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The Effect of Sensory-Motor Training on Foot Weight Distribution in Patients with Foot Burns

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A B S T R A C T

Background: Foot burns, although covering a relatively small percentage of the body surface area, can lead to significant functional impairments, including altered weight-bearing, balance deficits, and mobility challenges.

Purpose of the study: The study was carried out to evaluate the effect of sensory-motor training on foot weight distribution in patients with foot burns.

Methods: A total of 70 patients with foot burns were randomly assigned to two groups. Group A (n=35) received sensorimotor training in addition to traditional physical therapy, while Group B (n=35) received only traditional physical therapy. Foot weight distribution was assessed using the Pedoscan system before and after a 12-week intervention.

Results: Group A demonstrated significantly better improvements in foot weight distribution compared to Group B. Pedoscan measures showed a more even balance between the affected and unaffected feet in Group A after the intervention ($p < 0.05$). Group B, which received only traditional physical therapy, also showed improvements, but these changes were not statistically significant ($p > 0.05$).

Conclusion: Sensorimotor training, when combined with traditional physical therapy, is highly effective in improving foot weight distribution in patients with foot burns. This study suggests that sensorimotor training should be incorporated into rehabilitation protocols to optimize recovery and enhance functional outcomes in this population

Keywords: Burn; foot burns; foot weight distribution; sensory-motor training

1. Introduction

Burn injuries represent a significant global public health issue, leading to approximately 180,000 deaths annually, with most of these fatalities occurring in low- and middle-income countries. While advancements in burn care have significantly improved survival rates, non-fatal burns continue to cause profound physical, emotional, and social consequences for survivors. Specifically, foot burns, despite covering a relatively small percentage of the total body surface area, can result in long-term functional impairments (1). These impairments include altered foot weight distribution, balance deficits, and reduced mobility, all of which can severely impact a patient's quality of life. The unique challenges posed by foot burns stem from the critical role that the feet play in maintaining balance, posture, and mobility. When these functions are disrupted, patients may face prolonged rehabilitation and a diminished ability to perform daily activities (2).

In response to the pain, scarring, and proprioceptive deficits that accompany foot burns, patients often develop adaptive gait strategies. For example, they may reduce step length or slow down their gait speed to protect the affected area. While these compensations may be beneficial in the short term and help to alleviate discomfort, they can also contribute to long-term biomechanical problems if left uncorrected. Over time, these adaptive strategies can exacerbate functional impairments, leading to chronic issues such as altered gait patterns, joint strain, and muscle imbalances (3).

Traditional rehabilitation programs for foot burns typically focus on restoring range of motion (ROM), muscle strength, and functional mobility. However, such programs may not fully address the underlying proprioceptive deficits caused by the injury. These proprioceptive deficits are particularly important to target in rehabilitation because they play a critical role in maintaining balance and ensuring proper weight distribution across both feet (4).

Sensorimotor training has emerged as a promising intervention for addressing these proprioceptive deficits by improving the interaction between sensory inputs and motor responses. Unlike traditional physical therapy, sensorimotor training incorporates exercises designed to enhance proprioception, balance, and coordination. These exercises challenge the body's postural control systems and help patients regain more natural movement patterns (5). Through sensorimotor training, patients can improve weight-bearing symmetry, which is essential for restoring functional mobility and preventing long-term complications (6).

To the best of the authors' knowledge, no research has specifically evaluated the effectiveness of sensorimotor training on foot weight distribution in patients with foot burns. The existing evidence regarding their impact on improving balanced weight-bearing remains limited, emphasizing the need for further investigation. Considering the critical role of balanced weight distribution in post-burn recovery, it was hypothesized that a targeted intervention involving sensorimotor training would significantly enhance symmetrical weight-bearing patterns and reduce compensatory asymmetries in individuals with severe burns. Therefore, this study aimed to determine the effects of sensorimotor training on foot weight distribution in this population.

2. Methods

2.1 Study Design

The study was a two-armed, single-blind (assessor), parallel-group, randomized control trial. Randomization was performed using a computer-generated sequence to avoid selection bias, and allocation to the two treatment groups was concealed using sealed, opaque envelopes. The participants were divided into two groups sequentially: Group A (received sensorimotor training in addition to traditional physical therapy and Group B (received only traditional physical therapy. A blinded assessor, not involved in randomization nor treatment delivery, conducted baseline and post-intervention assessments, ensuring that outcome measurements were not influenced by treatment assignment. Following the 1st week of the randomization procedure, start of treatment dates might be set. And to ensure methodological rigor, the trial adhered to the CONSORT guidelines for randomized controlled trials, and all staff involved were trained in the assessment and intervention protocols.

2.2 Ethical approval and patient consent

The Institutional Ethical Committee (Approval Code: [P.T.REC/012/005257]) ensured that ethical standards were upheld, including patient safety and informed consent and was retrospectively registered in the Clinical Trial Registry (Registration Number: [NCT06632223]). ensuring that ethical standards were upheld, including patient safety and informed consent. All participants provided written informed consent before enrollment to confirm their understanding of the study's procedures, risks, and benefits.

2.3 Participants

Participants were recruited from the outpatient clinics of the Faculty of Physical Therapy, where they were screened based on specific inclusion and exclusion criteria. Eligible participants were from both genders (male and female), aged between 20 and 50 years, with completely healed second-degree foot burns (partial-thickness thermal injury), and had burns of affecting between 10% and 20% of Total Body Surface Area (TBSA) surface area. Additionally, participants had to be able to walk independently, with or without assistive devices, to ensure that they could engage fully in the rehabilitation exercises. The exclusion criteria aimed to eliminate confounding factors that could affect balance, proprioception, or the ability to participate in the intervention. Patients were excluded if they had other lower extremity injuries or deformities that might interfere with weight-bearing capacity, neurological conditions (such as stroke or multiple sclerosis) that impair proprioception or balance, or chronic diseases such as diabetes mellitus, which could influence wound healing or rehabilitation outcomes. Additionally, patients with severe cardiovascular or respiratory conditions that could limit their participation in physical activity were also excluded. Patients who refused to participate in the study nor sign a written consent form were also excluded. A total of 85 patients were initially screened for eligibility, and after applying the inclusion and exclusion criteria, 70 patients were deemed eligible and enrolled in the study. These participants were randomly assigned to one of the two groups using a computer-generated randomization sequence, with 35 participants in each group. The study was conducted between July 2024 and October 2024 at The Faculty of Physical Therapy, Giza, Egypt.

2.4 Interventions

Sensorimotor training

Participants in Group A (the study group) attended three sessions per week of sensorimotor training for 12 weeks, amounting to a total of 36 sessions. Each session lasted approximately 60 minutes. The exercises included balance training on wobble boards and balance discs, which required patients to shift their weight between their feet, promoting even weight distribution and improving proprioceptive feedback from the affected foot. Foam pads were used to further challenge balance and postural control, while stability balls were incorporated into dynamic exercises to enhance coordination and core stability. Each exercise was progressively adjusted in difficulty as the patients improved, ensuring that the intervention remained appropriately challenging throughout the 12-week period (7)

Traditional physical therapy

Both participants in Group A and B received the same traditional physical therapy which focused on restoring functional mobility and preventing complications such as contractures. The program included ROM exercises to maintain or improve the flexibility of the joints in the foot and ankle, which is crucial for effective gait and movement. Muscle strengthening exercises targeted the major muscle groups in the lower extremities, such as the calf muscles, quadriceps, and hamstrings, to support functional movement and prevent muscle atrophy. Stretching exercises were used to prevent contractures, particularly in areas affected by scar tissue, while gait training helped patients practice proper walking form to improve walking speed and minimize compensatory gait patterns. Each session in the traditional physical therapy program also lasted 60 minutes, with participants attending three sessions per week for 12 weeks (8).

2.5 Outcome Measures

The outcome measure of the study was foot weight distribution, which was assessed using the Pedoscan system. The Pedoscan system is a computerized pressure mapping tool that provides quantitative data on foot pressure distribution during both static (standing) and dynamic (walking) tasks. It calculates the percentage of body weight borne by each foot, allowing for the identification of asymmetries in weight distribution between the affected and unaffected feet. This system provides precise and reliable data, making it an ideal tool for objectively measuring changes in weight-bearing patterns (9). Measurements were taken at two times: baseline (before the intervention) and post-intervention (after the 12-week treatment period). At baseline, foot weight distribution was measured to establish the initial level of weight-bearing asymmetry in both groups. After the 12-week intervention, follow-up measurements were obtained to assess changes in foot weight distribution.

2.6 Sample size and statistical analysis

The calculation for sample size was based on the difference in means of COP sway range in degrees (10), with the intervention group having a mean of 17.42 and a standard deviation of 1.85, and the control group having a mean of 15.58 and a standard deviation of 3.11. Using a type 1 error (α) of 0.05 and a power (1-β) of 0.80, the sample size for each group will be 32. Accounting for potential dropouts, 35 participants will be allocated to each group, resulting in a total sample size of 70.

Data were analyzed using SPSS software (version 26.0). Descriptive statistics were used to summarize the demographic characteristics of the participants and their baseline Pedoscan measurements. Continuous variables, such as age and baseline foot weight distribution, were reported as means and standard deviations (SD), while categorical variables, such as gender and injury characteristics, were reported as frequencies and percentages.

To evaluate the effectiveness of the interventions, paired t-tests were performed to compare pre- and post-intervention results within each group, allowing for the determination of whether there were significant improvements in foot weight distribution. Independent t-tests were used to compare post-intervention outcomes between the two groups, assessing whether sensorimotor training led to significantly better improvements in foot weight distribution compared to traditional therapy alone. The significance level of $p < 0.05$ was used to determine statistical significance for all comparisons. Additionally, effect sizes were calculated to quantify the magnitude of the intervention's impact on foot weight distribution. The analysis was conducted on an intention-to-treat basis, which included all participants, even those who dropped out during the intervention, to ensure that the results reflected the entire study population and minimized bias due to attrition.

3. Results

Figure 1. represents the patients' flowchart, and Table 1 describes the subjects' demographic and initial Pedoscan measures, so it can be observed that there was no statistically significant difference among the two groups with regards to mean age, BMI, weight, height, percentage of burn covering the body, and gender distribution ($p > 0.05$).

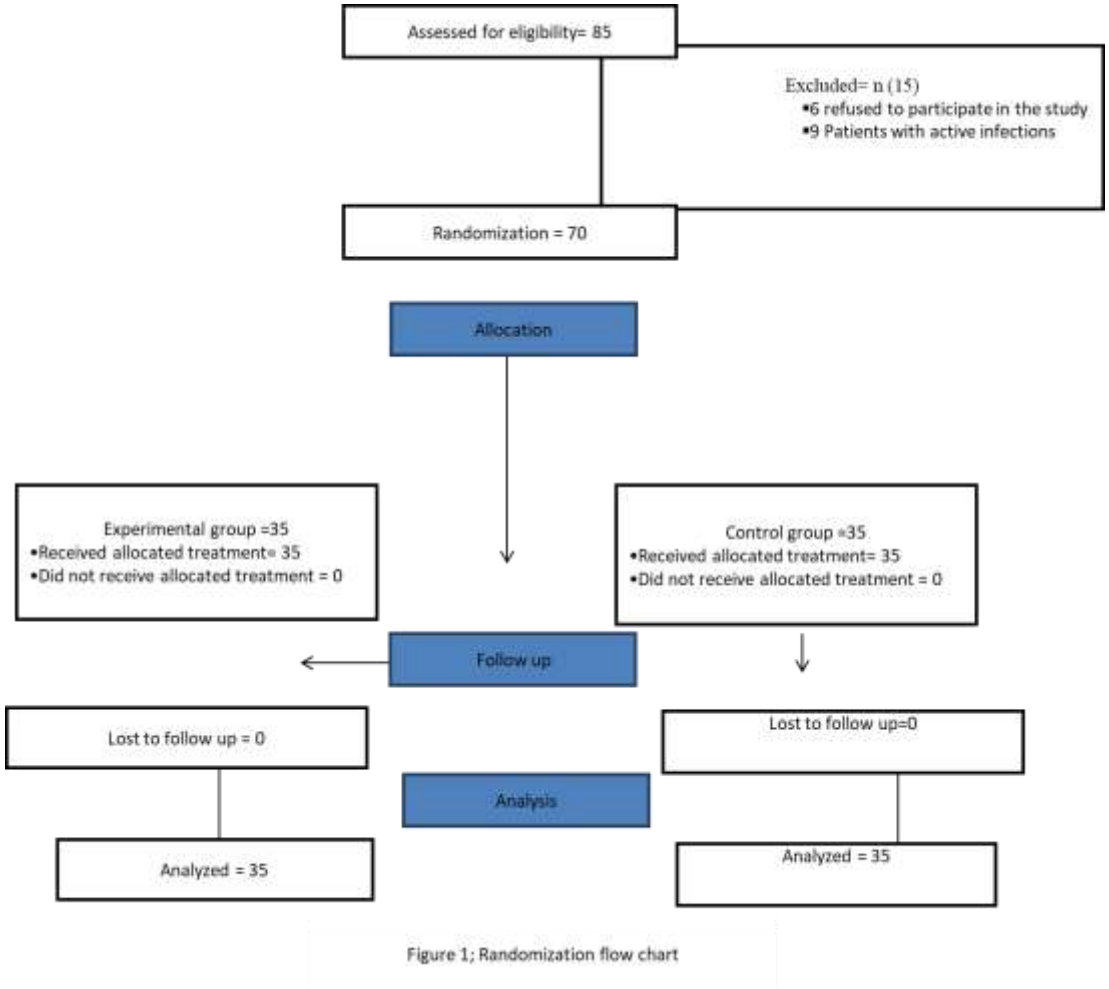

Figure 1; Randomization flow chart

Table 1: Demographic Characteristics

	Group A (n:35) Study		**Group B (n:35) Control**		**p-value**	**t-value**
	$\overline{X}$ **± SD**		$\overline{X}$ **± SD**			
Age (years)	36.31±5.240		38.31±6.337		0.155	-1.439
BMI (kg/m²)	24.9±2.7		25.9±2.7		0.628	-0.487
Height (cm)	172.29±3.618		172.23±3.482		0.947	0.067
Weight (kg)	74.14±3.533		74.29±3.839		0.872	-.162
% Burn	14.63±1.374		15.17±1.248		0.088	-1.730
	Male	**Female**	**Male**	**Female**		
Sex	51.4% (18)	48.6% (17)	51.4% (18)	48.6% (17)	1.000	

Regarding baseline physical characteristics, both groups displayed significant weight-bearing asymmetry as measured by the Pedoscan system. Group A had a baseline weight distribution of 48.314 % on the affected foot, while Group B exhibited a similar distribution of 48.237 % on the affected foot. These baseline values confirmed that both groups had comparable levels of asymmetry and that any subsequent improvements could be attributed to the interventions.

Changes in foot weight distribution after intervention within a group

Following 12 weeks of sensorimotor training combined with traditional physical therapy, Group A exhibited significant improvements in foot weight distribution when compared to their baseline measurements as shown in Table 2. In Group A (n=35), the Static Foot Weight Distribution showed a significant improvement from a pre-intervention value of 42.229 ± 0.1856 to a post-intervention value of 48.314 ± 0.2403 with a p-value of 0.001, indicating a statistically significant decrease. Similarly, the Dynamic Foot Weight Distribution improved from 45.134 ± 0.0482 pre-intervention to 50.226 ± 0.1804 post-intervention, with a p-value of 0.014, also reflecting a statistically significant change.

Table 2: Pre-post intervention differences in group A

	Group A (n:35) Pre-Intervention	**Group A (n:35) Post-intervention**	**P-value**
	$\overline{X}$ **± SD**	$\overline{X}$ **± SD**	
Static Foot Weight Distribution	42.229 ± 0.1856	48.314 ± 0.2403	0.001
Dynamic Foot Weight Distribution	45.134 ± 0.0482	50.226 ± 0.1804	0.014

The improvements in foot weight distribution were consistent across most participants in Group A. Additionally, participants reported subjective improvements in their ability to balance and stand for prolonged periods without discomfort, which was corroborated by dynamic Pedoscan measurements taken during walking tasks. These dynamic assessments showed that Group A participants were better able to distribute weight evenly during gait, with fewer compensatory movements such as limping or favoring the unaffected foot.

Group B, which received only traditional physical therapy, also demonstrated some changes in foot weight distribution, but these changes were minimal and did not reach statistical significance, as shown in Table 3. Pre-intervention, patients in Group B had a Static Foot Weight Distribution of 46.986± 0 .1332, which shifted slightly post-intervention to 47.237 ± 0.2143 (p = 0.348). Similarly, the Dynamic Foot Weight Distribution remained almost unchanged, moving from 46.190 ± 0.0406 pre-intervention to 47.190 ± 0.0406 post-intervention (p = 0.943). Both changes were not statistically significant (p > 0.05).

Table 3: Pre-post intervention differences in group B

	Group B (n:35) Pre-Intervention	**Group B (n:35) Post-intervention**	**P-value**
	$\overline{X}$ **± SD**	$\overline{X}$ **± SD**	
Static Foot Weight Distribution	46.986± 0 .1332	47.237 ± 0.2143	0.348
Dynamic Foot Weight Distribution	46.190 ± 0.0406	47.190 ± 0.0406	0.943

While these changes indicate a slight improvement in weight distribution, the magnitude of the improvement was smaller and less consistent compared to Group A. Moreover, dynamic Pedoscan measurements during walking tasks revealed that many patients in Group B continued to favor their unaffected foot, leading to persistent gait asymmetries. Participants in Group B also reported ongoing discomfort and difficulty maintaining balance during weight-bearing activities such as standing and walking, which may explain the smaller improvements noted in this group.

Between-group comparison

For Static Foot Weight Distribution, Group A recorded a mean ± SD of 48.314 ± 0.2403, while Group B had a significantly lowerr mean ± SD of 47.237 ± 0.2143 (p = 0.02, t = -200.892). Similarly, for Dynamic Foot Weight Distribution, Group A showed a mean ± SD of 50.226 ± 0.1804, compared to Group B's lower mean ± SD of 47.190 ± 0.0406 (p = 0.01, t = -36.233). Both parameters indicate statistically significant differences between the two groups, suggesting a notable variation in foot weight distribution under both static and dynamic conditions.

Table I: Between-Group Comparisons

	Group A (n:35) Study	**Group B (n:35) Control**	**P-value**	**t-value**
	$\bar{X}$ **± SD**	$\bar{X}$ **± SD**		
Static Foot Weight Distribution	48.314 ± 0.2403	47.237 ± 0.2143	0.02	-200.892
Dynamic Foot Weight Distribution	50.226 ± 0.1804	47.190 ± 0.0406	0.01	-36.233

4. Discussion

Patients with foot burns frequently experience proprioceptive deficits, resulting in adaptive gait strategies aimed at improving stability and control. These adaptations include slower walking speed, shorter step length, and increased contralateral foot-off time, which helps shift weight from the injured limb to the unaffected side, aiding balance and reducing pressure. Recognizing these patterns is essential for tailoring rehabilitation interventions to enhance mobility and prevent long-term gait impairments (2).

Traditional rehabilitation for foot burns typically focuses on range of motion, muscle strengthening, and mobility (3). However, this approach may not fully address the proprioceptive deficits and altered foot weight distribution caused by the injury. Sensorimotor training, which emphasizes the interaction between sensory inputs and motor responses, has been proposed as a complementary intervention to improve foot weight distribution and postural stability (11).

In the present study, we assessed the impact of the effect of sensory-motor training on foot weight distribution in patients with foot burns. The results of this study demonstrate that sensorimotor training, when combined with traditional physical therapy, significantly improves foot-weight distribution in patients with foot burns compared to traditional physical therapy alone. Patients in the sensorimotor training group (Group A) showed a marked reduction in weight-bearing asymmetry, achieving a more balanced distribution between the affected and unaffected feet. In contrast, patients receiving only traditional physical therapy (Group B) exhibited smaller improvements that were not statistically significant. These findings support the growing body of evidence that sensorimotor training plays an important role in rehabilitation after burn injuries, particularly in addressing proprioceptive deficits and functional asymmetries.

Several studies have investigated the effects of various rehabilitation interventions on functional outcomes following burn injuries, and the findings of this study align with and expand on those results. For instance, Ahmad et al. (2019) conducted a study evaluating the effects of sensorimotor training on balance and proprioception in patients with lower extremity burns and reported significant improvements in balance and weight-bearing symmetry after sensorimotor training. Their study specifically highlighted the importance of challenging postural control systems using unstable surfaces, which is consistent with the balance board and foam pad exercises used in our intervention and underscores the value of incorporating exercises that target sensory-motor integration to restore functional mobility (6).

Baker et al. (2015) investigated the role of balance training in patients with lower limb injuries, including those recovering from burns, and found that balance-focused exercises improved weight-bearing patterns and reduced compensatory movements. Their study used similar balance training tools, such as wobble boards and foam surfaces, and reported significant improvements in postural stability (12). Our findings are consistent with Baker et al., as patients in Group A showed substantial improvements in foot weight distribution and dynamic balance, further supporting the efficacy of balance-focused interventions in burn rehabilitation.

Dieter et al. (2017) examined the effects of sensorimotor training on chronic foot conditions, including those with proprioception deficits, and found that patients who underwent sensorimotor training exhibited better outcomes in terms of weight-bearing symmetry and mobility. They compared sensorimotor training to conventional therapy and found significant differences similar to those observed in our study. Dieter et al. suggested that sensorimotor training should be a standard component of rehabilitation for any condition affecting balance and proprioception, a recommendation that our results strongly support for foot burn patients (13).

González et al. (2018) conducted a randomized controlled trial comparing the effects of proprioceptive training and traditional therapy on balance and functional mobility in patients with lower limb injuries, including burns. Their results showed that proprioceptive training led to faster recovery of balance and functional independence compared to traditional therapy alone. In line with these results, our study demonstrated that sensorimotor training resulted in greater improvements in foot weight distribution and gait symmetry, supporting the idea that proprioceptive training accelerates functional recovery (14).

Salek et al. (2021) explored the use of proprioceptive training in patients with neuropathic foot conditions, including burns. Their study showed that exercises targeting sensory-motor feedback mechanisms significantly improved foot function and balance (15). They also used a computerized pressure mapping system to evaluate weight distribution, similar to our use of the Pedoscan system, and found that proprioceptive exercises led to more

symmetrical weight-bearing patterns. Our study's findings of improved foot weight distribution in Group A align closely with Salek et al., further validating the role of sensorimotor training in enhancing functional outcomes in patients with foot impairments.

Considering the results of current study concerned with the control group, Erdem et al. (2020) explored the impact of traditional physical therapy on functional mobility in burn patients. While their study showed improvements in range of motion, muscle strength, and overall mobility, they noted that persistent proprioceptive deficits were a limitation of traditional therapy (2). Our study builds on these findings by demonstrating that sensorimotor training can address proprioceptive deficits more effectively than traditional therapy alone, leading to better outcomes in foot weight distribution. Erdem et al. suggested that future interventions should include proprioceptive training, which our study confirms as a necessary component for optimizing rehabilitation outcomes.

The significant improvement in foot weight distribution observed in Group A can be attributed to the specific nature of sensorimotor training, which focuses on enhancing the interaction between sensory inputs and motor responses. Patients with foot burns often experience proprioceptive deficits due to scar tissue, pain, and altered sensation in the affected area. These deficits disrupt the normal feedback mechanisms that help regulate balance and weight distribution (16). Sensorimotor training, by incorporating exercises that challenge balance on unstable surfaces (such as balance boards and foam pads), stimulates the sensory receptors in the feet, improving proprioceptive awareness and postural control (17). In contrast, traditional physical therapy, while effective in improving joint range of motion and muscle strength, does not specifically target these sensory-motor pathways. This may explain why Group B showed smaller and less consistent improvements in weight distribution. Although traditional therapy helps restore functional mobility, it may not be sufficient to correct the underlying proprioceptive deficits that contribute to weight-bearing asymmetry.

5. Clinical Implications

The findings of this study have important implications for the rehabilitation of patients with foot burns. The significant improvements in foot weight distribution observed in Group A suggest that sensorimotor training should be integrated into standard rehabilitation protocols for burn patients, particularly those with lower extremity injuries. Addressing proprioceptive deficits early in the rehabilitation process can help prevent the development of compensatory movement patterns, reduce the risk of long-term biomechanical issues, and improve overall functional outcomes. Given the consistent positive results across multiple studies mentioned above, sensorimotor training is an effective intervention for improving weight-bearing symmetry in patients with foot burns. Incorporating such training into rehabilitation programs could lead to faster recovery times and better long-term outcomes for these patients.

6. Limitations and Future Research

While this study provides valuable insights into the benefits of sensorimotor training, there are some limitations to consider. First, the study was conducted on a relatively small sample size, and future studies with larger populations are needed to confirm these findings. Second, the study only assessed foot weight distribution and did not evaluate other functional outcomes such as balance, quality of life, or long-term mobility improvements. Future research should investigate the broader impact of sensorimotor training on these additional outcomes. It remains unclear whether the benefits of sensorimotor training would extend to patients with more severe burns or those with burns covering larger areas of the body.

7. Conclusion

In conclusion, this study provides strong evidence that sensorimotor training, when combined with traditional physical therapy, significantly improves foot weight distribution in patients with foot burns. Compared to traditional therapy alone, sensorimotor training resulted in a more balanced weight-bearing pattern and reducing compensatory asymmetries

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