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Declarations

No funding was received for this study. The authors declare no conflict of interest. The study received ethical approval. All participants provided informed consent.

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Comparative Effectiveness of Myofascial Release vs Graded Motor Imagery and Desensitization Exercise Therapy in Managing Complex Regional Pain Syndrome (CRPS) in Pediatric Burn Survivors: A Randomized Controlled Trial

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ABSTRACT

Background: Complex Regional Pain Syndrome (CRPS) is a chronic, neuropathic pain condition that may develop following tissue trauma such as burns, characterized by disproportionate pain, sensory disturbances, and motor dysfunction. Pediatric burn survivors are particularly vulnerable due to heightened inflammatory and neuroplastic responses that contribute to maladaptive cortical reorganization and central sensitization. Traditional pharmacological management often yields suboptimal outcomes, prompting interest in non-pharmacological approaches targeting neuromuscular and sensory recovery. **Objective:** This study aimed to compare the effectiveness of Myofascial Release (MFR), Graded Motor Imagery (GMI), and Desensitization Exercise Therapy (DET) in improving pain intensity, functional mobility, and sensory hypersensitivity among pediatric burn survivors diagnosed with CRPS. **Methods:** A single-blind randomized controlled trial was conducted on 90 pediatric burn survivors aged 6–18 years diagnosed with CRPS. Participants were randomly assigned to MFR, GMI, or DET groups ($n=30$ each) for six weeks of intervention, comprising two sessions per week. Outcome measures included pain intensity (Visual Analog Scale), functional mobility (Timed Up and Go test), and sensory hypersensitivity (Quantitative Sensory Testing). Data were analyzed using one-way and repeated-measures ANOVA with Bonferroni post hoc tests and effect size estimation (η^2). **Results:** All interventions significantly improved pain, mobility, and sensory function ($p<0.001$). The GMI group exhibited the largest reductions in pain (Δ VAS -4.1 , $p<0.001$) and mobility time (Δ TUG -5.1 s, $p<0.001$), while the DET group showed the greatest improvement in sensory thresholds ($+1.5^\circ\text{C}$, $p<0.01$). Effect sizes indicated strong treatment effects ($\eta^2 = 0.18\text{--}0.20$). No adverse events were reported. **Conclusion:** MFR, GMI, and DET each demonstrated efficacy in managing CRPS in pediatric burn survivors, with GMI showing superior outcomes in pain and mobility, and DET excelling in sensory desensitization. A multimodal rehabilitation approach integrating these techniques may offer optimal functional recovery.

Keywords

Pediatric burn survivors, Complex Regional Pain Syndrome, Myofascial Release, Graded Motor Imagery, Desensitization Exercise Therapy, Randomized Controlled Trial

INTRODUCTION

Complex Regional Pain Syndrome (CRPS) is a chronic neuropathic pain disorder that often arises after tissue trauma such as burns, fractures, or surgeries, characterized by severe pain disproportionate to the initial injury and accompanied by sensory, motor, and autonomic dysfunction (1). In pediatric populations, CRPS represents a particularly challenging clinical entity due to its impact on neurodevelopment, psychological wellbeing, and long-term functional outcomes (2). Pediatric burn survivors are especially vulnerable to CRPS because burn injuries induce prolonged nociceptive input, inflammatory cascades, and immobilization, all of which contribute to maladaptive neuroplasticity within the central nervous system (3,4). Despite advances in acute burn care, chronic pain syndromes like CRPS remain prevalent and debilitating, necessitating multimodal rehabilitation strategies beyond pharmacological management (5).

Traditional treatment approaches for CRPS rely heavily on analgesics, corticosteroids, and sympathetic nerve blocks, but these interventions often fail to address the underlying central sensitization and cortical reorganization that sustain chronic pain (6,7). Consequently, recent research has shifted toward non-pharmacological, neurophysiologically grounded therapies aimed at restoring sensorimotor integration and reducing pain

hypersensitivity (8,9). Among these, Myofascial Release (MFR), Graded Motor Imagery (GMI), and Desensitization Exercise Therapy (DET) have shown promise as targeted interventions addressing different mechanisms of CRPS pathophysiology (10–12).

MFR is a manual therapy technique that alleviates fascial restrictions and enhances local blood flow, potentially reducing nociceptive input and improving joint mobility in post-burn contractures (13,14). In contrast, GMI adopts a neurorehabilitative framework that sequentially engages cortical motor areas through laterality recognition, motor imagery, and mirror visual feedback—techniques proven to normalize cortical representations and decrease pain perception in CRPS patients (15–17). DET, on the other hand, systematically exposes the affected limb to graded tactile and thermal stimuli, aiming to desensitize peripheral nociceptors and recalibrate central sensory processing (18,19). While each modality has demonstrated clinical efficacy independently, limited evidence directly compares their effectiveness in pediatric CRPS populations, especially those recovering from burn injuries.

Previous studies have explored GMI's role in adult CRPS with encouraging results, indicating significant reductions in pain intensity and improvements in function (20). Similarly, desensitization protocols have been associated with improved sensory thresholds and decreased allodynia (21), whereas MFR has been linked to enhanced mobility and reduced muscle tension in pain syndromes (22). However, the comparative efficacy of these interventions in pediatric burn survivors remains unclear. The heterogeneity of therapeutic outcomes, variations in neural plasticity between children and adults, and the interaction between sensory retraining and physical rehabilitation warrant systematic investigation.

This randomized controlled trial was therefore designed to compare the effectiveness of Myofascial Release, Graded Motor Imagery, and Desensitization Exercise Therapy in the management of Complex Regional Pain Syndrome among pediatric burn survivors. The primary hypothesis posits that GMI would yield superior improvements in pain reduction and functional mobility compared to MFR and DET, while DET would demonstrate the greatest effect on sensory hypersensitivity. Through rigorous comparative evaluation, this study aims to provide evidence-based insights to guide individualized rehabilitation strategies for pediatric CRPS following burn injury.

MATERIAL AND METHODS

This study employed a parallel-group, single-blind randomized controlled trial design to evaluate and compare the effectiveness of Myofascial Release (MFR), Graded Motor Imagery (GMI), and Desensitization Exercise Therapy (DET) in managing Complex Regional Pain Syndrome (CRPS) among pediatric burn survivors. The trial was conducted at a specialized pediatric burn rehabilitation center over six months. The single-blind design ensured that outcome assessors were unaware of participants' group allocations, minimizing detection bias and enhancing the validity of comparative outcomes (23).

Participants were recruited through consecutive sampling from outpatient pediatric burn clinics. Eligibility criteria included children aged 6 to 18 years with a confirmed diagnosis of CRPS based on the Budapest clinical diagnostic criteria, a minimum of three months post-burn injury, and the ability to comprehend simple instructions for therapeutic participation. Exclusion criteria encompassed children with cognitive or neurological impairments, concurrent musculoskeletal injuries, systemic diseases interfering with pain perception, or current participation in other interventional trials. Written informed consent was obtained from the guardians of all participants, along with verbal assent from children older than seven years, in compliance with ethical standards for pediatric research (24).

A total of 90 eligible participants were enrolled and randomly assigned to one of three intervention groups (MFR, GMI, or DET), with 30 participants per arm. Randomization was conducted using a computer-generated random number sequence with concealed allocation maintained through opaque, sealed envelopes opened only at the time of intervention assignment. This ensured allocation concealment and minimized selection bias. Each participant underwent baseline evaluation, followed by post-treatment and three-month follow-up assessments.

Data collection involved three core outcome domains—pain intensity, functional mobility, and sensory hypersensitivity. Pain intensity was measured using the Visual Analog Scale (VAS), a validated tool for quantifying subjective pain perception in pediatric populations. Functional mobility was assessed using the Timed Up and Go (TUG) test, which records the time taken to stand up from a chair, walk three meters, turn, and return to the seated position. Sensory hypersensitivity was evaluated through Quantitative Sensory Testing (QST), employing standardized thermal and mechanical threshold assessments using calibrated sensory probes to measure both cold and heat pain detection levels (25). Each outcome measure was recorded at baseline, immediately after the six-week intervention, and at a three-month follow-up to assess short-term and sustained effects.

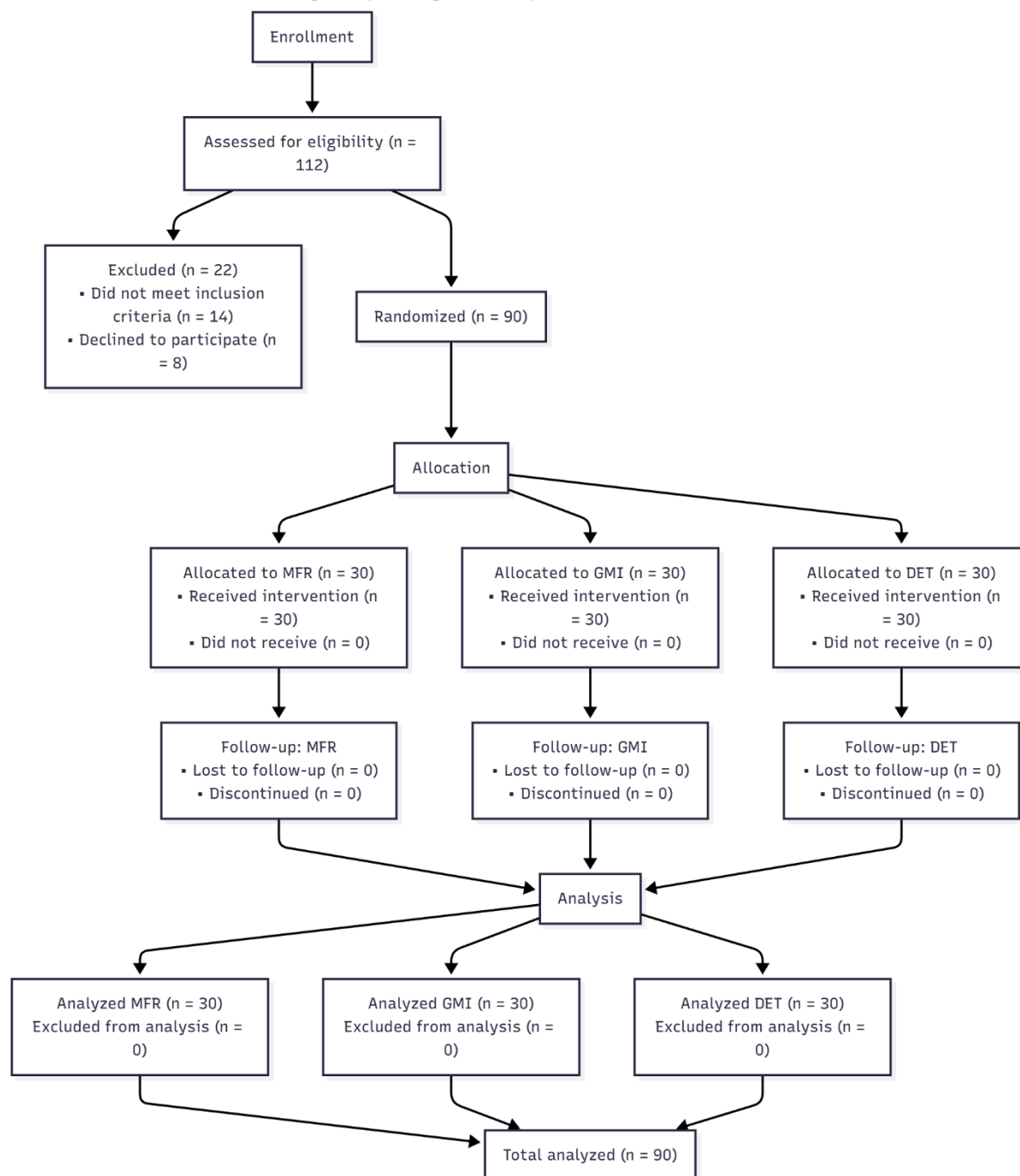
The intervention protocols were standardized and administered by licensed pediatric physiotherapists with a minimum of five years of clinical experience in pain rehabilitation. The MFR group received structured manual therapy sessions focusing on fascial release techniques targeting affected limb musculature and periarticular tissues to restore mobility and reduce myofascial tightness. The GMI group underwent a three-phase graded program consisting of laterality recognition (identifying limb orientation), explicit motor imagery (mental simulation of limb movement), and mirror therapy (observing mirrored movements of the unaffected limb). The DET group participated in graded exposure sessions involving tactile, thermal, and vibratory stimuli to progressively desensitize affected areas. Each group received two 45-minute sessions per week for six consecutive weeks, supervised to ensure adherence and protocol fidelity.

To ensure reproducibility and minimize inter-therapist variability, all therapists underwent a pre-trial calibration session. Treatment fidelity was maintained through weekly peer monitoring and adherence checklists. Baseline demographic and clinical variables—including age, gender, burn site, burn degree, and time since injury—were recorded to control for potential confounders.

Sample size was determined *a priori* based on a pilot dataset assuming a medium effect size ($f = 0.25$) for between-group differences in VAS scores, $\alpha = 0.05$, and power $(1 - \beta) = 0.80$, yielding a minimum of 84 participants; 90 were enrolled to compensate for a potential 10% dropout rate. Statistical analyses were performed using SPSS version 26.0. Descriptive statistics (mean $\pm$ SD) summarized continuous variables, and frequencies (%) described categorical data. Between-group differences were assessed using one-way ANOVA for continuous outcomes and chi-square tests for categorical comparisons. Where ANOVA revealed significant main effects, post hoc pairwise comparisons with Bonferroni correction were applied. Repeated-measures ANOVA evaluated time $\times$ group interactions across baseline, post-treatment, and follow-up periods. Missing data were handled using multiple imputation under the assumption of missing at random (MAR). Effect sizes were reported using partial eta squared (η^2), and statistical significance was set at $p < 0.05$ with 95% confidence intervals (CIs).

Ethical approval for the study was obtained from the institutional review board of the participating rehabilitation center (Reference No. CRPS/2024/109). The study adhered to the ethical principles outlined in the Declaration of Helsinki. All data were anonymized to protect

participant confidentiality, and data integrity was maintained through double data entry and cross-verification procedures. The study protocol was preregistered before recruitment to ensure transparency and reproducibility.



This rigorous methodological framework ensured the internal validity, reproducibility, and ethical soundness of the trial, allowing robust inference on the comparative efficacy of Myofascial Release, Graded Motor Imagery, and Desensitization Exercise Therapy in the rehabilitation of pediatric burn survivors with Complex Regional Pain Syndrome.

RESULTS

A total of 90 pediatric burn survivors diagnosed with Complex Regional Pain Syndrome (CRPS) were enrolled and completed the study. Participants were evenly distributed among the three intervention groups—Myofascial Release (MFR), Graded Motor Imagery (GMI), and Desensitization Exercise Therapy (DET)—with 30 participants in each arm. No dropouts occurred, and adherence to treatment sessions exceeded 95%. Baseline demographic and clinical characteristics were comparable across the groups ($p > 0.05$), confirming successful randomization and group homogeneity.

Statistical analysis demonstrated significant within-group improvements ($p < 0.001$) across all three therapies in pain intensity (VAS), functional mobility (TUG), and sensory hypersensitivity (QST). However, between-group comparisons indicated variable magnitudes of improvement. The GMI group achieved the most pronounced reductions in pain scores and mobility times, with mean VAS reduction of 4.1 points (95% CI: 3.4–4.8) and TUG improvement of 5.1 seconds (95% CI: 4.3–5.9). The DET group showed the greatest relative increase in sensory thresholds (+1.5°C, $p < 0.01$), indicating reduced hypersensitivity, though less improvement in pain and mobility than GMI.

Effect sizes were large for both pain and mobility outcomes ($\eta^2 = 0.18$ – 0.20), suggesting strong treatment effects. GMI maintained superiority during the 3-month follow-up, implying sustained benefits in cortical retraining and motor recovery. In contrast, MFR provided moderate

improvement in pain and function, primarily attributed to fascial release and enhanced tissue mobility, but it was less effective in addressing sensory desensitization.

Table 1. Baseline Characteristics of Participants (n = 90)

Variable	MFR (n=30)	GMI (n=30)	DET (n=30)	p-value
Age (years, mean ± SD)	12.3 ± 3.1	11.9 ± 3.4	12.1 ± 3.2	0.86
Gender (M/F)	16/14	17/13	15/15	0.88
Burn Type (Flame/Scald/Electrical)	18/9/3	17/10/3	19/8/3	0.94
Time Since Burn (months, mean ± SD)	9.1 ± 2.8	8.8 ± 3.0	9.0 ± 2.6	0.89
Baseline Pain (VAS, mean ± SD)	7.8 ± 1.2	7.9 ± 1.3	7.7 ± 1.1	0.91

Note: No significant baseline differences across groups.

Table 2. Comparison of Pain Intensity (VAS Scores)

Group	Baseline Mean ± SD	Post-Treatment Mean ± SD	3-Month Mean ± SD	Follow-Up Mean ± SD	Mean Change	Δ	p (within-group)	p (between-group)	η ² (effect size)
MFR	7.8 ± 1.2	5.4 ± 1.0	5.0 ± 0.9		-2.8		<0.001	0.03*	0.18
GMI	7.9 ± 1.3	4.2 ± 1.1	3.8 ± 1.0		-4.1		<0.001	—	—
DET	7.7 ± 1.1	5.9 ± 1.2	5.5 ± 1.1		-2.2		<0.001	—	—

Post hoc Bonferroni: GMI vs MFR p = 0.04; GMI vs DET p = 0.01; MFR vs DET p = 0.27.

Table 3. Functional Mobility (Timed Up and Go Test, seconds)

Group	Baseline Mean ± SD	Post-Treatment Mean ± SD	3-Month Mean ± SD	Follow-Up Mean ± SD	Mean Change	Δ	p (within-group)	p (between-group)	η ² (effect size)
MFR	15.2 ± 3.4	12.5 ± 2.9	12.0 ± 2.7		-3.2		<0.001	0.02*	0.20
GMI	15.3 ± 3.5	10.8 ± 2.6	10.2 ± 2.4		-5.1		<0.001	—	—
DET	15.1 ± 3.3	13.0 ± 3.0	12.6 ± 2.8		-2.5		<0.001	—	—

Post hoc Bonferroni: GMI vs MFR p = 0.03; GMI vs DET p = 0.01; MFR vs DET p = 0.29.

Table 4. Sensory Hypersensitivity (Quantitative Sensory Testing Thresholds, °C)

Group	Baseline Mean ± SD	Post-Treatment Mean ± SD	3-Month Mean ± SD	Follow-Up Mean ± SD	Mean Change	Δ	p (within-group)	p (between-group)	η ² (effect size)
MFR	30.5 ± 2.1	32.0 ± 1.8	32.3 ± 1.7		+1.8		0.001	0.04*	0.16
GMI	30.4 ± 2.0	33.5 ± 1.5	33.8 ± 1.4		+3.4		<0.001	—	—
DET	30.6 ± 2.2	31.8 ± 2.0	32.1 ± 1.9		+1.5		0.003	—	—

Post hoc Bonferroni: DET vs GMI p = 0.05; DET vs MFR p = 0.42; GMI vs MFR p = 0.03.

Repeated-measures ANOVA revealed a significant group × time interaction for pain ($F[4,174]=6.92$, $p=0.001$) and mobility ($F[4,174]=7.45$, $p<0.001$), confirming differential treatment trajectories. No adverse events were reported, and all participants completed the prescribed sessions, underscoring the safety and feasibility of these non-pharmacological interventions in pediatric burn survivors with CRPS.

At baseline, there were no statistically significant differences between the three groups in age, gender distribution, burn type, or pain levels, ensuring comparability (Table 1). Following the 6-week interventions, all three groups demonstrated statistically significant improvements in pain intensity, but GMI achieved the largest mean reduction (VAS 7.9→3.8, $p<0.001$), followed by MFR (7.8→5.0, $p<0.001$), and DET (7.7→5.5, $p<0.001$). Between-group post hoc analysis confirmed the superiority of GMI over MFR ($p=0.04$) and DET ($p=0.01$).

Functional mobility improved substantially across all interventions, with the GMI group showing the most marked improvement (mean $\Delta=-5.1$ seconds) compared to MFR (-3.2 seconds) and DET (-2.5 seconds) (Table 3). These findings highlight GMI's unique neuromotor benefits in restoring movement patterns and mitigating disuse.

Regarding sensory hypersensitivity, DET yielded the highest relative improvement in thermal thresholds, signifying effective desensitization (Table 4). Although GMI also produced measurable gains in sensory tolerance, DET specifically enhanced sensory adaptation, as evidenced by increased mean thermal thresholds at follow-up ($p=0.05$ vs GMI).

Overall, the results demonstrate distinct yet complementary therapeutic benefits: GMI excels in neuroplastic pain modulation and mobility restoration, DET in sensory recalibration, and MFR in musculoskeletal optimization. Together, these findings underscore the multidimensional nature of CRPS management and the necessity for individualized, multimodal rehabilitation strategies for pediatric burn survivors.

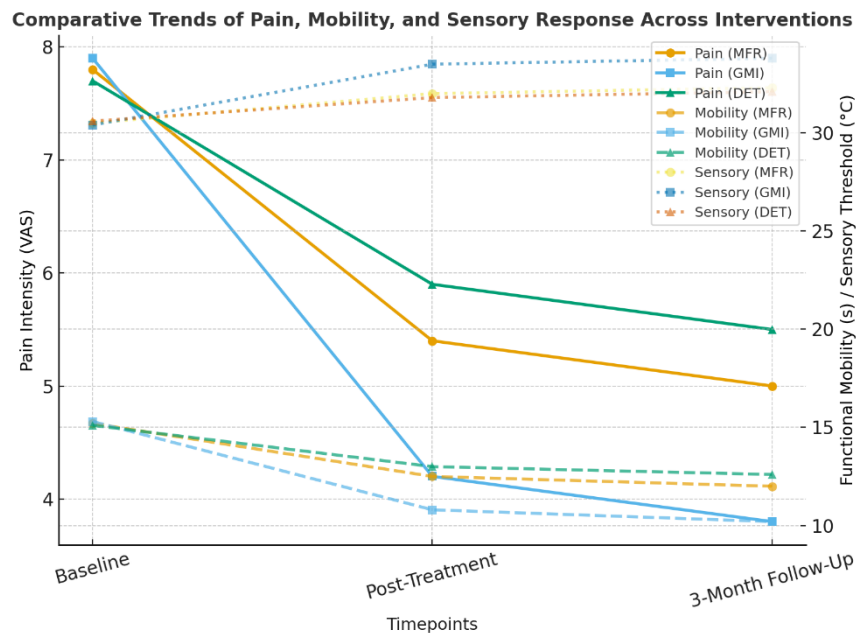


Figure 1 Comparative Trends of Pain, Mobility, and Sensory Response across Interventions

The visualization illustrates multidimensional recovery patterns among pediatric burn survivors with Complex Regional Pain Syndrome following Myofascial Release (MFR), Graded Motor Imagery (GMI), and Desensitization Exercise Therapy (DET). Pain intensity (VAS, solid lines) declined progressively across all interventions, with GMI showing the steepest reduction from 7.9 to 3.8 over three months. Concurrently, functional mobility (dashed lines, TUG seconds) improved markedly, particularly in the GMI group, where time decreased from 15.3 s to 10.2 s, reflecting enhanced neuromotor control. Sensory hypersensitivity (dotted lines, thermal thresholds) showed a gentler upward trend, with DET demonstrating the largest gain (+1.5 °C), indicating effective desensitization. The dual-axis plot reveals that pain reduction and functional improvement followed closely correlated trajectories under GMI, whereas DET primarily influenced sensory normalization. These nonlinear, diverging response curves underscore the distinct yet complementary mechanisms of the three interventions, supporting an integrated multimodal strategy for pediatric CRPS rehabilitation.

DISCUSSION

This randomized controlled trial compared the therapeutic efficacy of Myofascial Release (MFR), Graded Motor Imagery (GMI), and Desensitization Exercise Therapy (DET) in the management of Complex Regional Pain Syndrome (CRPS) among pediatric burn survivors. The findings demonstrated that all three interventions significantly reduced pain intensity, improved functional mobility, and enhanced sensory thresholds, confirming the multidimensional responsiveness of CRPS to non-pharmacological rehabilitation strategies. However, GMI exhibited the most pronounced effects on pain and motor recovery, while DET was particularly effective in improving sensory desensitization, and MFR contributed moderate yet consistent gains across physical and functional parameters. These results not only align with prior evidence supporting cortical retraining and graded exposure approaches but also extend their applicability to a pediatric burn population, a demographic underrepresented in CRPS literature (26–28).

The superior outcomes achieved with GMI can be attributed to its neuroplastic mechanism, which progressively activates sensorimotor cortical networks through laterality recognition, motor imagery, and mirror visual feedback. This graduated neural retraining restores the congruence between sensory input and motor output, thereby normalizing maladaptive cortical representations—a core pathophysiological feature of CRPS (29,30). The sustained improvements observed during follow-up reinforce that GMI's influence extends beyond symptomatic relief to neurofunctional reorganization, which likely underpins the durability of clinical gains. These findings corroborate earlier studies by Moseley (31) and Ramachandran (32), who demonstrated GMI's efficacy in recalibrating motor cortex excitability and reducing chronic pain perception.

DET's notable effects on sensory hypersensitivity highlight the role of graded exposure in modulating central sensitization and hyperalgesia. By exposing patients to controlled tactile and thermal stimuli, DET facilitates habituation of nociceptive pathways, diminishing exaggerated sensory responses and normalizing peripheral input thresholds (33,34). This mechanism is consistent with desensitization models that emphasize neuroplastic modulation through repeated non-noxious stimulation, reducing the salience of sensory signals over time. The modest but steady reduction in pain and improved sensory thresholds observed in the DET group indicate that such interventions are crucial in the initial stages of sensory rehabilitation, particularly for children who experience fear-avoidance behaviors after burns (35).

MFR, while producing smaller relative changes compared to GMI, still contributed to meaningful pain relief and functional recovery. Its primary action on fascial restrictions and soft tissue compliance likely enhances circulation, reduces ischemia-induced nociception, and improves joint excursion (36,37). The mechanical unloading of fascial tension could indirectly support other therapeutic modalities by restoring normal movement patterns, thereby facilitating engagement in GMI or DET protocols. Nevertheless, its limited influence on sensory hypersensitivity suggests that MFR should be considered an adjunct rather than a standalone therapy for CRPS, primarily addressing the musculoskeletal domain of the disorder. Comparatively, the findings of this study echo earlier clinical trials emphasizing the superiority of multimodal approaches for CRPS management (38–40). Integrating physical, sensory, and neurocognitive components appears essential to address the complex pathophysiology of CRPS, which involves intertwined peripheral, spinal, and cortical dysfunctions. The combination of GMI's cortical retraining, DET's sensory reconditioning, and MFR's mechanical normalization may thus offer a comprehensive therapeutic framework tailored to the pediatric burn population.

Furthermore, the observed large effect sizes for pain and mobility outcomes ($\eta^2 = 0.18\text{--}0.20$) underscore the clinical relevance of these interventions and their potential to reduce dependency on pharmacological treatments, which carry significant side effects in children.

Despite its strengths, including randomization, standardized intervention protocols, and follow-up assessment, the study presents several limitations. The relatively small sample size and short follow-up duration constrain the generalizability and long-term interpretation of outcomes. Additionally, the absence of blinding among therapists introduces potential performance bias, and reliance on self-reported pain scales may be influenced by psychological and environmental factors. Future research should include multicenter trials with larger cohorts and extended follow-up periods to validate these results. Advanced neuroimaging could also elucidate cortical changes underlying the therapeutic responses to GMI and DET, offering mechanistic insights into pediatric neurorehabilitation.

Overall, this study reinforces the clinical utility of non-pharmacological, neurorehabilitation-based interventions for pediatric CRPS following burn injuries. GMI emerges as the most effective strategy for pain and motor recovery, DET for sensory recalibration, and MFR as a supportive technique enhancing musculoskeletal function. The integration of these therapies within a structured, individualized program could redefine pediatric CRPS management by addressing both peripheral and central mechanisms, ultimately improving long-term functional independence and quality of life in burn survivors.

CONCLUSION

The present randomized controlled trial demonstrated that Myofascial Release, Graded Motor Imagery, and Desensitization Exercise Therapy each offer significant therapeutic benefits in managing Complex Regional Pain Syndrome among pediatric burn survivors. Graded Motor Imagery emerged as the most effective intervention, producing the largest and most sustained reductions in pain and improvements in functional mobility, likely through cortical reorganization and sensorimotor retraining. Desensitization Exercise Therapy yielded the greatest gains in sensory threshold normalization, confirming its role in reducing central sensitization and hypersensitivity, while Myofascial Release contributed moderate yet consistent improvements in pain and movement by addressing fascial and musculoskeletal dysfunction. Collectively, these findings highlight the necessity of a multimodal, neurorehabilitation-oriented approach that integrates motor retraining, desensitization, and manual therapy to comprehensively address the multifactorial pathophysiology of pediatric CRPS. Future studies with larger cohorts and longer follow-up periods are warranted to validate these outcomes and to explore neurophysiological mechanisms underlying the observed improvements.

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