1. Results

Seventy stroke patients were screened for eligibility, 29 did not match the specified inclusion criteria of the study, and the remaining 41 patients were enrolled in the study, where 35 completed the study **(fig. 1)**.

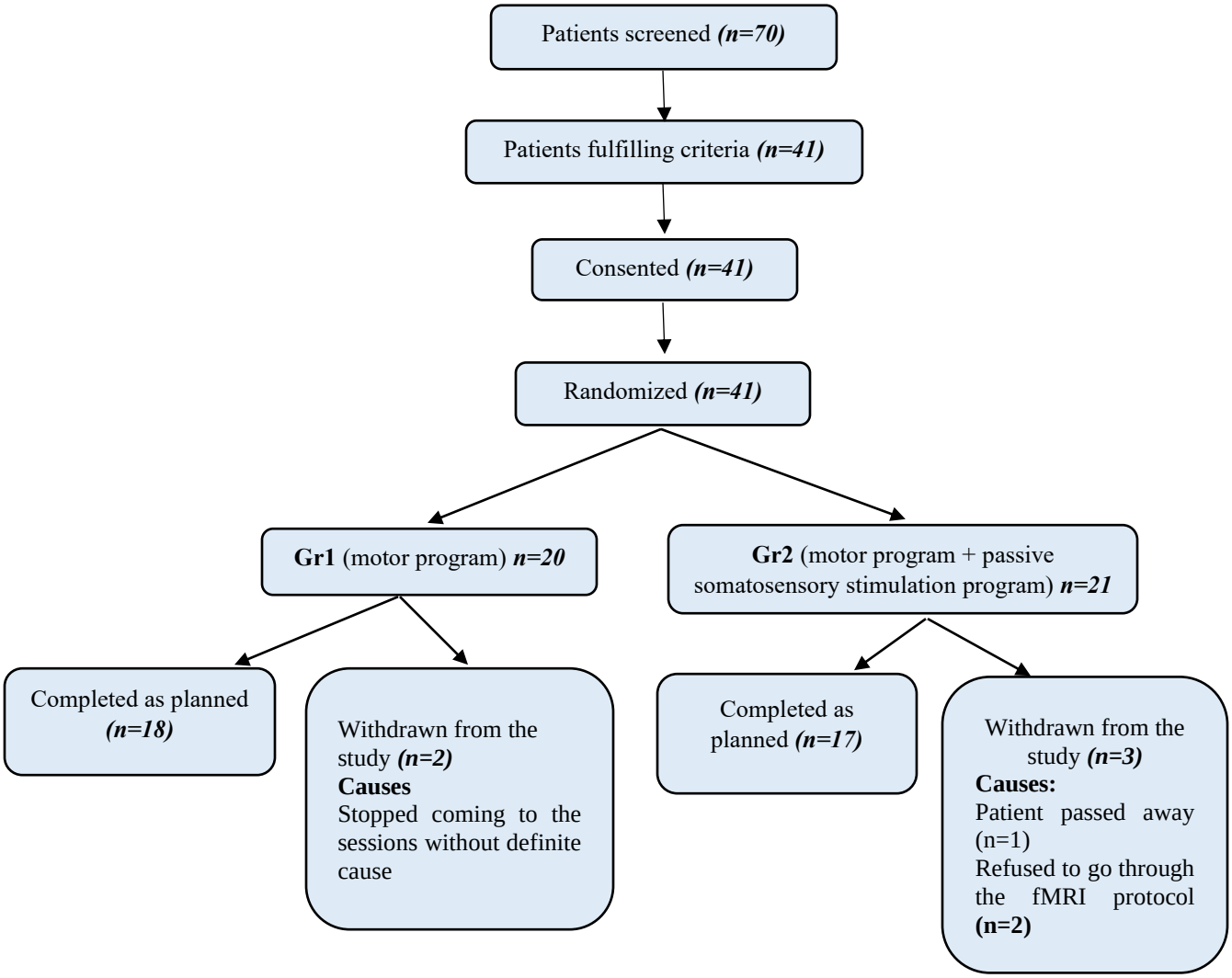

Figure (1). Study Design

1.1.Demographic Data and Clinical Characteristics

No statistically significant pre-treatment difference ($p > 0.05$) was present between **(Gr1)** and (**Gr2)** in age, duration of stroke (months) and side of affection **(table 1)**.

Table (1). Demographic and baseline clinical characteristics in both groups, pre-treatment.

	Gr1 (n=18)	Gr2 (n=17)	p-value
Age (years)	58.8 ±5.1	56.7 ±2.6	2.1[a]
Duration of stroke (months)	1 ±0.2	1 ±0	**0[a]**
Gender Male / Female	14/4	13/4	**0.93[b]**
Side of affection Right side/ Left side	10/8	13/4	**0.19[b]**

Unpaired t-test[a], Chi-squared test[b], p ≤ 0.05= significant *

1.2.Clinical Scales

1.2.1. Fugl- Meyer Assessment of the Upper Extremity (FMA-UE) scale

There were no significant changes in the motor function of the more affected (UE), in **(Gr1)** and **(Gr2)**, pre- and post-treatment ($p < 0.05$) **(table 2)**. On the other hand, there were significant changes, in the more affected (UE), in both groups, pre- and post-treatment **(table 3)**.

Table 2. Comparison between median values of the motor function in the more affected (UE), pre- and post-treatment in **(Gr1)** and **(Gr2)**.

			Gr1	Gr2	p-value
FMA-UE	**Pre-treatment**	Median ±SD	36 ±21.5	38 ±14.3	**0.790[b]**
	Post-treatment	Median ±SD	63 ±11.1	63 ±11.1	**2[b]**

Mann–Whitney test[a], Wilcoxon test[b], p ≤ 0.05= significant *, FMA-UE = Fugl- Meyer Assessment of the Upper Extremity

Table 3. Comparison between median values of motor function of the more affected (UE), pre- and post-treatment, in **(Gr1)** and **(Gr2)**.

			Pre- treatment	Post-treatment	Percentage of change	p-value
FMA-UE	**Gr.1**	Median ±SD	36 ±21.5	63 ±11.1	75	**0.011*[b]**

Mann–Whitney test[a], Wilcoxon test[b], p ≤ 0.05= significant *, FMA-UE = Fugl- Meyer Assessment of the Upper Extremity

1.2.2. Box and Block Test (BBT)

There were significant changes between the more affected and less affected (UE) pre- and post-treatment in (**Gr1)** and (**Gr2)** ($p < 0.05$) Additionally, there were significant changes between the more affected (UE) pre-and post- treatment and the less affected (UE) pre- and post-treatment in both groups ($p < 0.05$) **(table 4)**. On the other hand, no significant change between (**Gr1)** and (**Gr2)**, in the more affected (UE), pre-and post- treatment was reported while in the less affected (UE) there was significant change, post-treatment between (**Gr1)** and (**Gr2) (table 5)**.

Table (4). BBT scores of the more affected and less affected UE in **(Gr1)** and **(Gr2)**, pre-and post-treatment.

			More Affected side	Less Affected side	p-value
BBT	**Gr1**	**Pre-treatment**	23 ±21.9	40 ±14.2	**0.005*[a]**
		Post-treatment	38 ±22.1	45 ±13.4	**0.005*[a]**
		p-Value	**0.005*[b]**	**0.011*[b]**	
	Gr2	**Pre-treatment**	14 ±15.5	28 ±8.1	**0.002*[a]**
		Post-treatment	20 ±12.3	32 ±9.8	**0.010*[a]**
		p-Value	**0.002*[b]**	**0.005*[b]**	

Box and Block Test = BBT, Mann–Whitney test[a], Wilcoxon test[b], p ≤ 0.05= significant *

Table (5). BBT scores of the more and less affected UE between **(Gr1)** and **(Gr2)**, pre-and post-treatment.

			Gr1	Gr2	p-value
BBT	**Pre-treatment**	More affected UE	23 ±21.9	14 ±15.5	**0.517[a]**
		Less affected UE	40 ±14.2	28 ±8.1	**0.017*[a]**
	Post-treatment	More affected UE	38 ±22.1	20 ±12.3	**0.790[a]**
		Less affected UE	45 ±13.4	32 ±9.8	**0.017*[a]**

Box and Block Test = BBT, Mann–Whitney test[a], p ≤ 0.05= significant*

1.2.3. Perdue Pegboard Test (PPBT)

There was significant change between the more affected and less affected (UE) pre-treatment in (**Gr1)** and (**Gr2)** ($p < 0.05$) while there was no significant change post-treatment. Additionally, there were significant changes between the more affected (UE) pre-and post-treatment and the less affected (UE) pre- and post-treatment in both groups ($p < 0.05$) **(table 6)**. On the other hand, no significant change between (**Gr1)** and (**Gr2)** was reported in the more affected (UE), pre-and post- treatment while in the less affected (UE) there was a significant change between pre- and post-treatment **(table 7)**.

Table (6). PPBT scores of the more affected and less affected UE in **(Gr1)** and **(Gr2)**, pre-and post-treatment.

			More Affected side	Less Affected side	p-value
PPBT	**Gr1**	**Pre-treatment**	4.75 ±3.77	10.5 ±4.04	**0.007*[a]**
		Post-treatment	8.75 ±4.99	12 ±3.55	**0.079[a]**
		p-Value	**0.001*[b]**	**0.001*[b]**	
	Gr2	**Pre-treatment**	1.75 ±2.36	7 ±3.82	**0.004*[a]**
		Post-treatment	4.75 ±3.59	9.5 ±5.57	**0.078[a]**
		p-Value	**0.001*[b]**	**0.001*[b]**	

PPBT= Perdue Pegboard Test, Mann–Whitney test[a], Wilcoxon test[b], p ≤ 0.05= significant *

Table (7). PPBT scores of the more and less affected UE between **(Gr1)** and **(Gr2)**, pre-and post-treatment.

			Gr1	Gr2	p-value
PPBT	**Pre-treatment**	More affected UE	4.75±3.77	1.75±2.36	**0.052[a]**
		Less affected UE	10.5±4.04	7 ±3.82	**0.052[a]**
	Post-treatment	More affected UE	8.75±4.99	4.75±3.59	**0.079[a]**
		Less affected UE	12 ±3.55	9.5 ±5.57	**0.215[a]**

PPBT= Perdue Pegboard Test , Mann–Whitney test[a], p ≤ 0.05= significant*

1.2.4. Nottingham Sensory Assessment (NSA) scale

There were no significant changes between the more affected and less affected (UE) pre-treatment in (**Gr1)** and (**Gr2)** ($p < 0.05$) except in pre-treatment scores of tactile sensations of both groups with no significant changes reported post-treatment. Additionally, there was significant change between pre-and post-treatment scores of the tactile sensation only in both groups ($p < 0.05$) **(table 8)**. On the other hand, significant changes between (**Gr1)** and (**Gr2)**, in stereognosis, tactile sensations and kinesthetic sense, pre-treatment were reported in the more affected (UE), ($p < 0.05$), while no significant changes were reported post-treatment and in the less affected UE **(table 9)**.

Table (8). NSA scores of the more affected and less affected UE in **(Gr1)** and **(Gr2)**, pre-and post-treatment.

				More Affected side	Less affected side	p-value
NSA	**Stereognosis**	**Gr1**	**Pre-treatment**	22 ±2.7	22 ±0.0	**0.063[a]**
			Post-treatment	22 ±0.0	22 ±0.0	**1[a]**
			p-Value	**0.063[b]**	**1[b]**	
	Tactile sensation		**Pre-treatment**	16 ±0.0	48 ±0.0	**0.002*[a]**
			Post-treatment	48 ±8.4	48 ±0.0	**0.157[a]**
			p-Value	**0.003*[b]**	**1[b]**	
	Kinesthetic sense		**Pre-treatment**	12 ±1.7	12 ±0.0	**0.157[a]**
			Post-treatment	12 ±0.0	12 ±0.0	**1[a]**
			p-Value	**0.157[b]**	**1[b]**	
	Stereognosis		**Pre-treatment**	22 ±0.0	22 ±0.0	1[a]
			Post-treatment	22 ±0.0	22 ±0.0	**1[a]**

		Gr2	**p-Value**	**1[b]**	**1[b]**	
	Tactile sensation		**Pre-treatment**	16 ±15.8	48 ±0.0	**0.005*[a]**
			Post-treatment	48 ±0.0	48 ±0.0	1[a]
			p-Value	**0.005*[b]**	**1[b]**	
	Kinesthetic sense		**Pre-treatment**	12 ±0.0	12 ±0.0	**1[a]**
			Post-treatment	12 ±0.0	12 ±0.0	**1[a]**
			p-Value	**1[b]**	**1[b]**	

NSA= Nottingham Sensory Assessment, Mann–Whitney test[a], Wilcoxon test[b], p ≤ 0.05= significant *

Table (9). NSA scores (stereognosis, tactile sensation, and kinesthetic sense) of the more affected and less -affected UE between **(Gr1)** and **(Gr2)**, pre-and post-treatment.

				Gr1	Gr2	p-value
NSA	**Stereognosis**	**Pre-treatment**	More affected UE	22 ±2.7	22 ±0.0	**0.019*[a]**
			Less affected UE	22 ±0.0	22 ±0.0	**1[a]**
		Post-treatment	More affected UE	22 ±0.0	22 ±0.0	**1[a]**
			Less affected UE	22 ±0.0	22 ±0.0	**1[a]**
	Tactile sensation	**Pre-treatment**	More affected UE	16 ±0.0	16 ±15.8	**0.049*[a]**
			Less affected UE	48 ±0.0	48 ±0.0	**1[a]**
		Post-treatment	More affected UE	48 ±8.4	48 ±0.0	**0.112[a]**
			Less affected UE	48 ±0.0	48 ±0.0	**1[a]**
	Kinesthetic sense	**Pre-treatment**	More affected UE	12 ±1.7	12 ±0.0	**0.112[a]**
			Less affected UE	12 ±0.0	12 ±0.0	**1[a]**
		Post-treatment	More affected UE	12 ±0.0	12 ±0.0	**1[a]**
			Less affected UE	12 ±0.0	12 ±0.0	**1[a]**

NSA= Nottingham Sensory Assessment , Mann–Whitney test[a] p < 0.05= significant *

1.2.5. *Activation Patterns of Ipsilesional and Contralesional Primary motor area (M1), Premotor cortex (PMC), Supplementary motor area (SMA), Cerebellar hemispheres, Vermis, and Primary sensory area (S1) in (Gr. 1) and (Gr.2).*

Passive flexion and extension of the more affected wrist joint and fingers (metacarpophalangeal and proximal/ distal interphalangeal joints) was associated with different responses in the ipsilesional and contralesional hemisphere in both groups. Comparison between z scores of (M1) revealed significant difference in areas 4a and 4p (<0.05) between ipsilesional and contralesional (M1), in both groups respectively while post-treatment, the significant change was in Gr2 only. In the (PMC) and (SMA), there was significant changes pre- and post-treatment between the ipsilesional and contralesional hemisphere. It seems that the cerebellum in both groups showed significant changes between the ipsilesional and contralesional hemispheres. Finally, area (S1) **(table 10).**

On the other hand, comparison between the ipsilesional and the contralesional hemispheres, pre- and post-treatment revealed significant changes in both groups in areas (M1), (SMA), (PMC), (CB), vermis and (S1), yet improvement was greater in **(Gr2)** compared to **(Gr1)**.

Table 10. Comparison between median values of z - scores of ipsilesional and contralesional M1, PMC, SMA, CB, sides of the vermis, and S1 in **(Gr1)** and **(Gr2)**, pre-and post-treatment.

					Ipsilesional M1	Contralesional M1	p-value
Primary motor area (M1)	Area 4a	Gr1	Pre-treatment	Median ±SD	8.4 ±2	5.8 ±1.2	0.035*[a]
			Post-treatment		7.6 ±1.1	7.4 ±0.7	0.798[a]
	Area 4p		Pre-treatment	Median ±SD	8.4 ±1.8	5.1 ±1.4	0.035* [a]
			Post-treatment		7.6 ±1.1	7 ±1	0.201 [a]
	Area 4a	Gr2	Pre-treatment	Median ±SD	7.9 ±1.5	6.2 ±1.1	0.002** [a]
			Post-treatment		9.5 ±1.4	7.3 ±0.9	0.002** [a]
	Area 4p		Pre-treatment	Median ±SD	7.9 ±1.5	5.4 ±1.3	0.002** [a]
			Post-treatment		9.5 ±2	6.6 ±0.6	0.021* [a]
Premotor cortex (PMC)					Ipsilesional PMC	Contralesional PMC	p-value
		Gr1	Pre-treatment	Median ±SD	7.4 ±1.7	6.3 ±1.1	0.035* [a]
			Post-treatment		7.6 ±1.3	7.7 ±0.9	0.878 [a]
		Gr2	Pre-treatment	Median ±SD	7.5 ±1.3	6.2 ±1.2	0.002** [a]
			Post-treatment		9.3 ±0.9	7.3 ±0.9	0.002** [a]
Supplementary motor area (SMA)					Ipsilesional SMA	Contralesional SMA	p-value
		Gr1	Pre-treatment	Median ±SD	5.7 ±1.9	5 ±1.2	0.673 [a]
			Post-treatment		5.9 ±1.9	6.2 ±1.2	0.167 [a]
		Gr2	Pre-treatment	Median ±SD	5.9 ±0.8	4.1 ±0.7	0.002** [a]
			Post-treatment		6.6 ±0.7	6.2 ±0.7	0.021* [a]
Cerebellar hemispheres					Ipsilesional cerebellar hemisphere	Contralesional cerebellar hemisphere	p-value
		Gr1	Pre-treatment	Median ±SD	3.2 ±0.8	4.2 ±0.5	0.011* [a]
			Post-treatment		4.4 ±1.2	5.8 ±0.8	0.012* [a]
		Gr2	Pre-treatment	Median ±SD	4.5 ±0.9	4.3 ±0.3	0.021* [a]
			Post-treatment		5.4 ±1	4.5 ±0.8	0.002** [a]
Vermis					Ipsilesional side of the vermis	Contralesional side of the vermis	p-value
		Gr1	Pre-treatment	Median ±SD	2.2 ±1.1	3 ±0.8	0.011* [a]
			Post-treatment		3.8 ±1.3	6.1 ±2	0.036* [a]
		Gr1	Pre-treatment	Median ±SD	3.9 ±0.9	2.6 ±1.4	0.021* [a]
			Post-treatment		4.6 ±1.6	3.8 ±0.8	0.002** [a]
Primary sensory area (S1)					Ipsilesional S1	Contralesional S1	p-value
	Area 1	Gr1	Pre-treatment	Median ±SD	8.4 ±1.4	7 ±0.8	0.035* [a]
			Post-treatment		7.6 ±1	6.8 ±0.8	0.506 [a]
	Area 2		Pre-treatment	Median ±SD	8.4 ±1.9	6.8 ±0.9	0.260 [a]
			Post-treatment		7 ±1	6.2 ±1.1	0.092 [a]
	Area 3b		Pre-treatment	Median ±SD	7.3 ±2.3	3.7 ±1	0.035* [a]
			Post-treatment		6.4 ±1.8	6.2 ±1.4	0.506 [a]
	Area 1	Gr2	Pre-treatment	Median ±SD	7.7 ±1.7	6.2 ±1.1	0.002** [a]
			Post-treatment		9.5 ±1.3	7.3 ±0.9	0.002** [a]
	Area 2		Pre-treatment	Median ±SD	7.8 ±1.6	6.1 ±0.9	0.002** [a]
			Post-treatment		7.1 ±1.5	6.9 ±1.1	0.021* [a]

	Area 3b		Pre-treatment	Median ±SD	6.1 ±1.5	5.2 ±1.1	0.002** [a]
			Post-treatment		5.7 ±1.9	5.4 ±0.8	0.302 [a]

Mann–Whitney test[a], Wilcoxon test[b], p ≤ 0.05= significant *

Table (11). Median values of z scores of the ipsilesional and contralesional side of M1, PMC, SMA, CB, sides of the vermis, and S1 pre-and post-treatment, in **(Gr1)** and **(Gr2)**.

					Pre-treatment	Post-treatment	Percentage of change	p-value
Primary motor area (M1)	Area 4a	Gr1	Ipsilesional M1	Median ±SD	8.4 ±2	7.6 ±1.1	-9.5	0.574 [b]
			Contralesional M1		5.8 ±1.2	7.4 ±0.7	27.6	0.122 [b]
	Area 4p		Ipsilesional M1	Median ±SD	8.4 ±1.8	7.6 ±1.1	-9.5	0.574 [b]
			Contralesional M1		5.1 ±1.4	7 ±1	37.3	0.122 [b]
	Area 4a	Gr2	Ipsilesional M1	Median ±SD	7.9 ±1.5	9.5 ±1.4	20.3	0.002** [b]
			Contralesional M1		6.2 ±1.1	7.3 ±0.9	17.7	0.002** [b]
	Area 4p		Ipsilesional M1	Median ±SD	7.9 ±1.5	9.5 ±2	20.3	0.002** [b]
			Contralesional M1		5.4 ±1.3	6.6 ±0.6	22.2	0.002** [b]
Premotor cortex (PMC)					Pre-treatment	Post-treatment	Percentage of change	p-value
		Gr1	Ipsilesional PMC	Median ±SD	7.4 ±1.7	7.6 ±1.3	2.7	0.385 [b]
			Contralesional PMC		6.3 ±1.1	7.7 ±0.9	22.2	0.122 [b]
		Gr2	Ipsilesional PMC	Median ±SD	7.5 ±1.3	9.3 ±0.9	24	0.002** [b]
			Contralesional PMC		6.2 ±1.2	7.3 ±0.9	17.7	0.002** [b]
Supplementary motor area (SMA)					Pre-treatment	Post-treatment	Percentage of change	p-value
		Gr1	Ipsilesional SMA	Median ±SD	5.7 ±1.9	5.9 ±1.9	3.5	0.798 [b]
			Contralesional SMA		5 ±1.2	6.2 ±1.2	24	0.011* [b]
		Gr2	Ipsilesional SMA	Median ±SD	5.9 ±0.8	6.6 ±0.7	11.9	0.812 [b]
			Contralesional SMA		4.1 ±0.7	6.2 ±0.7	51.2	0.002** [b]
Cerebellar hemispheres					Pre-treatment	Post-treatment	Percentage of change	p-value
		Gr1	Ipsilesional cerebellar hemisphere	Median ±SD	3.2 ±0.8	4.4 ±1.2	37.5	0.012* [b]
			Contralateral cerebellar hemisphere		4.2 ±0.5	5.8 ±0.8	38.1	0.035* [b]
		Gr2	Ipsilesional cerebellar hemisphere	Median ±SD	4.5 ±0.9	5.4 ±1	20	0.812 [b]
			Contralateral cerebellar hemisphere		4.3 ±0.3	4.5 ±0.8	4.7	0.812 [b]
Vermis					Pre-treatment	Post-treatment	Percentage of change	p-value
		Gr1	Ipsilesional side of the vermis	Median ±SD	2.2 ±1.1	3.8 ±1.3	72.7	0.005** [b]
			Contralesional side of the vermis		3 ±0.8	6.1 ±2	10.3	0.035* [b]
		Gr2	Ipsilesional side of the vermis	Median ±SD	3.9 ±0.9	4.6 ±1.6	17.9	0.812 [b]
			Contralesional side of the vermis		2.6 ±1.4	3.8 ±0.8	46.2	0.812 [b]
Primary sensory area (S1)					Pre-treatment	Post-treatment	Percentage of change	p-value
	Area 1		Ipsilesional S1	Median ±SD	8.4 ±1.4	7.6 ±1	-9.5	0.385 [b]
			Contralesional S1		7 ±0.8	6.8 ±0.8	-2.9	1 [b]

	Area 2	**Gr1**	**Ipsilesional S1**	**Median ±SD**	**8.4 ±1.9**	**7 ±1**	**-16.7**	**0.385** [b]
			Contralesional S1		**6.8 ±0.9**	**6.2 ±1.1**	**-8.8**	**0.574** [b]
	Area 3b		**Ipsilesional S1**	**Median ±SD**	**7.3 ±2.3**	**6.4 ±1.8**	**-12.3**	**0.385** [b]
			Contralesional S1		**3.7 ±1**	**6.2 ±1.4**	**67.6**	**0.122** [b]
	Area 1	**Gr2**	**Ipsilesional S1**	**Median ±SD**	**7.7 ±1.7**	**9.5 ±1.3**	**23.4**	**0.002****
			Contralesional S1		**6.2 ±1.1**	**7.3 ±0.9**	**17.7**	**0.002****
	Area 2		**Ipsilesional S1**	**Median ±SD**	**7.8 ±1.6**	**7.1 ±1.5**	**-9**	**0.021***
			Contralesional S1		**6.1 ±0.9**	**6.9 ±1.1**	**13.1**	**0.002****
	Area 3b		**Ipsilesional S1**	**Median ±SD**	**6.1 ±1.5**	**5.7 ±1.9**	**-6.6**	**0.021***
			Contralesional S1		**5.2 ±1.1**	**5.4 ±0.8**	**3.8**	**0.021***

Mann–Whitney test[a], Wilcoxon test[b], $p \leq 0.05$= significant *