# EFFECT OF FOCAL MUSCLE VIBRATION THERAPY ON REACTION TIMING, SPASTICITY, IMPAIRMENT AND VOLUNTARY CONTROL OF UPPER LIMB FUNCTION IN TRAUMATIC BRAIN INJURY PATIENTS

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# ABSTRACT

**Background & purpose:** Traumatic brain injury (TBI) is a dysfunction of the brain cells that disturbs the normal brain function and impacting individuals and society with long- term impairments. Along with the emotional and behavioral consequences, other common manifestation includes impaired hand functions as a result of spasticity, increased response time, and loss of volitional control. The current study aimed to assess the effect of focal muscle vibration therapy (FMVT) on reaction timing, spasticity, impairment and voluntary control of hand functions in TBI patients.

**Materials & Methods:** An OPD and multispecialty hospital based randomized controlled trial (RCT) was conducted. Sixty participants meeting the inclusion criteria were selected and allocated into experimental and control group. The experimental study received FMVT and modified constraint movement therapy (M-CIMT) for 6 weeks. In contrast, the control group underwent sustained stretching, PNF hold-relax, and M-CIMT for a period of 6 weeks. Post- assessments were conducted at week 3 and 6.

**Result:** Following the 6 weeks protocol, the study findings indicated improvement in both the groups for all four variables. The group that received FMVT showed significant improvement in all the clinical outcome measures. The conventional therapy group also showed improvements, though less pronounced. When comparing the two groups, FMVT demonstrated superior efficacy over the control group across all the outcome measures.

**Conclusion:** FMVT has been proven to significantly improve hand functions. Additionally, the study explored a relatively novel outcome of reaction timing, providing valuable insights on its impact in TBI population.

**Keywords:** Focal Muscle Vibration Therapy, Spasticity, Traumatic Brain Injury, Reaction Time, Hand Function

# INTRODUCTION

TBI disrupts the brain function following an external insult to the brain in the form of vehicular accidents, falls or assaults4, comprising of a wide array of temporary or a more permanent consequences1,2 in the form of physical, emotional and behavioural impairments.6 It is a key cause for an increased disability and death toll globally5 with an estimated population of roughly 50 million affected by TBI and 1.2 million dying from it every year9, causing a major financial load on the society.7

The incidence of TBI widely varies across the globe with maximum occurrence of 30% in the younger population under the age of 45 years.10 RTA’s are the prime cause of head injuries responsible for 60% of such cases, with 70 lives lost every 10,000 vehicles.7

Survivors of traumatic brain injury (TBI) often face immense hurdles that deeply impact their daily lives and independence. One of the most difficult consequences for many is skeletal muscle spasticity

,a result of upper motor neuron lesion14 typically affecting upper limb more severely than lower limbs13and making daily tasks like reaching for an object or grooming more challenging. Cognitive issues add more complexities with memory lapses, problems with attention, and decision-making. The emotional battle is profound too, often leading to feelings of sadness and sense of isolation, further hindering their recovery. Hand function is often majorly impaired by brain injury, mostly due to muscle spasticity and its related complications22, leading to impaired voluntary control 21, compromised motor function20, and increased response time17,18,19

The recovery journey in TBI involves a holistic approach with a team of dedicated healthcare professionals creating a tailor-made rehabilitation programme to patient’s specific needs and goals. Traditional techniques that includes slow sustained stretch and PNF are widely used in treating spasticity and has been proven quite effective.23 **Dafda Renuka H et al in 2021** demonstrated the effectiveness of static stretching and PNF hold-relax technique in reducing elbow flexor spasticity in stroke population.23 In recent years, a relatively new, innovative and well tolerated27 tool called focal muscle vibration therapy.

(FMVT) has emerged as a promising addition to neurological rehabilitation. FMVT involves the vibratory stimulus applied directly on the targeted muscle at a therapeutic dose of high frequency and low amplitude, resulting in altered cortico-spinal pathway and activation of reciprocal inhibition.25 In a study by **Tomokazu et al in 2020** indicated marked reduction in upper extremity spasticity on a direct application of vibration in post stroke patients.28

While there are numerous studies with strong evidence supporting the effectiveness of FMV therapy in reducing spasticity among stroke survivors, there's a noticeable dearth of research exploring its potential benefits for TBI cases, which calls for further research to help refine treatment protocols and maximize functional outcomes for individuals with TBI. The current study aimed to investigate the effects of FMVT on reaction timing, spasticity, motor impairments, and voluntary control of upper limb function in traumatic brain injury patients.

# MATERIALS AND METHODOLOGY

## Methods

The IEC approval was obtained from the Ethical committee (EC- MPT/23/PHY/013). The participants and their guardian were explained about the study purpose. A written consent for participation after explanation were obtained from the subject/guardian individually.

Study design was a Randomized Controlled Trial and simple random sampling was done to select the participants. The subjects were randomly divided into control and experimental group and equally assigned with 30 in each group. Patients were advised to continue their prescribed medications throughout the study. The total duration of study was 1 year and was conducted in OPD, home settings and multispecialty hospital setup in Bengaluru. Sixty subjects were recruited on the basis of selection criteria. The inclusion criteria included Both male and female population diagnosed with Traumatic Brain Injury, in the age group of 18-40 years57 having moderate to severe TBI with GCS score- 9-12 in accordance to mayo classification for TBI severity58. The subjects were required to have a minimum 10 degrees of wrist extension, thumb abduction and finger extention.59 whereas patients with Severe head injury (GCS<3)60, Spastic hand, Deformities of hand and Cognitive impairment (MMSE score <24) were excluded.

## Outcome measures

The Modified Ashworth Scale was used to evaluate spasticity. Ruler-drop test was used to assess reaction time where subject was asked to sit on the couch and asked to attempt to stop a falling ruler, and the height fallen was used to determine the time taken to react to the event. Similarly Fugl-Meyer scale was used to evaluate motor hand impairment. Patient was asked to sit on the couch and using paper, ball, pencil and a small jar, the patient was assessed for motor impairment and scored based on direct observation of performance. Brunnstrom voluntary control grading was used to analyze motor performance of patient. The patient was asked to perform specific tasks and attempt to move their limbs voluntarily through various stages of recovery. The quality and extent of voluntary movement exhibited by the patient were observed and the stage of the Brunnstrom was assigned. The six component stages were used to assess the TBI subjects that described the voluntary control.

## Intervention Procedure

Pre-test score measurements for spasticity, reaction timing, hand impairment and voluntary control were taken for both the groups before the commencement of the intervention, using Modified Ashworth Scale (MAS), Ruler-Drop test, Fugl Meyer Scale and Brunnstrom Voluntary Control Grading respectively.

Structured M-CIMT was administered to both control and experimental group as a baseline intervention for 10 minutes. In Structured M-CIMT, the patient was instructed to wear a constraint glove on the non-affected arm for 5 hours per day, 5 days a week for 6 weeks.63 The steps of the functional tasks relevant to everyday function were taught and encouraged to repetitively practice it in home therapy sessions under the supervision of caregiver for 10 minutes per day for a duration of 6 weeks. Four functional task were included.

Stacking blocks- patient was made to sit comfortably at a table with a variety of blocks within easy reach. The activity was started first by using bigger block and gradually smaller blocks were introduced with improvement in skill. The stacking of blocks one on top of the other was first demonstrated to make patient understand the activity better. The patient was then asked to stack the block with the affected limb and the activity was repeated multiple times. Similarly for reaching and grasping objects, patient was made to sit comfortably and a variety of objects with different shape, size and weight were kept within patient’s reach. Patient was asked to reach out, touch and pick the object with the affected hand. The activity was started with large and light weighted object and slowly transitioned to smaller and heavy objects as the skills developed.  **​**Tapping tasks required patient in sitting position. A tapping board with markings was placed on the table within easy reach. Task was first demonstrated and was then asked to tap on the marked targets on the tapping board with the affected hand. The task was repeated several times. Lastly, for hand cupping/scooping task, patient was in sitting position with a bunch of coins placed on the table within easy reach. Scooping task was demonstrated and the patient was informed to use the involved hand in the same way to scoop coins from the table and transfer them to the unaffected had. The task was practiced several times.

In Control Group, Sustained stretching was given to wrist flexors with patient in supine position with hand supinated and supported by a towel under the wrist23 the patient’s upper arm was held and elbow was gently extended in order to put a stretch on elbow flexors. The stretch was maintained for 30 seconds. It was applied for 15 minutes, thrice a week for 6 weeks.

PNF-Hold-relax was also given to the patient in supine position with hand supinated and supported by a towel under the wrist23 The patient’s upper arm was held gently and the elbow was extended to the point of mild discomfort (initial stretch). The patient was then instructed to try to bend the elbow against resistance for about 5-10 seconds and was then instructed to relax the elbow flexors while the muscle was further stretched, increasing the range of motion. It was applied for 15 minutes, thrice a week for 6 weeks.

In Experimental Group, FMV therapy was given over the bulky part of the common wrist extensor33 with patient in supine position with hand pronated and supported by a towel roll. The setting on muscle vibrator was set at 100 Hz. The vibrator was then placed at the muscle belly and vibratory stimulus was applied, while continuously monitoring the patient for any sign of discomfort or pain. The patient was instructed to perform deep breathing throughout the treatment period. The duration of treatment was 30/ session , thrice a week26 for 6 weeks.

# STATISTICAL ANALYSIS

The analysis was conducted using SPSS 21.0, a statistical programme. A combination of inferential and descriptive analysis was the approach taken. Both parametric and non-parametric tests were appropriately used. The graphical editors MS-WORD and SPSS were used to create the tables in the proper manner.

**RESULTS**

After analyzing the data, the results obtained showed improvements in both the groups for all the outcome measures. In the control group, reaction time on RDT improved from 227.10 ± 21.43 ms at baseline to 211.13 ± 17.77 ms at week 3, and 203.02 ± 13.02 ms at week 6 (Table-5). The experimental group had even better results, with reaction times decreasing from 231.90 ± 23.54 ms at baseline to 194.30 ± 8.25 ms at week 3, and 185.90 ± 9.12 ms at week 6 (Table-4). The control group's MAS scores improved from 3.43 ± 0.82 at baseline to 2.43 ± 0.86 at week 3, and 1.95 ± 0.81 at week 6. The experimental group had even greater improvements, with scores decreasing from 3.47 ± 0.62 at baseline to 2.27 ± 0.61 at week 3, and 1.67 ± 0.84 at week 6. The pre- and post-test results for upper limb impairment demonstrated significant differences in mean and SD. Observing the control group, it was seen that FMS scores improved from baseline levels of 6.50±2.14 to 8.73 ±1.81 at week 3 , and were further enhanced by week 6 to 8.97 ±1.77. In the experimental group, scores were also improved from baseline level of 6.77±1.83 to week 3 with 9.77 ± 1.71, with continued progress noted at week 6, reaching 10.40 ± 1.71. The control group experienced improvements in voluntary control on BVCG scale, with the gains from a baseline of 2.97 ±0.61to 3.63±0.65at week 3 and further to 4.43±0.54 at week 6. The experimental group, however, progressed from baseline of 3.07 ±0.64 to 4.57 ± 0.67 at week 3 and continued to show substantial improvements through week 6, reaching 5.17 ± 0.69. Comparisons study was done between the experimental and control groups for both post-test 1 and post-test 2 and revealed that the experimental group consistently outperformed the control group indicated by significant differences favouring the experimental group (p<0.005) as shown in table 6 and 7.The results strongly indicated that FMVT group significantly outperformed the control group in improving reaction timing, reducing muscle tone, and enhancing voluntary motor control and overall impairment in TBI patients.

**Table-1**: **Distribution of traumatic brain injury patients in both groups.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **S. No.** | **Gender** | **Group** | | P= 0.795  NS |
| **Group-A**  **Experimental** | **Group-B Control** |
| 1 | **Male** | 17(56.7%) | 16(53.3%) |
| 2 | **Female** | 13(43.3%) | 14(46.7%) |
| The above table infers the homogenous distribution of both the genders in each group (p>0.05). | | | | |

**Table-2**: **Range, mean and SD of age of the traumatic brain injury patients in both the groups.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **S.No.** | **Variable** | **Group-A:**  **Experimental** | | **Group-B: Control** | | **Unpaired t-test** |
| **Range** | **Mean ± SD** | **Range** | **Mean ± SD** |
| 1 | **Age in years** | 21-40 | 32.27±5.23 | 21-40 | 30.30±5.77 | t=1.382,  p=0.172, NS |
| 2 | **Height(m)** | 1.50-  1.70 | 165.93±7.11 | 1.53-1.76 | 166.30±6.57 | t=0.207,  p=0.836, NS |
| 3 | **Weight(kg)** | 45-81 | 64.50±11.35 | 53-87 | 67.20±10.05 | t=1.040,  p=0.187, NS |
| 4 | **BMI** | 17.40-  31.50 | 23.95±3.90 | 18.80-33.31 | 24.31±3.45 | t=0.404,  p=0.687, NS |
| The above table shows the demographic data of the study population indicating homogeneity (p>0.05). | | | | | | |

**Table-3: Comparison of pre interventional outcomes of traumatic brain injury patients in between the groups**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **S. No.** | **Outcome Measures** | **Pre interventional** | | | | **Mann Whitney U test**  **/Unpaired t-**  **test, p-value** |
| **Group-A:**  **Experimental** | | **Group-B: Control** | |
| **Range** | **Mean ± SD** | **Range** | **Mean ±**  **SD** |
| 1 | **FMS** | 4-10 | 6.77±1.83 | 2-9 | 6.50±2.14 | z=0.233  p=0.816 |
| 2 | **MAS** | 2-4 | 3.47 ±0.62 | 2-4 | 3.43±0.82 | z=0.330,  p=0.742 |
| 3. | **RDT(m sec)** | 189-271 | 231.90  ±23.54 | 191-271 | 227.10  ±21.43 | t=0.734,  p=0.466 |
| 4. | **BVCG** | 2-4 | 3.07 ±0.64 | 2-4 | 2.97  ±0.61 | z=0.622  p=0.534 |
| The above table shows the comparison of pre-test score measurement for both the group, implying the similarity of the baseline scores for the outcome measures of FMS, MAS, RDT and BVCG in both the group (p>0.005). | | | | | | |

**Table-4**: **Pre and post interventions of outcome measures of traumatic brain injury patients in group-A**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S.No.** | **Outcome measures** | **Group-A: Experimental** | | | | | | Friedman test ANOVA/ F-  test ANOVA |
| **Pre test** | | **Post test-1** | | **Post test-2** | |
| **Range** | **Mean ±SD** | **Range** | **Mean ±SD** | **Range** | **Mean**  **±SD** |
| 1 | **FMS** | 4-10 | 6.77±1.83 | 6-12 | 9.77 ±1.71 | 6-13 | 10.40  ±1.71 | Fr=40.467, p=0.000 |
| 2 | **MAS** | 2-4 | 3.47 ±0.62 | 1-3 | 2.27±0.61 | 0-3 | 1.67±0.  84 | Fr=52.019, p=0.000 |
| 3. | **RDT(m**  **sec)** | 189-  271 | 231.90  ±23.54 | 182-  215 | 194.30  ±8.25 | 178-  219 | 185.90  ±9.12 | F=68.147, p=0.000 |
| 4. | **BVCG** | 2-4 | 3.07 ±0.64 | 3-6 | 4.57±0.67 | 4-6 | 5.17±0.  69 | Fr=57.728, p=0.000 |
| Pairs of **Pre with post-1:** | | * FMS: z=4.398, p=0.000, S * MAS: z=4.830, p=0.000, S * RDT: t=8.819, p=0.000, S * BVCG: t=10.570, p=0.000, S | | | Pairs of **Post-1 with post-2:** | * FMS: z=3.827, p=0.000, S * MAS: z=3.272, p=0.001, S * RDT: t=2.396, p=0.023, S   BVCG: t=4.039, p=0.000, S | | |
| Pairs of **Pre with post-2:** | | * FMS: z=4.648, p=0.000, S * MAS: z=4.823, p=0.000, S * RDT:t=9.294, p=0.000, S   BVCG: t=37.696, p=0.000, S | | | |  | | |

The above table depicts the scores obtained in the experimental group following the intervention with the pre-test scores at week 0, post-test 1 score at week 3 and post-test 2 score at week 6 indicating the significance (p<0.005).

**Table-5**: **Pre and post interventions of outcome measures of traumatic brain injury patients in group- B**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S.No.** | **Outcome measures** | **Group-B: Control** | | | | | | Friedman test ANOVA/ F-  test ANOVA |
| **Pre test** | | **Post test-1** | | **Post test-2** | |
| **Range** | **Mean ±SD** | **Range** | **Mean ±SD** | **Range** | **Mean**  **±SD** |
| 1 | **FMS** | 2-9 | 6.50±2.14 | 5-13 | 8.73 ±1.81 | 6-13 | 8.97  ±1.77 | Fr=21.394, p=0.0000 |
| 2 | **MAS** | 2-4 | 3.43±0.82 | 1-3 | 2.43 ±0.86 | 0-3 | 1.95  ±0.81 | Fr=38.655, p=0.000 |
| 3. | **RDT(m**  **sec)** | 191-  271 | 227.10  ±21.43 | 185-  248 | 211.13  ±17.77 | 183-  225 | 203.02  ±13.02 | F =14.321, p=0.000 |
| 4. | **BVCG** | 2-4 | 2.97 ±0.61 | 2-5 | 3.63±0.65 | 4-5 | 4.43±0.  54 | Fr=42.297, p=0.000 |

|  |  |
| --- | --- |
| Pairs of **Pre with post-1:** | * FMS: z=3.112, p=0.019, S * MAS: z=3.271, p=0.001, S * RDT: t=6.909, p=0.000, S   BVCG: t=2.511, p=0.036, S |
| Pairs of **Pre with post-2:** | * FMS: z=2.964, p=0.026, S * MAS: z=2.845, p=0.031, S * RDT: t=3.421, p=0.001, S   BVCG: t=4.832, p=0.000, S |
| Pairs of **Post-1 with post-2:** | * FMS: z=1.913, p=0.063, NS * MAS: z=0.699, p=0.485, NS * RDT: t=2.215, p=0.035, S   BVCG: t=3.442, p=0.001, S |
| The above table indicates the scores obtained in the control group following the conventional therapy with the pre-test scores at week 0, post-test 1 score at week 3 and post-test 2 score at week 6 indicating the significance (p<0.005). | |

**Table-6: Comparison of Post interventional-1 outcomes of traumatic brain injury patients in between the groups**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **S.No.** | **Outcome Measures** | **Post interventional-1** | | | | **Mann Whitney U test**  **/Unpaired t- test, p-value** |
| **Group-A:**  **Experimental** | | **Group-B: Control** | |
| **Range** | **Mean ± SD** | **Range** | **Mean ±**  **SD** |
| 1 | **FMS** | 6-12 | 9.77 ±1.71 | 5-13 | 8.73  ±1.81 | z=2.240  p=0.033 |
| 2 | **MAS** | 1-3 | 2.27±0.61 | 1-3 | 2.43  ±0.86 | z=2.140, p=0.012 |
| 3. | **RDT(m sec)** | 182-215 | 194.30  ±8.25 | 185-248 | 211.13  ±17.77 | t=2.152,  p=0.031 |
| 4. | **BVCG** | 3-6 | 4.57±0.67 | 2-5 | 3.63±0.65 | z=4.010  p=0.000 |
| The above table shows the comparison of post-test 1 scores, indicating significant difference in between the groups with the FMVT group better than the control group (p<0.005). | | | | | | |

**Table-7: Comparison of Post intervention-2 outcomes of traumatic brain injury patients in between the groups**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **S.No.** | **Outcome Measures** | **Post interventional-2** | | | | **Mann Whitney U test**  **/Unpaired t- test, p-value** |
| **Experimental (n=30)** | | **Control (n=30)** | |
| **Range** | **Mean ± SD** | **Range** | **Mean ± SD** |
| 1 | **FMS** | 6-13 | 10.40  ±1.71 | 6-13 | 8.97  ±1.77 | z=2.656  p=0.009 |
| 2 | **MAS** | 0-3 | 1.67±0.84 | 0-3 | 1.95  ±0.81 | z=3.087,  p=0.002 |
| 3. | **RDT(m sec)** | 178-219 | 185.90  ±9.12 | 183-225 | 203.02  ±13.02 | t=4.847,  p=0.000 |
| 4. | **BVCG** | 4-6 | 5.17±0.69 | 4-5 | 4.43±0.54 | z=3.941  p=0.000 |
| The above table shows the comparison of post-test 2 scores, indicating significant difference in between the groups with the FMVT group better than the control group (p<0.005). | | | | | | |

# DISCUSSION

TBI often lead to slower response times18, hypertonicity, and difficulties with coordination and motor functions16 leading to long-term consequences64. It can also affect cognitive and emotional well-being.65 The study's objective was three-fold, aiming to explore the impact of focal muscle vibration therapy, conventional therapy, and their comparative effects on reaction timing, spasticity, hand function impairment, and voluntary control of upper limb function in TBI patients. The study included 60 participants, divided into two groups of 30 each. The assessment parameters were reaction timing, spasticity, motor hand impairment, and voluntary control, measured using the ruler-drop test (RDT), Modified Ashworth Scale (MAS), Fugl Meyer Scale (FMS), and Brunnstrom Voluntary Grading Scale (BVGS), respectively**.**

In the control group, reaction time improved to 203.02 ± 13.02 ms whereas in the experimental group it was further more improved to 185.90 ± 9.12 ms at post-test 2. Overall, the experimental group significantly outperformed the control group in improving reaction timing. The control group's MAS scores improved to 1.95 ± 0.81 and the experimental group showed even greater improvements, with scores decreasing to 1.67 ± 0.84 at post-test 2. Overall, the experimental group's improvement was significantly greater than that of the control group in decreasing the muscle tone.

The pre- and post-test results for upper limb impairment demonstrated significant differences in mean and SD. Observing the control group, it was seen that FMS scores improved to 8.97 ±1.77. However, In the experimental group, scores were also improved with continued progress noted at post-test 2, reaching 10.40 ± 1.71. A substantial difference was revealed in the comparison between groups, with significantly better outcomes shown by the experimental group.

Both groups experienced improvements in voluntary control on BVCG scale. Control group scores improved to 4.43±0.54 and experimental group, however, progressed and continued to show substantial improvements and reached to 5.17 ± 0.69 at post-test 2. Comparison study was done between the experimental and control groups for both post-test 1 and post-test 2 and revealed that the experimental group consistently outperformed the control group indicated by significant differences favouring the experimental group (p<0.005).The results strongly indicated the effectiveness of FMVT in improving reaction timing, reducing spasticity, and enhancing voluntary motor control and overall impairment in TBI patients.

The findings of this study showed improved reaction times, consistent with the research by **Antonella Macerollo et al. (2018)**, who reported significantly faster mean reaction times of 302.83 ± 52.82 ms following high-frequency peripheral vibration at 80Hz.66 Additionally, the current study found a reduction in spasticity with focal muscle vibration (FMV), aligning with earlier work by **Casale R et al. (2014)** who demonstrated improvements in spastic biceps (P=0.0001) when using 100 Hz vibration

combined with physiotherapy to antagonist muscle.53 This study also indicated significant improvements in hand impairment, supporting **Lian Wang et al. (2023)**, where upper limb function showed good improvement with focal vibration as measured by FMA-UE with the p score of 0.029.31 However, the current study finding is not in favor of **Niyousha Mortaza et al. (2019)** in upper limb functional movement, with a standard mean difference of -0.32 following vibration therapy, highlighting the need for larger study population.67

FMV is known to induce activation of muscle proprioceptors, generate adaptive synaptic changes, and lead to long-term potentiation in the CNS. This is supported by findings that show FMV's ability to generate 1a afferent impulses which alters the cortico spinal pathway influencing the inhibitory interneurons at spinal cord level.24 Furthermore, it has been indicated that this modulation affects proprioceptive reflex circuits**69**.

The significance seen in the conventional therapy group by the application of Constraint-Induced Movement Therapy (CIMT) can be attributed to the plasticity of dendrites in the sensory motor cortex70 has been shown to promote the recovery of motor function by enhancing AMPA receptor-mediated synaptic transmission in the ischemic hemisphere. Additionally, CIMT enhances the plasticity of dendrites and dendritic spines in both the ipsilateral and contralateral sensorimotor cortex**70** .It also promotes neurogenesis and angiogenesis by increasing the expression of factor-1α and vascular endothelial growth factor, ultimately inducing neuroprotection and functional recovery after cerebral ischemia**73**. Additionally, mCIMT effectively reduces the glutamate content in the contralateral hippocampus**74**.CIMT may induce greater changes in the unlesioned hemisphere due to the nonuse of the unaffected arm. Conversely, repetitive training (RT) may induce more pronounced changes in the lesioned hemisphere due to the high number of repetitions performed with the paretic arm**42**.

Sustained stretching aims at promoting muscle relaxation and effective elongation. Stretch force to a muscle-tendon unit leads to change in length, thereby eliciting the stretch reflex. However reciprocal inhibition may also facilitate the stretching process by inhibiting the antagonist muscle and allowing for a deeper stretch to agonist muscle. Additionally, Golgi Tendon Organ (GTO) plays an inhibitory effect, known as autogenic inhibition that enables reflexive muscle relaxation. The traditional explanation of the underlying mechanisms of PNF stretching posits that reflexive relaxation occuring as a result of autogenic or reciprocal inhibition, resulting in decreased resistance of the muscle to stretch stimulus78.

# LIMITATION AND RECOMMENDATION

The study has several limitations that must be acknowledged. Firstly, the findings may not apply to other neurological conditions since the study focused exclusively on individuals with traumatic brain injuries. Long term follow-ups were not done which limits our understanding on the durability of intervention effects beyond the immediate post-intervention period. Furthermore, variations in how well participants adhered to the M-CIMT intervention protocols, such as home exercises, could have influenced the overall study findings. Despite the favourable results observed in TBI patients, implementing long-term follow-ups to assess intervention durability, developing strategies to enhance participant adherence, and exploring applicability to broader neurological patient populations through further research is recommended

# CONCLUSION

The study findings revealed significant improvements in all outcome measures within the experimental group (FMV therapy). The control group (conventional therapy) also showed improvements, though less pronounced. When comparing the two groups, FMV therapy demonstrated superior efficacy across all measured outcomes. The results suggested that FMV therapy is highly effective over the conventional therapy in enhancing reaction timing, reducing the spasticity, improving hand function, and increasing voluntary control, thus enhancing quality of life for individuals with TBI.

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# CONFLICT OF INTEREST

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