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Effect of Exercise on Gait Mechanics in a Patient with Severe Gait Disorder Due to Chronic Ischaemic Stroke: A Case Study

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Abstract

We describe the effects of an exercise programme based on the American Heart Association and American Stroke Association guidelines for stroke patients on gait mechanics in a patient with severe gait disorder due to chronic ischaemic stroke. A 74-year-old female patient, with right hemiparesis as a result of a stroke attack before 18 months followed an 8-week exercise programme, consisting of three hourly sessions per week. Patient's gait mechanics were evaluated before and after the intervention using a three-dimensional gait analysis system, with six infrared cameras, two force plates, and an electronic timing system. Exercise led to increase of spatial and decrease of temporal gait parameters, increase of joint range of motion and lower limb muscle powers during the entire gait cycle and increase of the moments in the support phase. In conclusion, exercise had a positive effect on this patient's gait pattern and improved her functionality.

Keywords

Exercise, Gait Analysis, Rehabilitation, Stroke

1. Introduction

Stroke is the most common cause of serious long-term disability [1]. Although the rate of neurological recovery is rapid in the first 4 weeks after the stroke [2], functionality improvement seems to extend beyond this period, possibly through the development of compensatory strategies against neurological deficits [3].

However, patients often adopt a sedentary lifestyle that leads to dependence on other people, but also to increased risk of falls and recurrence of stroke [4], or other cardiovascular events [5] [6]. In particular, patients after stroke are significantly less physically active in comparison with the elderly who suffer from chronic musculoskeletal diseases or other cardiovascular diseases [7] [8] [9] [10]. A sedentary lifestyle exacerbates further their cardiovascular function and the already impaired functional capacity [11] [12]. Furthermore, it leads to increased fatigue, muscle atrophy and weakness, osteoporosis and impaired circulation in the lower limbs. Finally, the greater dependence of patients with stroke on others for daily activities and their impaired ability for usual social activities can have serious negative psychological effects [13].

In 2014, the American Heart Association and American Stroke Association (AHA/ASA) published the revised recommendations on exercise in patients with stroke [14]. Nevertheless, to the best of our knowledge, there is no data concerning the effect of the above exercise programme on patients' gait pattern. Importantly, gait pattern affects muscle and joint loads during movement and thus on the long-term function of the skeletal system [15] [16] [17]. We herein describe the effect of an exercise programme based on these recommendations on gait mechanics in a patient with severe gait disorder resulting from an ischaemic stroke in the chronic phase of rehabilitation.

2. Case Description

A 74-year old female patient, with right hemiparesis as a result of a stroke attack before 18 months followed an exercise programme Patient's characteristics were summarized in **Table 1**. She was selected from the hospital discharge registry of the General Hospital of Komotini, based on the diagnosis at discharge "Stroke" 12 - 18 months before the search, which was performed as part of another study, aiming to evaluate the effect of a group exercise programme on the gait mechanics in patients with chronic stroke. Other inclusion criteria in the above study were the ability to walk without the aid of assistive or orthotic devices, the ability to understand and follow simple instructions, free medical history concerning musculoskeletal, other neuromuscular or serious cardiovascular diseases, and good vision. The said patient was excluded from the group exercise programme because she had serious gait disorder and she was dependent on crutches. Therefore, it was decided to study her independently of the other sample. Previously, she had followed a rehabilitation programme (10 home physiotherapy sessions per month) during the first 6 months after the stroke, *i.e.* the time period provided by the insurance fund, but then she had remained isolated in her house.

Table 1. Patient's characteristics (NIHSS: National Institutes of Health Scale, mRS: modified Rankin Scale).

Height (cm)	Weight (Kg)	mRS	Barthel Index	NIHSS
143	68	4	80	6

2.1. Intervention

The patient followed an exercise programme including strength, endurance and flexibility training, as well as neuromuscular activities [14]. The duration of the programme was 2 months with 3 hourly sessions per week. Each session started with warming-up for 5 to 10 minutes, with low-intensity aerobic exercises, and stretching exercises. Then the main part was taking place, consisting of : 1) neuromuscular coordination exercises twice a week for 20 minutes; 2) strength exercises 2 days per week; 3) moderate-intensity aerobic exercise 3 times per week for about 30 minutes; and 4) flexibility exercises twice a week. Finally, cooling down was performed with low-intensity aerobic exercises and stretching exercises for five minutes. Both the intensity and the main principles of exercise were determined according to the guidelines of the American College of Sports Medicine (ACSM) [18].

2.2. Assessment

Patient's gait mechanics were evaluated before and after the intervention using a three-dimensional gait analysis system, with six infrared cameras, two force plates, and an electronic timing system. Detailed description of the equipment and measurement process is presented elsewhere [19].

2.3. Efficacy: Spatiotemporal Parameters

Table 2 presents the means of the spatiotemporal gait parameters for both lower limbs, with and without paresis, according to the measurements before and after the intervention, as well as the % difference between the initial and final measurement. Increase of the spatial parameters (stride and step length) and decrease of the temporal parameters (stride and step duration, single and double support duration) were observed on both lower limbs. Gait velocity increased by 328%.

Table 2. Spatiotemporal gait parameters of the lower limbs before (pre) and after (post) exercise, and % difference (% diff.). Frequency is measured in steps/minute, step stride durations, (single sup.) and double support (double sup.) in seconds, stride and step length in meters and velocity in meters/second.

	Non paretic leg			p	Paretic leg			p
	Pre	Post	% diff.		Pre	Post	% diff.	
Cadence	40.08	87.84	119.14	0.000	44.48	85.54	92.33	0.001
Stride time	3.05	1.37	55.08	0.001	2.83	1.41	50.18	0.008
Step time	1.70	0.69	59.41	0.000	1.49	0.68	54.48	0.002
Single sup.	0.52	0.43	16.67	0.441	0.20	0.41	104.95	0.083
Double sup.	2.23	0.54	75.61	0.003	1.51	0.56	62.55	0.205
Stride length	0.33	0.68	104.97	0.000	0.36	0.71	98.20	0.000
Step length	0.10	0.32	208.56	0.000	0.23	0.36	54.51	0.002
Velocity	0.12	0.49	328.19	0.000	0.12	0.51	328.86	0.000

2.4. Efficacy: Kinematic and Kinetic Parameters

Figure 1 and Figure 2 present kinematic and kinetic parameters of the 5 gait cycles before and after the intervention. Before the intervention, severe impairment of the gait pattern was observed. After the completion of the exercise programme, the waveforms of all parameters approached the typical pattern. As regards kinematic parameters increased range of motion (ROM) was observed in the joints of the hips, knees and ankles in the anterior-posterior plane in both lower limbs. In addition, faster initiation of triple joint flexion in the lower limbs (hip-knee-ankle dorsiflexion) was observed during the swing phase (immediately after 60% of gait cycle). These changes were correlated with remarkable increase in muscle powers in the lower limbs from the three joints at the anterior-posterior plane throughout the gait cycle. Moreover, improved waveforms of the moments were observed, mainly during the support phase. Improved waveforms were also observed in the frontal and transverse planes, in all the parameters studied.

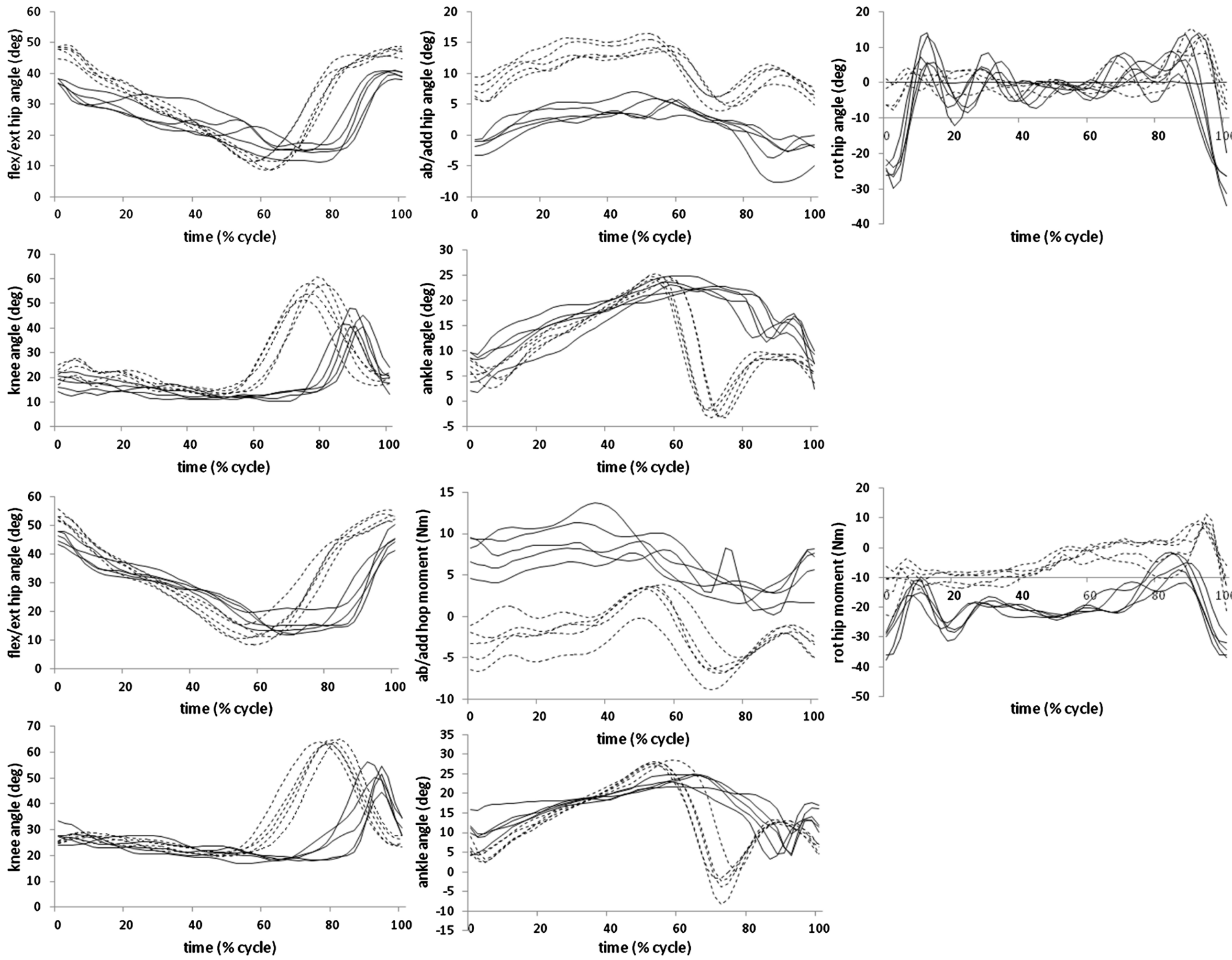

Figure 1. Gait kinematic parameters graphs from five gait cycles before the intervention (continuous lines) and five gait cycles after eight weeks of exercise (dashed lines). The first 5 graphs (two upper lines) concern the paretic lower limb and the next five (two lower lines) the non-paretic lower limb.

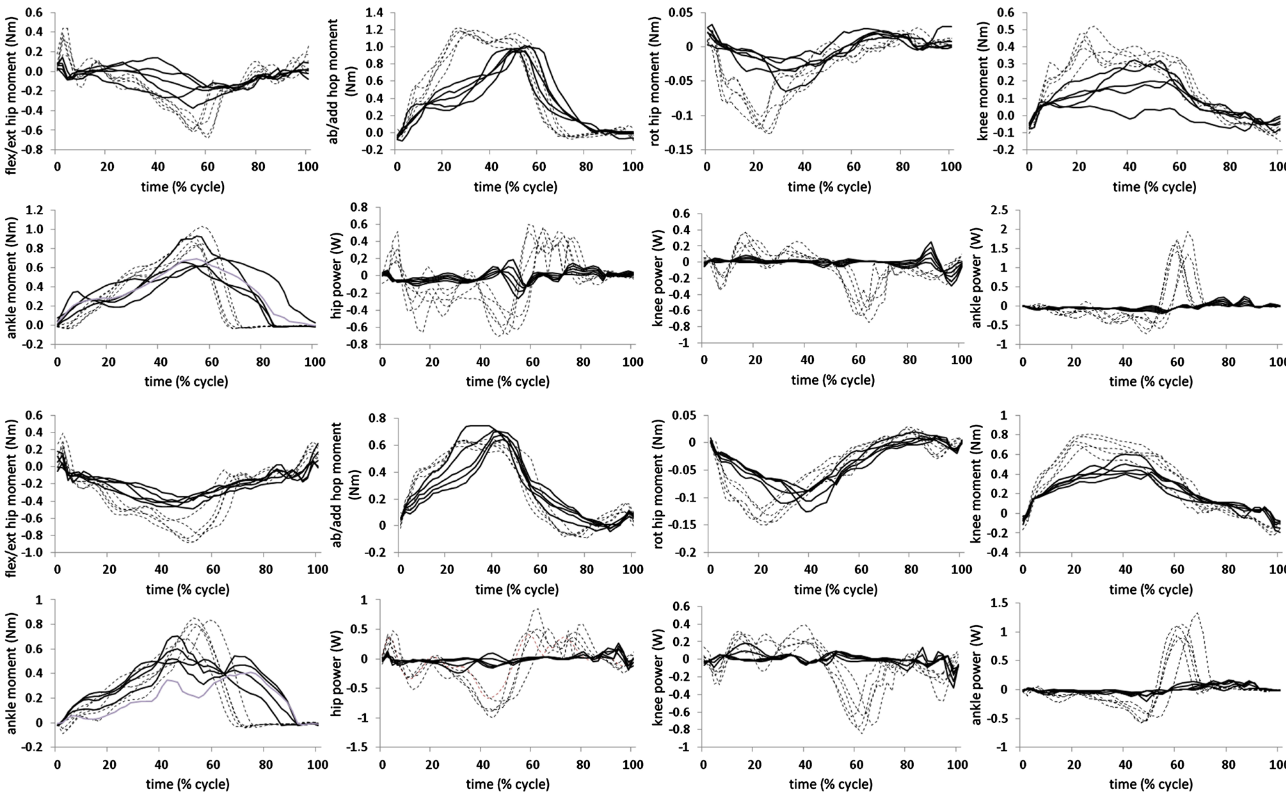

Figure 2. Gait kinetic parameters graphs (moments-powers) from five gait cycles before the intervention (continuous lines) and five gait cycles after 8 weeks of exercise (dashed lines). The first eight graphs (2 upper lines) concern the paretic lower limb and the next eight (2 lower lines) the non-paretic lower limb.

3. Discussion

3.1. Spatiotemporal Parameters

The parameter showing the most pronounced change was gait velocity. Gait velocity plays a crucial role in human functionality. For a pedestrian to move around in the city, to cross the road, for example, gait speed must be from 1.1 to 1.5 m per sec [20] [21]. The patient's final gait velocity was approximately 0.5 m per sec, which is still much lower. Nevertheless, the initial value of her gait was only 0.12 m per sec, and her improvement ensured her autonomy for domestic activities. Indeed, the modified Rankin Scale after the completion of the intervention decreased to 3. Moreover, the above changes were achieved after only eight weeks of intervention. An extension of the intervention programme could lead to further increases in gait velocity.

Moreover, temporal gait parameters improved, consistent with the observations of Onley and Richards [22] on the spatiotemporal gait parameters in stroke patients, which are attributed to muscle weakness. Therefore, the improved spatiotemporal gait parameters suggest her muscle strength improvement.

Another improvement was the increase of the spatial gait parameters, attributable to improved balance. Indeed, Espy *et al.* [23] observed that the elderly adopt a gait pattern characterised by slow velocity and small step length to allow better balance, but this slow gait velocity actually facilitates imbalance, which is simply compensated by smaller step length. Moreover, Teixeira-Salmela *et al.* reported that the reduced gait velocity, reduced length of stride and increased duration of double support are mainly related to the fear of falling and not the actual risk of falling [24].

3.2. Kinematic Parameters

The increase of joint ROM at the anterior-posterior plane could be attributed to the reduction of spasticity of the extensor muscles and/or to the improvement of flexor muscle strength. An alternative explanation is improved balance. The latter may have rendered the patient more confident, without the need to keep the lower limb close to the floor through an incomplete triple flexion during the swing phase, so as to react promptly in case of imbalance. Thus, released from the fear of falling, she could achieve more effective triple flexion [22].

3.3. Kinetic Parameters

The patient achieved increased moments during the support phase, probably due to her increased strength [22]. Increased gait velocity explains the power waveform improvement in all 3 joints bilaterally [25].

In conclusion, the exercise programme that was based on AHA/ASA guidelines had a positive effect on this patient's gait pattern. There was an increase in spatial and decrease in temporal gait parameters, increase in joint ROM and lower limb muscle powers during the entire gait cycle and increase in the moments during the support phase. These findings are indicative of the effectiveness of the above exercise programme on the gait pattern of patients with chronic stroke. A study on the effects of exercise in more patients with different levels of disability and during different rehabilitation phases will allow drawing safe conclusion and generalise the findings.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Mozaffarian, D., Benjamin, E., Go, A., Arnett, D., Blaha, M., Cushman, M., Mohler, E., *et al.* (2015) Heart Disease and Stroke Statistics—2015 Update: A Report from the American Heart Association. *Circulation*, **131**, e29-e322. https://doi.org/10.1161/CIR.0000000000000152

[2] Lee, K., Lim, S., Kim, K., Kim, K., Kim, Y., Chang, W., Hwang, B., *et al.* (2015) Six-Month Functional Recovery of Stroke Patients: A Multi-Time-Point Study. *International Journal of Rehabilitation Research*, **38**, 173-180. https://doi.org/10.1097/MRR.0000000000000108

[3] Kwakkel, G., Kollen, B. and Wagenaar, R. (2001) Long Term Effects of Intensity of Upper and Lower Limb Training after Stroke: A Randomised Trial. *Journal of Neurology, Neurosurgery, and Psychiatry*, **72**, 473-479.

[4] Go, A., Mozaffarian, D., Roger, V., Benjamin, E., Berry, J., Blaha, M., Mackey, R., *et al.* (2014) Heart Disease and Stroke Statistics—2014 Update: A Report from the American Heart Association. *Circulation*, **129**, e28-e292. https://doi.org/10.1161/01.cir.0000441139.02102.80

[5] Hornnes, N., Larsen, K. and Boysen, G. (2010) Little Change of Modifiable Risk Factors 1 Year after Stroke: A Pilot Study. *International Journal of Stroke*, **5**, 157-162. https://doi.org/10.1111/j.1747-4949.2010.00424.x

[6] Michael, K., Allen, J. and Macko, R. (2005) Reduced Ambulatory Activity after Stroke: The Role of Balance, Gait, and Cardiovascular Fitness. *Archives of Physical Medicine and Rehabilitation*, **86**, 1552-1556. https://doi.org/10.1016/j.apmr.2004.12.026

[7] Ashe, M., Miller, W., Eng, J. and Noreau, L. (2009) Older Adults, Chronic Disease and Leisure-Time Physical Activity. *Gerontology*, **55**, 64-72. https://doi.org/10.1159/000141518

[8] Goljar, N., Burger, H., Vidmar, G., Leonardi, M. and Marincek, C. (2011) Measuring Patterns of Disability Using the International Classification of Functioning, Disability and Health in the Post-Acute Stroke Rehabilitation Setting. *Journal of Rehabilitation Medicine*, **43**, 590-601. https://doi.org/10.2340/16501977-0832

[9] Rand, D., Eng, J., Tang, P., Jeng, J. and Hung, C. (2009) How Active Are People with Stroke? Use of Accelerometers to Assess Physical Activity. *Stroke*, **40**, 163-168. https://doi.org/10.1161/STROKEAHA.108.523621

[10] Sullivan, K. and Cen, S. (2011) Model of Disablement and Recovery: Knowledge Translation in Rehabilitation Research and Practice. *Physical Therapy*, **91**, 1892-1904. https://doi.org/10.2522/ptj.20110003

[11] Macko, R., Ivey, F., Forrester, L., Hanley, D., Sorkin, J., Katzel, L., Goldberg, A., *et al.* (2005) Treadmill Exercise Rehabilitation Improves Ambulatory Function and Cardiovascular Fitness in Patients with Chronic Stroke: A Randomized, Controlled Trial. *Stroke*, **36**, 2206-2211. https://doi.org/10.1161/01.STR.0000181076.91805.89

[12] Pang, M., Eng, J., Dawson, A., McKay, H. and Harris, J. (2005) A Community-Based Fitness and Mobility Exercise Program for Older Adults with Chronic Stroke: A Randomized, Controlled Trial. *Journal of the American Geriatrics Society*, **53**, 1667. https://doi.org/10.1111/j.1532-5415.2005.53521.x

[13] Roth, E. (1994) Heart Disease in Patients with Stroke, Part II: Impact and Implications for Rehabilitation. *Archives of Physical Medicine and Rehabilitation*, **75**, 94-101.

[14] Billinger, S., Arena, R., Bernhardt, J., Eng, J., Franklin, B., Johnson, C., Roth, E., *et al.* (2014) Physical Activity and Exercise Recommendations for Stroke Survivors. *Stroke*, **45**, 2532-2553. https://doi.org/10.1161/STR.0000000000000022

[15] Patterson, K. (2010) Gait Asymmetry Post-Stroke. University of Toronto, Toronto.

[16] Seireg, A. and RJ, A. (1975) The Prediction of Muscular Load Sharing and Joint Forces in the Lower Extremities during Walking. *Journal of Biomechanics*, **8**, 89-102. https://doi.org/10.1016/0021-9290(75)90089-5

[17] van Tunen, J., Dell'Isola, A., Juhl, C., Dekker, J., Steultjens, M., Thorlund, J. and Lund, H. (2018) Association of Malalignment, Muscular Dysfunction, Proprioception, Laxity and Abnormal Joint Loading with Tibiofemoral Knee Osteoarthritis—A Systematic Review and Meta-Analysis. *BMC Musculoskeletal Disorder*, **19**, 273. https://doi.org/10.1186/s12891-018-2202-8

[18] Thompson, W., Gordon, N. and Pescatello, L. (2009) American College of Sports Medicine—ACSM's Guidelines for Exercise Testing and Prescription (Eighth Edition). Lippincott Williams & Wilkins, Philadelphia.

[19] Fotiadou, S., Aggeloussis, N., Gourgoulis, V., Malliou, P., Papanas, N., Giannakou, E. and Piperidou, H. (2018) Reproducibility of Gait Kinematics and Kinetics in Chronic Stroke Patients. *Neurorehabilitation*, **42**, 53-61. https://doi.org/10.3233/NRE-172195

[20] Carr, J. and Shepherd, R. (2003) Stroke Rehabilitation: Guidelines for Exercise and Training to Optimize Motor Skill. Butterworth-Heinemann, Oxford.

[21] Dobkin, B. (1999) An Overview of Treadmill Locomotor Training with Partial Body Weight Support: A Neurophysiologically Sound Approach Whose Time Has Come for Randomized Clinical Trials. *Neurorehabilitation and Neural Repair*, **13**, 157-165. https://doi.org/10.1177/154596839901300301

[22] Olney, S. and Richards, C. (1996) Hemiparetic Gait Following Stroke. Part I: Characteristics. *Gait and Posture*, **4**, 136-148. https://doi.org/10.1016/0966-6362(96)01063-6

[23] Espy, D., Yang, F., Bhatt, T. and Pai, Y. (2010) Independent Influence of Gait Speed and Step Length on Stability and Fall Risk. *Gait Posture*, **32**, 378-382. https://doi.org/10.1016/j.gaitpost.2010.06.013

[24] Teixeira-Salmela, L., Nadeau, S., Mcbride, I. and Olney, S. (2001) Effects of Muscle Strengthening and Physical Conditioning Training on Temporal, Kinematic and Kinetic Variables during Gait in Chronic Stroke Survivors. *Journal of Rehabilitation Medicine*, **33**, 53-60. https://doi.org/10.1080/165019701750098867

[25] Olney, S., Griffin, M., Monga, T. and McBride, I. (1991) Work and Power in Gait of Stroke Patients. *Archives of Physical Medicine and Rehabilitation*, **72**, 309-314.