The effect of repetitive rhythmic precision grip task-oriented rehabilitation in chronic stroke patients: a pilot study

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Most chronic stroke patients present difficulty in the manipulation of objects. The aim of this study was to test whether an intensive program of precision grip training could improve hand functioning of patients at more than 6 months after a stroke. This was a cross-over study; hence, at inclusion, the patients were randomly divided into two groups: one group started with the bilateral movement therapy and the other group started with the unilateral movement therapy. The patients were assessed on four separate occasions across a 12-week period: (a) at inclusion in the study, (b) 4 weeks later, immediately before the first rehabilitation session, (c) after 4 weeks of one therapy, and (d) after a further 4 weeks of the other therapy. Ten patients completed two consecutive 4-week sessions (1 h, 3 days/week) of therapy. The therapy comprised unilateral and bilateral repetitive grip-lift task-oriented rehabilitation with rhythmic auditory cueing. The grip-lift force coordination, digital dexterity, manual ability, and the level of satisfaction (with activities and participation) were assessed. A one-way repeated-measure analysis of variance across the four evaluations did not detect any objective improvement in the measured variables after 8 weeks of specific intensive training. Precision grip training was shown to not generate significant improvement in the grip-lift task, digital dexterity, manual ability, or satisfaction in chronic stroke patients.

Bei den meisten Schlaganfallpatienten im chronischen Stadium ist die Manipulation von Objekten erschwert. Mit der vorliegenden Studie soll geprüft werden, ob ein umfassendes Programm mit Präzisionsgriff-Training die Handfunktion von Patienten mehr als 6 Monate nach einem Schlaganfall verbessern kann. Bei dieser Studie handelte es sich um eine Crossover-Studie, bei der die Patienten bei der Rekrutierung randomisiert auf zwei Gruppen aufgeteilt wurden: Eine Gruppe begann mit der bilateralen Bewegungstherapie, die andere mit der unilateralen Bewegungstherapie. Die Patienten wurden bei vier verschiedenen Gelegenheiten über einen 12-wöchigen Zeitraum hinweg beurteilt: (a) bei Studienaufnahme, (b) 4 Wochen später, unmittelbar vor der ersten Reha-Sitzung, (c) 4 Wochen nach einer Therapie und (d) nach weiteren 4 Wochen nach der anderen Therapie. Zehn Patienten schlossen zwei konsekutive 4-Wochen-Therapiesitzungen (1 h, 3 Tage/Woche) ab. Die Therapie besteht aus einer aufgabenorientierten Rehabilitation mit wiederholter unilateraler und bilateraler Griff-Hebe-Funktion und rhythmisch-auditorischer Stimulation. Beurteilt wurden die Koordination der Griff-Hebe-Funktion, die Fingerfertigkeit, die Handfertigkeit sowie die allgemeine Zufriedenheit (mit den Aktivitäten und der Teilhabe). Eine einfaktorielle Varianzanalyse mit Messwiederholungen über die vier Beurteilungskomponenten hinweg ergab keine objektive Verbesserung der Messvariablen nach 8 Wochen spezifischen intensiven Trainings. Das Präzisionsgriff-Training wies keine signifikante Verbesserung der Griff-Hebe-Funktion, der Fingerfertigkeit, der Handfertigkeit oder der allgemeinen Zufriedenheit von Schlaganfallpatienten im chronischen Stadium auf.

La mayoría de pacientes con ictus crónico tienen dificultad para manipular objetos. El objetivo de este estudio fue evaluar si un programa intensivo de entrenamiento del agarre de precisión podía ayudar a mejorar la capacidad manual de estos pacientes transcurridos un mínimo de 6 meses después del ictus. Se trató de un estudio transversal; por lo tanto, tras su admisión los pacientes fueron divididos de forma aleatoria entre dos grupos: uno de los grupos comenzó con la terapia de movimiento bilateral y el otro, con la terapia de movimiento unilateral. Los pacientes fueron evaluados en cuatro ocasiones a lo largo de un período de 12 semanas: (a) en el momento de admisión en el estudio, (b) 4 semanas más tarde, inmediatamente después de la primera sesión de rehabilitación, (c) 4 semanas después de finalizar uno de los entrenamientos, y (d) 4 semanas después de finalizar el otro entrenamiento. Diez pacientes participaron en dos sesiones consecutivas de terapia de 4 semanas cada una (1 h, 3 días/semana). La terapia consistía en ejercicios prácticos repetitivos de rehabilitación mediante agarre y levantamiento unilateral y bilateral con ayudas auditivas rítmicas. Se evaluó la coordinación de las fuerzas de agarre y levantamiento, la destreza dactilar, la capacidad manual y el nivel de satisfacción (con las actividades y la participación). El análisis de varianza de una vía con medidas repetidas al que se sometieron las cuatro evaluaciones no detectó ninguna mejora objetiva en las variables analizadas tras 8 semanas de entrenamiento intensivo específico. Se demostró que el entrenamiento del agarre de precisión no produce mejoras significativas en el ejercicio de agarre y levantamiento, la destreza dactilar, la capacidad manual o el nivel de satisfacción en pacientes con ictus crónico.

La plupart des patients victimes d'accidents cardio-vasculaires en phase chronique ont des difficultés pour manipuler les objets. Cette étude avait pour objet de vérifier si un programme intensif de rééducation de la précision de préhension pouvait améliorer le fonctionnement de la main des patients plus de 6 mois

après un AVC. L'étude était de conception transversale. Par conséquent, à l'inclusion, les patients ont été répartis aléatoirement en deux groupes : un groupe a commencé par une thérapie par mouvement bilatéral et l'autre par thérapie par mouvement unilatéral. Les patients ont été évalués à quatre reprises sur une période de 12 semaines : (a) à l'inclusion dans l'étude, (b) 4 semaines plus tard, juste avant la première séance de rééducation, (c) après 4 semaines de l'une des thérapies, et (d) après 4 semaines de l'autre thérapie. Dix patients ont suivi deux programmes consécutifs de thérapie de 4 semaines (1½h, 3 jours / semaine). La thérapie comprenait des tâches de rééducation répétitives de préhension-levage unilatérale et bilatérale avec signaux auditifs rythmiques. La coordination de la force de préhension-levage, la dextérité digitale, l'habileté manuelle et le niveau de satisfaction (avec les activités et la participation) ont été évalués. Une analyse de la variance de mesure répétée d'un mouvement simple sur les quatre évaluations n'a pas permis de détecter d'amélioration objective dans les variables mesurées au bout de 8 semaines de rééducation intensive spécifique. Il a été constaté que la rééducation de la précision de préhension ne produisait pas d'amélioration significative des tâches de préhension-levage, de dextérité digitale, d'habileté manuelle ni de satisfaction chez les patients souffrant d'AVC. *International Journal of Rehabilitation Research* 00:000–000 © 2012 Wolters Kluwer Health | Lippincott Williams & Wilkins.

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Introduction

Hands are essential for the dexterous manipulation of objects in activities of daily life. Following a stroke, the ability to hold an object between the thumb and the index finger can be impaired because of limitations in sensibility, force, and digital dexterity.

The grip-lift task analysis procedure provides a means to objectively quantify the way an object is held between the thumb and the index finger (Westling and Johansson, 1984). Dynamic and temporal variables are classically studied for the perpendicular [grip force (GF)] and tangential force [load force (LF)] to the contact surfaces. In stroke patients, some of the grip-lift variables become modified (McDonnell *et al.*, 2006).

A range of different therapies have led to satisfactory results for the recovery of the upper limbs in chronic stroke patients (Nowak and Hermsdorfer, 2009; Shi *et al.*, 2011). For example, constraint-induced movement therapy involves treatment mechanisms that are supported by established behavioral learning theory and evidence of brain plasticity (Sterr and Saunders, 2006).

In contrast, because strokes induce reorganization in contralesional motor networks, repetitive bilateral training is increasingly being used. This intracortical inhibition and facilitation therapy uses a rhythm-based auditory cue to prompt the realization of functional tasks or repetitive arm movements (Whitall *et al.*, 2000; Mccombe Waller *et al.*, 2008).

Hence, interest in establishing the effectiveness of a treatment that combines both unilateral and bilateral therapies is justified. Furthermore, current guidelines for the design of poststroke upper limb rehabilitation programs also emphasize the importance of promoting distal motor capacities (Oujamaa *et al.*, 2009). Therefore, in the current study, we focused on developing a modification of the two bilateral and unilateral therapies, specifically targeting the distal extremity of the upper limb. To our knowledge, the current study is the first to focus on the recovery of precision grip capability, taking into consideration grip-lift parameters by means of a repetitive unilateral and bilateral grip-lift task-oriented rehabilitation procedure with rhythmic auditory cueing in chronic stroke patients. Therefore, the aim of the present study was to test whether such a precision grip rehabilitation program could improve hand functioning of patients at more than 6 months after a stroke.

Methods

This study was approved by the School of Medicine Ethical Committee of the Université catholique de Louvain (Belgium). All participants provided informed and written consent.

Patients

Ten chronic hemiparetic patients (mean age 66±11.1 years, nine men and one woman) were initially allocated to the treatment. To be included to the study, the patients had to have had a stroke (evidenced by MRI) a minimum of 6 months before participating in the study. All the patients had completed a neurological clinical evaluation that established hemiparesis by means of the Stroke Impairment Assessment Set (Chino *et al.*, 1996; Liu *et al.*, 2002). The patients had to be able to lift and hold an object of 250 g between the thumb and the index finger for a few seconds. A mini-mental state evaluation was carried out, in which the patient had to score above 26/30, which implied a capability to understand the injunctions and respond to self-reported questionnaires.

Patients with other upper-limb pathologies were excluded.

Protocol

An independent evaluator, who operated under 'blind' conditions with respect to the treatment allocation of each of the patients, was designated to assess the upper limbs.

The patients were assessed on four separate occasions across a 12-week period. The first assessment (t_0) was carried out when the patient was included in the study. The second assessment (t_1) was carried out after a period of 4 weeks, during which time the patient did not receive any specific treatment. This allowed for comparison between t_0 and t_1 to confirm that the patients were in a chronic phase with no spontaneous recovery of the upper limb function. The third evaluation (t_2) was carried out 4 weeks later, during the time the patient had completed the first half of the specific grip-lift task-oriented rehabilitation. The final evaluation (t_3) was carried out after another 4 weeks, following the completion of the second half of the specific rehabilitation program.

This was a cross-over study; hence, at inclusion, the patients were randomly divided into two groups: one group started with the bilateral movement therapy and the other one started with the unilateral movement therapy. The therapy sessions occurred for a period of 1 h, three times a week, for 8 weeks (i.e. 4 weeks of bilateral movement therapy and 4 weeks of unilateral movement therapy). For the entire period of the program, ongoing treatments were kept unchanged.

Rehabilitation intervention

Bilateral movement therapy

Seven bilateral grip-lift task-oriented exercises with auditory cueing were performed in a random order. The bilateral movement therapy comprised of four simultaneous bilateral tasks (Fig. 1a–d) and three alternated bilateral movements tasks (Fig. 1e–g). All exercises were specifically focused on the grip-lift task. AQ2

Each task, except for task 3 (oscillation task, Fig. 1c), was auditory cued. The rhythm (speed of cueing) was selected as the maximal rhythm required by the patient to properly execute the task beforehand during a test trial (minimum 24 bpm). The rhythm and task difficulty level were adapted across the sessions to encourage improvement in patient performance.

Unilateral movement therapy

Unilateral movement therapy comprised the same exercises that are described in the bilateral movement section above. However, each task was completed exclusively with the paretic hand of the patient. The rhythm and task difficulty level were also adapted across the sessions.

International classification of functioning-based, disability-based, and health-based upper limb assessment

Body structures and functions

The patients sat on a chair in front of a table to complete the grip-lift tasks. The patients were required to grasp a manipulandum between the thumb and the index finger (Fig. 2a), lift it off the table, hold it for about 10 s, and replace it on the table. Each patient performed six of these grip-lift trials with each hand, starting with the nonparetic hand. AQ3

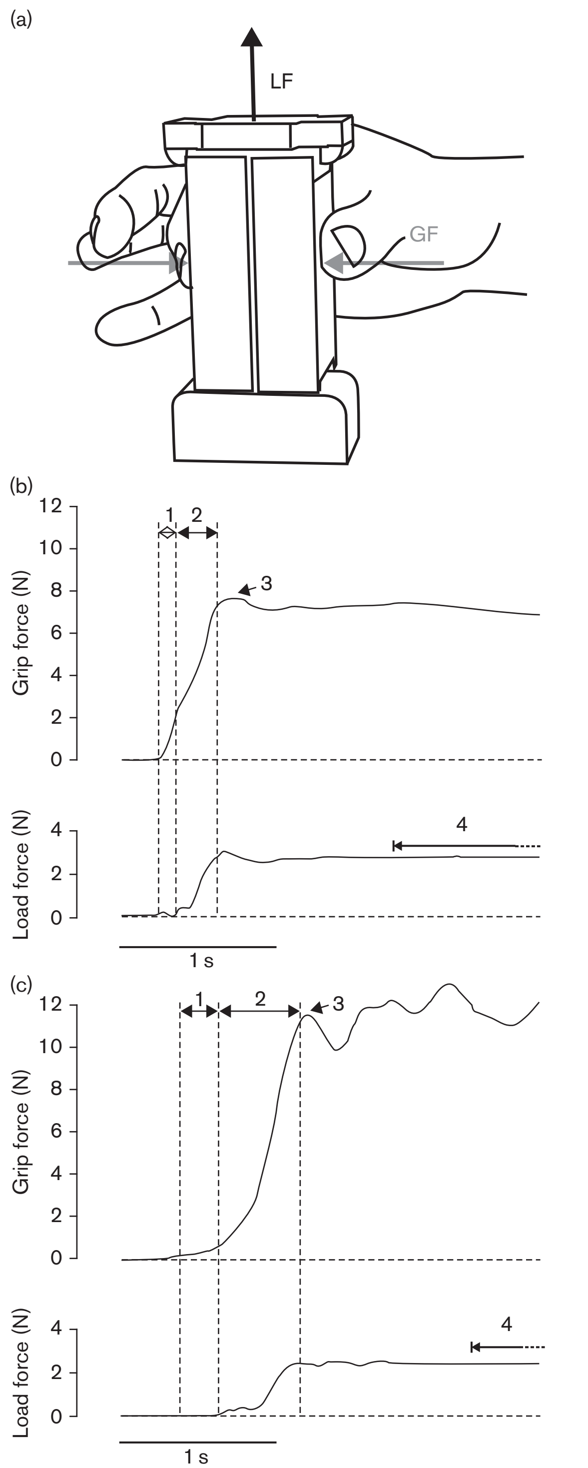
The manipulandum was instrumented with full Wheatstone Bridges incorporating three strain gauges to allow the force perpendicular to each contact surface to be measured (GF left and GF right), in addition to the total tangential force applied on the object (LF). Each sensor used a binocular design of yield strength 300 N. The manipulandum was calibrated to a maximum scale of 30 N in each direction, and showed a maximum nonlinearity of 0.70 and 0.35% of full scale for the LF and both GF directions, respectively. The analogue signals were amplified and filtered using a four-pole Bessel filter, with a low-pass 150 Hz cut-off filter, and then sampled at 2000 Hz with a 16-bit resolution. The data were stored for off-line analysis. Typical traces of grip-lift trials for a dominant hand of a healthy individual and the paretic hand of a chronic stroke patient are shown in Fig. 2.

The following parameters were measured from the force traces (Fig. 2b–c) (Duque *et al.*, 2003; McDonnell *et al.*, 2006): (1) the preloading phase, that is, the delay between the onset of GF and the onset of LF (threshold 0.1 N), (2) the loading phase, that is, the delay during which both GF and LF increased until LF equaled the weight of the manipulandum (2.75 N), (3) GF_{max}, that is, the maximum GF when the object was lifted off the table, and (4) the hold ratio, that is, the mean GF/mean LF during the stable phase that was started a minimum of 1 s after the GF_{max} was reached, and that lasted for a duration of at least 2 s. Additional parameters were extracted from the first derivative of GF and LF during the preloading and loading phase, including (a) the mean GF rate, which was calculated between the onset and the peak of GF (dGF/dt), and (b) the peak GF rate. The precise synergy between GF and LF was calculated for each trial by means of a cross-correlation function between dLF/dt and dGF/dt. To determine the larger coefficient of correlation between the two signals, one signal was shifted with respect to the other by steps of 2.5 ms. This method yielded two values for each trial: (a) the maximum coefficient of correlation, which indicates the similarity between the profiles of the force rates,

Fig. 1

Grip lift-oriented bilateral movement therapy comprising of four simultaneous bilateral tasks (a–d) and three alternated bilateral movements tasks (e–g). (a) Simultaneous pile-up task. (b) The patient was required to remove and replace blocks from the four horizontal branches of a tree-like apparatus, with both hands simultaneously. (c) Simultaneous bilateral oscillation task at a spontaneous rhythm. (d) This task required the patient to, simultaneously with both hands, separate and then rejoin two rows of blocks. (e) Tower building one hand after the other. (f) Blocks of decreasing size were placed on a wooden stem by one hand after the other. (g) Copying a drawing with the same blocks to be placed with one hand after the other.

Fig. 2



(a) Diagrammatic representation of the manipulandum held between the thumb and the index fingers. Light gray arrows indicate the grip force (GF), whereas the black arrow indicates the load force (LF) exerted on the contact surfaces. (b) Typical trace of a grip-lift trial realized with the dominant hand of a healthy individual. (c) Paretic hand, of a chronic stroke patient, grip-lift trial typical trace. Both traces (b, c) indicate the preloading phase (1), the loading phase (2), the GF peak (3), and part of the stable phase (4).

and (b) a time shift, which indicates the asynchrony between dGF/dt and DLF/dt (Duque *et al.*, 2003).

The Purdue pegboard test was used to evaluate the digital dexterity (Tiffin and Asher, 1948; Desrosiers *et al.*, 1995). Both hands were tested three times each, with the final score being expressed as the mean of the number of pegs that were picked up from a cup and inserted into the holes of the board within a 30-s period.

Activity and participation

The manual ability, defined as the capacity to manage daily activities requiring the use of upper limbs (i.e. peel potatoes, open jar, wash hands), whatever the strategies involved, was assessed using the ABILHAND questionnaire (Penta *et al.*, 2001). The SATIS-Stroke questionnaire was used to measure the activities and participation (i.e. moving outside your home, managing your incomes, participating in ceremonies) in the actual environment experienced by patients after chronic stroke (Bouffioulx *et al.*, 2008). Both questionnaires were Rasch-built self-reported questionnaires and the results were expressed as logit scores.

Statistical analyses

To observe the respective effects of unilateral and bilateral therapy, a two-way repeated measure analysis of variance (RM-ANOVA) was applied to the results of the paretic hand at t_1, t_2, and t_3. A one-way RM-ANOVA was used to compare the evolution of the paretic and nonparetic hand of each patient across each evaluation. At t_1, paired *t*-tests were used to compare (a) the difference between the nonparetic and the paretic hand. Statistical significance was considered when the *P*-value was less than 0.05.

Results

Prerehabilitation assessment

An overview of the initial evaluation status of the 10 patients who participated in the study is provided in Table 1. All the patients showed a moderate level of hemiparesis as indicated by the Stroke Impairment Assessment Set scores. Nevertheless, the digital dexterity was significantly impaired for the paretic hand (Table 3).

Effect of rehabilitation

Comparison of the t_0 and t_1 results did not show any significant difference. This confirmed that the stroke patients were in the chronic phase, with no spontaneous recovery.

The two-way RM-ANOVA applied to the results of the paretic hand at t_1, t_2, and t_3 did not detect any difference between the bilateral and the unilateral movement therapies ($P > 0.144$ in all instances). Given these results, a one-way RM-ANOVA was used to quantify the evolution of paretic hand capability following 8 weeks

Table 1 Summary of the prestudy (t_0) evaluation results for the 10 chronic stroke patients

Patient (sex)	Age (years)	Groups	Hemiparetic side	MMSE/30	SIAS/76	Lesion description (MRI)	Time since stroke (months)
1 (M)	53	A	Right	28	64	Left thalamic stroke	37
2 (M)	75	B	Right	28	67	Left ischemic capsulolenticulostriated stroke	37
3 (M)	60	A	Right	29	69	Left deep sylvian stroke (extended on M1)	33
4 (M)	69	B	Left	28	67	Right deep and superficial sylvian stroke	111
5 (M)	81	A	Left	27	61	Right basal pontic ischemia	10
6 (M)	67	B	Right	29	72	Left deep sylvian stroke	7
7 (M)	49	A	Left	30	66	Right deep and superficial sylvian stroke	18
8 (M)	67	B	Left	26	60	Right deep sylvian stroke	6
9 (F)	81	A	Right	29	67	Left lenticulostriated stroke	12
10 (M)	58	A	Right	28	75	Left thalamic stroke	8

F, female; group A, starting with unilateral movement therapy; group B, starting with bilateral movement therapy; M, male; MMSE, mini-mental state evaluation; SIAS, stroke impairment assessment set.

Table 2 Evolution of the paretic hand grip-lift and dexterity during rehabilitation of the 10 chronic stroke patients at inclusion in the study (t_0), 4 weeks later, immediately before the first rehabilitation session (t_1), after 4 weeks of the first exercise type (t_2), and after a further 4 weeks of the second exercises (t_3)

	t_0	t_1	t_2	t_3	*P*-value
Body structure and function					
Grip-lift parameters					
Preloading phase (ms)	965 (1758.3)	383 (358.9)	612 (640.5)	538 (497.4)	0.453
Loading phase (ms)	385 (110)	465 (204.8)	439 (194.7)	467 (193.7)	0.354
GF_{max} (N)	11 (5.2)	12 (5.6)	11 (5.7)	11 (3.8)	0.497
Hold ratio (GF/LF)	3.5 (1.8)	3.8 (1.66)	4.1 (1.89)	3.4 (1.25)	0.794
Cross-correlation coefficient	0.72 (0.169)	0.75 (0.147)	0.72 (0.213)	0.77 (0.161)	0.274
Time shift (ms)	106 (43.7)	86 (55.8)	94 (48.0)	93 (60.3)	0.749
Digital dexterity (*n*)	4 (3.8)	5 (4.1)	5 (4.1)	5 (3.9)	0.193
Activity limitation					
Manual ability (logits)	1.4 (2.06)	1.9 (2.06)	1.8 (1.91)	2.2 (2.02)	0.072
Satisfaction					
Satisfaction in activities and participation (logits)	1 (1.47)	0.6 (1.13)	0.9 (1.39)	1.0 (1.76)	0.261

GF, grip force; LF, load force.
Data are presented as mean (SD).

Table 3 Comparison of the grip-lift parameters and the digital dexterity between the nonparetic and the paretic hand of the 10 chronic stroke patients

Body structure and function	Nonparetic hand	Paretic hand	*P*-value
Grip-lift parameters			
Preloading phase (ms)	248 (190.7)	383 (358.9)	0.329
Loading phase (ms)	312 (86.6)	465 (204.8)	0.048
GF_{max} (N)	11 (8.5)	12 (5.6)	0.784
Hold ratio (GF/LF)	4.7 (5.2)	3.8 (1.66)	0.507
Cross-correlation coefficient	0.79 (0.121)	0.75 (0.147)	0.601
Time shift (ms)	69 (47.7)	86 (55.8)	0.479
Digital dexterity (*n*)	12 (1.5)	5 (4.1)	<0.001

GF, grip force; LF, load force.
Data are presented as mean (SD).

of specific grip-lift task therapy (Table 2). No significant change was observed for the body structures and functions [grip-lift parameters ($P > 0.193$ in all instances), digital dexterity ($P = 0.193$)], manual ability ($P = 0.072$), or patient satisfaction with activities and participation in daily life ($P = 0.261$).

Table 3 presents the results of the paretic and nonparetic hand assessment of the 10 stroke patients before rehabilitation at t_1. A highly significant difference between both hands was detected for digital dexterity ($P < 0.001$). The temporal grip-lift parameters tended to take longer; however, only the loading phase showed a significant difference between both hands ($P = 0.048$). Surprisingly, the grip-lift dynamics (GF_{max} and hold ratio) showed no significant difference between the paretic and the nonparetic hand ($P > 0.507$ in all instances).

Discussion

Comparison of the ability of the paretic and nonparetic hands of stroke patients before the onset of therapy showed a significant difference for digital dexterity and for the loading phase during the grip-lift task. Surprisingly, few parameters of the grip-lift task were disturbed in the paretic hand, whereas only the digital dexterity of the paretic hand was markedly impaired. A similar study (McDonnell *et al.*, 2006) reported a correlation between grip-lift capabilities, measured within 6 months of a stroke, and the overall upper limb function (Action Research Arm Test) (Hsieh *et al.*, 1998). That study evidenced significantly longer preloading phases, greater minimal negative loads before lifting the object, and smaller cross-correlation coefficients for the paretic hand.

In contrast, chronic stroke patients in this study presented a longer loading phase with the paretic hand. During the loading phase, GF changed in parallel to the applied load, following a forward sensorimotor program (Johansson, 2002; Hermsdorfer *et al.*, 2003). Quantification of the observed parallel change in GF and LF, using the cross-correlation coefficient, indicated that the chronic stroke patients in our study showed no significant difference between both hands. Similarly, negligible time lags were found by Hermsdörfer *et al.* (2003) for cerebral chronic and acute stroke patients, which was considered to be because of a reasonable motor command, whereby the adjustment of GF was synchronized with arm movement in vertical cyclic oscillation movements.

The addition of specific grip-lift rhythmic task-oriented auditory-cued therapy did not improve grip-lift parameters, dexterity, activity, and satisfaction in our chronic stroke patients. On the one hand, the effect on repetitive training of the upper limb is still unclear (French *et al.*, 2010). On the other, the lack of improvement could suggest that the patients had already reached their plateau of recovery or that the therapy was not constraining enough. Nevertheless, a personal interview with each participant indicated that all the patients were tired at the end of the session and could hardly increase the number and/or the duration of the training sessions.

The inclusion criteria have restricted the number of participants. Each participant had to present manual disability, but be able to execute the grip-lift task at inclusion. The limited number of participants could have affected the statistical significance of our tests. However, the differences between each evaluation were small and not clinically relevant. In addition, the sample size required to observe a significant modification for the tested parameters was high ($\geq$ 87 patients), suggesting that the therapy did not show a clinically relevant possible effect. Therefore, we conclude that the lack of statistically and clinically significant results indicates that this approach is not worth pursuing.

Finally, in contrast to our study, published literatures from other countries indicate positive improvements as a result of conventional therapy in chronic stroke patients (Muellbacher *et al.*, 2002). The current study was carried out in Belgium, and we are of the opinion that the participating individuals may have already reached a recovery plateau as a result of an intensive long-term rehabilitation program since the acute phase after stroke. Considerable differences in the type of rehabilitation care and outcome of different countries have already begun to be documented (Brandt, 2007; De Wit *et al.*, 2007). Knowledge of the therapy offered to patients in different countries would provide a more objective means of comparing the resultant capabilities of test participants in the published literature, as well as identifying combinations of therapies at specific time periods following stroke, which may contribute towards accelerating recovery (French *et al.*, 2010).

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Conflicts of interest

There are no conflicts of interest.

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