# Effects of Inclined Treadmill Training on Gait and Balance in Stroke Patients

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**Abstract: Background:** Stroke is the most leading cause to functional disability and gait problems.**Objectives:** The purpose of this study was to determine the effect of inclined treadmill training on balance and kinematic characteristics of gait in stroke patients.**Methods:** Thirty male stroke patients participated in this study. The patients were assigned randomly into two equal groups, (study and control). Patients in the study group received treadmill training with 10% of inclination in addition to selected physical therapy program for Stroke patients. Patients in the control group received treadmill training without inclination in addition to the selected physical therapy program including: strengthening exercises, PNF technique, stretching exercises.**The Outcome Measures:** Biodex gait trainer 2 TM was used to assess selected gait kinematics (walking speed, step length of paretic leg, step length of non-paretic leg, time on paretic foot and time on non-paretic foot) before and after six weeks training period (end of treatment) for both groups. Biodex Balance System SD was used to assess patients balance (Overall stability index). **Results**: There was a statistical significant improvement in balance and gait speed post training in the study group. There was no statistical difference between both groups in step length of paretic, non-paretic legs and time on paretic and non-paretic feet. There was a statistical significant increase in step length of paretic and non-paretic leg in the study group. There was statistical significant increase in time on paretic leg and decrease time on non-paretic leg on both groups.**Conclusion:** Inclined treadmill training is effective in improving balance and selected gait kinematics in stroke patients when added to the selected physical therapy program.

## 1. Introduction

The World Health Organization (WHO) defined stroke as a clinical syndrome characterized by rapidly developing clinical symptoms and/ or signs of focal (or global) disturbance of cerebral function, with symptoms lasting 24 hours or longer or leading to death, with no apparent cause other than of vascular origin (1).

Stroke is a leading cause of disability world-wide. Common stroke-related impairments, such as loss of strength, sensation and coordination, lead to difficulties in walking, balance, and upper limb function. This can have a significant impact on an individual's independence, safety and quality of life. Therefore, the implementation of effective interventions to optimize recovery is critical. Physical therapy has been shown to aid recovery after stroke. A recent systematic review and metaanalysis demonstrates strong evidence in favor of physical therapy interventions for gait training, balance, upper limb function, activities of daily living and physical fitness. Although the optimal dosage and type of activity for improving outcomes after stroke remains unclear, research generally favors intensive and repetitive task specific training (2).

Gait in patients after stroke is characterized by reduced preferred walking speed, cadence, and stride length as well as reduced symmetry, prolonged stance duration on the non-paretic side and reduced step length on the paretic side (3).

Following stroke, patients lose functions of the motor, sensory and higher brain cognitive faculties to various degrees which lead to diminished balance. It has been documented that hemiplegic or hemiparetic stroke patients presented with more posture sway, asymmetric weight distribution, impaired weight-shifting ability and decreased stability capability (4).

A treadmill is one of the most frequently used training devices for optimizing dynamic balance skills during locomotion. A balance-training program incorporating a treadmill has been proven to be superior to traditional neuromuscular rehabilitation

methods in improving the balance skill of patients who had stroke (5).

Inclined surfaces poses significant challenges to the locomotor control system, in addition to resulting in substantial complications for subjects with pathologic gait caused by neurologic impairment. Thus, kinematic alterations and possible adjustments in limb trajectory may lead to a decrease in compensatory strategies and, in turn, to a decrease in energetic cost, greater access to certain environments, and reduced risk of falling (6).

## 2. Methodology

Thirty male stroke patients participated in this study. The patients were selected from outpatient clinic of physical therapy of the faculty of Physical Therapy Cairo University. The patients were diagnosed as having cerebrovascular stroke in the domain of carotid artery based on neurological examination, radiological investigation as CT and MRI. The patients were divided randomly into two equal groups (Group A) was the study group that was treated by inclined treadmill training in addition to selected physical therapy program and (Group B) was the control group that was treated by treadmill training without inclination in addition to the same selected physical therapy program.

**The patients were chosen under the following criteria:**
- Patient's age ranges from 40-60 years.
- Duration of illness > 6 months after stroke.
- Spasticity of lower limbs ranges from (grade 1:1+) according to modified Aschworth scale.
- Muscle power of the affected lower limb not less than grade 3 according to manual muscle test.
- Body Mass Index $\leq 30$.
- Ability of the patient to walk without assistive device for at least 10 meters.
- Patients with sufficient cognitive abilities that enable them to understand and follow instructions (Mini-Mental Scale >24).

- **The Current study excluded patients who have:**
- Neurological diseases that affect gait other than stroke (e.g.: Multiple sclerosis, Peripheral neuropathy, Parkinsonism…etc.).
- Musculoskeletal disorders (deformity or contracture) which may limit gait ability.
- Cardiovascular problems (unstable angina, recent myocardial infarction within the last three months, congestive heart failure, significant heart valve dysfunction, or unstable hypertension) or pulmonary disorders.
- Medically unstable or uncooperative patients.

- Cognitive impairments (Mini-Mental Scale <24).

A verbal explanation about the important justification and main points of achievement of the study was explained to every patient.

**The procedures of the current study were divided into two main categories:**

**Measurement procedures:**

**a) Initial evaluation procedures (initial phase)**
- Each patient was examined medically in order to exclude any abnormal medical problems which previously mentioned.
- Each patient's history was taken in previously prepared questionnaire to collect information about, name, age, BMI and determination about any functional, social, psychological problems.
- The purpose of evaluation procedures were explained in steps for each patient in each group.

**b) Technical measurements phases**

The patients were assessed before and after the study using:

**Biodex gait trainer 2 TM treadmill:** was used for assessment of kinematic gait parameters including walking speed (m/sec), step length of paretic leg (m), step length of non-paretic leg (m), time on paretic foot (%) and time on non-paretic foot (%). Each patient was allowed to be familiar with the gait trainer before starting the recording by allowing him to walk over the tread belt of the device for continuous three to five minutes. To start the evaluation process, the tread belt will ramp up slowly to 0.3 m/hour (by default). Then the therapist increases the speed gradually to be comfortable for each patient and allow him to walk for continuous four minutes. The gait parameters values then can be displayed on the display. Each step of the evaluative procedure was practiced three times with a rest period in between and the average was taken.

**Biodex Balance System SD:** was used to assess balance pre and post treatment at the Biodex lab: The Overall Stability Index was measured. The protocol used is as follows: TEST DURATION: 20 seconds LEVEL: 8 TRIALS: 5REST BETWEEN TRIALS: 30 seconds STANCE.

**Therapeutic Procedures:**

**Group A**

Patients in this group received selected physical therapy program in addition to treadmill gait training with 10% of inclination 20-min training sessions three times a week for six weeks (18 sessions in total), patients will be allowed to rest if necessary.

**Group B**

The patients in this group received the selected physical therapy program in addition to treadmill gait training without inclination 20-min training sessions

three times a week for six weeks (18 sessions in total); patients will be allowed to rest if necessary.

**Selected physical therapy program**

- Strengthening exercises for weak upper limb muscles mainly (shoulder flexors, elbow extensors and wrist extensors)
- Strengthening exercises for weak lower limb muscles mainly (hip flexors & abductors, knee flexors & extensors and ankle dorsiflexors).
- Stretching exercises for the affected lower limb muscles mainly (hip adductors, knee flexors and ankle planter flexors. Repetition of each exercise was ranged from three to five times according to each patient ability.
- Proprioceptive Neuromuscular Facilitation technique.

**Statistical Analysis**

Statistical analysis was conducted by using SPSS for windows, version 22 (SPSS, Inc., Chicago, IL). The current test involved two independent variables. The test involved six tested dependent variables (Overall stability index, Average walking speed, step length of paretic leg, step length of non-paretic, Time on right foot and Time on left foot). 2x2 mixed MANOVA test was used to compare the tested variables of interest at different measuring periods at both groups. With the initial alpha level set at 0.05.

**3. Results**

No significant differences in demographical (age and gender) or clinical (duration of illness) variables at inclusion were detected between groups (Table 1).

**Table (1): General characteristics of both groups (A & B).**

| Items | Group A | Group B | Comparison | | S |
|---|---|---|---|---|---|
| | Mean ± SD | Mean ± SD | t-value | P-value | |
| Age (years) | 55.66±3.51 | 55.46±4.79 | 0.13 | 0.897 | NS |
| Body mass (Kg) | 71.66±6.65 | 76.2±7.47 | -1.755 | 0.09 | NS |
| Height (cm) | 163.6±4.4 | 165.46±2.58 | -1.415 | 0.168 | NS |
| Duration of illness (years) | 2.2±1.08 | 2.2±0.86 | 0.000 | 0.999 | NS |

*SD: standard deviation, P: probability, S: significance, NS: non-significant.

There was a statistical significant increase in overall stability index and gait speed post training in the study group (Table2, 3). There was no statistical difference between both groups in step length of paretic, non-paretic legs and time on paretic and non-paretic feet (Table 4, 5, 6, 7). There was statistical significant increase in step length of paretic, non-paretic in the study group (Table 4, 5). There was statistical significant increase in time on paretic leg and decrease time on non-paretic leg on both groups (Table 6, 7).

**Table (2): Mean ±SD and p values of Overall stability index pre and post-test at both groups.**

| Overall stability index | Pre test | Post test | MD | % of change | p- value |
|---|---|---|---|---|---|
| | Mean± SD | Mean± SD | | | |
| Group A | 3.32±0.97 | 2.18 ±0.77 | 1.14 | 34.33 | 0.0001* |
| Group B | 3.55 ±1.03 | 3.44±0.81 | 0.11 | 3.09 | 0.46 |
| MD | -0.22 | -1.25 | | | |
| p- value | 0.541 | 0.0001* | | | |

*Significant level is set at alpha level <0.05 SD: standard deviation
MD: Mean difference p-value: probability value

**Table (3): Mean ±SD and p values of Average walking speed pre and post-test at both groups.**

| Average walking speed (meters/sec ) | Pre test | Post test | MD | % of change | p- value |
|---|---|---|---|---|---|
| | Mean± SD | Mean± SD | | | |
| Group A | 0.39±0.04 | 0.46 ±0.05 | -0.08 | 20.51 | 0.0001* |
| Group B | 0.4 ±0.07 | 0.41±0.068 | -0.001 | 0.25 | 0.247 |
| MD | -0.011 | 0.06 | | | |
| p- value | 0.628 | 0.012* | | | |

*Significant level is set at alpha level <0.05          SD: standard deviation
MD: Mean difference          p-value: probability value

**Table (4): Mean ±SD and p values of step length of paretic leg pre and post-test at both groups.**

| step length of paretic leg (meters) | Pre test Mean± SD | Post test Mean± SD | MD | % of change | p- value |
|---|---|---|---|---|---|
| Group A | 0.46±0.11 | 0.56 ±0.08 | -0.1 | 21.73 | 0.0001* |
| Group B | 0.47±0.10 | 0.51±0.09 | -0.04 | 8.51 | 0.173 |
| MD | -0.011 | 0.057 | | | |
| p- value | 0.779 | 0.083 | | | |

*Significant level is set at alpha level <0.05          SD: standard deviation
MD: Mean difference          p-value: probability value

**Table (5): Mean ±SD and p values of step length of Non-paretic leg pre and post-test at both groups.**

| step length of non-paretic leg (meters) | Pre test Mean± SD | Post test Mean± SD | MD | % of change | p- value |
|---|---|---|---|---|---|
| Group A | 0.23±0.11 | 0.32 ±0.08 | -0.09 | 39.13 | 0.0001* |
| Group B | 0.28 ±0.10 | 0.31±0.09 | -0.03 | 10.71 | 0.059 |
| MD | -0.044 | 0.012 | | | |
| p- value | 0.295 | 0.717 | | | |

*Significant level is set at alpha level <0.05          SD: standard deviation
MD: Mean difference          p-value: probability value

**Table (6): Mean ±SD and p values of Time on paretic foot pre and post-test at both groups.**

| Time on paretic foot (%) | Pre test Mean± SD | Post test Mean± SD | MD | % of change | p- value |
|---|---|---|---|---|---|
| Group A | 40.8±6.34 | 44.33±5.34 | -3.53 | 8.65 | 0.0001* |
| Group B | 39.06 ±8.17 | 41.86±6.93 | -2.8 | 7.16 | 0.0001* |
| MD | 1.73 | 2.47 | | | |
| p- value | 0.522 | 0.284 | | | |

*Significant level is set at alpha level <0.05          SD: standard deviation
MD: Mean difference          p-value: probability value

**Table (7): Mean ±SD and p values of Time on non-paretic foot pre and post-test at both groups.**

| Time on non-paretic foot (%) | Pre test Mean± SD | Post test Mean± SD | MD | % of change | p- value |
|---|---|---|---|---|---|
| Group A | 59.2±6.34 | 55.66 ±5.34 | 3.54 | 5.97 | 0.0001* |
| Group B | 60.93±8.17 | 58.13±6.93 | 2.8 | 4.59 | 0.0001* |
| MD | -1.7 | -2.46 | | | |
| p- value | 0.552 | 0.284 | | | |

*Significant level is set at alpha level <0.05          SD: standard deviation
MD: Mean difference          p-value: probability value

## 4. Discussion

The present study was conducted to examine the effect of inclined treadmill training on improving balance and selected gait kinematics in stroke patients. Thirty male patients suffered from hemiparesis due to cerebrovascular stroke participated in this study. The patients were randomly assigned into two equal groups: the study group (group A) and the control group (group B). The study group was treated by treadmill training with 10% of inclination and the selected physical therapy program. The control group was treated by treadmill training without inclination in addition to the same selected physical therapy program.

The results of the present study revealed significant difference in the overall stability index post treatment between both groups and the significant reduction was in favor to the study group (group A). The improvement of balance may be due to the fact

that repetitive stepping on a treadmill is an example of task-specific training which allows for highly specific, repetitive practice in a controlled and a stable environment and assists the natural pattern of functional recovery, strengthens the lower paretic limb, restores balance and gait in agreement to that reported by **Tally et al., (2017)** (7)**.**

The results of the present study revealed significant difference in the average walking speed post treatment between both groups and the significant increase was in favor to the study group (group A) The increase in gait velocity may be due to increased step length and cadence in agreement to that reported by **Kelvin and Margaret (2011)** (8)**.**

In stroke patients, shortened step length of the paretic side, may be attributed to impaired propulsion generating capacity, makes gait velocity slow and reduces gait ability **(Balasubramanian et al., 2007)** (9). This impaired propulsion is caused by weakened

muscle strength of the triceps surae muscle and the loss of muscle contraction timing. Recovery of this function would improve gait ability **(Turns et al., 2007)** (10).

The current study showed also a statistical significant increase in step length of the affected leg in the study group at post treatment in compare to pretreatment. In spite of there was no statistical significant difference between group A and group B, there was clinical difference and high percept of improvement in favour to group A. This findings was in agreement with **Gama et al (2015)** who reported that after gait training on an inclined treadmills stroke patients walked faster and took a longer paretic step, which may be because of the reduced pass retract phenomenon and excessive hip flexion during swing phase to provide toe clearance, followed by fast high retract in terminal swing to passively extend the lower leg. When walking on an inclined surface stroke patients may hit the ground earlier, resulting in longer strides Thus, the reduced pass retract phenomenon performed while stroke patients walk on an inclined surface may be transferred to over ground walking after training (11).

The current study showed that there was no significant statistical difference in step length of the non-affected leg between both groups. This findings was in agreement with **Moreno et al (2011)** who reported that spatial-temporal variables including step length, cycle time, step time and paretic limb swing time were minimally affected by inclined treadmill training and this may be caused by the constant speed and speed variability of individuals who walked at a comfortable, self-selected speed (6).

The results of the present study revealed a statistical significant decrease in temporal asymmetry (increase in percent of time on the foot of the paretic side post treatment) in both groups (A and B). These results are in close agreement with **Patterson et al., (2008)** who found that in the paretic limb, significant differences were seen in relative stance, relative single time stance and stance/swing ratio. These variables decrease in the paretic limb during treadmill walking. Interlimb symmetry and relative temporal phasing are also important (12).

## Conclusions

In view of the results of this study, it can be concluded that inclined treadmill training has a beneficial effect on selected gait kinematics and balance in stroke patients, so it is recommended to be added to the physical therapy program for stroke patients who had gait problems.

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