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ORIGINAL RESEARCH ARTICLE

Effects of Treadmill Inclination on Hemiparetic Gait

Controlled and Randomized Clinical Trial

ABSTRACT

Gama GL, de Lucena Trigueiro LC, Simão CR, de Sousa AVC, de Souza e Silva EMG, Viana Pinheiro Galvão ÉR, Lindquist ARR: Effects of treadmill inclination on hemiparetic gait: controlled and randomized clinical trial. Am J Phys Med Rehabil 2015;94:718–727.

Objective: The aim of this study was to analyze the effects of inclined treadmill training on the kinematic characteristics of gait in subjects with hemiparesis.

Design: A blind, randomized, controlled study was conducted with 28 subjects divided into two groups: the control group, submitted to partial body weight–support treadmill gait training with no inclination, and the experimental group, which underwent partial body weight–support treadmill training at 10% of inclination. All volunteers were assessed for functional independence, motor function, balance, and gait before and after the 12 training sessions.

Results: Both groups showed posttraining alterations in balance ($P < 0.001$), motor function ($P < 0.001$), and functional independence ($P = 0.002$). Intergroup differences in spatiotemporal differences were observed, where only the experimental group showed posttraining alterations in velocity ($P = 0.02$) and paretic step length ($P = 0.03$). Angular variables showed no significant differences in either group.

Conclusions: In subjects with hemiparesis, the addition of inclination is a stimulus capable of enhancing the effects of partial body weight–support treadmill gait training.

Key Words: Gait, Stroke, Paresis, Physical Therapy Modalities, Kinematics

Compromised gait significantly limits daily activities and, consequently, restricts the functional independence of individuals with hemiparetic stroke.[1] Thus, gait recovery is considered an important goal in many poststroke rehabilitation programs.[1]

The daunting challenge faced by professionals involved in the rehabilitation of subjects with a history of stroke is to find the ideal stimulus to maximize reorganization of the central nervous system and promote improvements in the functional performance of stroke patients.[2] Literature findings suggest that task-specific training, repetitive execution of a task, specific to the intended outcome, is more effective in recovering function and that treadmill training seems to produce better results than conventional approaches, by recovering isolated components of gait such as lower limb strengthening, weight bearing, and balance.[3]

On the basis of the concept of task-specific training, the use of treadmill has become increasingly popular in stroke rehabilitation.[4–6] In this context, a partial body weight support system (PBWS) is coupled to a treadmill to facilitate lower limb movements by reducing biomechanic overload on lower limbs and promoting better trunk alignment during treadmill training.[5,7] The effects of treadmill training with PBWS on stroke patients have been reported[3,7–12]; however, in subjects with time since stroke onset of greater than 6 mos, overload training seems to produce better results.[4,13,14]

In clinical practice, another therapeutic strategy used in stroke patient rehabilitation is gait training on inclined surfaces, which aims at promoting accessibility, given that walking on inclined surfaces is a challenge commonly faced by individuals with compromised locomotor performance.[15] Moreover, Norman et al.[16] suggested that treadmill modifications in walking training, such as the addition of inclination, may promote better recovery in patients with compromised locomotor performance who have already recovered some walking capacity. However, little scientific evidence supports the effects of gait training on inclined surfaces for gait recovery of stroke patients.

It is known that the locomotor pattern of both healthy subjects[17] and those with hemiparesis[15,18] adapts itself to the level of inclination of the support surface on which gait is performed. When walking on inclined surfaces, subjects with hemiparesis exhibit an increase in maximum hip and knee flexion during the swing phase and initial contact (IC) as well as that of ankle dorsiflexion during IC.[18] There is also an increase in range of motion (ROM) of knee and hip joints. Moreover, they show reduced cadence, greater stride length, higher symmetry in swing time,[15] and an increase in paretic limb stance time.[18]

Adjustments in locomotor pattern on inclined surfaces reduce compensatory movements commonly performed by individuals with hemiparesis, which could promote better accessibility and reduce the number of falls in this population, in addition to decreasing energy costs for carrying out the task.[18] However, it is not known whether these adjustments are transferred to overground gait after a training protocol on an inclined surface.

Thus, given the need to optimize the rehabilitation process of subjects who experienced a stroke, the aim of this study was to investigate the effects of incline treadmill training on the kinematic characteristics of gait in subjects with hemiparesis after 12 sessions and determine whether there are alterations in their locomotor pattern during overground walking. It is suggested that, after the intervention protocol, cadence declines and stride length and symmetry in swing time increases as well as hip and knee ROM in the sagittal plane.

METHODS

A blind, randomized, controlled clinical trial parallel with two arms was conducted. The study followed CONSORT [Consolidated Standards of Reporting Trials] recommendations (Fig. 1) and was approved by the research ethics committee of Onofre Lopes University Hospital (protocol number 0364.0.000.294-11), registered in the Brazilian registry of clinical trials under number RBR-6kcc3w, and entitled “Effects of gait training on sloping surfaces on the gait of individuals with chronic hemiparesis—Randomized controlled trial.” All subjects gave their informed consent. Researcher 1 was responsible for the randomization procedures of subjects and application of intervention protocols, and researcher 2 was responsible for assessment procedures. Neither of them knew which group of subjects was allocated to interventions.

Sample Characterization

The sample consisted of 28 subjects with chronic unilateral hemiparesis after an ischemic or hemorrhagic stroke (more than 6 mos with the lesion), recruited by nonprobabilistic convenience sampling. The sample size was determined from the number of subjects who agreed to participate in training and met the eligibility criteria.

The following inclusion criteria were adopted: absence of orthopedic or pulmonary pathology or other neurologic impairment that could compromise gait or

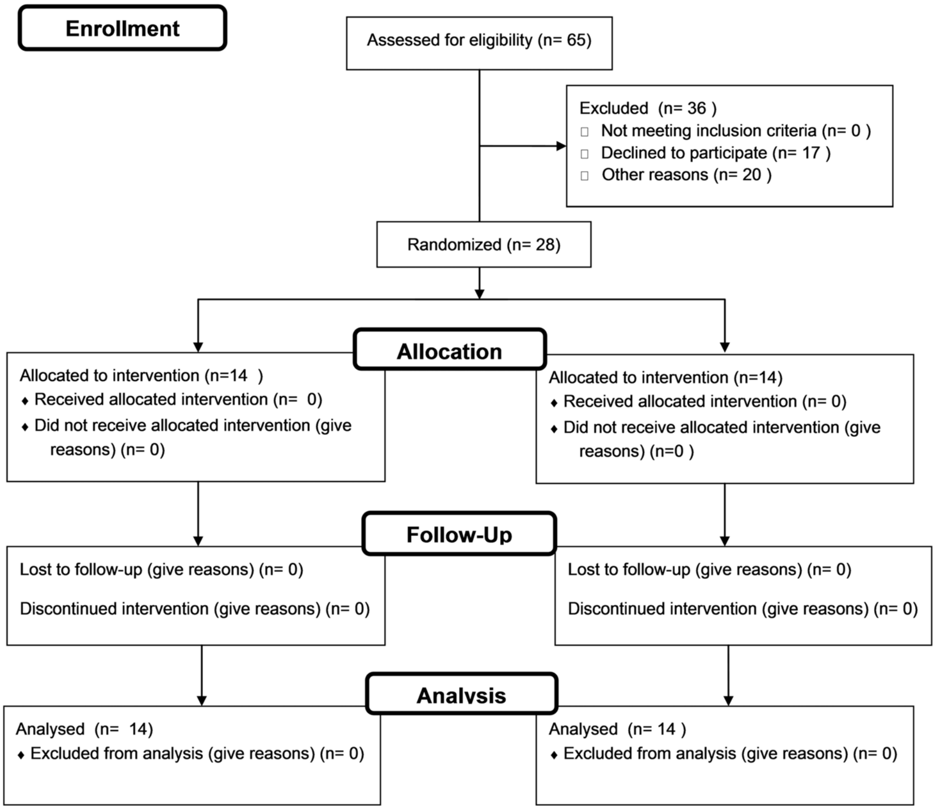

FIGURE 1 *Flow diagram of the study following CONSORT recommendations.*

training; absence of clinical signs of cardiac alterations, arrhythmia, or angina (New York Heart Association, degree 1)[19]; ability to obey simple verbal commands; walking ability classified between levels 3 and 5 by the Functional Ambulatory Category; and spasticity of the affected lower limb classified between levels 0 and 2 according to the Modified Ashworth Spasticity Scale. Exclusion criteria were the presence of any instability in general health status that might pose a significant risk to training and being absent from more than two consecutive training sessions or more than three overall.

Assessment Procedures

Anthropometric and demographic data, such as type of stroke, lesion time, weight, height, and age, were collected from the subjects. Patients were assessed for neurologic status by the National Institutes of Health Stroke Scale, functional independence by the Functional Independence Measure (FIM) motor domain, balance by Berg Balance Scale, and motor skills by the Fugl-Meyer scale lower limb domains.

Gait assessment was performed using the Qualisys System (Qualisys Motion Capture System-Qualisys Medical AB 411 13; Gothenburg, Sweden), a video-based photogrammetry system with eight cameras (Qualisys Oqus 300) interconnected in series and with a data acquisition frequency of 120 Hz.

At this assessment stage, spherical passive reflective markers between 15 and 19 mm wide were placed on the body. Reference markers were placed on the anterosuperior iliac crests, the right and left greater trochanter, the lateral and medial epichondyles, the medial and lateral malleoli, the first right and left metatarsal head, the fifth right and left metatarsal head, and the right and left calcaneus. Tracking markers were placed noncollinearly on clusters fixed onto the middle third of the lateral surface of the legs, thighs, and at the base of the sacrum between the posterior iliac spines. The reference markers of the right and left malleolus, right and left calcaneus, and right and left fifth metatarsal head were also considered tracking markers.

After marker positioning, statistical collection was carried out to identify the segments, with subjects in the orthostatic position and arms crossed for 5 secs. The reference markers were then removed to perform dynamic collections, where subjects were instructed to walk at a comfortable self-selected speed along an 8-m-long walkway ten times. None of the subjects used an orthosis during assessments.

On the day after the last training system, subjects were reassessed, following the same methodologic criteria.

Intervention Protocol

After initial assessment, subjects were randomized into two training groups: the control group (CG), submitted to PBWS treadmill gait training, without inclination, and the experimental group

(EG), submitted to the same training with 10% of inclination. The decision to use 10% of inclination is based on results obtained by Werner et al.,[15] who found that up to 8% of inclination increased heart rate without exceeding critical levels, in addition to improving gait symmetry pattern and stride length in stroke patients. Moreover, while walking on a treadmill inclined at 10%, stroke survivors exhibited an increase in stance time, hip flexion, and ankle dorsiflexion at IC and hip and knee ROM compared with walking on 0% of inclination.[18] Both groups underwent twelve 20-min training sessions three times a week. The random allocation sequence was made using a Web-available application (randomization.com), which provides a randomized list for subject allocation. In the first training session, researcher 1 allocated subjects according to a previously established randomized list sequence.

A Gait Trainer 2 (Biodex Medical Systems, NY) treadmill coupled to a PBWS Unweighing System (Biodex Medical Systems, NY) was used during the sessions.

During training, all subjects used the PBWS system with initial support of 30%. This percentage was gradually reduced as subjects' tolerance to exercise improved, and they were able to support body weight on the affected leg, maintaining torso and limb alignment without the help of a therapist during training.[18] During training sessions, subjects were encouraged by the therapist to walk at maximum speed.

All training stages were conducted in the laboratory for human movement analyses of Federal University of Rio Grande do Norte, Natal, Rio Grande do Norte, Brazil.

Data Reduction

Data acquisition was performed using Qualisys Track Manager 2.6 software, and processing was conducted by the Visual 3D program, in which the biomechanic model was constructed, based on reference marker coordinates and anthropometric data. Dynamic collections were later associated to this model, which allowed determination of spatiotemporal variables and angular displacements during the gait cycle.

To determine angular displacements, body segments, considered in this model as rigid bodies, were associated to the system of coordinates by Cardan angle sequences. The orthostatic position was considered as reference. A low-pass Butterworth filter with a frequency of 6 Hz was used to eliminate the noise created by the movement of markers during collection.

The angular displacement of three joints was analyzed throughout the gait cycle (0%–100%). To delineate the gait cycles, four consecutive IC events were determined, two performed with the paretic foot and two performed with the contralateral foot. The moment the foot left the ground (toe off) after, each IC was also determined. Gait events were based on the graphic representation on the y-axis of markers located on the calcaneus and the fifth metatarsal.

The five most homogeneous cycles were selected for analysis. The following spatiotemporal variables were analyzed: speed (m/sec), cadence (steps/min), stride length (m), paretic and nonparetic step length (m), single paretic and nonparetic stance time (sec), double stance time (sec), paretic and nonparetic lower limb swing time (sec), and interlimb symmetry ratio: swing time of the paretic leg/swing time of the nonparetic leg.[13] The angular variables were determined from angular displacement in the sagittal plane of each joint (hip, knee, and ankle)—hip: maximum swing flexion, maximum stance extension, range of movement, and angle on IC; knee: maximum swing flexion, maximum stance extension, ROM, and angle on IC; and ankle: maximum swing dorsiflexion, plantar flexion on toe-off, ROM, and angle on IC.

The following clinical variables were analyzed: functional independence evaluated by motor FIM, balance by Berg Balance Scale, and motor skills by the Fugl-Meyer scale lower limb domains.

Statistical Analysis

The Statistical Package for the Social Sciences 17.0 was used for data analysis, at a significance level of 5%. Descriptive analysis was performed, followed by the Kolmogorov-Smirnov test to determine data normality. The nonpaired Student's *t* test was used for intergroup comparisons before training. Two-way analysis of variance with repeated measures was applied to verify intergroup interaction before and after intervention. When necessary, the post hoc Tukey test was used to identify possible interactions between groups.

RESULTS

The sample was composed of 28 subjects of both sexes (9 women and 19 men) with chronic hemiparesis, aged between 39 and 70 yrs (55.28 ± 9.02), and lesion time was between 6 and 144 mos (35.57 ± 31.71). Of these, 60.7% exhibited left hemiparesis, and 75% exhibited ischemic lesion. The clinical, demographic, and anthropometric characteristics of the subjects are described in Table 1.

Before onset of the intervention protocol, eight CG and ten EG subjects used assistive devices during

TABLE 1 Sample characterization according to the intervention group

Characteristics	Intervention Groups		
	CG	EG	*P*
Age, yrs	57.64 ± 8.15	52.92 ± 9.51	0.17
Lesion time, mos	35.78 ± 36.96	35.36 ± 26.87	0.88
Body mass, kg	71.82 ± 10.43	74.21 ± 15.94	0.23
Height, cm	162.42 ± 8.06	164.17 ± 8.54	0.95
NIHSS	5.14 ± 4.29	4.71 ± 2.16	0.74
Ashworth			
Hip (max, 5)	1.36 ± 0.13	1.57 ± 0.14	
Knee (max, 5)	1.57 ± 0.13	1.64 ± 0.14	
Ankle (max, 5)	1.5 ± 0.14	1.7 ± 0.12	
FAC (max, 5)	4.28 ± 0.16	4.21 ± 0.15	

FAC, Functional Ambulation Category; NIHSS, National Institutes of Health Stroke Scale.

gait (CG, one Canadian walking stick and seven conventional walking sticks; EG, four Canadian walking sticks and six conventional walking sticks). At the end of the intervention, only one CG and three EG subjects intermittently used a device during gait.

Clinical Variables

The recovery of motor function, functional independence, and balance were assessed using Fugl-Meyer scale, FIM, and Berg Balance Scale, respectively. After training, differences were observed in the time factor for motor function ($F_{1,26}$ = 51.29, $P <$ 0.001), functional independence ($F_{1,26}$ = 13.52, P = 0.001), and balance ($F_{1,26}$ = 90.74, $P <$ 0.001). All the variables improved after training. No differences were observed in the group × time interaction factor (motor function, $F_{1,26}$ = 0.002, P = 0.96; functionality, $F_{1,26}$ = 0.46 P = 0.5; and balance, $F_{1,26}$ = 1.12, P = 0.3) (see Table 2).

Spatiotemporal Variables

The spatiotemporal variable values of subjects before and after training are described in Table 3. Statistical differences were observed for the time factor in the following variables: gait speed ($F_{1,26}$ = 19.38, $P <$ 0.001), paretic ($F_{1,26}$ = 9.66, P = 0.005) and nonparetic ($F_{1,26}$ = 16.48, $P <$ 0.001) step length, and stride length ($F_{1,26}$ = 11.42, P = 0.002), where better results were obtained after training. Gait speed ($F_{1,26}$ = 5.23, P = 0.031) and paretic step length ($F_{1,26}$ = 9.66, P = 0.005) also showed differences for time × group interaction. Tukey post hoc tests revealed that the EG performed these two variables better than the CG ($P <$ 0.05). Gait speed in the CG improved by 6.82%, and there was no increase in paretic step length; however, gait speed and step length in the EG improved by 20.83% and 11.44%, respectively. Statistical power was 0.58 for gait speed and 0.50 for paretic step length. The other variables did not significantly change after training in either group (see Table 3).

Angular Variables

Hip ROM showed a significant difference in time factor ($F_{1,26}$ = 6.87, P = 0.014) and better results after intervention. The remaining variables exhibited no statistical differences: maximum hip flexion in swing, ($F_{1,26}$ = 0.28, P = 0.060), maximum hip extension in stance ($F_{1,26}$ = 1.01, P = 0.32), maximum knee flexion

TABLE 2 Values of clinical variables in the training groups

	Intervention Groups				Within Interventions		Between Interventions
	Before Training		After Training		After-Before Training		After-Before Training
Variable	CG	EG	CG	EG	CG	EG	EG-CG
Motor FIM	83.14 ± 4.6	86.14 ± 4.1	84.28 ± 4.7	86.92 ± 3.8	1.14 ± 1.6[a]	0.78 ± 1.12[a]	0.3 (0.98–0.26)
BBS	42.85 ± 5.1	43.28 ± 7.0	46.57 ± 5.9	47.92 ± 6.2	3.71 ± 2.4[a]	4.64 ± 2.17[a]	0.9 (−2.85 to 0.99)
F-M	69.57 ± 8.4	68.57 ± 6.9	74.85 ± 6.6	73.78 ± 7.8	5.28 ± 4.4[a]	5.23 ± 3.19[a]	0.07 (−3.56 to 3.42)

[a]Statistical significance after training.

BBS, Berg Balance Scale; F-M, Fugl-Meyer Scale.

in swing ($F_{1,26} = 0.47, P = 0.5$), knee ROM ($F_{1,26} = 0.22$, $P = 0.64$), ankle dorsiflexion in swing ($F_{1,26} = 2.5$, $P = 0.12$), plantar ankle flexion in toe-off ($F_{1,26} = 1.79$, $P = 0.19$), and ankle ROM ($F_{1,26} < 0.001$, $P = 0.98$). Figure 2 shows the graphic representation of hip, knee, and ankle joint angles during the gait cycle before and after intervention.

During training sessions, there were no differences between mean speed and percent suspension adopted by the EG and CG ($P > 0.05$) (see Table 4). From the ninth training session onward, all individuals, irrespective of intervention group, were able to walk on the treadmill without the help of the PBWS system.

DISCUSSION

The most important finding of the present study was that inclined treadmill gait training was more effective in improving gait speed and paretic step length when compared with treadmill training without inclination. Moreover, after training, differences were observed in the clinical variables assessed in both groups, and no alterations were observed in most of the angular variables, regardless of inclination angle on the support surface.

After gait training on an inclined treadmill, stroke patients walked faster and took a longer paretic step, which may be because of the reduced pass retract phenomenon[15] and excessive hip flexion during swing phase to provide toe clearance, followed by fast thigh retract in terminal swing to passively extend the lower leg.[20] When walking on an inclined surface, stroke patients may hit the ground earlier, resulting in longer strides.[15] Thus, the results of the present study suggest that the reduced pass retract phenomenon performed while stoke patients walk on an inclined surface may be transferred to overground walking after training. Furthermore, the increase in step length observed in the EG may be related with improvements in gait speed, because, according to Olney and Richards[21] (1996), in stroke subjects with mean walking speed of greater than 0.33 m/sec, an increase in this variable seems to be associated primarily to longer step length rather than cadence.[21]

Another factor that may have caused subjects to walk faster overground after gait training is improved cardiovascular fitness, given that the inclination surface may help stroke patients attain a preset target heart rate much faster to perform aerobic gait training.[15,22] However, because no cardiovascular fitness measure was investigated in the present study, this hypothesis needs to be investigated in future studies.

Although most subjects that survive a stroke regain the ability to walk, this skill is generally

TABLE 3 Values of spatiotemporal variables in the training groups

	Intervention Groups				Within Intervention		Between Interventions
	Before Training		After Training		After-Before Training		After-Before Training
Variable	CG	EG	CG	EG	CG	EG	EG-CG
Speed, m/sec	0.44 ± 0.1	0.48 ± 0.2	0.47 ± 0.1	0.58 ± 0.2	0.03 ± 0.07	0.1 ± 0.08[a]	0.07 (−0.001 to 0.14)[b]
Cadence, steps/min	70.1 ± 19.54	67.2 ± 20.21	69.2 ± 15.61	70.2 ± 20.51	0.84 ± 11.1	2.98 ± 5.7	2.14 (−35.9 to 15.43)
Stride length, m	0.67 ± 0.04	0.76 ± 0.05	0.71 ± 0.04	0.85 ± 0.05	0.03 ± 0.06[a]	0.08 ± 0.07[a]	0.05 (−0.005 to 0.9)
Step length P, m	0.37 ± 0.06	0.38 ± 0.11	0.37 ± 0.08	0.43 ± 0.11	0.001 ± 0.04	0.04 ± 0.04[a]	0.04 (0.018 to 0.07)[b]
Step length NP, m	0.30 ± 0.09	0.38 ± 0.1	0.33 ± 0.11	0.41 ± 0.09	0.03 ± 0.05[a]	0.04 ± 0.03[a]	0.01 (0.38 to 0.005)
P stance time, %	64.55 ± 4.68	63.93 ± 6.02	64.17 ± 5.06	62.53 ± 6.28	0.39 ± 5.9	1.4 ± 2.5	1.02 (−5.10 to 3.07)
NP stance time, %	75.28 ± 7.25	77.00 ± 7.06	75.41 ± 4.02	74.99 ± 6.38	0.13 ± 5.13	2.01 ± 2.05	2.14 (−5.28 to 1.00)
Double stance time, secs	0.64 ± 0.26	0.83 ± 0.68	0.63 ± 0.2	0.71 ± 0.57	0.02 ± 0.13	0.12 ± 0.13	0.10 (−0.21 to 0.2)
P swing time, %	35.44 ± 4.68	36.06 ± 6.02	35.83 ± 5.06	37.48 ± 6.28	0.39 ± 5.9	1.4 ± 2.5	1.02 (−3.07 to 5.10)
NP swing time, %	24.71 ± 7.25	22.99 ± 7.03	24.58 ± 4.02	25.00 ± 6.38	0.13 ± 3.04	2.01 ± 1.52	2.14 (−1.00 to 5.28)
Symmetry ratio	1.50 ± 0.32	1.66 ± 0.39	1.49 ± 0.29.	1.55 ± 0.32	0.01 ± 0.39	0.11 ± 0.21	0.09 (−0.34 to 0.16)

[a]Statistical significance after training.
[b]Statistical significance between groups after training.
NP, nonparetic leg; P, paretic leg; symmetry ratio, swing time of the paretic leg/swing time of the no paretic leg.

limited,[23] which restricts its efficacy and the social reintegration of these subjects at home or in the community.[24] In this respect, walking speed is considered an important indicator of independence,[23,24] locomotor skill,[25] degree of motor recovery,[26] and quality of life[27] in subjects with hemiparesis. The importance of faster walking for stroke patients reinforces the need for training protocols that increase walking speed and gait training strategies that could leverage gait speed. In the present study, a significant improvement in walking speed was only achieved by the group that underwent gait training on an inclined surface, showing that inclination can improve gait training with PBWS.

Norman et al.[16] (1995) suggest that treadmill modifications for walking training may promote gait adaptations in subjects with locomotor impairment that can manifest themselves in overall functional improvements after intervention protocols. Specifically in individuals with chronic hemiparesis, inclined surfaces seem to be responsible for lower limb adjustments such as increased hip and knee ROM; increased hip, knee, and ankle flexion in IC[18]; and changes in spatiotemporal and temporal gait parameters such as stride length and gait symmetry,[15] resulting in reduced compensatory movements. Their results show that these adjustments seem to promote general gait modifications in individuals with chronic hemiparesis, after 12 training sessions on an inclined surface, even though no significant changes were observed in a number of variables that improved during walking on inclined surfaces in previous studies.[15,18] The absence of alterations in most variables may be associated to the need for more extended training in subjects with chronic hemiparesis.[13,28] On the other hand,

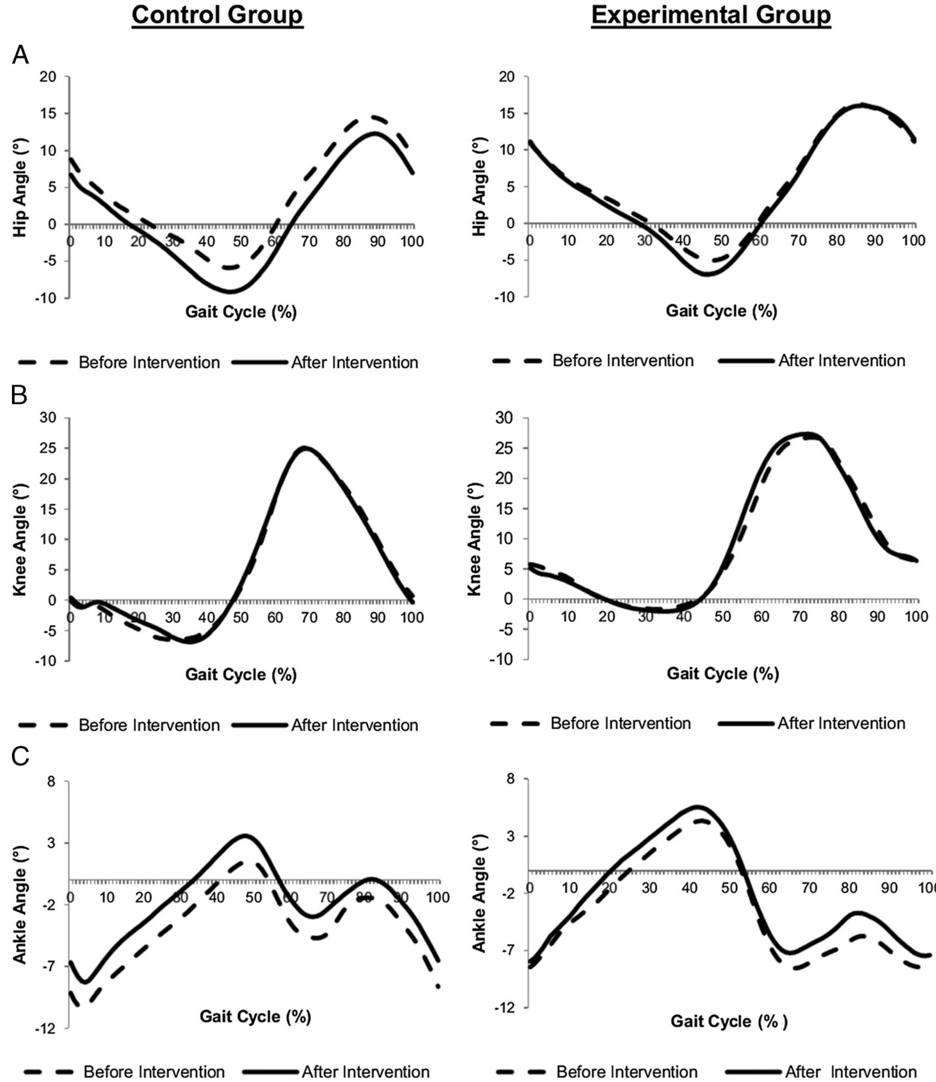

FIGURE 2 *Angle displacement of the hip (A), knee (B), and ankle (C) during the gait cycle (expressed in percentage) in the control group and experimental group. Positive values indicate hip and knee flexion and ankle dorsiflexion.*

TABLE 4 Suspension and gait speed during training sessions

Training Session	Mean Speed (m/sec)			Percent Suspension (%)		
	CG	EG	*P*	CG	EG	*P*
1	0.34 ± 0.93	0.39 ± 0.11	0.27	30 ± 0.0	30 ± 0.0	—
2	0.41 ± 0.11	0.46 ± 0.13	0.31	25.35 ± 1.33	25.35 ± 1.33	1
3	0.46 ± 0.11	0.52 ± 0.14	0.19	20.71 ± 2.67	20.35 ± 1.33	0.66
4	0.54 ± 0.16	0.59 ± 0.17	0.38	15.71 ± 2.67	15.35 ± 1.33	0.66
5	0.59 ± 0.15	0.65 ± 0.18	0.34	10.35 ± 3.07	10.35 ± 1.33	1
6	0.62 ± 0.15	0.68 ± 0.17	0.35	5 ± 3.39	5.35 ± 1.33	0.72
7	0.65 ± 0.15	0.72 ± 0.17	0.23	0.71 ± 2.67	0.35 ± 1.33	0.66
8	0.66 ± 0.14	0.75 ± 0.18	0.14	0.35 ± 1.33	0	0.33
9	0.66 ± 0.14	0.79 ± 0.2	0.07	0	0	—
10	0.69 ± 0.15	0.83 ± 0.22	0.07	0	0	—
11	0.66 ± 0.17	0.82 ± 0.28	0.06	0	0	—
12	0.35 ± 0.38	0.44 ± 0.44	0.06	0	0	—
Median	0.59 ± 0.19	0.61 ± 0.14	0.79	—	—	

adding inclination seems to improve the benefits promoted by treadmill gait training with PBWS.

The best results observed in the EG cannot be attributed to the level of support or speed adopted by subjects during training, because no intergroup differences were found in these two parameters during the course of the training sessions. The only difference exhibited between the proposed protocols was the inclination level of the support surface, suggesting that any intergroup difference observed after training is associated to this parameter.

The use of a PBWS system has become popular[6] in the gait recovery of hemiparetic subjects. These systems relieve body weight on lower limbs during gait, minimize biomechanic restrictions, and enhance the dynamic responses of balance during execution of the task.[29] In training protocols, the association between the treadmill and PBWS allows more intense training sessions, with repetition of a larger number of gait cycles, which is the basis of an intense learning and memorization process that results in improved movement patterns in these subjects during gait.[4,16] Furthermore, to simultaneously simulate the three essential components of walking—posture, balance, and step execution[30]—this type of approach is also able to promote not only improvements in gait but also balance and motor function.[3] In the present study, the two groups underwent PBWS treadmill gait training, and the improvement in balance and motor function seems to be associated to the use of this type of system and the treadmill.

It is also known that balance contributes to functional independence, because it is an important element in the performance of daily functional activities,[31] which are also influenced by the individual's motor skills.[32] Thus, enhanced balance and motor skills after PBWS treadmill training seem to have a positive influence on the functional independence of the individuals assessed, as measured by FIM in both groups. Treadmill gait training with PBWS also promoted improvements in parameters such as nonparetic step length and stride length, regardless of the inclination angle on the support surface, as reported in other studies.[10,33] This improvement is favored by enhanced balance and hip ROM as well as the possible improvement in the ability to transfer and support body weight on the affected limb promoted by PBWS gait training, as described in earlier studies.[10,12]

Although some studies reported improvements in the angular variables of subjects with hemiparesis after PBWS training,[29,34] similar results were not observed here. This may be related to the consolidation of compensatory movements acquired in the subacute phase of recovery,[28] which seems to require more prolonged training protocols to obtain significant differences.

Study limitations are the small sample and training intensity (the number and duration of sessions), which may have caused the variable results observed after training. The authors suggest that more prolonged studies involving a larger sample should be conducted. Furthermore, given that changes in muscle activation pattern and ground reaction force could clarify the strategies used by subjects, the authors also suggest that these evaluations should be used in future studies.

The hypothesis raised was not accepted, because no posttraining differences were observed in most angular and spatiotemporal variables. The differences observed in spatiotemporal variables may be associated to the control strategies used during gait on inclined and flat surfaces.[35] However, adding inclination to PBWS gait training produced similar results to those observed after training on a flat surface in addition to an improvement in walking speed and paretic step length, suggesting that the addition of inclination may be an overload stimulus in poststroke rehabilitation.

CONCLUSIONS

Treadmill PBWS gait training on an inclined surface seems to be more beneficial in the gait recovery of individuals with chronic hemiparesis than gait training on a treadmill with no inclination. Thus, the addition of inclination to gait training is a promising strategy for the rehabilitation of subjects with chronic hemiparesis and may be a strengthening stimulus of the training effects of PBWS treadmill gait in this population.

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