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ORIGINAL ARTICLE

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Karim Jamal [1,2,*], Stéphanie Leplaideur [1,3,4], Chloé Rousseau [5], Sébastien Cordillet [1], Annelise Moulinet Raillon [1,6], Simon Butet [1], Armel Cretual [2], Isabelle Bonan [1,4]

1 Physical and Rehabilitation Medicine Department, University Hospital of Rennes, France
2 M2S laboratory – EA 1274, University of Rennes 2, France
3 Neurology Physical and Rehabilitation Medicine Department, CMRRF KERPAPE, France
4 Unit EMPENN, ISERM, INRIA -Unit 1228 University Rennes 1, France
5 Department of Clinical Pharmacology, Clinical Investigation, Center INSERM 1414, University Hospital of Rennes, France
6 Physical and rehabilitation medicine department, Hospital of Saint Vallier, France

Corresponding author
Karim JAMAL
2 rue Henri Le Guilloux 35000 Rennes
02 99 28 43 21
Karim.jamal@chu-rennes.fr

Abstract

Objective: We aimed to test a repeated program of vibration sessions of the neck muscles (rNMV) on postural disturbances and spatial perception in patients with right (RBD) *versus* left (LBD) vascular brain damage. **Methods:** Thirty-two chronic stroke patients (mean age 60.9±10 yrs and mean time since stroke 4.9±4 yrs), 16 RBD and 16 LBD, underwent a program of 10 sessions of NMV over two weeks. Posturography parameters (weight-bearing asymmetry (WBA), Xm, Ym, and surface), balance rating (Berg Balance Scale (BBS), Timed Up and Go (TUG), space representation (subjective straight ahead (SSA), longitudinal body axis (LBA), subjective visual vertical (SVV)), and post-stroke deficiencies (motricity index, sensitivity, and spasticity) were tested and the data analyzed by ANOVA or a linear rank-based model, depending on whether the data were normally distributed, with lesion side and time factor (D-15, D0, D15, D21, D45). **Results:** The ANOVA revealed a significant interaction between lesion side and time for WBA ($p<0.0001$) with a significant shift towards the paretic lower limb in the RBD patients only ($p=0.0001$), whereas there was no effect in the LBD patients ($p=0.98$). Neither group showed a significant modification of spatial representation. Nonetheless, there was a significant improvement in motricity ($p=0.02$), TUG ($p=0.0005$), and BBS ($p<0.0001$) in both groups at the end of treatment and afterwards. **Conclusions:** rNMV appeared to correct WBA in RBD patients only. This suggests that rNMV could be effective in treating sustainable imbalance due to spatial cognition disorders.

Keywords: neck muscle vibration, postural asymmetry, spatial representation, stroke

Running title: neck-muscle vibration and post-stroke postural disturbances

INTRODUCTION

One of the causes of disability in patients following a stroke is postural imbalance, characterized by increased postural sway and weight-bearing asymmetry (WBA) as evaluated on a force-platform [16, 27, 28]. WBA is recurrent and long-lasting, with a prevalence of 50% in chronic stroke patients [24], even higher in those with right brain damage [28, 33]. WBA is often associated with level of independent self-care and length of hospital stay [37]. Thus, there is an interest in correcting WBA.

Apart from sensory and motor deficit [3, 16, 37], WBA may also be at least partially due to a bias in body orientation in space [7, 36]. Spatial bias, such as neglect or biased subjective vertical (SV), subjective straight ahead (SSA) and longitudinal body axis (LBA) parameters, are common after stroke and related to poor balance [3, 8, 18, 26]. These spatial biases are more frequent and longer lasting in RBD patients, probably because spatial cognition, in particular the central process of the representation of the body in space, is located within the right cerebral hemisphere [2, 8, 36, 38]. This could explain why patients with right brain damage (RBD) have an excessive WBA compared to patients with left brain damage (LBD) and have poorer prognosis in terms of balance [8, 28, 33].

A previous study conducted by our group showed encouraging results after one session of neck muscle vibration (NMV) in patients with acute stroke [23]. Our hypothesis is that the stimulation of sensory information reduces WBA, probably through reduction of bias in orientation [7]. No study has yet examined a program of repeated vibration sessions on the neck muscles of chronic stroke patients.

The first objective of the study was to compare the effect of a program of repeated vibration sessions on the neck muscles on WBA in patients with RBD versus those with LBD. We hypothesized that repeated sensory stimulation would be effective in the treatment of imbalance due to body orientation bias and consequently lead to a greater reduction of WBA in RBD patients, due to the correction of body orientation disorders, which correspond at least partially to the WBA of these patients. We also studied the effect of the program on other spatial biases of our patients in order to better understand the mechanism of action of such stimulation.

METHODS

Patients

Stroke patients were recruited from a list of patients who were treated in the Department of Physical Medicine and Rehabilitation (PMR) at the University Hospital of Rennes. From March 2017 to February 2018, patients who fulfilled the inclusion criteria were contacted by telephone and those who immediately responded were included in the study. All patients received information concerning the protocol and gave their signed consent. The inclusion criteria were as follows: right or left brain supratentorial vascular damage, more than one year since the stroke, and age < 80 years. Chronic patients were considered, as they may show little or no evolution of their balance and may still have a postural imbalance dating from the time of their stroke. As WBA was the principal criteria, selected patients had to be able to maintain an upright position for at least 30 s with their eyes closed for the force-platform test. Previous studies [24] have defined the normal range of weight bearing as between 47 and 53%; patients who were within this range were considered to be symmetrical and were therefore excluded. Patients who had either an ischemic or hemorrhagic brainstem stroke, bilateral hemispheric stroke, an orthopedic and/or rheumatological history affecting the distribution center of pressure when standing, a visual history that did not allow assessment of their vision, and those with major comprehension disorders were also excluded. The sample size calculation was based on a result obtained during a program of repetitive prism adaptation, *i.e.* the percentage correction of WBA +3.5%(±1) in the chronic RBD group with initial WBA of 30.4%(±10.6) [18]. The goal was to achieve the same benefit. We determined that subgroups of 16 patients would ensure 95% power, with an alpha risk of 5%. This study was approved by the local Ethics Committee of Rennes University Hospital, number 16.23, and registered (Clinicaltrial.gov NCT03112616).

Evaluations

Posturography parameters

Postural assessment of the patient was performed using a double force platform (FP) (PostureWin V143 TechnoConcept©). Patients stood on the platform in their bare feet with their feet 14 cm apart, with the instruction to stand as straight as possible with their arms alongside the body while looking straight ahead. The percentage of the weight on the nonparetic limb (WBA), mean mediolateral (Xm), and anterolateral (Ym) position of the center of pressure (COP) (mm) and surface (mm^2) were calculated as the mean of four trials, each lasting 30s: two with opened eyes (OP) and two with closed eyes, with the patient wearing a blindfold (CE).

Evaluation of spatial representations

Subjective Straight Ahead (SSA) haptic (Fig.1) [11].

Evaluation of the SSA haptic was carried out on a measuring table. Patients were instructed to point "straight ahead", so as to divide the space into two parts, with no imposed time limit in 10 starting positions in a randomized sequence with the right arm for RBD and the left arm for LBD patients. A positive sign corresponded to the ipsilesional side. The value (in degrees up to 0.5°) obtained consisted of the mean (M) and standard deviation of 10 measurements (SD).

Longitudinal Body Axis (LBA) (Fig.2) [1].

Evaluation of the LBA was performed using a light strip in front of the patient in a supine position, in complete darkness, with the head, trunk, and lower limbs aligned and maintained by cushions. The patient was given the task of indicating when the strip was parallel to the axis of his body. No visual reference other than the wand was available and there was no time limit. A positive sign corresponded to the ipsilesional side. The value (in degrees up to 0.5°) obtained consisted of the M and SD of 10 measurements.

Subjective Visual Vertical (SVV)

Evaluation of the SVV was performed in a sitting position with the head fixed, using a virtual reality helmet (Oculus®, Virtualis). From an imposed starting position, the patient was presented with a blue background with an oblique red line with 10 different starting positions in a random sequence (-10°/5°/-15°/10°/30°/-5°/-20°/15°/-30°/20°). No visual reference, other than the red line, was available and there was no time limit. The patient was given the task of indicating when the line was aligned with the vertical axis and the position of the head was monitored throughout the exercise task. A positive sign corresponded to the ipsilesional side. The value (in degrees up to 0.5°) consisted of the M and SD of 10 measurements.

Assessment of post-stroke deficiencies

A lower limb motricity test (motricity index) with a score of 100 [13]; a spasticity test (Ashworth modified MAS) [6], which targets the sural triceps, quadriceps, and adductors; and a sensory test, consisting of two clinical examinations and the sum of the obtained results were conducted. The first test consisted of tactile localization on the lower limb and the second, an arthrokinetic sensitivity test on the knee, ankle, and toes. Four tests of visuospatial neglect were also conducted: the bell cancellation test [34], 20-cm line bisection [34], the Fluff test [12], and the OTA test [25]. Visuospatial neglect was considered if the patient had at least three out of four positive tests. Finally, the presence or absence of homonymous hemianopia was clinically tested with a confrontation visual field test on each quadrant with a ball.

Balance Rating

Evaluation of functional impact of balance disorders was carried out using the Timed Up and Go (TUG) [32], and the Berg Balance Scale (BBS) [4].

Protocol

The intervention consisted of NMV in a dark room with one session per day, five days per week, for two weeks. Evaluations were performed two weeks before the intervention (D-15), just before the first intervention (D0), at the end of the intervention (D15), one week later (D21), and one month later (D45) (Fig.3). Vibration was carried out in a sitting position using a VB 115® vibrator (TechnoConcept, France) at a frequency of 80 Hz and an amplitude of 0.4 mm. The examiner manually positioned the vibrator on the left side of the neck muscle for RBD patients and on the right for patients with LBD. The position of the vibrator was individualized by looking first at the position in which the subject perceived a maximum deviation of a visual target placed in front of them and moving to the opposite side of the vibrated muscle side. If there was no deviation, the vibrator was placed under the occiput. In this position, vibration was applied above the semispinalis and splenius. Then the patient was blindfolded, and the intervention applied for 10 min. In addition to repetitive NMV rNMV), all patients received their usual rehabilitation treatment.

Statistical analysis

Statistical analysis was performed using SAS 9.3 Software. The clinical data between the patients with RBD and LBD were compared using Student's t-test or the Mann Whitney test (normality of the distribution was assessed using the Kolmogorov–Smirnov test). A comparison of the posturography parameters (WBA, Xm, Ym, Surface) and Balance rating

(TUG and BBS) at D-15 and D0 in both groups (RBD and LBD) was performed using a Student's t-test for paired data in order to verify the absence of evolution under their usual rehabilitation. Posturography parameters (WBA, Xm, Ym, and surface), spatial reference data (SSA, LBA, and SVV), and characteristics of hemiplegia (motricity and sensitivity) were separately analyzed using ANOVA for repeated measures (rmANOVA) for normally distributed data and a generalized linear model with the gamma law or ranks for non-normally distributed data, with a between subjects factor, "lesion side" (RBD and LBD), and within subject factor, "time" (DO, D15, D21, D45). Tukey's *post-hoc* test was performed for all significant results. All tests were conducted at a significance level of p = 0.05.

RESULTS

Forty-two patients from the list of chronic stroke patients followed by the physicians of the department were contacted by telephone, based on the inclusion criteria. All patients provided their approval, except two who refused to participate and one who died. After informing the patients and obtaining their consent, 39 were enrolled in the study. Five RBD patients and two LBD patients were excluded at D-15, as they did not show any signs of WBA on the force platform. Thirty-two patients, 26 men and six women, with an average age of 60.9 ± 10 years and an average time since their stroke of 4.9 ± 4 years, divided between two groups of 16 RBD and 16 LBD, were included (Fig. 4). Patients were similar in age (p=0.55), time since stroke (p=0.7), motricity (p=0.7), sensitivity (p=0.1) and balance ratings (BBS p=0.79, TUG p=0.78) (Table 1). WBA was different between the RBD and LBD patients (WBA in RBD = 65.95%±9.4 versus 60.6%±4.5 in LBD p=0.05). There was no difference in any of the posturography parameters (WBA, Xm, Ym, Surface) and Balance rating (TUG and BBS) between D-15 and D0 showing the absence of evolution (WBA RBD p=0.38; LBD p=0.09; Xm RBD p=0.6; LBD p=0.4; Ym RBD p=0.6; LBD p=0.9; surface RBD p=0.8; LBD p=0.5; TUG RBD p=0.9; LBD p=0.8; BBS RBD p=1; LBD p=0.1).

The rmANOVA revealed a significant interaction between lesion side and time for WBA ($F[4;120]=5.25$ $p<0.0001$) with a reduction of WBA only in the RBD patients and only at D15 (4.4%±3.5), confirmed by the post-hoc test (D0 *vs* D15 p=0.0001 and D0 *vs* D21 p=0.43). The results were similar when accounting for Xm (lesion side x time $F[4;120]=12.45$; $p<0.0001$), with a significant shift in the RBD group (D0 *vs* D15 $p<0.0001$). The rmANOVA revealed no effect or interaction between lesion side and time for Ym ($F[4;120]=0.51$; $p=0.72$) and the Surface ($F[4;120]=0.42$; $p=0.79$) (Table 2).

Difference between the mean for RBD and LBD patients were found only between the standard deviation for SVV_SD p=0.005 and LBA_SD p=0.01 (Table 1). The rmANOVA revealed no effect or interaction between lesion side and time (SSA F[4;120]=1.46; p=0.21; SVV F[4;120]=1.83; p=0.09; LBA F[4;120]=0.93; p=0.44) (Table 2).

Vibration did not induce any change in sensitivity test values over time (F[4;120]=2.25; p=0.07) or by group (F[1;30]=1.67; p=0.2). Motricity improved for both groups of patients over time (F[4;120]=3.25; p=0.02), independently of lesion side (F[1;30]=0.02; p=0.89). The post-hoc test revealed an improvement at D15 (p=0.02) and D21 (p=0.02). The TUG of the patients improved at D21 (F[4;120]=6.9; p=0.0005) (p=0.003) and D45 (p=0.01), independently of the lesion side (F[1;30]=0.17; p=0.68). The BBS of the patients also improved over time (F[4;120]=9.23; p<0.0001), as revealed by the *post-hoc* test at D15 (p<0.0001), D21 (p<0.0001), and D45 (p<0.0001), independently of lesion side (F[1;30]=0.11; p=0.74) (Table 3).

DISCUSSION

We obtained a reduction in WBA after NMV as expected. This effect was only observed in the group of RBD patients. Surprisingly, balance ratings and motricity improved for patients of both groups (RBD and LBD) after the program, with a long-lasting effect.

WBA was higher in RBD patients before rNMV, even though the same time had elapsed since the stroke for both patients with RBD and LBD [8, 28, 33]. This disparity, repeatedly found in the literature, has been assumed to be due to body misorientation in space, which occurs mostly in RBD patients [7, 36]. Following rNMV, the degree of WBA of RBD patients moved closer to that of the LBD patients before the program (Fig.5). RBD patients shifted in the medio-lateral plane towards the hemiplegic leg without any change in the antero-posterior plane, whereas there was no significant effect on the posturography parameters for LBD patients. These results strongly suggest that the effect of NMV on RBD patients may be due to correction of the component of the WBA that is due to spatial cognition disorders. Indeed, the right hemisphere is thought to be responsible for spatial cognition [36, 38]. Additionally, stimulation of sensory information, *i.e.* prism adaptation, vestibular caloric stimulation, or galvanic vestibular stimulation, modifies the postural asymmetry of the subject, irrespective of the sensorial modality [9, 18, 23], with a close relationship between the effects of different sensory modalities [9]. This suggests that sensory stimulation affects supramodal sensorial cerebral structures in the right hemisphere [7], as already shown by Bottini *et al.* [10]. who studied the effects of proprioceptive sensory stimulation by vibration on regional cerebral blood flow, measured using positron emission tomography.

Neck muscles are directly linked to the vestibular and oculomotor systems and may play a crucial role in egocentric perception of the body in space [5]. The information obtained from proprioceptive receptors of the neck muscles, together with that of the oculomotor muscles and vestibular system, is involved in the location of objects relative to the body. NMV produces a subjective perception of deviations of the axis of the body [20], suggesting that NMV could act on the relative position of the body in space and consequently displace the position of CoP towards the paretic limb. We would thus expect a change in both aspects of egocentric spatial representation, *i.e.* SSA and LBA. However, our chronic post-stroke patients had normal spatial bias deviation with the exception of a greater uncertainty in the perception of SVV and LBA. We also observed no significant change for either SSA or LBA. A slight change in SSA could be viewed as a mirror image of the change in WBA (Fig.6). Our results differ from those of two previous studies [18, 20]. The first reported an SSA shift towards the vibrated side during NMV [20] and a pilot study established an association between both the shift in SSA and WBA with another form of sensorial stimulation (prism adaptation) [18]. However, our study did not initially focus on SSA and our calculation of the number of patients to be included was based on WBA and not the assessment of spatial representation. Another possible explanation for the absence of the effect of NMV on spatial representation could be related to the cortical dissociation between the different evaluations already mentioned in the literature [31, 38, 35] and particularly when considering the posture and the modality assessed. Indeed, Pérennou *et al.* [30], when investigating the perception of verticality by different modality in a group of patients with hemispheric and brain stem stroke, did find a dissociation between postural verticality (PV) and SVV and this was possibly due to different brain regions involved in this spatial process. Therefore, it could be of interest when investigating the perception of verticality to assess the PV in addition to the SVV in further studies.

The reduction of WBA was obtained without decreasing postural stability, as shown by the stability of the surface of the displacement of the CoP, which is a platform parameter that expresses bodily stability. This is an additional argument that suggests that the part of WBA corrected by rNMV is not a compensatory behavior to postural instability, but rather due to a primary disorder, in this case, a spatial cognition disorder. Therefore, WBA can be considered not only as an adaptation to postural disturbance due to motor and sensitivity weakness, but also the reflection of a disturbance in spatial cognition, at least in RBD patients [16, 19]. As a result, it may be beneficial to correct at least this aspect of WBA. This result merits exploration of the possibility of obtaining an effect at an early stage after stroke. NMV is a clinical technique that does not require active participation of the patients, unlike top-down techniques, and is easy to implement and inexpensive. This creates new treatment possibilities early after stroke, when spatial cognition disorders are very troublesome, especially in RBD patients, with the hope to more rapidly improve balance in these patients.

The effect induced by rNMV was evident at the end of the program but was not maintained one week later. In this regard, our program may have been insufficient in terms of intensity, duration or number of sessions. Indeed, Karnath *et al.* [21] showed that increasing the vibration time resulted in a more stable effect with regards to SSA. It will therefore be necessary in future work to further investigate this sustained effect by increasing the intensity and duration of stimulation. It was also revealed that sensorial stimulation such as neck muscle vibration combined with another stimulation [22] or standard rehabilitation exercises [39] is more effective than a sensorial stimulation on its own and this could possibly be another additional investigation in order to enhance the effect.

Surprisingly, rNMV improved lower-limb strength and dynamic balance (TUG and BBS) in both LBD and RBD patient groups. This unexpected outcome suggests that there may be other mechanisms simultaneously at work aside from the effects on body orientation observed in the RBD patients. However, its direct influence is not evident. It has been hypothesized that that there is a close interconnection between the sensory and motor cortices, initially recognized in animals [17]. Fasold *et al.* [14], by functional MRI, showed that NMV stimulated cerebral activity in both motor and multisensory integration areas in healthy subjects. It is therefore possible that sensory stimulation by NMV can improve motor recovery. The improved motor control in both RBD and LBD patients following rNMV may involve central activation of the motor areas. However, the observed improvement favors the hypothesis of an effect remote from the stimulation site. It is therefore important to determine the mechanism of NMV and compare it to another type of sensory stimulation, such as transcutaneous electrical stimulation (TNS), to gain a better understanding of its effects. Similar to NMV, TNS equally improves both lower-limb strength and postural balance [40]. Moreover, TNS may modulate the sensory-motor cortex, which is stimulated [15]. In addition, Pérennou *et al.* [29] reported an improvement in postural balance in stroke patients with neglect when TNS was applied to the neck muscles. Nonetheless, no study has been carried out to assess lower limb strength after TNS of neck muscles. The results of these authors [29] are in accordance with ours and support the interest of stimulating the neck muscles. Neck muscles have a specific role in postural control through their direct link with the vestibular system and could also act on tonus regulation of lower limbs.

Our study had several methodological limitations. Our primary choice was to exclusively include chronic patients. Caution was taken to ensure that there was no modification of WBA or spatial representation during a period of 15 days before the intervention to avoid a confounding bias. In this study, the effect of neck muscle vibration was compared in patients with RBD versus those with LBD without any sham group. Therefore, this design does not allow us to be certain of the real effect of NMV and should as a consequence be repeated with a sham control group in order to confirm our result. Concerning our selection criteria, patients were recruited based on their ability to maintain an upright position for at least 30 seconds with their eyes closed, to allow performance of the force-platform test. As a consequence, the generalizability of our results is limited to patients who are not severely disabled and further studies need to be undertaken with more patients who are at an acute stage and with more marked spatial cognition disorders.

CONCLUSION

In conclusion, repeated NMV may be effective in treating postural disorders caused by spatial cognition disorders. There was a non-significant trend towards maintaining the positive effect longer term. A possible reason for lack of significant long-term effect in our study is that the stimulation may have been insufficient, either in its intensity or duration. This also raises the issue of whether such stimulation should be started at an early stage of stroke. Further studies are necessary to investigate other NMV protocols and the effect of duration. Our second result was an improvement in lower limb strength, as well as the dynamic balance (TUG and BBS) in both LBD and RBD patient groups. This result suggests an effect remote from the stimulation site, highlighting the relevance of vibrating the neck muscles in the course of stroke rehabilitation.

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Conflict of interest The authors declare that they have no competing interests.

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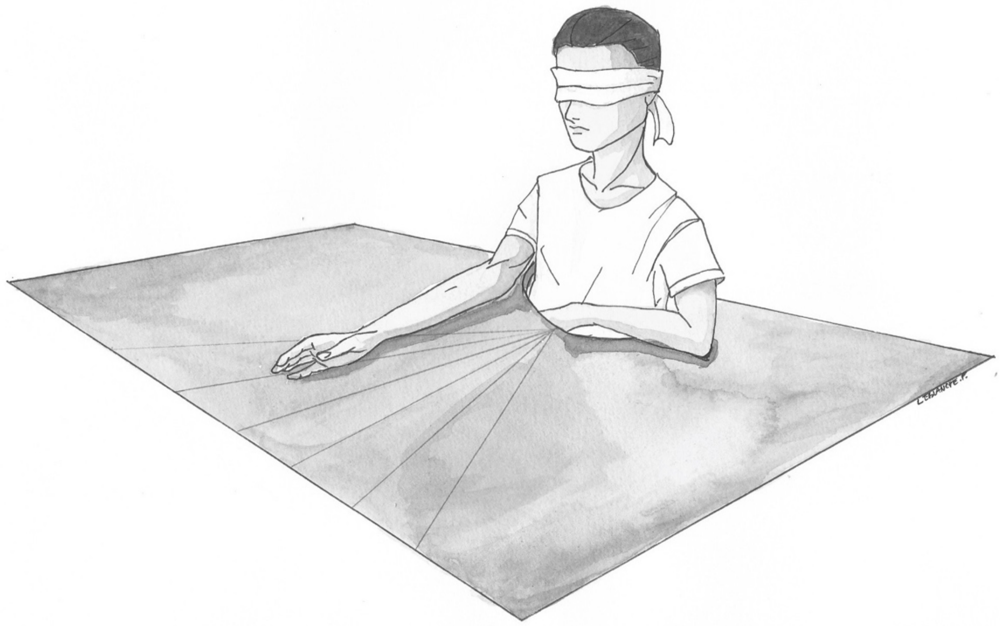
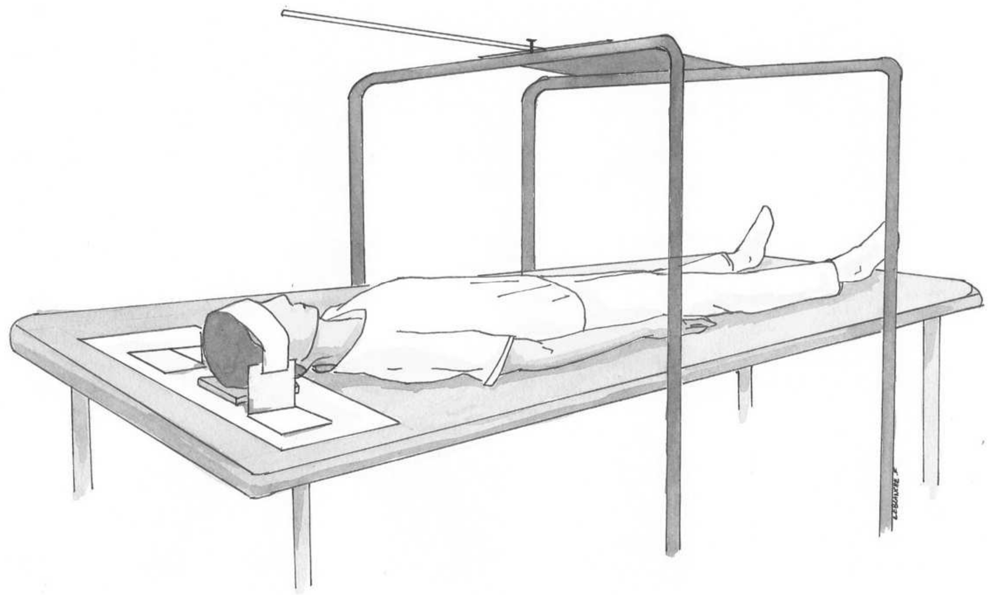
Figure 1: Experimental set-up of the Subjective Straight Ahead (SSA)



Evaluation of the SSA haptic was carried out on a measuring table on which the patient was required to move his hand while blindfolded. The table was graduated, and a one-degree angle corresponded to one linear cm. The midsagittal line coincided with the middle of the table with the head and trunk of the patient placed in strict alignment. From a starting position, with 10 starting positions, in a randomized sequence (-10°/5°/-15°/10°/30°/-5°/-20°/15°/-30°/20°) in which the arm of the patient was placed by the examiner, the patients were instructed to point “straight ahead”.

Figure 2: Experimental set-up of the Longitudinal Body Axis (LBA)



Evaluation of the LBA was performed using a light strip in front of the patient in a supine position, in complete darkness, with the head, trunk, and lower limbs aligned and maintained by cushions. The rotation center of the light wand was aligned with the patient's navel and the plumb line. The light wand was moved around its axis of rotation by the examiner from a starting position, with 10 starting positions, in a randomized sequence (-10°/5°/-15°/10°/30°/-5°/-20°/15°/-30°/20°). The patient was given the task of indicating when the strip was parallel to the axis of his body.

Figure 3: Protocol with evaluation time and neck muscle vibration intervention

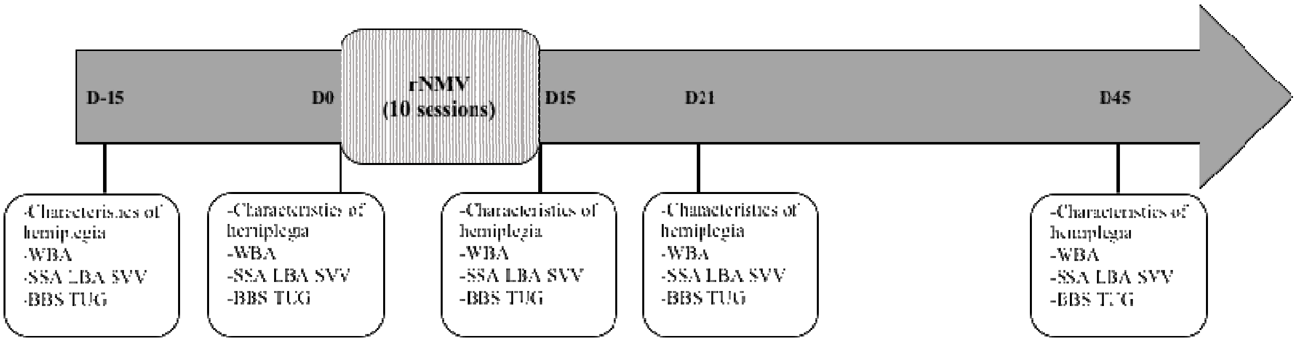


Figure 4: Flowchart of participants (RBD : right brain damage; LBD: left brain damage; FP : Force Plateform)

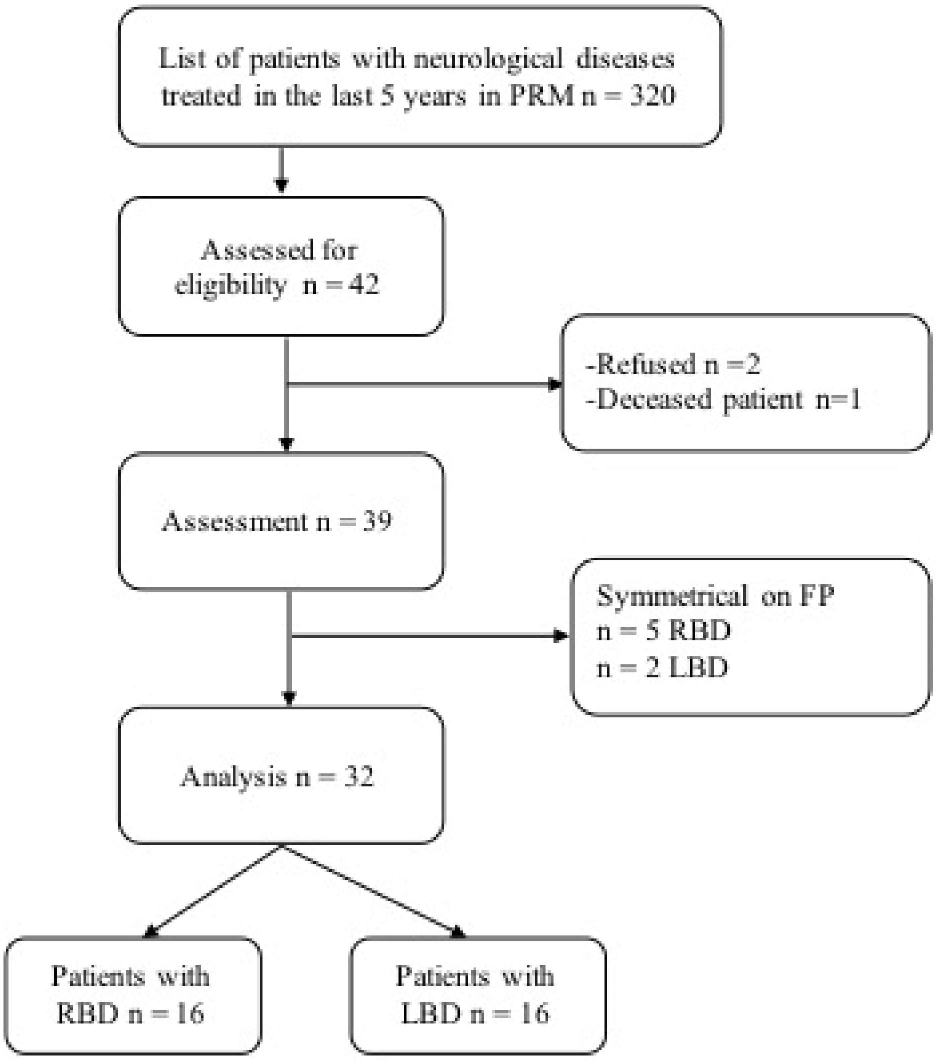


Figure 5: Evolution of Weight Bearing Asymmetry (WBA) of patients with Right brain damage (RBD) and patients with Left brain damage (LBD) Repetitive neck muscle vibration (rNMV). (★) significant effect.

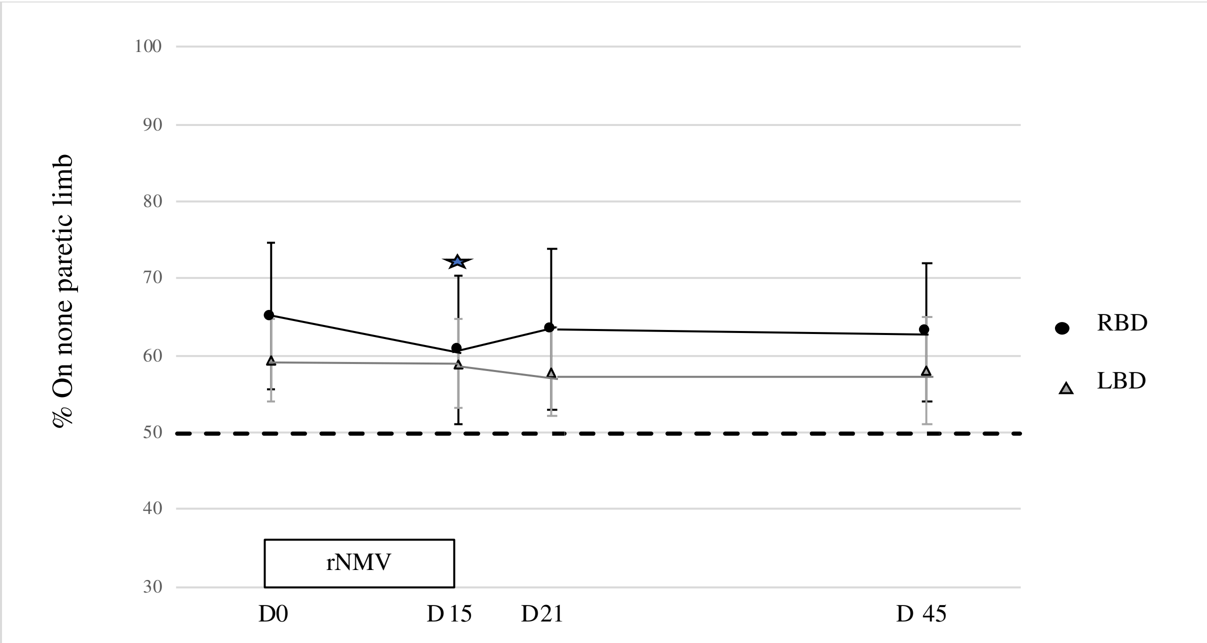


Figure 6: Evolution of both weight-bearing asymmetry (WBA) and spatial representation assessment. Longitudinal body axis (LBA), Subjective straight ahead (SSA), Subjective visual vertical (SVV) in Right brain damage patients. (★) significant effect

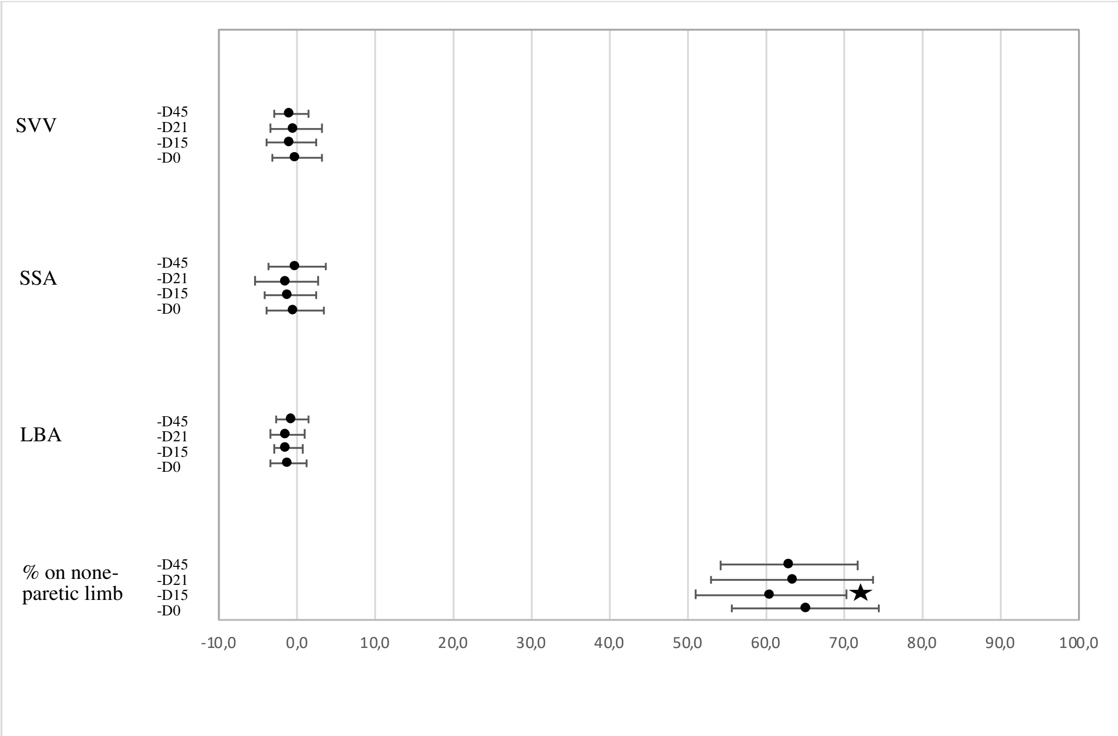


Table 1: Clinical data, patients with right brain damage (RBD) and patients with left brain damage (LBD). Berg Balance Scale (BBS), Longitudinal Body Axis (LBA), Subjective Straight Ahead (SSA), Subjective Visual Vertical (SSV), Timed Up And Go (TUG), Weight Bearing Asymmetry (WBA)

	RBD (n=16)	LBD (n=16)	p
Male/Female	14/2	12/4	-
Ischemic /hemorrhagic	9/7	12/4	-
Age (Years)	62.1(11.3)	59.8(10.2)	0.55
Delay-post (Years)	5.27(4)	4.71(4)	0.7
Motricity (/100)	69(16)	71(17)	0.77
Sensitivity (/6)	4(1)	5(1)	0.15
Visuo-spatial neglect	11/16	0/16	-
Hemianopia	0/16	0/16	-
WBA (%)	65.95(9.4)	60.6(4.5)	0.05
LBA_M (°)	-0.81	-0.54	0.1
LBA_SD (°)	2.73	1.76	0.01
SSA_M (°)	-1.1	1.54	0.1
SSA_SD (°)	2.59	3.27	0.1
SVV_M (°)	0.94	0.58	0.5
SVV_SD (°)	3.21	2.26	0.0005
TUG (sec)	26(17)	24(18)	0.78
BBS (/56)	43(8)	42(11)	0.79

Table 2: Mean and Standard deviation of posturography parameters and spatial representation after rNMV. Longitudinal body axis (LBA), Left brain damage (LBD), Right brain damage (RBD), Subjective straight ahead (SSA), Subjective visual vertical (SVV). (*) significant effect.

	D0	D15	D21	D45
Posturography parameters				
RBD				
% on none-paretic limb	65,1(9)	60,7(9)*	63,4(10)	63(8)
Xm (mm)	38,6(23)	26,1(24)*	33,6(25)	32,9(22)
Ym (mm)	35,5(21)	35,5(18)	35,8(21)	39,4(21)
Surface (mm2)	320 (228)	358(199)	322(147)	308(176)
LDB				
% on none-paretic limb	59,4(5)	58,9(5)	57,9(5)	58(6)
Xm (mm)	-21(12)	-20,5(15)	-19,2(15)	-18(18)
Ym (mm)	34,6(9)	38,4(9)	36,8(10)	37,5(8)
Surface (mm2)	298(211)	291(258)	350 (305)	326(317)
Spatial representation				
RBD				
LBA (°)	-1(2)	-1,1(2,7)	-1,2(1,3)	-0,5(2,1)
SSA (°)	0,1(3,8)	-1,4(4,4)	-1,4(3,9)	-0,2(3,1)
SVV (°)	0,1(0,7)	-0,5(3,6)	0,1(2,1)	-0,4(2,1)
LDB				
LBA (°)	-0,5(2,6)	-0,1(1,9)	-0,1(2)	-0,7(1,9)
SSA (°)	0,9(3,6)	1,3(3,9)	0,8(3,4)	0,1(2,4)
SVV (°)	1(2,5)	0,5(2)	0,5(1,8)	1(1,8)

Table 3: Mean and Standard deviation of the assessment of post-stroke deficiencies; sensory testing, motricity index, TUG and BBS of patients with left and right brain damage (*) significant effect.

	D0	D15	D21	D45
Severity of hemiplegia				
Motricity Index (100)	70,1(16)	73(18)*	73,6(17)*	73(17)
Sensitivity (6)	4,7(1)	5(1,7)	4,9(1,5)	4,8(1,6)
Balance rate				
Berg Balance Scale (56)	43(10)	44,4(10)*	44,5(10)*	44,6(10)*
Timed Up and Go (s)	24,4(16)	23,3(16)	23,1(16)*	23,6(17)*