Use of recognition of laterality through implicit motor imagery for the improvement of postural control and balance in subacute stroke patients: a randomized controlled study

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Introduction. Motor Imagery techniques may be used as a complement to the recovery of motor sequelae after a stroke, as during the evocation of a movement the activation of neuronal circuits involved in the actual execution of the movement occurs.

Patients and methods. A simple-blind randomized controlled trial was conducted. A total of 38 patients were randomly assigned to a study group. Both groups performed, for four weeks, five weekly sessions of neurorehabilitation and three weekly sessions of experimental or control intervention, respectively.The experimental group training the recognition of laterality, while the control group the recognition of body parts. Participants were evaluated pre and post intervention with posturography parameters –Sway area (AREA), Sway path length (LONG), difference in weigthload between lower limbs (DIFLOAD)–, the Berg Balance scale (BBS), the Barthel Index (BI), the Time Up and Go Test (TUG), the Functional Ambulation Categories (FAC), and the quality-of-life scale for stroke (ECVI-38).

Results. After performing the intragroup analysis, statistical significance was obtained for AREA ($p < 0.001$), LONG ($p = 0.04$), DIFLOAD ($p = 0.02$), BBS ($p < 0.001$), BI ($p < 0.001$), FAC ($p < 0.001$), and ECVI-38 ($p < 0.001$) in the experimental group; and for DIFLOAD ($p = 0.01$), BBS ($p = 0.001$), BI ($p = 0.001$), TUG ($p = 0.04$), FAC ($p = 0.03$), and ECVI-38 ($p = 0.003$) in the control group. In the intergroup analysis, statistical significance was obtained for AREA ($p = 0.03$), BBS ($p = 0.03$), FAC ($p = 0.02$) and ECVI-38 ($p = 0.002$) at postintervention time.

Conclusions. Combined use of physical rehabilitation and recognition of laterality through implicit motor imagery tasks, improves balance and functions related to postural control in subacute stroke patients.

Key words. Hemiparesis. Mental imagery. Mental practice. Recognise© flashcards. Rehabilitation. Stroke.

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Introduction

One of the most frequent sequelae after a stroke is the involvement of motor function in the form of hemiparesis [1] caused by the death of nerve cells in the infarcted area and cellular dysfunction of anatomically and functionally related areas [2]. These somatosensory and motor deficits will cause an alteration in the afferences that build the body scheme [3,4], that entails a lack of postural control and balance of these subjects [1-4].

Motor imagery (MI) is the technique used to activate neural networks involved in the preparation and execution of a movement through its implicit or explicit evocation, without the existence of an actual movement [5-7]. Changes at the excitability levels of sensorimotor structures during MI training reveal the integration of received inputs to construct and modulate the motor program in real time, even in the absence of voluntary movement [7], creating a neural representation of evoked movement, from which motor learning can benefit. The use of MI is supported on neurophysiological basis of neural mirror circuits, which are considered a fundamental part of the connection between the action we observe, the action belonging to the repertoire of movement patters and the cortical representation we have of them [8,9].

Numerous studies show that during the evocation of a movement the activation of neuronal circuits involved in the actual execution of the movement occurs [10-12]. In most studies [13-17] explicit MI (EMI) has been used, but in people who have suffered a stroke, their ability to imagine movement involving their plegic limbs may be impaired [18,19]. However, there are studies that demonstrate

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the similarity in the activation of neural networks involved in the movement of a body segment both in the evocation of said movement (EMI) and in performing laterality recognition tasks (implicit MI, IMI) [7,20,21]. During IMI tasks, prefrontal and insular areas, anterior cingulate area, and premotor cortex contralateral to the hemibody being imaged; and cerebellum and basal ganglia with bilateral activity are activated [22,23]. Studies by Parson et al [22,23] conclude that laterality judgement tasks respect joint biomechanical constraints, and since no overt movement occurs, the task should be solved with a mental simulation of such movement, but implicitly. Jia et al· [24] studied the use of IMI-type tasks in subjects who had suffered a stroke, concluding that they can solve these tasks as well as healthy subjects, so it can be assumed that this ability is not altered after a stroke.

The purpose of this study was to assess with reliable outcome measures tested in stroke people, whether the combined use of neurorehabilitation and IMI for recognition of laterality using Recognise© flashcards, is beneficial for the improvement of postural control, balance, and quality of life in the subacute phase of people with hemiparesis.

Patients and methods

Study design

A prospective longitudinal study was conducted. The CONSORT guideline for the verification of randomized clinical trials was followed. Once the subjects were recruited, they were randomly assigned to a group using random numbers generated by a computer. The study was carried out in a simple blind manner with blind evaluation by third parties, where neither the evaluator nor the subjects know to which group each evaluated person belongs. The trial was registered with the Australian New Zealand Clinical Trials Registry, with the registration number ACTRN12620000107921.

Patients

The patients were recruited from the Rehabilitation Service of the Rey Juan Carlos University Hospital derived from the Neurology Service with a medical diagnosis of hemiparesis secondary to stroke.

The subjects had to meet the following inclusion criteria: a) first stroke of less than six months of evolution; b) aged over 18; c) ability to maintain stable standing for 1 minute without support; d) not suffer from co-morbid pathology that prevented intensive rehabilitation; e) not use a support product to assist walking prior to the stroke, and f) not suffer from medical diagnosis of cortical blindness or blindness prior to the injury that prevented the use of work material.

A baseline evaluation was carried out to identify the socio-demographic characteristics of the sample, determining the age, sex, characteristics of the stroke (type, location of the lesion), manual dominance, time since stroke (days) and the National Institute of Health Stroke Scale (NIHSS) during hospital admission. Table I presents the main data.

This study followed the Helsinki declaration and was approved by the Ethics Committee of the Rey Juan Carlos University Hospital. All participants gave their informed consent for voluntary participation in writing.

Intervention

The present study based its intervention on the combined application of neurorehabilitation with the specific work of recognition of laterality for the lower limb, using Recognise© flashcards. These cards were designed by the Neuro Orthopaedic Institute (NOI group) and devised for 'the recognition, discrimination and restoration between right and left trial at cortical level for patients suffering from dysfunction in the recognition of laterality' [25].

Once each possible candidate had been recruited, the principal investigator verified that they met the inclusion criteria and administered the *Mini-mental State Examination* tests [26] and the Boston comprehension subtest [27].

Once the initial data had been obtained, all the participants underwent five weekly rehabilitation sessions of 40 minutes each, based on the recommendations of the clinical practice guidelines [28], in which their own neurological rehabilitation techniques were applied to restore the patient's previous functional level. These techniques were carried out by professionals trained in neurorehabilitation with proven experience of at least three years. The sessions were carried out for a period of four weeks until 20 sessions had been completed. To ensure safety during the Covid-19 stage, the therapists used personal protective equipments.

The experimental group took part in three weekly sessions using the Recognise© flashcards on the recognition of the left/right laterality task with images of feet in different positions (Fig. 1), before of the rehabilitation session. The estimated duration of the sessions was 5-10 min each one. Different

Figure 1. Experimental group task.

Figure 2. Control group task.

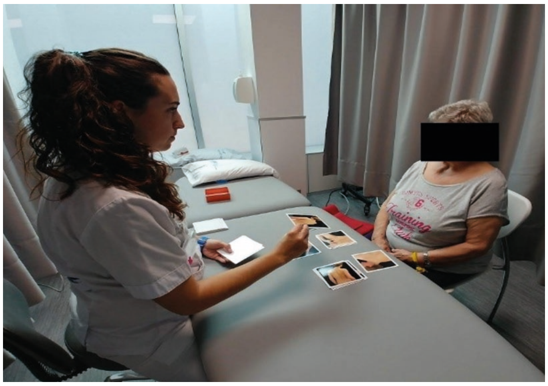

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Table I. Socio-demographic data.

	Gender (%)	Age (years)	Damaged hemisphere (%)	Laterality (%)	Injury evolution time (days)	Type of stroke (%)	NIHSS (points)
Experimental	68.18, male 31.81, female	62.31 ± 11.03	59.09, right 40.91, left	86.36, right 13.64, left	54.86 ± 55,31	18.18, hemorrhagic 81.82, ischemic	3.9 ± 2.97
Control	43.75, male 56.25, female	66,06 ± 13,77	56.25, right 43.75, left	100, right	57.75 ± 84,47	18.75, hemorrhagic 81.25, ischemic	4.56 ± 4.28

NIHSS: National Institute of Health Stroke Scale.

images were presented in which the subject identified whether it was a left or right member; in each of the sessions the test was repeated three times with different cards, up to a total of 60 images, with a one-minute break between one repetition and another, when the task was corrected. A total of 12 sessions were carried out with the help of a physiotherapist to perform laterality training.

The control group participated in three weekly sessions using the Recognise© flashcards for a task of recognition of body parts in which they only had to indicate which part of the body was being treated (Fig. 2), before of the rehabilitation session. 60 images were presented in three series with a one-minute rest between repetitions. A physiotherapist supervised the completion of the proposed task during the 12 sessions.

Outcome measures

Outcome measures were classified in main and secondary based on its better test-retest reliability in stroke people.

Data collection was carried out pre- and post-intervention period.

Main outcome measures

Berg Balance Scale (BBS) was developed to assess balance (excellent test-retest reliability; ICC = 0.99). The scale consists of a series of 14 items, each valued on an ordinal scale of 0 to 4, where 0 is the lowest level of function and 4 is the highest. The total test score is 56 points; a score below 40 can be associated with a higher risk of falls [29].

Functional Ambulation Categories (FAC) was developed to evaluate ambulation ability (excellent test-retest reliability; $\kappa = 0.95$). This scale is made up of 6 score that determine the functionality of each subject's gait. The score of 0 indicates that the subject cannot walk. The score between 1 to 3 indicates a dependent gait that requires more to less support from another person. The score of 4 describes an independent gait in level surfaces; and in any surface in score of 5 [30].

Quality-of-life scale for stroke (ECVI-38). The Likert scale consisted of 38 items with five response

Figure 3. Posturography.

options, organized into eight subscales: physical state, communication, cognition, emotions, feelings, basic activities of daily living, common activities of daily living, and social and family functioning [31]. A percentage score is obtained from each subscale through an algorithm, and a total score averaging the percentages of each subscale [31-33].

Secondary outcome measures

Posturography. A Satel PF8CTM posturograph was used (Fig. 3), with which three repetitions of the Romberg test [34] were performed with eyes open and on a stable surface for 60 seconds. The study posturography variables used were: a) AREA: the swing area (mm^2) produced by the oscillation of the pressure center; b) LONG: the oscillation path length (mm) produced by the subject, and c) DIFLOAD: the percentage of difference in weightload between lower limbs, determined by the coordinates of the center of pressure related to the average position.

Time Up and Go Test (TUG). It was developed to assess balance and functional mobility to determine the risk of falling. The test consists in timing the time it takes for the subject to perform the action of getting up from a chair, walking 3 meters in a straight line, turning around, and sitting back in the chair. The test is performed three consecutive times and the average value is scored. The longer time it takes to perform the test, the greater the risk of falling or non-functional gait [35,36].

Barthel Index (BI). Scale developed to assess the level of independence in carrying out the activities of daily life. A total score of between 0 and 100 is obtained; the higher the score, the greater the degree of independence of the subject [37,38].

Statistical analysis

The IBM Statistics SPSS 27© package was used to perform the statistical analysis.

It was initially assessed whether the data samples followed a normal distribution through the Shapiro-Wilk test, since the samples comprised fewer than 50 subjects.

Once the normality hypothesis had been verified, intragroup statistics were performed using the nonparametric Wilcoxon test since the variables did not follow a normal distribution. The comparisons between groups were made using the Mann-Whitney U test at precondition and post intervention time.

The sample size was calculated using the G*Power software (version G*Power 3.1.9.2). We established the following parameters to obtain the sample size using a correlation model: two tails, an error alpha of 0.05, a power of 0.80, and an effect size of 0.9, resulting in a sample size requirement of 22 participants.

Results

Sixty-three subjects were evaluated between January 2018 and December 2020 having been invited to participate in the study, 14 of whom were excluded, 12 of them for not meeting the inclusion criteria and two for refusing to participate.

Eventually, 49 subjects were recruited; 29 were randomly assigned to the experimental group, 22 of whom completed the four-week intervention (four were transferred to another center, one died, one voluntarily dropped out, one suffered a new stroke), while 20 were included in the control group, 16 of whom completed the four-week intervention (one was transferred to another center and three were unable to complete the protocol due to the COVID-19 pandemic) (Fig. 4).

Experimental group

After performing the intragroup analysis, statistical significance was obtained for the variables AREA ($p < 0.001$), LONG ($p = 0.04$), DIFLOAD ($p = 0.02$), BBS ($p < 0.001$), BI ($p < 0.001$), FAC ($p < 0.001$), and ECVI-38 ($p < 0.001$), as shown in table II.

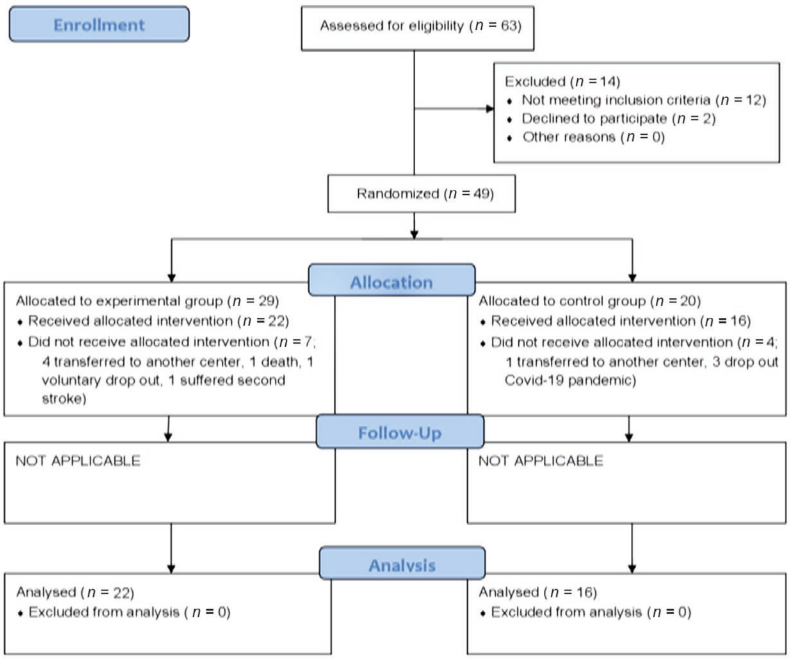
Control group

The control group, however, obtained statistical significance after analysing the data for the variables DIFLOAD ($p = 0.01$), BBS ($p = 0.001$), BI ($p = 0.001$), TUG ($p = 0.04$), FAC ($p = 0.03$), and ECVI-38 ($p = 0.003$), as shown in table II.

Intergroup analysis

After verifying the results of intergroup analysis, we found that the variables AREA ($p = 0.03$), BBS ($p = 0.03$), FAC ($p = 0.02$) and ECVI-38 ($p = 0.002$) showed statistical significance in favor of the experimental group at postintervention time as shown in table II.

Figure 4. CONSORT flow diagram.



Discussion

It is known that the premotor and supplementary motor cortices have direct connections to structures related to motor control located in the brainstem and spinal cord [39], so we can suppose that they exert direct control over them. Furthermore, Riddle and Baker [40] in their studies reported that the reticulospinal pathway (originating in the brainstem) and the corticospinal pathway descend in parallel and have overlapping effects on spinal interneurons and motor neurons, significantly influencing the limb muscles and postural control [41]. Ortiz et al [42] and Herbert et al [43] also demonstrated significant contributions of the reticulospinal pathway to motor production and recovery. This leads us to hypothesize that strengthening the available reticulospinal pathway projections, through stimulation of the premotor and supplementary cortex thanks to the use of MI, can be used to promote relearning and acquisition of motor skills. There is evidence that the use of IMI activates premotor and supplementary areas by activating mirror neuron circuits through the transformation of visual information across parietofrontal circuits [44,45].

Beirnesser et al. [46] studied the strategies used in the training of mental rotation of hands in healthy subjects, determining that before the training the visuospatial processes predominate; however, motor processing increases after training, which may suggest that motor integration strategies will be increased with training in mental rotation tasks, such as recognition of laterality.

In our study, improvements were obtained in both groups according to the results of the BBS, the BI, and the ECVI-38. The experimental group obtained improvements in AREA, which indicates an improvement in static balance and postural control in standing; these findings are supported by the studies of Schuter et al [47] and Iestwaard et al [48]. No improvements in walking speed were obtained in experimental group, however, improvements in gait ability and support required for walking were obtained. This result is supported by different authors who reported improvements in gait when combining MI with rehabilitation, using treadmill training programs or in task-oriented training [13,14,49].

The findings of the intergroup analysis show that an improvement was obtained in ECVI-38, the BBS, the FAC and the sweep AREA in the subjects who were trained with recognition of laterality through IMI. These results are supported by the findings ob-

Table II. Statistical análisis.

	Experimental group[a]			Control group[a]			Experimental vs control[b]			
							Pre		Post	
	Pre	Post	*p*	Pre	Post	*p*	U	*p*	U	*p*
AREA	380.10 ± 360.68	229.86 ± 267.92	**<0.001**	891.33 ± 1191.35	329.98 ± 838.01	0.05	137.00	0.25	104.00	**0.03**
LONG	800.65 ± 365.41	670.14 ± 354.58	**0.04**	937.92 ± 773.71	718.69 ± 696.94	0.10	144.00	0.35	157.00	0.58
DIFLOAD	13.30 ± 14.15	5.55 ± 11.30	**0.02**	11.05 ± 13.15	4.15 ± 12.92	**0.01**	166.50	0.78	175.00	0.98
BBS	39.50 ± 15.75	51.50 ± 6.25	**<0.001**	35.50 ± 15.25	46.50 ± 10.75	**0.001**	151.50	0.47	105.50	**0.03**
IB	77.50 ± 21.25	100.00 ± 11.25	**<0.001**	62.50 ± 30.00	92.50 ± 40.00	**0.001**	148.50	0.42	117.00	0.08
TUG	15.65 ± 15.80	11.38 ± 6.16	0.20	17.66 ± 18.32	10.70 ± 6.59	**0.04**	165.50	0.75	165.00	0.75
FAC	2.00 ± 1.00	4.00 ± 2.00	**<0.001**	1.50 ± 1.75	3.00 ± 2.00	**0.03**	174.00	0.96	101.00	**0.02**
ECVI-38	39.84 ± 26.23	21.77 ± 19.62	**<0.001**	54.04 ± 17.57	43.78 ± 22.49	**0.003**	110.00	0.05	75.50	**0.002**

AREA: swing area; BBS: Berg balance scale; BI: the Barthel Index; DIFLOAD: percentage of difference in weightload between lower limbs; ECVI-38: quality-of-life scale for stroke; FAC: functional ambulatory categories; LONG: oscillation path length; TUG: Time Up and Go test. [a] Experimental group and Control group: Wilcoxon signed-rank test. Data are expressed as median ± interquartile range. [b] Experimental vs Control: Mann-Whitney U Test.

tained in clinical trials where the effect of using MI combined with physical rehabilitation to improve the function of the lower limbs was evaluated [49,50], reporting improvements in postural control, balance, and gait ability. In addition, Verma et al [13] concluded that the use of combined MI reduces the time to starting independent walking.

This preliminary study is limited by the small sample, the exclusive approach in a subacute phase of the stroke with a wide range of participants in terms of time of injury evolution, and by the use of short-term follow-up only, so other studies are required that will determine its long-term effect and in chronic stroke patients since the results may be conditioned by the spontaneous evolution of the subacute period. In addition, although hard outcome measures such as posturography were used, observational measures were also used that could be a source of bias since they are not exempt from the subjectivity of the evaluator.

Nevertheless, the results obtained allow us to conclude that the combined use of IMI through Recognise© flashcards and physical rehabilitation improves the balance and functions related to postural control, which positively affects the quality of life of people who have suffered a stroke.

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Uso del reconocimiento de la lateralidad a través de imaginería motora implícita para la mejora del control postural y el equilibrio en pacientes con ictus subagudo: un estudio controlado aleatorizado

Introducción. Las técnicas de imaginería motora pueden utilizarse como complemento a la recuperación de las secuelas motoras tras un ictus, ya que durante la evocación de un movimiento se produce la activación de los circuitos neuronales implicados en la ejecución de éste.

Pacientes y métodos. Se realizó un ensayo controlado aleatorizado simple ciego. Treinta y ocho pacientes en total fueron asignados aleatoriamente a cada grupo de estudio. Ambos grupos realizaron, durante cuatro semanas, cinco sesiones semanales de neurorrehabilitación y tres sesiones semanales de intervención experimental o control. El grupo experimental entrenaba el reconocimiento de la lateralidad, mientras que el grupo de control lo hacía con el reconocimiento de partes del cuerpo. Los participantes fueron evaluados antes y después de la intervención con parámetros posturográficos (área de barrido, longitud del recorrido de oscilación y porcentaje de diferencia de carga de peso entre los miembros inferiores), la escala de equilibrio de Berg (BBS), el índice de Barthel, el test *Time Up and Go,* la clasificación funcional de la deambulación (FAC) y la escala de calidad de vida para el ictus (ECVI-38).

Resultados. Después de realizar el análisis intragrupo, se obtuvo significación estadística para el área de barrido (p < 0,001), la longitud del recorrido de oscilación (p = 0,04), el porcentaje de diferencia de carga de peso entre los miembros inferiores (p = 0,02), la BBS (p < 0,001), el índice de Barthel (p < 0,001), la FAC (p < 0,001) y la ECVI-38 (p < 0,001) en el grupo experimental; y para el porcentaje de diferencia de carga de peso entre los miembros inferiores (p = 0,01), la BBS (p = 0,001), el índice de Barthel (p = 0,001), el *Time Up and Go* (p = 0,04), la FAC (p = 0,03) y la ECVI-38 (p = 0,003) en el grupo de control. En el análisis intergrupo se obtuvo significación estadística para el área de barrido (p = 0,03), la BBS (p = 0,03), la FAC (p = 0,02) y la ECVI-38 (p = 0,002) en el momento posterior a la intervención.

Conclusiones. El uso combinado de rehabilitación física y reconocimiento de la lateralidad a través de tareas de imaginería motora implícita mejora el equilibrio y las funciones relacionadas con el control postural en pacientes con ictus subagudo.

Palabras clave. Hemiparesia. Ictus. Imaginería mental. Práctica mental. Recognise© flashcards. Rehabilitación.