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Time since injury limits but does not prevent improvement and maintenance of gains in balance in chronic stroke

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ABSTRACT

Objective: To determine the influence of time since injury on the efficacy and maintenance of gains of rehabilitation of balance after stroke.
Method: Forty-seven participants were assigned to a least (6–12 months), a moderate (12–24 months), or a most chronic (>24 months) group. Participants trained for 20 one-hour sessions, administered three to five times a week, combining conventional physical therapy and visual feedback-based exercises that trained the ankle and hip strategies. Participants were assessed before, after the intervention, and one month later with a posturography test (Sway Speed and Limits of Stability) and clinical scales.
Results: In contrast to other subjects, the most chronic participants failed to improve their sway and to maintain the benefits detected in the Limits of Stability after the intervention. Although all the participants improved in those clinical tests that better matched the trained skills, time since injury limited the improvement, and over all, the maintenance of gains.
Conclusion: Time since injury limits but does not prevent improvement in chronic stages post-stroke, and this effect appears to be more pronounced with maintaining gains. These findings support that training duration and intensity as well as type of therapy may need to be adjusted based on time post-stroke.

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Introduction

In the last decade, vast resources have been invested to understand brain mechanisms after stroke. Current knowledge on pathophysiology has formed the basis of evidence-based neurorehabilitation (1). The existing evidence supports that endogenous neurological recovery occurs with peak intensity within the first three months post-stroke and then declines and ends at six months (2). Traditionally, the idea of recovery plateau has strongly influenced the way that rehabilitation has been administered (3). There is a general agreement among clinicians that the earlier the rehabilitation starts, the greater the benefits that patients can obtain (2). Efficacy of early interventions has been supported by longitudinal studies that demonstrate greater improvement at earlier stages post-stroke (4). In addition, different attempts to determine the ideal timing for rehabilitation have shown that early interventions may provide greater benefits to functional independence for persons post-stroke in the acute (5) and sub-acute phase (6).

However, the boundaries of the window of opportunity for rehabilitation are still a matter of debate with clinical, economical, and ethical consequences (3). Recent literature has questioned the existence of a plateau, evidencing instead the lifelong potential of the neurobiological systems to adapt and reorganize. In accordance with this, it has been shown that functional improvements still occur after six months, supported by brain mechanisms that, although possible, must be externally driven (7). Functional and brain recovery is well documented after rehabilitation of upper limb function in the chronic phase (8,9). Different interventions have also shown to improve balance and postural control at this phase. One-on-one strength training interventions have reported benefits to individuals post-stroke more than one year after the onset (10). Group programs have also provided similar results after more than one (11) and 2 years (12). Task-oriented training involving reaches, steps, and raises has been reported to improve balance after one year since injury (13). Similar intense mobility training focusing on obstacle avoidance, walking, sit-to-stand, stair-climbing, and coordination tasks has also provided benefits to balance six (14) and nine months after the onset (15). Provision of visual feedback on force plate has been also reported to promote benefits not only six months (16) but also years after stroke (17). In addition virtual reality-based training of the ankle and hip strategies (18,19) and the stepping strategies (20,21) at this stage have been also shown to provide benefits in balance to individuals with stroke.

All these results support the evidence that, first, greater improvements are expected in early stages, but, second, rehabilitation of balance is possible in chronic stages. Unfortunately, differences in the intervention, dosage, and participants of the

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previous studies prevent accurate characterization of the effect of time since injury in the rehabilitation of balance in this phase (22,23). Characterization of this effect would help to better define rehabilitation interventions, over all, in the chronic stages.

According to the existing evidence, we hypothesized that time since injury would limit, but not nullify, the effect of an intensive training on balance function and postural control and the maintenance of gains after the intervention. The objective of this study was to determine the efficacy of a visual feedback-based intervention in groups of chronic post-stroke subjects with different time since injury. The intervention focused on the training of the ankle and hip strategies using force plates, and was previously included in the standard practice of both units, motivated by the positive effects of this (18,19) and similar interventions (16,17) reported in chronic subjects with variable time since injury.

Materials and methods

Participants

All the stroke outpatients who were attending a rehabilitation program in two specialized neurorehabilitation centres were candidates to participate in this study. The inclusion criteria were as follows: (1) age ≥ 50 and ≤ 65 years old; (2) time since onset > six months; (3) time from admission > three months; (4) Mini-Mental State Examination (24) score above 23; and (5) ability to walk 10 m indoors with or without assistive devices or orthotics. Subjects were excluded if they presented: (1) inability to follow instructions defined by Mississippi Aphasia Screening Test (25) score below 45; (2) unilateral spatial neglect; (3) ataxia or any other cerebellar symptom; and (4) severe auditory or visual impairments.

The study was approved by the Institutional Review Board of both medical centres. Written consent was obtained from all of the subjects who satisfied the inclusion criteria and accepted to participate in the study.

Intervention protocol

Immediately prior to the intervention, all the participants were enrolled in a long-term neurorehabilitation program in one of both centres that included conventional physical therapy 3–5 days a week. Participants were assigned to one of three groups according whether their time since injury was less than one year, from one to two years, and greater than two years. These artificial cut-offs were chosen as being representative of the literature (10–14,16). The intervention involved 20 sessions, one-hour long, administered 3–5 days a week. Training sessions combined 20 minutes of conventional physical therapy with 40 minutes of specific training of the ankle and hip strategies through virtual reality-based customized exercises on a balance board (18,19), with two-minute breaks each 10 minutes. After the intervention, participants returned to the conventional physical therapy program. The conventional balance training consisted of one-on-one exercises including the following exercises: (1) static standing exercises in different positions (Romberg position, tandem stance, single stance, etc.) using verbal, visual, and perceptual cues to increase weight bearing to the affected lower limb; (2) stepping tasks to increase weight transfer and improve the stepping strategy; (3) static and dynamic balance exercises including arm activities during functional tasks to improve balance self-confidence in daily activities; and (4) walking exercises under different conditions (obstacle course, indoor and outdoor walking, stair climbing, etc.). The virtual reality-based training of the ankle and hip strategies consisted of six different exercises that promoted the training of the ankle and hip strategies (see Supplemental File for further information). Exercises provided audiovisual information of the centre of pressure and required participants to displace it towards different targets in a virtual environment through weight transferences and postural readjustments.

The difficulty of the conventional physical therapy, including that prior and subsequent to the intervention, and the customized training of the ankle and hip strategies were established every two weeks by an experienced physical therapist according to the particular needs, condition, and progress of each participant. The maximum excursion of the centre of pressure in the training of the ankle and hip strategies was defined as the 80% of the limits of stability of each participant.

All the participants were assessed before and after the intervention, and one month after, with a posturography test that studied Sway Speed during the modified Clinical Test of Sensory Interaction on Balance and Limits of Stability (26), and with a battery of clinical scales that included the Berg Balance Scale (BBS) (27), the Functional Reaches Test (FRT) (28), the 30-Second Sit-to-Stand Test(30CST) (29), the Stepping Test in the paretic and non-paretic side (30), the Timed Up-and-Down Stairs Test (31), the Timed Up-and-Go Test (32), and the 10-m Walking Test (33).

Statistical analysis

Demographical and clinical comparisons between groups at baseline were performed with analysis of variance (ANOVA) and Chi-squared or Fisher exact tests, as appropriate. Repeated-measures ANOVA with time as the within-subjects factor and chronicity as between-subjects factor were performed for all the tests and scales. The main effects of time, chronicity, and the time-chronicity interaction effects were evaluated. ANOVA findings that violated the sphericity assumption were accommodated by Greenhouse and Geisser's conservative degrees of freedom adjustment. For each repeated-measures ANOVA, we present the partial eta squared (η^2_p) as a measure of effect size; values may range between 0 and 1, with higher values representing higher proportions of variance explained by the independent variable.

The α level was set at 0.05 for all analyses (two-sided). All analyses were computed with SPSS Statistics, version 22 (IBM®, Armonk, NY, USA).

Results

Participants

A total pool of 167 outpatients was screened. Among them, 51 subjects (30.5%) met inclusion criteria and agreed to participate in the study. As explained above, participants were classified according to their time since stroke. Two participants of the moderately chronic group and one of the most chronic

Table 1. Characteristics of the participants.

Characteristic	Least chronic group (n = 16)	Moderately chronic group (n = 15)	Most chronic group (n = 16)	Significance
Gender (n, %)				NS (p = 0.240)
Male	10 (62.5%)	13 (86.7%)	10 (62.5%)	
Female	6 (37.5%)	2 (13.3%)	6 (37.5%)	
Age (years)	58.7 ± 8.6	58.7 ± 8.0	59.9 ± 5.0	NS (p = 0.876)
Etiology (n, %)				NS (p = 0.705)
Ischemic	12 (75.0%)	11 (73.3%)	10 (62.5%)	
TACI	4 (33.3%)	3 (27.3%)	2 (20.0%)	
PACI	6 (50.0%)	6 (54.5%)	5 (50.0%)	
LACI	2 (16.7%)	1 (9.1%)	2 (20.0%)	
POCI	0 (0.0%)	1 (9.1%)	1 (10.0%)	
Hemorrhagic	4 (25.0%)	4 (26.7%)	6 (37.5%)	
Hemiparesis (n, %)				NS (p = 0.761)
Right	9 (56.3%)	7 (46.7%)	7 (43.8%)	
Left	7 (43.7%)	8 (53.3%)	9 (56.3%)	
Chronicity (days)	245.7 ± 60.1	476.1 ± 87.4	2174.9 ± 1136.8	p = 0.000
Berg Balance Scale	39.1 ± 7.4	40.5 ± 11.8	44.7 ± 5.5	NS (p = 0.168)

Age, chronicity, and scores in the Berg Balance Scale are defined in terms of mean and standard deviation. Gender, etiology, and hemiparesis are expressed as a number and percentage of total number of participants. TACI: total anterior circulation infarct; PACI: partial anterior circulation infarct; LACI: lacunar infarct; POCI: posterior circulation infarct; NS: non-significant.

group were discharged, and one participant of the least chronic group suffered a second stroke and their data were, consequently, excluded. Final analysis included the data of 47 participants (Table 1). No significant differences in demographical or clinical data at inclusion were detected between the groups.

Posturographic assessment

Different responses of the groups were detected in the Sway Speed ($p = 0.030$, $\eta^2_p = 0.11$). The least and moderately chronic participants similarly reduced their sway after the intervention, and continued improving at the follow-up examination. However, no change in this variable was detected in subjects with greatest chronicity. The differences between groups were more pronounced for the Limits of Stability. All the participants increased their limits after the intervention but only the least chronic subjects continued improving at follow-up, while the moderately chronic subjects maintained the gains, and the most chronic subjects failed to retain those gains ($p = 0.000$, $\eta^2_p = 0.12$). Posturographic data are shown in Table 2 and depicted in Figure 1.

Clinical scales and tests

Significant differences between the three groups were detected in the BBS ($p = 0.005$, $\eta^2_p = 0.15$), the FRT ($p = 0.044$, $\eta^2_p = 0.12$), and the 30CST ($p = 0.017$, $\eta^2_p = 0.10$). All the participants improved their scores in these tests after the intervention, even though more limited changes were reached by the most chronic group. Examination at follow-up evidenced that only the least chronic subjects continued improving in the three tests, while the moderately chronic subjects improved in the BBS and the FRT and maintained the gains in the 30CST, and the most chronic subjects maintained the gains in the BBS, but slightly worsened their scores in the FRT and 30CST. Clinical data are shown in Table 3, and significant measures are depicted in Figure 2.

Discussion

This paper reports on the efficacy of a visual feedback-based intervention that focused on postural adjustments through the use of the ankle and hip strategies in subjects post-stroke with different times since injury who were enrolled in a conventional physical therapy program immediately prior to the study. Our results support that this intervention improved balance and postural control for persons at the chronic stages post-stroke, and more importantly, that time since injury modulated improvement as well as the ability to maintain gains.

Time since injury does not prevent improvement

The improvement in posturographic data after the intervention in all groups, evidenced by increased Limits of Stability and reduced Sway Speed, supports previous reports in chronic populations (16). Even though a decrease in postural sway does not necessarily reflect improvement of the balance ability (34),

Table 2. Posturographic data.

	Initial assessment	Final assessment	Follow-up assessment	Significance (p, effect size)
Sway Speed (cm/s)				
Least	2.4 ± 0.3	2.2 ± 0.5	2.1 ± 0.5	T**(p = 0.001),
Moderately	1.8 ± 0.4	1.7 ± 0.4	1.6 ± 0.4	GxT**(p = 0.030),
Most	1.9 ± 1.1	1.8 ± 0.9	1.9 ± 0.9	$\eta^2_p = 0.11$
Limits of Stability (%)				
Least	92.8 ± 24.0	98.7 ± 17.4	101.9 ± 15.0	T**(p = 0.000),
Moderately	81.9 ± 9.0	95.0 ± 10.8	94.7 ± 13.0	GxT**(p = 0.000),
Most	81.4 ± 29.3	94.3 ± 26.6	86.4 ± 23.6	$\eta^2_p = 0.12$

Data are given in terms of mean and standard deviation. T: time effect. GxT: group by time effect. *: p < 0.05, **: p < 0.01. NS: non-significant.

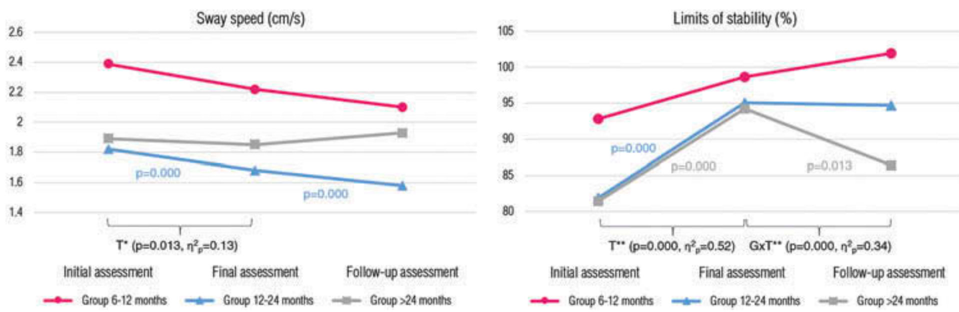

Figure 1. Progress on posturographic data. Statistical significance is provided for each group in those time intervals with a significant time effect. The significant time effects and group-by-time effects detected in each time interval and their effect size are provided beneath them.

Table 3. Clinical data.

	Initial assessment	Final assessment	Follow-up assessment	Significance (p, effect size)
Berg Balance Scale				
Least	39.1 ± 7.4	43.0 ± 6.1	44.7 ± 5.6	T**(p = 0.000),
Moderately	40.5 ± 11.8	45.6 ± 9.5	48.0 ± 8.1	GxT**(p = 0.005),
Most	44.7 ± 5.5	47.9 ± 5.3	47.7 ± 5.5	$\eta^2_p = 0.15$
Functional Reaches Test (cm)				
Least	24.1 ± 8.9	27.4 ± 7.1	29.0 ± 6.7	T**(p = 0.000),
Moderately	24.5 ± 4.1	27.7 ± 6.8	28.9 ± 7.2	GxT**(p = 0.044),
Most	24.4 ± 5.9	26.0 ± 6.2	25.2 ± 5.8	$\eta^2_p = 0.12$
30-Second Sit-to-Stand Test	8.8 ± 7.7	10.6 ± 4.7	11.7 ± 4.8	T**(p = 0.004),
Least	9.9 ± 3.6	12.1 ± 4.3	12.0 ± 4.1	GxT**(p = 0.017),
Moderately	9.2 ± 4.0	9.9 ± 4.0	9.6 ± 5.1	$\eta^2_p = 0.10$
Most				
Stepping Test – paretic (n)				NS
Least	6.6 ± 3.7	7.2 ± 4.1	7.2 ± 4.3	
Moderately	6.9 ± 4.8	7.4 ± 3.6	7.0 ± 3.8	
Most	7.5 ± 5.0	7.8 ± 4.0	7.8 ± 4.1	
Stepping Test – non-paretic (n)				NS
Least	6.9 ± 4.1	7.7 ± 4.2	8.1 ± 4.0	
Moderately	7.5 ± 2.7	7.9 ± 2.5	7.7 ± 2.9	
Most	7.6 ± 3.1	7.6 ± 2.6	7.5 ± 2.2	
Timed Up-and-Down Stairs Test (s)				NS
Least	20.9 ± 4.7	19.2 ± 4.1	20.0 ± 3.0	
Moderately	15.5 ± 6.6	14.3 ± 7.9	14.3 ± 8.5	
Most	16.6 ± 10.7	16.9 ± 11.7	16.3 ± 8.3	
Timed Up-and-Go Test (s)				
Least	24.6 ± 12.2	23.1 ± 12.6	22.9 ± 13.7	NS
Moderately	23.7 ± 12.4	23.0 ± 13.8	22.9 ± 12.3	
Most	23.8 ± 18.5	23.6 ± 22.8	23.6 ± 21.8	
10-m Walking Test (s)				
Least	27.8 ± 27.5	26.3 ± 27.7	26.4 ± 26.8	
Moderately	14.2 ± 5.6	12.8 ± 5.7	13.0 ± 5.5	
Most	21.1 ± 13.1	20.4 ± 12.8	20.4 ± 12.9	

Data are given in terms of mean and standard deviation. T: time effect. GxT: group by time effect. *: $p < 0.05$, **: $p < 0.01$. NS: non-significant.

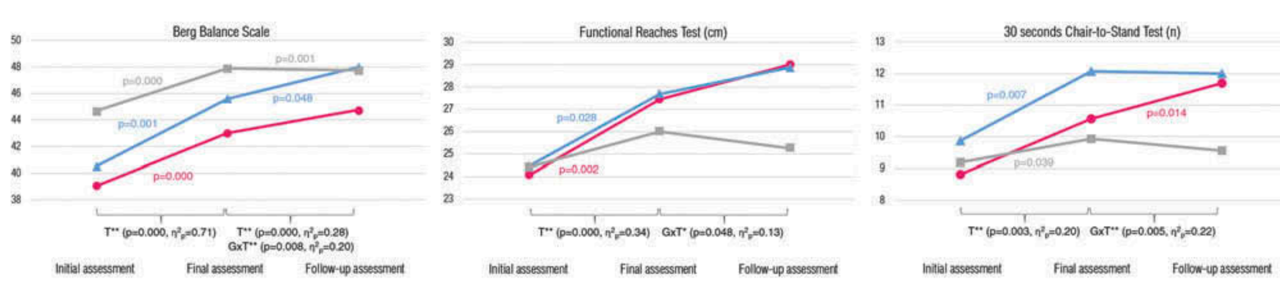

Figure 2. Progress on significant clinical data. Statistical significance is provided for each group in those time intervals with a significant time effect. The significant time effects and group-by-time effects detected in each time interval and their effect size are provided beneath them.

results in the clinical variables confirmed this relationship in our study. As proof, our data showed improvement in all groups in the BBS, the FRT, and the 30CST, like preliminary studies with similar interventions (18,19).

It is important to highlight that the significant clinical changes were detected in those tests that involved bilateral symmetrical lower extremity loading and consequently better match the trained skills. No significant changes were detected in more dynamic and gait tests, which may be explained by specificity of the training. However, this hypothesis should be further studied. Our results are in agreement with previous evidence (10–21) that documents that it is possible to improve balance and postural control months and even years after the onset.

Time since injury limits the improvement

The different responses to training of the three groups in the sway speed indicated a negative effect of time since injury on the efficacy of the intervention in postural control. This effect was not reflected in the Limits of Stability, where the least chronic group showed the lowest increase. This finding might be interpreted as a ceiling effect on this measure, since this group had a mean baseline score of 92.8, more than 10 points higher than the other groups.

Results in the clinical outcomes are in line with the existing evidence. Greater improvement has been reported in functional independence in individuals with less time since injury (5,6), although the effect of this variable in the efficacy of an intervention could be less evident in the acute phase (35) and more pronounced over time. This relationship has been also confirmed in the motor function of upper extremities, where greater motor improvement has been detected at more acute stages (36) in comparison to that at chronic stages (37) after similar interventions. Our results support previous evidence that endorses greater improvement at early stages after stroke.

Time since injury limits the maintenance of gains

The responses of the participants of the least chronic groups confirm previous findings after a similar intervention, where participants with similar characteristics were able to maintain the gains and even improve after the intervention (19). The return to the conventional physical therapy program after the intervention could have provided these participants with a sufficient dose and intensity of rehabilitation to maintain the benefits and even to be a solid background for further improvements. In contrast, the change of intervention could have interrupted the progress of the most chronic participants, who might need more time to show comparable improvements and to maintain part of the benefits obtained during the intervention. This effect could be especially detrimental in those skills that better matched the training, as reflected by the difficulty to maintain the gains in the Limits of Stability and the FRT; both tests require specific control of the ankle and hip strategies. A large number of studies have reported the progress of individuals post-stroke months and even years after the onset. Although some contradictory reports exist, a great body of research reveals that clinical deterioration is common after discharge of rehabilitation, not only with regards to dependency (38), but also to function (39). However, literature about the maintenance of gains when returning to a physical therapy program after a specific intervention is more limited, especially in virtual reality-based interventions, where few empirical studies exist (21,40). Our results might reflect an overall increased difficulty in maintaining specific body function and structural improvements in the very chronic stages, while evidencing a preserved capability to retain the improvement in global balance.

Limitations

First, although the number of participants is comparable and even higher to similar interventions, it can be considered small. However, the similarity of the three groups on other variables, demographic or clinical, supports that time because injury could be a determining factor for improvement and maintenance of gains. Second, the specificity of the visual feedback-based intervention could restrict extrapolation to the results to other interventions. Third, follow-up assessment was at one month after the intervention making long-term effects of the intervention unknown. Finally, the design of our study precludes specific identification of the source of improvement. Consequently, it is not possible to discern whether the improvement was caused by the intervention itself, by the change of intervention, or by both.

Clinical implications

The results of this study may have several implications for the clinical practice. First, the data provide evidence that persons post-stroke are able to improve their balance even at chronic stages. In line with previous work, this questions the existence of a ceiling effect in the rehabilitation of functional deficits after stroke (3). As a great percentage of stroke survivors will present motor deficits throughout their lifetime, and reduced balance is common following stroke, negatively impacting independence and safety (41), the findings presented here raise the important question of when patients should be discharged from neurorehabilitation programs. Our results presented as well as previous literature (10–21), argue that a serious proportion of the discharges are in response to economic factors or resources rather than to rehabilitation criteria, resulting in some individuals not be receiving sufficient rehabilitation to reach their full recovery potential (42).

Second, as persons in the most chronic phase post-stroke did not maintain the gains from the program, one might speculate that they may need training of greater duration or greater dose than those who are less chronic. Third, although it is not possible to determine if the change from conventional to a visual feedback-based program was the source of improvement in our study, the change of intervention has been suggested to promote motor improvement in individuals who had plateaued (3). Different studies have corroborated the efficacy of novel rehabilitation interventions in this condition (43,44). Our results support the temporary use of intensive virtual reality-based balance training to overcome the plateau in the motor recovery promoted by conventional physical therapy in chronic individuals.

Finally, our results suggest that the chronic state post-stroke should be understood as a continuum rather than a single unchanging phase. Research should focus on scrutinizing the range of time post-stroke as there may be groups of chronic subjects (as was the case in this study) that respond differently.

Conclusions

Our results suggest that time since injury restricts, but does not prevent, the efficacy of physical interventions on balance and postural control and, over all, the maintenance of functional improvements in specific skills. However, despite these limitations, the improvement experienced by all the participants and the maintenance of gains in the global balance condition support the inclusion of individuals with chronic stroke in balance rehabilitation programs.

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Declaration of interest

The authors report no declarations of interest

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