GAIT KINEMATIC PARAMETERS WITH DIFFERENT ARM MOVEMENTS IN STROKE PATIENTS

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ABSTRACT

Background: Stroke is one of the main leading causes of morbidity and mortality worldwide. The upper limb swing function during walking has not yet been clarified, and still subject of debate.

Aim: the purpose of this study was to compare between different arm restraining conditions on spatiotemporal gait parameters in stroke patients.

Methods: thirty male patients with chronic stroke participated in this study in Neurological Rehabilitation Clinic, Faculty of physical therapy, Cairo university- Egypt. All patients performed over ground ten-meter walk test (10-MWT) without any assistive devices at self-selected comfortable walking speed (SSCWS) in three different conditions: normal arm swing, affected arm restraining using arm sling and powerful arm swing randomly for three trails each to calculate average walking speed. The same speed calculated was set on the treadmill of Biodex Gait Trainer 2 TM system in meter per second (m/sec.) Subjects performed a three-minute walk under each of the previous conditions randomly for recording spatiotemporal gait parameters.

Results: Manova with repeated measures were conducted to investigate the effect of the three different conditions on spatiotemporal gait parameters. Normal swing vs arm sling, Normal swing vs powerful swing and arm sling vs powerful swing are significant in walking speed (m/s), Total distance (m), Step cycle (cycle/s) and Ambulation index parameters, while non-significant in step length of the affected side (m) and step length of the non-affected side (m) parameters.

Conclusion: Powerful arm swing seems to be a good choice to improve spatiotemporal gait parameters in chronic stroke patients.

Key words: Stroke- Biodex gait trainer2 TM system- Spatiotemporal gait parameters- Ten- meter walk test.

I. INTRODUCTION

Stroke had been reported that about two million people suffer from stroke every year1. It also can cause difficulty in activities of daily living (ADL)2. Human locomotion involves the smooth advancement of Centre of gravity (COG) with the least amount of mechanical and physiological energy expenditure This natural movement requires interaction between lower limbs, trunk, and upper limbs3.

Arm swing is considered as a distinctive apparent characteristic of human walking. Arms tend to swing out of phase with legs. It has several positive effects as improving metabolic efficiency by generating a torque that opposes the
contralateral swing leg, and enhancing balance, equilibrium, and postural control for smoothing the walking motion. It significantly affects gait performance. Slow velocity, decreased cadence, prolonged swing duration on the paretic side, prolonged stance duration on the non-paretic side, and step length asymmetry are the most common spatiotemporal patterns of hemiparetic gait compared with healthy subjects.

Other studies suggest that wearing hemi-sling for long periods impedes functional activities and intensifies flexor synergy. Some studies suggested that powerful swing of upper extremities instead of natural movement is more helpful for improving weight shifting of the trunk, and gait velocity because of the activation of latissimus dorsi muscle and gluteus maximus that are connected by the thoracolumbar fascia.

This connection can make it possible to transfer the force, enhance trunk rotation and reduce vertical displacement of the pelvis on the most affected side. On the opposite hand, most studies on gait tend to ignore arm swing at all and reported that the swing of the upper limbs does not improve walking stability. It was suggested that arm swing was entirely passive, due to inertia, gravity, and the movements of the thorax, pelvis, and lower limbs.

This study was designed to compare between different arm restraining conditions on spatiotemporal gait parameters in stroke patients to take it into consideration during gait rehabilitation post stroke.

II. MATERIALS AND METHODS

Sample Size:
The sample size for this study was calculated by using the G*power program 3.1.9 (G power program version 3.1, Heinrich-Heine-University, Düsseldorf, Germany) for a one-tailed test. Sample size calculation was based on F tests (MANOVA: Special effects and interactions), Type I error (α) = 0.05, power (1-β error probability) = 0.80, Pillai V = 0.6650, and effect size f2 (V) = 0.199423, with 2 independent groups’ comparison for 4 major variable outcomes. The appropriate minimum sample size was 30 patients.

Participants:
This cross-sectional study was administered over three months from October 2020 to December 2020. Thirty male patients suffering from chronic stroke were participated in this study. The patients were diagnosed and referred from a neurologist. Computed tomography scan and/or MRI was used to confirm the diagnosis. The patients were selected from Outpatient Clinic of Faculty of physical therapy, Cairo University and EL-Kasr EL-Ainy Hospital in Egypt. This study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Faculty of Physical Therapy Ethical Committee, Cairo University, Egypt (P.T. REC/012/002784) and informed consent was obtained from all subjects involved in the study.

Inclusion criteria: The patient's age ranges from 45 to 60 years old. Duration of illness from six months to two years post stroke. Patients with sufficient cognitive abilities that enables them to understand and follow instructions. Body Mass Index less than thirty. Upper and Lower limb spasticity will be ranged from one to one plus according to modified Ashworth scale. and Brunnstrom stage of recovery for the upper, lower extremities: IV, V.

Exclusion Criteria: The patients were excluded if they had neurological diseases that affect gait other than unilateral stroke (e.g.: Multiple sclerosis, Peripheral neuropathy, Parkinsonism…. etc.). Musculoskeletal disorders affecting gait kinematics such as severe arthritis, knee surgery, total hip joint replacement, lower limb fractures less than 6 months or contractures of fixed deformity, leg length discrepancy. Cardiovascular problems or medical contraindications to performing treadmill walking. (unstable angina, recent myocardial infarction within the last three months, congestive heart failure, significant heart valve dysfunction, or unstable hypertension) or pulmonary disorders. Shoulder subluxation. Visual, auditory problems. And cognitive impairment.

Clinical Evaluation:
All the patients signed an informed consent form after receiving information on the study purpose, procedure, possible benefits and risks, privacy and use of data then the following assessment steps were applied: All the
patients perform overground 10-MWT without any assistive devices over a 15-m walkway. 2.5 meters were provided prior to and following the timed portion to allow acceleration and deceleration to occur outside the timed region (10 meters) at self-selected speed in 3 different conditions: normal arm swing, affected arm restraining with arm sling and powerful arm swing randomly for 3 trails each to calculate average walking speed (m/s). The same speed calculated was set on the treadmill of Biodex Gait Trainer 2 TM system in meter per second (m/sec.) The participants walked on the treadmill for three minutes to familiarize themselves with treadmill walking. Treadmill walking speed was adjusted if the participant feels that the speed was not the comfortable walking speed. Subjects performed a 3-minute walk under each of the previous conditions randomly with time interval 20 minutes between tests for recording of average time on affected side during gait cycle.

**Statistical Analysis**

Descriptive statistics in form of mean, standard deviation, median, interquartile range and frequency was conducted for the subject’s characteristics. One-way MANOVA with repeated measures was conducted to compare the spatiotemporal parameters between the normal arm swing, with arm sling and bilateral reinforced arm swing. Significant results were followed by Bonferroni correction test for pairwise comparison. The level of significance for all statistical tests was set at p < 0.05. All statistical tests were performed through the statistical package for social studies (SPSS) version 22 for windows. (IBM SPSS, Chicago, IL, USA).

### III. RESULTS

Thirty-seven stroke patients were screened for eligibility. One did not match the specified inclusion criteria of the study, six refused to provide consent, and the remaining 30 patients completed the study.

**Subject Characteristics**

Thirty male subjects with chronic stroke participated in this study. 11 (37%) subjects had the right side affected and 19 (63%) subjects had the left side affected. 10 (33%) subjects had grade I spasticity and 20 (67%) subjects with grade I+ in upper limb while 15 (50%) subjects had grade I and 15 (50%) subjects had grade I+ for lower limb. The participant characteristics of the study group showed on Table 1 Effect of different arm conditions on the spatiotemporal parameters

MANOVA with repeated measures was conducted to investigate the effect of arm swing condition on spatiotemporal parameters. There was a significant effect of arm swing condition on spatiotemporal parameters (F = 23.86, p = 0.001). There was a significant increase in walking speed, total distance and ambulation index at powerful arm swing compared with that at normal and arm sling conditions (p < 0.01) and significant increase in walking speed, total distance and ambulation index at normal arm swing compared with that at sling arm condition (p < 0.001). There was a significant increase in step cycle at powerful and normal arm swing compared with that at sling arm (p < 0.05), while there was no significant difference between normal and powerful arm swing conditions (p > 0.05).

<table>
<thead>
<tr>
<th>Table (1) Basic characteristics of participants.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ±SD</td>
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<tr>
<td>----------</td>
</tr>
<tr>
<td>Age (years)</td>
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<tr>
<td>Weight (kg)</td>
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<tr>
<td>Height (cm)</td>
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<tr>
<td>BMI (kg/m²)</td>
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<tr>
<td>Duration of Illness (Months)</td>
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<tr>
<td>MMS</td>
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</tbody>
</table>
SD, standard deviation, MMS, Mini Mental Scale

There was a significant increase in step length of the affected side at normal arm swing compared with that at sling and powerful swing conditions (p < 0.001) while there was no significant difference in step length of the affected side between sling arm and powerful arm swing conditions (p > 0.05). There was no significant difference in step length of the non-affected side between the three conditions (p > 0.05) as showed on table (2).

Table 2. Mean of the spatiotemporal parameters at different arm conditions.

<table>
<thead>
<tr>
<th></th>
<th>Normal mean ± SD</th>
<th>Sling mean ± SD</th>
<th>Powerful mean ± SD</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking speed (m/s)</td>
<td>0.89 ± 0.17</td>
<td>0.77 ± 0.14</td>
<td>0.99 ± 0.18</td>
<td>0.001</td>
</tr>
<tr>
<td>Total distance (m)</td>
<td>154.43 ± 29.4</td>
<td>137.26 ± 27.52</td>
<td>173.63 ± 33.85</td>
<td>0.001</td>
</tr>
<tr>
<td>Step cycle (cycle/s)</td>
<td>0.82 ± 0.1</td>
<td>0.76 ± 0.13</td>
<td>0.87 ± 0.11</td>
<td>0.02</td>
</tr>
<tr>
<td>Step length of the</td>
<td>0.54 ± 0.09</td>
<td>0.46 ± 0.08</td>
<td>0.46 ± 0.08</td>
<td>0.99</td>
</tr>
<tr>
<td>affected side (m)</td>
<td>0.56 ± 0.11</td>
<td>0.55 ± 0.12</td>
<td>0.59 ± 0.17</td>
<td>0.26</td>
</tr>
<tr>
<td>Ambulation index</td>
<td>81.6 ± 11.65</td>
<td>78.36 ± 12.04</td>
<td>84.43 ± 9.76</td>
<td>0.001</td>
</tr>
</tbody>
</table>

SD, Standard deviation; p-value, Level of significance

Normal swing vs arm sling, Normal swing vs powerful swing and arm sling vs powerful swing are significant in walking speed (m/s), Total distance (m), Step cycle (cycle/s) and Ambulation index parameters, while non-significant in step length of the affected side (m) and step length of the non-affected side (m) parameters.

IV. DISCUSSION

The current study was conducted to compare between different arm restraining conditions on spatiotemporal gait parameters in chronic stroke patients to consider it during gait rehabilitation. The result revealed a significant increase in the average walking speed during walking with powerful arm swing in comparison with walking with normal arm swing or during walking with affected arm restraining using arm sling. This result agreed with Kim et al. which studied the effects of swing speed of upper extremities during gait on the muscle activation in lower extremities. There was a significant change of muscle activation of latissimus dorsi and gluteus maximus muscles which are connected through thoraco-lumbar fascia according to the swing speed. There was significant change of those muscles during natural according to the extinction of loading on upper extremities. Also, with Kim and Kwon which reported that when intended swing movement of upper extremities increased not only spatiotemporal gait parameters but also significant improvement of gait speed.

In the current study, it was concluded that walking with reinforced arm swing improves the contraction of latissimus dorsi, resulting in the increase of gait speed. This result contradicted with Fayez & El-wishy which studied found that arm sling has positive effects in enhancing gait patterns especially during gait training sessions in hemiparetic patients who have excessive motion of COG and increase walking speed by playing it which is a very important role as a feedback tool or a reminder of the patient's arm to assist postural adjustments in patients with impaired body image.
The discrepancy between the present and Fayez & El-wishy may be due to difference of stages of recovery according to Brunnstrom of upper limbs for subjects participated in both studies in their study. Brunnstrom stages of recovery for upper extremities was less than or equal to stage III rather, in current study Brunnstrom stages of recovery for upper extremities was stage IV or V and the patients were excluded if they have shoulder pain or subluxation. So, in this study it was suggested that swinging the upper limbs may change depending on the severity of paralysis of both upper and lower limbs. This means that powerful arm swing is one of the preferred methods in improving gait speed in chronic hemiparetic stroke patients during gait rehabilitation sessions.

The result of the current study revealed a significant increase in the average total distance spent in three minutes during walking with bilateral reinforced arm swing in comparison with walking with normal arm swing or during walking with affected arm restriction using arm sling. This means that powerful arm swing has positive effect in improving distance of walking. While there is no significant difference between walking with bilateral reinforced or normal arm swing, but when looking at measured values, number of cycles was more in powerful than normal arm swing.

This result agreed with Fukuchi Cavan et al. which reported that all the spatiotemporal gait parameters were generally affected by walking speed in all age groups (children, young adults, old adults), with large effect sizes. Cadence and stride length had been reported as key determinants of walking speed in human locomotion, so it was confirmed that cadence (steps/min) and stride length increased as the speed increased\(^\text{12}\).

A significant decrease of average step length on the affected side during walking with powerful arm swing than walking with normal arm swing was observed in the current study. This result agreed with Punt et al. which confirmed that excessive arm swing significantly increases local dynamic stability of human gait\(^\text{13}\).

It was assumed that people with an increased risk of falling should swing their arms excessively. It was thought that powerful arm swing reduces ground reaction moments which probably reduces energy costs, because these moments do not reach zero when using a normal arm swing in hemiplegic patients\(^\text{14}\).

A significant decrease of average step length on the affected side during walking with affected arm restriction using arm sling than walking with normal arm swing was observed in this study. This result agreed with Yavuzer and Ergin who was reported that the double support time of the paretic side and excursion of COG decreased in sagittal, coronal, and transverse planes. Arm slings could serve as a feedback mechanism to remind the patient of his arm, helping postural adaptations and correction for patients who have attention deficit or paretic side neglect\(^\text{15}\).

This result also agreed with Hong et al. who demonstrated that the step length of the paretic side was reduced from 39.61 ± 11.33 cm during walking with normal arm swing and spontaneous speed to 37.47 ± 12.03 cm during walking with arm sling that affected arm restricted in anterior direction and sound side restricted in posterior direction\(^\text{16}\).

**Limitations**

1. Further studies are required on a bigger sample size and for longer durations of treatment.
2. Patients with subluxation of shoulder and shoulder pain were excluded, there is a difficulty generalizing the result to all stroke patients.
3. Subjects included in this study were only males then the results were difficult to be generalized to all stroke patients.
4. This study included patients only with mild spasticity, so the results were difficult to be generalized to stroke patients with more marked spasticity.
V. CONCLUSIONS

Powerful arm swing significantly improves spatiotemporal gait parameters in chronic stroke patients. so, it is recommended to motivate the patient to swing arm powerfully as much as can during gait training sessions.

Acknowledgments:
The authors acknowledge all patients and their family for their co-operation. Also, we acknowledge our collages in Neurological Rehabilitation Clinic, Faculty of physical therapy, Cairo university- for their help.

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