

The comparison of two physiotherapeutic approaches for gait improvement in sub-acute stroke patients

MACIEJ KRAWCZYK^{1,2*}, EWA SZCZERBIK³, MAŁGORZATA SYCZEWSKA³

¹ Faculty of Physiotherapy J. Piłsudski's Academy of Physical Education, Warsaw, Poland.

² 2nd Dept. of Neurology, Institute of Psychiatry and Neurology, Warsaw, Poland.

³ Dept. Paediatric Rehabilitation, The Children's Memorial Health Institute, Warsaw, Poland.

The functional gait problems encountered by stroke patients include impaired balance, abnormal gait pattern with marked asymmetry, pathological trunk and spinal motion. Many different methods of physiotherapy are used to improve functional ability (especially gait) in stroke patients, but their efficacy and outcome are often not objectively assessed. The goal of this paper is to compare two therapeutic programs: one that is traditionally used in our rehabilitation facilities (exercises in lying position, "open chain" exercises, isolated movements of extremities with trunk stabilization) and the new one (exercises in vertical position, sitting or standing, "closed chain" exercises involving whole paretic side of the body). Fifty one stroke patients, aged 34 to 79 years, participated in the study. Patients were randomly allocated to one of the two groups. Patients underwent clinical assessment (Fugl-Meyer, Rivermead Motor Assessment, Berg Balance Scale) and instrumented gait analysis (using six-camera VICON 460 system) simultaneously three times: prior to the beginning of the rehabilitation program, after 6 weeks of the program, and after another 6 weeks of physiotherapy, at the end of rehabilitation program. Results demonstrated that both rehabilitation programs improved the gait function and clinical status in patients suffering from stroke. Despite the differences between the two programs the progress achieved by the patients in locomotor function is similar. Two equivalent physiotherapy programs could be applied during rehabilitation process depending on the patient's individual preferences and needs, as the amount of functional improvement provided by them is comparable.

Key words: gait, stroke, rehabilitation programs

1. Introduction

Stroke is one of the most common neurological conditions, is the third leading cause of the mortality among adults, and is the primary cause of long term disability in adult population [1]. Approximately 75% of all patients surviving the first 5 years after the stroke will recover the independent walking [1]. The functional problems encountered by stroke patients include impaired balance [2], abnormal gait pattern with marked asymmetry [3], abnormal trunk and spinal motion [4]. The gait abnormalities include: increased double support phase [5], abnormal movement of hips, knee, ankle [6] and pelvis, and de-

creased walking speed [7]. One of the aims of rehabilitation is the improvement of gait pattern, which enables better everyday activity and mobility of the stroke patients. Many different methods of treatment of stroke patients have been used until now, but they rarely are compared with each other [8] thus their impact on the patient's functional improvement is difficult to assess [9]–[11]. Specialists are constantly looking for new therapies which would be more efficient, but also better accepted by the patients [8], including gait training with body weight support [12], video games [13], and functional electrical stimulation [14].

Results of biomechanical research suggest that "closed chain" exercises, i.e., when the limb's distal

* Corresponding author: Maciej Krawczyk, 2nd Department of Neurology, Institute of Psychiatry and Neurology, ul. Sobieskiego 9, 02-957 Warsaw, Poland. Tel: +48-22-4582810, fax: +48-22-8422634, e-mail: krawczyk@ipin.edu.pl

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part is stabilized (against floor, wall, etc.), improves the muscle coordination pattern much better than “open chain” exercises, i.e., when the limb’s distal part can move freely [15]–[18]. There is evidence that exercises performed in vertical positions (i.e., while sitting or standing) better improve balance and posture function in comparison to standard therapy [16], [17]. Some experiments have also shown that functional reorganization in the brain appears in the regions involved in performing the skill [18], and thus the improved body posture and whole-body control help to guide and improve the accuracy of ‘voluntary’ movements of the head, lower and upper extremities in space [19]–[23]. The shortcoming of the studies comparing “open chain” and “closed chain” approach is that the outcome measured was a selected coordination movement or muscle activation pattern [14], [15]: no global gross motor function was evaluated.

As the “closed chain” approach is based on the normal activity performed during daily routines, this might be better accepted by patients during rehabilitation, and could be used as a substitution for the standard rehabilitation program, assuming that the efficacy and outcome of both programs are comparable. Therefore the aim of this project is to compare two therapeutic programs: one which is traditionally used in rehabilitation facilities in Poland, based on isotonic exercises in lying position, “open chain” exercises and isolated movements of extremities with stabilized trunk, and the new one, based on isometric exercises (at the beginning of therapy) carried out in vertical position (i.e., while sitting or standing) and “closed chain” exercises (with limb’s distal part stabilized) engaging simultaneously whole paretic side of the body. The main feature of closed chain” exercises is the engagement of the whole involved side of the body during rehabilitation while maintaining as much as possible vertical trunk orientation, i.e. mimicking the normal, every-day activity of the patient. The outcome of the rehabilitation programs was compared using instrumented gait analysis, an objective method used to assess treatment results in many studies [5], [7], [18], [25]–[26]

2. Materials and methods

Participants

Fifty one stroke patients, aged 34 to 79 years (mean 59.0, SD 10.0), treated in the Institute of Psychiatry

and Neurology in the years 2007–2009, who fulfilled the inclusion criteria participated in the study. There were 36 left side hemiplegic patients, and 15 right side hemiplegic patients, 13 women and 38 men. Mean time from the onset of stroke to the time of inclusion to the study was 39.6 days (SD = 17.0). Mean Body Mass Index was 28.0 (SD = 4.2).

The inclusion criteria were as follows: patients within 3 months of first ischemic stroke at the time of inclusion into the study, patients were willing to cooperate, and were capable of independent walking without aids a minimum distance of 10 m.

The exclusion criteria were as follows: neglect syndrome (diagnosed clinically by neuropsychologist), deep dysphasia (3 points or more on the Goodglass-Kaplan Aphasia Examination) or medical contraindications to perform intensive training. The Local Ethical Committee approved the study, and each patient gave his/her informed consent prior to the enrolment.

Gait analysis

Patients underwent instrumented gait analysis three times: prior to the beginning of the rehabilitation program at the time of inclusion into the study, after 6 weeks of the program, and third time after 12 weeks from the first analysis. Gait analysis was performed using six-camera VICON 460 (ViconPeak) system, with 60 Hz camera frequency. Patients walked several times before the collection of the data to get accustomed to the procedure. They were supervised all the time by a skilled physiotherapist in order to avoid any fall or other problems. For each patient at least six gait trials were collected. Patients walked at their natural, self-selected speed. The Helen Hayes marker set with Plug-In-Gait model were used, the data were analysed and averaged using Polygon software. The averaged data were used for further analysis.

From the gait data the Gillette Gait Index was calculated [26], and additionally the following gait variables were analysed: stance phase, single stance phase (both expressed as the percentage of the gait cycle), pelvic tilt, range of pelvic tilt, step width normalized to pelvic width, hip and knee range in sagittal plane, speed, cadence and step length. The last three parameters were normalized to sex and age matched reference data [27]. The data were arranged into paretic and non-paretic side.

Clinical evaluation

All patients simultaneously with gait analysis underwent clinical evaluation: Fugl-Meyer subscale

for lower extremity [28], [29], The Lower Extremity Section of the Rivermead Motor Assessment scale (LE RMA) [30], and Berg Balance Scale (BBS) [31]. The clinical evaluation was done on the same day as the gait analysis. Additionally the size of the brain lesion was assessed by a radiologist from CT scans using the ASPECTS scale.

Rehabilitation programs

Patients were randomly allocated to one of the two groups: standard or “closed chain” rehabilitation program. Randomization was stratified (by computer program) for age (≤ 65 years or > 65 years), profoundness of the lower extremity motor deficit (< 5 score in LE RMA or ≥ 5 LE RMA), for the size of the cerebral ischemia (≤ 7 score ASPECTS Scale or > 7) [32]–[34], and Body Mass Index. This ensured the similarity of the two groups at the beginning of the study. All patients participated in one of the two 12 week rehabilitation programs: standard one, or “closed

chain” one. At the beginning all patients were treated for 6 weeks at the inpatient neurorehabilitation department, and then received physiotherapy for 6 weeks at the outpatient neurorehabilitation department. Individual physiotherapy in both groups was based on movement therapy, and lasted for 2 hours daily.

Standard rehabilitation program

1. Kinesiotherapy conducted in lying position of the patient (at least for 50% of total time of treatment). Standing position was used only when standing or walking skills (activity level) were practised.

2. Most of the time the trunk was stabilized, and the limbs were moving freely during exercise. The type of exercises was independent of the amount of motor deficit.

3. Lack of exercises simultaneously engaging whole paretic side of the body.

Table 1. Description of the rehabilitation programs

Description of standard physiotherapy program	Description of experimental physiotherapy program
1. Motor therapy carried out mostly in lying supine, lying prone or lying on side (horizontal positions) for at least 50% of total time of treatment. Vertical position was used only when skills (activity level) while standing or walking were practised.	1. Motor therapy carried out mostly in standing or sitting postures. Patients remained in horizontal position only when rolling to the weak side or to the strong side were practised.
2. Exercises which separately engaged single body segments (lower extremities, upper extremities and trunk were separately trained). Physiotherapist and patient executed only movements of one body segment at a time.	2. Exercises which concurrently incorporated into activity all segments of paretic body side (lower extremity, upper extremity and trunk). Physiotherapist stimulated patient in isolated, individually chosen postures, which enabled him to evoke muscle activity simultaneously in leg, arm and trunk. Examples: a. symmetrical bridging backwards, b. asymmetrical bridging backwards, c. symmetrical bridging forwards, d. asymmetrical bridging forwards.
3. Paretic foot and hand remained often free (open chain) during exercises. Examples: a. Patient tried to bend his/her hip and knee joint in supine lying. b. Patient tried to make a step forwards and backwards with his/her paretic leg while standing.	3. Paretic foot and hand were a part of base of support for most of the exercise time (closed chain). Examples: a. Patient sit on the edge of bed with feet on the floor. Paretic hand was supported on ironing board (board was perpendicular to the bed).
4. Voluntary movements were always initiated and continued in isotonic conditions. Actions carried out in isometric muscle work were avoided except of those necessarily required. Example: a. Patient tried to rise his/her arm in supine lying	4. Voluntary movements were always initiated in isometric conditions. Actions carried out in isotonic muscle work were initiated after isometric motor control had been gained. Examples of easier and more difficult activities: a. Patient sit on the edge of bed with feet on the floor. Paretic hand was supported on ironing board and patient lifted weight with sound hand over his/her head. Paretic extremities were stabilized by physiotherapist. b. In the previous posture patient tried to bend his/her hips but trunk remained in neutral position.

“Close Chain” rehabilitation program

1. Kinesiotherapy conducted mainly in standing or sitting positions.

2. In the first period of therapy (when motor deficit was more severe) most of the exercises were done in isokinetic condition (co-contraction of antagonistic muscles) and exercises with mobility of the joints were introduced gradually, according to degree of motor recovery. Increasing the range of motion depended on the improved patient’s motor control.

3. Most exercises were of “closed chain” type; i.e., when the extremity (either arm or leg) was stabilized distally to stable surface (ironing board, wall, coach), object (ladder, spade) or other part of the body (clasped hands).

4. Only exercises simultaneously engaging whole paretic side of the body were performed.

Detailed description of both rehabilitation programs is presented in Table 1.

Statistics

The normality of the variables was checked using Kolmogorov–Smirnow and Shapiro–Wilk tests. The normally distributed variables were summarized by means and standard deviations, variables with non-normal distribution by medians and ranges. The

comparisons of the variables between the groups were done using Student’s *t*-test for normally distributed variables, and Mann–Whitney test for non-normally distributed variables. For evaluation of the changes of variables with time the Friedman ANOVA for repeated measures was used. All calculations were performed using STATISTICA (StatSoft) software.

3. Results

Fifty one patients (who fulfilled the criteria) were included into the study. Tables 2 and 3 summarize the results of gait data and clinical tests. Table 2 presents a summary of the normally distributed variables, and Table 3 the non-normally distributed variables. The comparisons of variables between the group with standard rehabilitation program and group with “closed chain” rehabilitation program revealed that there were no statistically significant differences between the two groups at any time point. As the patients were allocated to the two groups according to stratified random sampling protocol there were no differences between groups in mean time from the onset of stroke (mean 40 days, SD 17 days), and size of the brain lesion (8 points with SD = 3, measured in ASPECTS scale).

Table 2. Summary of the normally distributed variables for standard and “close chain” therapy groups in 1st, 2nd and 3rd examinations (mean and sd)

Variable	Standard therapy	Group	“Close chain” therapy	Group
	Mean (1st/2nd/3rd)	Standard deviation (1st/2nd/3rd)	Mean (1st/2nd/3rd)	Standard deviation (1st/2nd/3rd)
Fugel-Meyer lower extremities (0–34 points)	21.8/27.0/28.8	6.4/5.3/4.2	18.4/24.8/27.6	5.2/5.0/4.6
Normalized step width	0.728/0.965/0.685	0.152/1.380/0.150	0.739/0.703/0.668	0.151/0.164/0.165
Pelvic tilt (degrees)	9.3/10.3/8.8	4.6/4.9/5.4	8.5/8.5/8.8	5.1/4.5/3.2
Hip range in sagittal plane paretic side (degree)	22.0/26.3/28.0	7.5/7.1/7.3	22.1/29.2/29.3	7.9/8.0/7.7
Hip range in sagittal plane non-paretic side (degree)	28.3/31.0/31.9	8.7/7.0/6.3	30.0/35.4/36.3	9.1/6.1/6.1
Knee range in sagittal plane paretic side (degree)	27.2/33.7/35.8	11.4/14.9/15.7	27.8/34.5/37.4	9.6/13.7/13.3
Knee range in sagittal plane non-paretic side (degree)	42.1/46.5/47.4	12.8/12.1/12.3	41.0/48.2/51.1	11.8/8.5/7.3
Cadence (% of reference value)	61.4/72.1/74.5	12.8/12.9/11.9	62.8/72.1/74.5	15.2/12.9/11.8
Step length % of reference value paretic side (cm)	48.6/59.7/66.0	18.7/18.9/20.4	56.2/68.9/71.3	14.0/18.4/19.3
Step length % of reference value non-paretic side	49.4/61.1/67.9	18.2/17.4/18.9	52.1/69.1/71.6	25.0/18.3/18.8
Single stance paretic side (%)	26.8/33.4/32.2	8.5/5.7/5.3	25.4/32.3/30.8	8.7/5.7/6.0
Single stance non-paretic side (%)	30.7/33.1/35.8	8.9/5.6/4.0	28.8/33.5/37.2	8.8/6.7/2.9

No differences between control and experimental groups at all time points.

Table 3. Summary of the non-normally distributed variables for standard and “close chain” therapy groups in 1st, 2nd and 3rd examinations (median and min and max values)

Variable	Standard therapy			“Close chain” therapy		
	Median	Min	Max	Median	Min	Max
1st examination						
RMA trunk and lower extremity (0–10)	6.5/9.0/9.5	4.0/5.0/7.0	10.0/10.0/10.0	6.0/9.0/9.0	3.0/5.0/5.0	9.0/10.0/10.0
Berg Balance Scale (0–56)	49.5/53.0/54.0	38.0/48.0/48.0	56.0/56.0/56.0	47.0/52.0/53.0	21.0/41.0/46.0	54.0/56.0/56.0
Stance phase paretic side (%)	65.1/64.8/64.9	55.9/57.3/59.0	86.4/78.4/75.6	64.3/63.2/62.8	56.3/53.1/56.9	83.3/73.4/78.3
Stance phase non-paretic side (%)	73.2/68.4/62.9	61.6/57.9/54.2	88.0/79.5/76.2	72.1/68.1/64.4	60.4/58.1/58.8	92.8/82.9/79.0
Tilt range (degrees)	3.0/3.0/3.0	1.0/1.0/1.0	10.0/8.0/10.0	6.0/4.0/4.0	1.0/2.0/2.0	10.0/11.0/10.0
GGI paretic side (index)	142.5/102.1/114.1	54.0/37.5/37.4	593.4/337.4/380.4	126.8/101.1/101.3	46.6/42.7/35.4	762.5/443.6/332.5
GGI non-paretic side (index)	165.7/93.1/98.5	35.0/24.6/27.6	563.1/290.0/557.0	131.6/99.6/125.6	27.9/37.0/39.8	574.0/460.6/336.2
Speed % of reference value	27.5/35.5/40.0	11.0/18.0/19.0	66.0/85.0/90.0	36.0/55.0/54.0	5.0/12.0/24.0	76.0/87.0/98.0

Table 4. Results of the comparison of variables during rehabilitation using Friedman ANOVA test for repeated measures. The variables which change with time during the whole rehabilitation treatment are bolded

Variable	Chi-square	<i>p</i>
Fugl–Meyer lower extremities	42.829	<0.001
RMA trunk and lower extremities	68.698	<0.001
Berg Balance Scale	69.588	<0.001
Stance phase paretic side	7.193	0.027
Stance phase non-paretic side	52.310	<0.001
Step width	5.012	0.082
Pelvic tilt	3.317	0.190
Range of pelvic tilt	2.471	0.291
Hip range of motion paretic side	35.84	<0.001
Hip range of motion non-paretic side	28.386	<0.001
Knee range of motion paretic side	12.152	0.002
Knee range of motion non-paretic side	12.809	0.002
GGI paretic side	4.127	0.127
GGI non-paretic side	9.489	0.008
Speed % of reference value	63.544	<0.001
Cadence % of reference value	45.259	<0.001
Step length % reference value paretic side	39.673	<0.001
Step length % reference value non-paretic side	53.163	<0.001
Single stance paretic side	42.129	<0.001
Single stance non-paretic side	29.872	<0.001

To determine which aspects of gait and clinical aspects improved during the rehabilitation program the data were pooled together and the Friedman ANOVA test was performed to examine the changes in the analysed variables during the time of treatment.

The statistically significant differences in clinical variables (Fugl-Meyer, LE RMA and BBS)

occurring during treatment are summarised in Table 4.

In the case of gait variables the analysis revealed that some variables were stable during treatment: normalized step width, pelvic tilt, and GGI for paretic side. All other variables demonstrated statistically significant improvement following the treatment.

4. Discussion

The results demonstrated that a 12 week rehabilitation program improved the gait function in patients suffering from stroke, regardless of the type of the rehabilitation program followed by the patients.

Two groups of patients did not differ in basic clinical parameters neither at the beginning of the study, nor at the end of the programs. The most important features of the standard physiotherapy program were passive and active movements of the paretic lower and upper extremity (with stabilized trunk) executed mostly in patient's horizontal position (i.e., in lying position). Patients were encouraged to actively move their extremities without stabilization of the distal parts ("open chain"). Upper and lower extremities were exercised separately. In contrast, in the "closed chain" program [35] the most important feature was the introduction of muscle activity with isometric contractions and the gradual increase of active range of motion (isotonic contraction). The amount of increase depended on the level of reduced motor deficit. At the beginning of the physiotherapy program distal parts of paretic extremities were stabilized, but the trunk was allowed to move in relation to the ground. Physiotherapy was conducted for most of the time in standing or sitting positions, which required active maintenance of body posture.

The results obtained indicate that the type of rehabilitation program does not influence the rate of patient's progress during the treatment. Despite the differences between the programs the progress achieved by the patients in locomotor function and in clinical assessment was similar. The treatment was neither less nor more effective in the group following the "closed chain" rehabilitation program. These results indicate that those two physiotherapy strategies may be administered alternatively, according to the patient's individual needs, capabilities and preferences, and the facility in which the rehabilitation is administered.

The Gillette Gait Index (GGI) is the only number which assesses the difference between the patterns of the patient's gait from the gait pattern of healthy subjects [26]. In our study, there was no change in time of the GGI in the paretic lower limb, in contrast to the non-paretic limb. Stroke patients have, obviously, much more control of the non-paretic side; therefore they develop more compensatory mechanisms on this side [36]–[38]. The diminishing

of the GGI in non-paretic side during the rehabilitation treatment suggests the optimisation and minimization of the compensatory mechanisms which occur in time in this side.

The rehabilitation of stroke patients varies from patient to patient, and from centre to centre, quite often without well described guidelines and standards. The efficacy of new rehabilitation methods is often proved in time, but not against each other [8]. Additionally stroke patients often suffer from cognitive and affective impairments, which make their rehabilitation more difficult due to problems with understanding the instructions, motivation and applying instructions given by medical staff [38]. Therefore, the availability of two different approaches which improve patients' functional status with the same efficacy, and validated against each other, would help adjust the rehabilitation program to personal preferences and limitations of the stroke patients.

The gait speed, cadence, step length (of paretic and non-paretic limbs), hip and knee ranges of motion increased during the rehabilitation program, achieving values closer to the reference values of healthy subjects. These results reflect the increasing functional capabilities of the patients, and the improvement of their functional status. The improvement did not depend on the type of the rehabilitation program, thus pointing again to the fact that the standard and "closed chain" programs are equivalent. The shortcoming of this study is that gait analysis was based on kinematics of pelvis and lower extremities, and spatio-temporal parameters. Muscle activity and movement of the trunk and upper extremities had not been analysed. Many compensatory mechanisms could occur in the trunk and upper extremities, and they were not controlled in this study.

5. Conclusions

Two very different concepts of motor exercises, that is, "open chain" exercises and "closed chain" exercises, may lead to similar rate of recovery after stroke. The similarity of the achieved improvements in both groups of patients proves that the physiotherapists can offer the stroke patients two equivalent treatment programs. These programs could be applied depending on the patient's individual preferences and needs. Searching for new and more effective methods of physiotherapy after stroke is

necessary in order to meet expectations of present-day general public.

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