Journal of Bodywork & Movement Therapies (2014) **18**, 526–532

Available online at www.sciencedirect.com

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journal homepage: www.elsevier.com/jbmt

STROKE REHABILITATION: PRELIMINARY STUDY

Effects of a training program based on the Proprioceptive Neuromuscular Facilitation method on post-stroke motor recovery: A preliminary study

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Received 27 July 2013; received in revised form 23 November 2013; accepted 3 December 2013

KEYWORDS
Stroke;
Rehabilitation;
Recovery of function;
Gait

Summary This preliminary study sought to analyze the effects of a training program based on the Proprioceptive Neuromuscular Facilitation (PNF) method on motor recovery of individuals with chronic post-stroke hemiparesis. Eleven individuals with chronic hemiparesis (mean lesion time of 19.64 months) after unilateral and non-recurrent stroke underwent training based on PNF method for twelve sessions, being evaluated for motor function - using the Stroke Rehabilitation Assessment of Movement (STREAM) instrument; functionality, by the Functional Independence Measure (FIM); and gait kinematic (using the Qualisys Motion Capture System), at baseline and post-training. Significant changes in FIM (from median 67 to median 68;

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http://dx.doi.org/10.1016/j.jbmt.2013.12.004

$P = .043$) and STREAM scores (from median 47 to median 55; $P = .003$) were observed. Data showed significant changes in motor function and functionality after training, suggesting that this program can be useful for rehabilitation of chronic stroke survivors.

Introduction

Stroke survivors commonly exhibit uni or bilateral sensory-motor impairments, loss of coordination, visual field disorders as well as cognitive, perceptive and language deficits (World Health Organization, 2006). In physical therapy, the main goals of treatment after stroke are to restore motor control in gait and gait-related activities and to improve upper limb function, as well as to learn to cope with existing deficits in activities of daily living (ADL) and to enhance participation in general (Van Peppen et al., 2004).

Although there are currently several rehabilitation treatments for stroke, traditional approaches — such as the Neurodevelopmental method (Bobath) and Proprioceptive Neuromuscular Facilitation (PNF) - continue to be used in clinical practice, showing good results (Pollock et al., 2007). The PNF method was originally developed to facilitate motor performance in individuals with impaired movements. It involves maximum resistance to movement, which must be executed in a spiral and diagonal direction, promoting a larger neuromuscular response in proprioceptors, thereby facilitating biarticular muscle activation (Kofotolis et al., 2005). It also involves exploring postural reflexes (primarily the stretch reflex) and the use of eccentric contractions to facilitate agonist muscle activity (Shimura and Kasai, 2002).

Despite the theoretical basis and its clinical use, there are scant scientific publications based on this method on post-stroke rehabilitation (Dickstein et al., 1986; Ozdemir et al., 2001; Trueblood et al., 1989). In addition, the differing forms of the application of PNF method hinder the comparison between studies, and, especially, the reproduction of the protocol. This significantly reduces the evidence about the method. Two systematic reviews (Pollock et al., 2007; Van Peppen et al., 2004) found the effects of neurophysiological approaches, including PNF, in individuals with hemiparesis and did not find enough evidence to generalize results regarding the potential clinical impact of these treatments. Finally, no studies indicate a program or the best mode of PNF application to improve motor function in these patients.

Thus, we developed a training program based on the PNF method, designed to improve the functionality, motor function and gait in individuals with chronic hemiparesis post-stroke. To verify if this protocol is reproducible and if is able to promote the wanted effects, we decided to conduct a feasibility study (a preliminary study) prior to the implementation of this program in larger scale.

Methods

Participants

Eleven individuals (six men and five women), aged between 40 and 70 years, with chronic hemiparesis (mean lesion time of 19.64 ± 9.81 months) after unilateral and non-recurrent stroke were recruited by convenience sampling from clinics and hospitals in the city of Natal-RN. Subjects should had spasticity classified between levels 0 and 2 on the Modified Ashworth Scale (MAS) of muscle spasticity for the lower limb affected (Biering-Sørensen et al., 2006) and ambulatory capacity classified between levels 3 and 5 on the Functional Ambulatory Category — FAC (Mehrholz et al., 2007). Furthermore, subjects had to be able to walk 10 meters on a flat surface without personal assistance and/or assistive devices/orthesis, no clinical signs of cardiac alterations (New York Heart Association, degree I), capable of obeying simple commands and not exhibit any other orthopedic and/or neurological impairment that could alter gait. Exclusion criteria were individuals whose heart rate (immediately after exercise) exceeded 75% of age-adjusted maximum heart rate, according to the formula proposed by Tanaka et al. (Tanaka et al., 2001). The study was approved by the local ethics research committee.

Measuring instruments

The FAC was used to determine walking capacity. Scores range from 0 to 5, where 0 represents walking incapacity or needing help from two therapists, and 5 indicates locomotion independence, including climbing stairs (Mehrholz et al., 2007).

The National Institute of Health Stroke Scale (NIHSS) was used to categorize neurological status, from minimal impairment (scores 0—1) to severe impairment - scores over 20 (Montaner and Alvarez-Sabin, 2006).

The MAS was applied to assess muscle tone in the paretic lower limb (Biering-Sørensen et al., 2006). The following muscle groups were tested: quadriceps, hamstrings, triceps surae and ankle muscle dorsiflexors.

The Stroke Rehabilitation Assessment of Movement (STREAM) protocol evaluated motor function. STREAM analyzes voluntary limb movement and basic mobility with a maximum score of 70 points (higher scores indicate better function) (Daley et al., 1999).

Functional Independence Measure (FIM) assesses the level of assistance required to perform activities such as self-care, mobility, locomotion, sphincter control, communication and social cognition (Riberto et al., 2001, 2004). In this study, we only used the motor domain of the FIM (motor FIM), which excludes communication and social cognition items. Higher scores demonstrating greater independence.

Gait analysis was obtained using the Qualisys system (Qualisys Motion Capture System — Qualisys Medical AB 411 13, Gothenburg, Sweden). Three cameras (Qualisys Oqus 300) that emit and capture infrared light reflected by spherical passive markers were used. Data were captured at a frequency of 120 Hz, using Qualisys Track Manager 2.3 (QTM) acquisition software, and exported to Visual 3D processing software (Visual3D Standard, 4.75.33 — C-

Motion, Rockville, MD, USA). A biomechanical model was built to analyze spatial-temporal and angular variables of gait.

Assessment protocol

After the initial approach to obtain anthropometric measures, clinical diagnosis, use of medication, vital signs and complementary information, clinical assessments (using FAC, NIHSS, MAS, STREAM and FIM scales) and kinematic analysis of gait were carried out.

For kinematic analysis, after Qualisys calibration, data were collected for 10 s, with subjects wearing shoes and standing, in order to create a biomedical model for application in dynamic collections. During dynamic captures, subjects were instructed to walk along a 10 m walkway at a comfortable pace. Ten non-consecutive gait cycles were recorded. The entire assessment protocol was applied in the week prior to the onset of intervention, and was repeated in the week following the end of intervention.

Data reduction

Data captured by Qualisys were processed in QTM software and were export and processing with Visual 3D software, in which a biomechanical model can be constructed for analysis. In Visual 3D, joint angular displacements were obtained according to the sequence of Cardan angles (Cole et al., 1993), with the standing position adopted as the neutral position. Angular displacement of the hip, knee and ankle were represented in percentage of gait cycle (0%—100%).

Only the most homogeneous cycles were selected for analysis. Spatial and temporal variables of gait were speed (m/s), stride length (m), and symmetry ratio of swing time. The following formula was used to calculate the symmetry ratio:

$$\text{Symmetry ratio of swing time} = \text{swing time}(P)*/\text{swing time}(NP)*$$

*where P = paretic lower limb and NP = non-paretic lower limb

With respect to angular variables, angular hip, knee and ankle displacements (°) of the paretic lower limb in the sagittal plane were investigated. For the hip, maximum stance extension and maximum swing flexion were analyzed; for the knee, maximum swing flexion; and for the ankle, plantarflexion during push-off (PO) and maximum dorsiflexion over the swing phase.

Experimental protocols

The intervention protocol consisted of three 30-min weekly sessions for four consecutive weeks (Wang, 1994). During this period, individuals did not undergo any other therapy, including conventional physical therapy or physical exercises.

The program training consisted of functional activities (task-specific stimulation), including mobility and gait-related activities, in conjunction with the PNF method, using its basic procedures and facilitation patterns. Manual contact, stretching and maximum resistance were emphasized during the following activities: waist dissociation in lateral decubitus; sitting and rising; transfer of body weight in both the anteroposterior and latero-lateral direction in the standing position; and frontal and lateral gait (Adler et al., 2007; Coelho et al., 2004).

Sessions were initiated with the waist dissociation movement by scapular and pelvic patterns, in lateral decubitus. The anterior elevation/posterior depression and anterior depression/posterior elevation diagonals were requested from patients. For scapular waist dissociation, manual contact was on the paretic shoulder, where the therapist guided and resisted the diagonal movement of shoulder; for pelvic dissociation, the therapist guided and resisted anterior and posterior pelvic inclination (elevation and depression), with hands positioned on the illiac crest, on the paretic side.

Next, participants were instructed to sit and rise. Patients, initially seated, were encouraged to get up, while therapists placed their hands on the iliac crests. Patients then sat up, with therapists positioning their hands on the posterior portion of the illiac crests, resisting and supporting torso and hip flexion. With the patient standing, weight was transferred in the antero-posterior and latero-lateral direction, in which the therapist controlled and resisted pelvic movement during weight transfer from one lower limb to another. For antero-posterior transfer, therapists placed their hands on the illiac crests bilaterally; for latero-lateral transfer, on only one illiac crest laterally. Similar positioning was applied during frontal and lateral gait. This activity was executed on parallel bars for greater patient safety (Fig. 1).

Stretch reflex was performed in the same direction as the required movement, applied immediately before its execution, in order to facilitate contraction of adjacent muscles. In points of manual contact, movement was initially guided/controlled (only for demonstration) and after was resisted by the therapist.

The therapist gave verbal encouragement and instructions related to correct posture during the exercises. Average duration was 30 minutes, with the therapist focusing on activities according to the needs of individuals and their progress over the course of training (Table 1). Resistance to movement was increased at each session, and once patients improved their strength levels on a given activity, the number of repetitions was increased. All participants were monitored for heart rate and blood pressure before and after each session, using a digital arm tensiometer.

Three trained therapists conducted training sessions, one therapist per individual. These therapists have at least two years of practice in Physical Therapy, and were trained more specifically for this PNF program application during the two months prior intervention, by the main study researcher (whose experience in Physical Therapy and PNF application exceeds three years).

Data analysis

Statistical analysis was conducted using SPSS 17.0 software (Statistical Package for the Social Sciences), at a significance

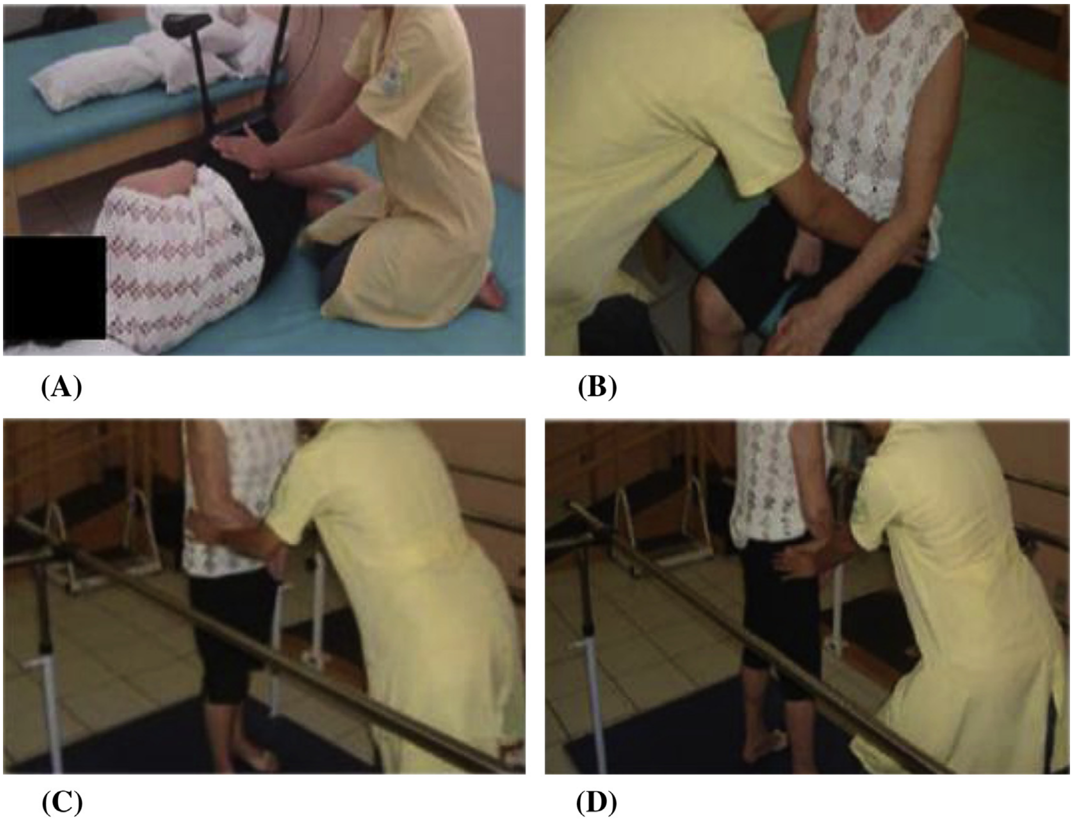

Figure 1 Activities of the program based on the PNF method. **(A)** Waist dissociation in lateral decubitus; **(B)** Sitting and rising; **(C)** Positioning for anteroposterior transfer of body weight and frontal gait; **(D)** Positioning for latero-lateral transfer of body weight and lateral gait.

Table 1 Description of PNF training program.

Activity	Mean duration (minimum number of repetitions)
Waist dissociations	5 min (20 repetitions)
Sitting and rising from a chair	10 min (20 repetitions)
Anteroposterior and latero-lateral weight transfer	5 min (40 repetitions)
Frontal and lateral gait	10 min (10 repetitions)

Abbreviation: PNF, Proprioceptive Neuromuscular Facilitation; min, minutes.

level of 5%. Demographical and clinical data were expressed by measures of central tendency and dispersion. For outcome measures, nonparametric tests, were applied considering the sample size (less than 30). Then, the Wilcoxon test for related samples was applied to compare the variables at baseline and post-training, which were expressed in median and quartiles (percentiles 25th—75th).

Results

The sample was composed of 11 individuals (six men and five women), mean age of 57.54 (standard deviation of 8.30) years and mean lesion time of 19.64 (standard deviation of 9.81) months. None of the participants wore orthotics lower limb in daily activities. All participants completed the study uneventfully.

Regarding to the neurological status, there was significant improvement in NIHSS scores: from 5 (1—8) to 4 (1—8), $P = .024$. In relation to walking capacity and muscle tone, however, no significant alterations were observed in FAC or MAS scores, which remained stable at 3 (3—4) and 1 (1—2), respectively.

The STREAM scale showed a statistically significant increase in all of its items, comparing the baseline and post-training, indicating improvement in several aspects of motor function (Table 2).

Table 2 STREAM scores ($n = 11$) at baseline and post-training.

Items	Baseline	Post-training	*P*
UL	14 (5—19)	17 (7—20)	.010*
LL	11 (10—13)	14 (13—16)	.005*
BM	21 (17—25)	24 (19—27)	.011*
T	47 (35—55)	55 (39—63)	.003*
%	69 (51—83)	79 (57—90)	.003*

Abbreviations: UL, Upper Limbs; LL, Lower Limbs; BM, Basic Mobility; *T*, Total; %, Percentage of maximum score (70 points) of STREAM scale.
NOTE. Values expressed as median and percentiles (25th—75th).
$P = P$ value.
*Statistical significance.

Table 3 Scores of the FIM Motor scale (*n* = 11) at baseline and post-training, according to the items of the questionnaire.

Items	Baseline	Post-training	*P*
Eating	6 (4–6)	6 (4–6)	1.00
Grooming	6 (4–6)	6 (4–6)	1.00
Bathing	5 (3–7)	6 (4–7)	.109
Dressing – upper body	4 (4–6)	4 (4–6)	.180
Dressing – lower body	4 (4–6)	4 (3–6)	.414
Toileting	6 (6–6)	6 (6–7)	.317
Bladder management	4 (2–7)	4 (3–7)	1.00
Bowel management	7 (6–7)	7 (6–7)	.180
Transfer to the chair	6 (6–6)	6 (6–6)	1.00
Transfer to the toilet	6 (6–6)	6 (6–6)	.317
Transfer to the bathroom	6 (6–6)	6 (6–6)	1.00
Locomotion	6 (4–6)	6 (4–6)	.317
Stairs	5 (3–6)	6 (3–6)	.083
Total FIM	67 (61–74)	68 (63–78)	.043*

Abbreviations: FIM, Functional Independence Measure.
NOTE. Values expressed as median and percentiles (25th–75th).
P = *P* value.
*Statistical significance.

In relation to functional dependence assessed by motor FIM, no significant difference in the sub-items, only in the total value, which showed a statistically significant increase (Table 3).

Gait cycle variables (spatio-temporal and angular) showed no statistically significant differences after training (Table 4). Angular variables, represented by the mean joint angles of the hip, knee and ankle, at baseline and post-training, are illustrated in Figure 2.

Discussion

This preliminary study investigated the effects of a program based on the PNF method on post-stroke motor recovery to verify if this program is able to modify the characteristics of gait, motor function and functionality of these patients, in the chronic phase of stroke.

Limb movements and mobility are important outcome indicators for patients with stroke (Hsieh et al., 2008).

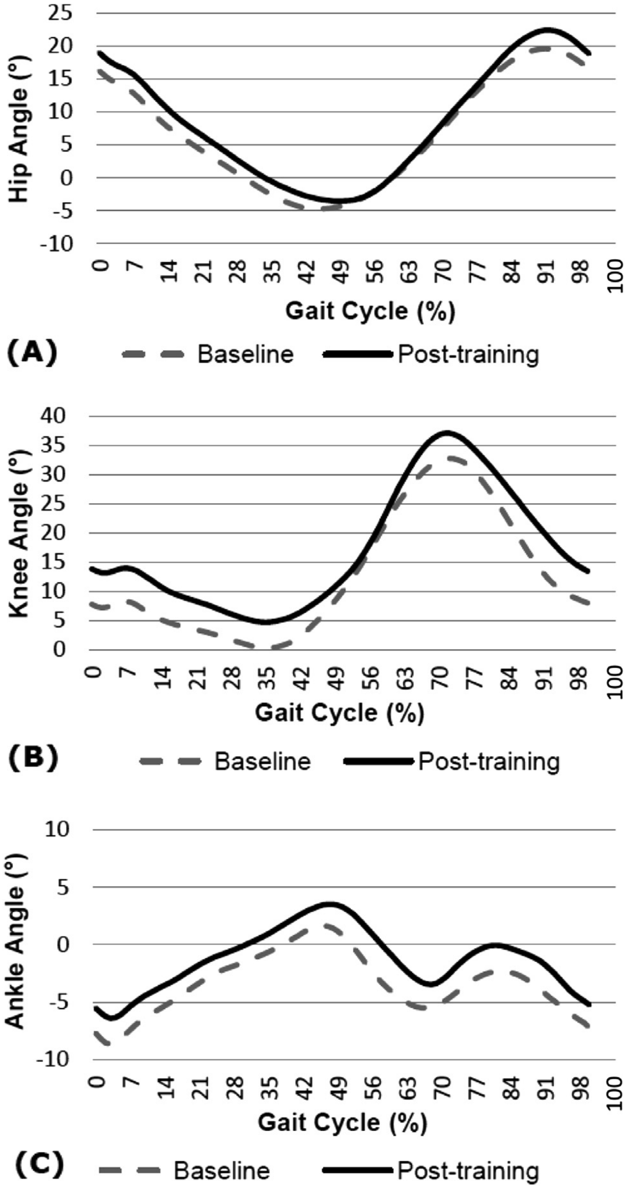

Figure 2 Mean joint hip **(A)**, knee **(B)** and ankle **(C)** angles during the gait cycle (expressed in percentage). Positive values indicate hip and knee flexion and ankle dorsiflexion.

Table 4 Gait cycle variables (*n* = 11) at baseline and post-training.

Variables	Baseline	Post-training	*P*
Max. hip extension (°)	−5.97 (−11.26 – .83)	−6.18 (−11.50 – .48)	.286
Max. hip flexion (°)	19.11 (15.62 – 26.72)	22.20 (16.48 – 31.08)	.050
Max. knee flexion (°)	33.65 (29.23 – 49.24)	38.84 (32.51 – 48.30)	.110
Plantarflexion PO (°)	−8.61 (−12.36 – 3.69)	−8.00 (−9.49 – .52)	.050
Max. dorsiflexion (°)	3.75 (1.35 – 8.78)	4.88 (1.54 – 8.40)	.286
Speed (m/s)	.40 (.32 – .45)	.38 (.30 – .48)	1.00
Stride length (m)	.67 (.52 – .76)	.62 (.50 – .75)	.859
Symmetry ratio	1.46 (1.38 – 1.91)	1.48 (1.35 – 1.88)	.110

Abbreviations: Max, Maximum; PO, Push-Off.
NOTE. Values expressed as median and percentiles (25th–75th).
P = *P* value.

In the present study, STREAM showed substantial improvement in lower and upper limb motor function and basic mobility, indicating that applying of PNF program can result in overall benefits. Positive findings in basic mobility and lower limb function may be the direct result of mobility activities and of gait-related activities. Diagonal movements for the scapular waist and gait training in parallel bars favored waist dissociation and the use of upper limbs, which could have enhanced the voluntary mobility of upper limbs.

Pohl and colleagues (Pohl et al., 2002) in a study with a similar form of training (three weekly sessions of 30 minutes each, during four weeks), compared three groups — one group using conventional physiotherapy with the PNF method and the others using treadmill training —, in patients with more than one month of stroke onset. They found an improvement in mobility in all groups, evidenced by higher FAC scores. Ozdemir et al. (2001) also used the PNF method in patients with acute hemiparesis, obtaining gains in status motor. Although it is known that motor recovery occurs preferentially during the acute phase (Chen et al., 2003), in the current study, the choice of chronic patients aimed to reduce the variation of spontaneous motor recovery at different periods after stroke. Thus, the improvement observed in these patients reinforces the idea that the training applied should have contributed effectively to this result, possibly by development of compensatory strategies that favored the motor function, overcoming the inertia caused by chronicity.

Besides improvements in motor function, improvements were also observed in functionality (assessed by motor FIM). Dickstein and colleagues (Dickstein et al., 1986) compared the effects of conventional physiotherapy, PNF method and Bobath in rehabilitating post-stroke patients. Although there was no significant difference between approaches, enhanced motor function and functionality were observed in patients submitted to PNF sessions, in line with findings of the present study.

Ozdemir et al. (2001) also found that subjects with hemiparesis using the PNF training method obtained functional gains measured by FIM. These authors suggest that improved functionality and motor function in patients after training with the FNP technique is due to motor relearning, since this method emphasizes task-based activities and repetitive movement training. Wang (1994) says that, when performed the intervention using PNF in long-term is able to improve motor learning even in chronic patients recovering from stroke.

There was no statistically significant improvement in individual items of the motor FIM; however, the overall improvement may have resulted from the motor learning and the transfer of learning of the program activities for the day-to-day. For example, sitting and standing and weight transfer while standing are directly related to the transfer to the toilet; gait training, with locomotion and climbing stairs; scapular waist dissociation and activities on the parallel bars, with the use of the upper limb to bathing and dressing. All of these items showed some increase (although not significant), which may have contributed to the total result. It is worth noting, however, that, unlike the results of STREAM, the improvement in motor FIM was lower and this may represent less clinical significance.

Although not expected, there was an improvement in the NIHSS scores after the training. This scale is more suitable to detect changes on the acute phase of stroke; however, the gain of motor function and functionality may have improved the global neurological status of study patients, even though this had not been the focus of our work.

Taking into account the importance of gait, considerable attention has been focused on the measurement and improvement of gait velocity in persons with stroke (Patterson et al., 2008). Nevertheless, no speed modifications were observed after training with PNF in our study. It is suggested that individuals with chronic hemiparesis need training overload for speed-related alterations to occur (Sullivan et al., 2002). In the current study, subjects were encouraged to correctly execute exercises, focusing on the quality of tasks performed. Gait training at maximum speed was not emphasized, since the individuals were encouraged to walk at a comfortable, self-adjusted speed. Thus, training may not have promoted sufficient overload to increase gait velocity. Furthermore, speed stabilization may have contributed to maintaining stride length and swing time of both lower limbs.

Coelho et al. (2004) applied gait training with PNF method during three weeks in chronic stroke patients, and also observed that this training did not alter gait velocity, stride length symmetry or other gait cycle variables.

Of all the studies using the PNF method for hemiparetic gait rehabilitation, only Trueblood et al. (1989) investigated changes in the angular parameters. These authors report that after training there was an increase in knee flexion during the swing phase and in the extension of this joint during the stance phase. In our study, the program based on PNF showed no significant modifications in the kinematic characteristics of hip, knee or ankle joints.

Given that several gait variables, including angular, are velocity-dependent (Trueblood et al., 1989), the absence of speed alterations in gait also may justify the fact that no statistically significant difference was observed in these variables.

Limitations of this study include the absence of a control group and sample size, which may have interfered in the results obtained. However, considering that the study patients were all in the chronic phase of stroke (mean lesion time of 19.64 ± 9.81 months), it is not expected that the observed improvements were due to spontaneous recovery. In addition, this was a preliminary study. We suggest that the training program based on PNF can be applied in experimental studies with a larger sample size and control group for comparison, allowing more effective generalization of the results with respect to the PNF technique in rehabilitating functionality, motor function and hemiparetic gait.

Conclusion

This study evaluated the effects of a training program based on PNF, which was proposed to enhance motor recovery of chronic stroke survivors. The results indicated that the program resulted in improvement of motor function and functionality, suggesting that this program may be beneficial for these outcomes, although PNF does not seem to be effective for restoring hemiparetic gait.

Conflicts of interest

None declared.

References

Adler, S.S., Beckers, D., Buck, M., 2007. Proprioceptive Neuromuscular Facilitation: an Illustrated Guide, 2^a ed. Manole, São Paulo.

Biering-Sørensen, F., Nielsen, J.B., Klinge, K., 2006. Spasticity-assessment: a review. Spinal. Cord 44, 708–722.

Chen, C.L., Chen, H.C., Tang, S.F.T., Wu, C.Y., Cheng, P.T., Hong, W.H., 2003. Gait performance with compensatory adaptations in stroke patients with different degrees of motor recovery. Am. J. Phys. Med. Rehabil. 82, 925–935.

Coelho, J.L., Abrahão, F., Mattioli, R., 2004. Muscular torque increase after treadmill training with body weight support in chronic hemiparesis. Braz. J. Phys. Ther. 8 (2), 137–143.

Cole, G.K., Nigg, B.M., Ronsky, J.L., Yeadon, M.R., 1993. Application of the joint coordinate system to three-dimensional joint attitude and movement representation: a standardization proposal. J. Biomech. Eng. 115 (4A), 344–349.

Daley, K., Mayo, N., Wood-Dauphinée, S., 1999. Reliability of scores on the stroke rehabilitation assessment of movement (STREAM) measure. Phys. Ther. 79 (1), 8–23.

Dickstein, R., Hockerman, S., Pillar, T., Shaham, R., 1986. Stroke rehabilitation: three exercise therapy approaches. Phys. Ther. 66, 1233–1238.

Hsieh, Y.W., Wang, C.H., Sheu, C.F., Hsueh, I.P., Hsieh, C.L., 2008. Estimating the minimal clinically important difference of the stroke rehabilitation assessment of movement measure. Neurorehabil. Neural. Repair. 22 (6), 723–727.

Kofotolis, N., Vrabas, I.S., Vamvakoudis, E., Papanikolaou, A., Mandroukas, K., 2005. Proprioceptive neuromuscular facilitation training induced alterations in muscle fibre type and cross sectional area. Br. J. Sports Med. 39, e11.

Mehrholz, J., Wagner, K., Rutte, K., Meißner, D., Pohl, M., 2007. Predictive validity and responsiveness of the functional ambulation category in hemiparetic patients after stroke. Arch. Phys. Med. Rehabil. 88, 1314–1319.

Montaner, J., Alvarez-Sabin, J., 2006. La escala de ictus del National Institute of Health (NIHSS) y su adaptación a el español. Neurología 21 (4), 192–202.

Ozdemir, F., Birtane, M., Tabatabaei, R., Kokino, S., Ekuklu, G., 2001. Comparing stroke rehabilitation outcomes between acute inpatient and nonintense home settings. Arch. Phys. Med. Rehabil. 82, 1375–1379.

Patterson, K.K., Parafianowicz, I., Danells, C.J., Closson, V., Verrier, M.C., Staines, W.R., Black, S.E., McIlroy, W.E., 2008. Gait asymmetry in community-ambulating stroke survivors. Arch. Phys. Med. Rehabil. 89, 304–310.

Pohl, M., Mehrholz, J., Ritschel, C., Ruckriem, S., 2002. Speed-dependent treadmill training in ambulatory hemiparetic stroke patients: a randomized controlled trial. Stroke 33, 553–558.

Pollock, A., Baer, G., Pomeroy, V., Langhorne, P., 2007. Physiotherapy treatment approaches for the recovery of postural control and lower limb function following stroke. Cochrane Database Syst. Rev. 24 (1), CD001920.

Riberto, M., Miyazaki, M.H., Filho, D.J., Sakamoto, H., Battistella, L.R., 2001. Reproductivity of the Brazilian version of functional independence measure. Acta Fisiat. 8 (1), 45–52.

Riberto, M., Miyazaki, M.H., Jucá, S.S.H., Sakamoto, H., Pinto, P.P.N., Battistella, L.R., 2004. Validation of the Brazilian version of functional independence measure. Acta Fisiat. 11 (2), 72–76.

Shimura, K., Kasai, T., 2002. Effects of proprioceptive neuromuscular facilitation on the initiation of voluntary movement and motor evoked potentials in upper limb muscles. Hum. Mov. Sci. 21, 101–113.

Sullivan, K.J., Knowlton, B.J., Dobkin, B.H., 2002. Step training with body weight support: effect of treadmill speed and practice paradigms on poststroke locomotor recovery. Arch. Phys. Med. Rehabil. 83 (5), 683–691.

Tanaka, H., Monahan, K.D., Seals, D.R., 2001. Age – predicted maximal heart revisited. J. Am. Coll. Cardiol. 37, 153–156.

Trueblood, P.R., Walker, J.M., Perry, J., Gronley, J.K., 1989. Pelvic exercise and gait in hemiplegia. Phys. Ther. 69 (1), 18–26.

Van Peppen, R.P., Kwakkel, G., Wood-Dauphinee, S., Hendriks, H.J., Van der Wees, P.J., Dekker, J., 2004. The impact of physical therapy on functional outcomes after stroke: what's the evidence? Clin. Rehabil. 18 (8), 833–862.

Wang, R.I., 1994. Effect of proprioceptive neuromuscular facilitation on the gait of patients with hemiplegia of long and short duration. Phys. Ther. 74 (12), 1108–1115.

World Health Organization, 2006. WHO STEPS Stroke Manual: The WHO STEPwise Approach to Stroke Surveillance. Geneva. Available at: http://www.who.int/chp/steps/Stroke/en/. Accessed in 2012 Apr.