic parameters in part two, three and four of WGS. It also seems necessary to compare results of gait assessments after stroke performed with WGS and the global gait indexes such as Gait Deviation Index (GDI) and Gait Variability Index (GVI), which are objective methods of assessing gait taking into account parameters identified during 3-dimensional analysis.

5. Conclusion

The study shows that temporal and spatial gait parameters observed during 3-dimensional examination correspond, at a moderate and good level, to gait assessment performed with observational WGS scale. WSG is a useful and simple tool for assessing gait in post stroke hemiparetic patients. There is a need to more thoroughly analyze the specific items of WGS and compare them with selected objective parameters acquired using 3-dimensional gait analysis.

Conflict of interest

None declared.

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None declared.

Ethics

The work described in this article has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans; Uniform Requirements for manuscripts submitted to Biomedical journals.

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