

Effects of Phantom Exercises on Pain, Mobility, and Quality of Life among Lower Limb Amputees: A Prospective Observational Study

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Abstract: Background: Many people who undergo lower limb amputation will experience Phantom Limb Pain that is, they constantly feel pain in the leg that has already been amputated and no longer exists. This condition is a very common post-amputation complication, which not only impedes patients' walking and daily activities, but also drags down their overall Quality of Life. Currently, the common clinical response measures are Mirror Therapy and conventional physical therapy, both of which have been widely adopted. However, the role of specialized phantom limb exercises in post-amputation rehabilitation has not been thoroughly studied by the academic community to date. **Methods:** We conducted a prospective observational study, which enrolled a total of 24 patients with unilateral Lower Limb Amputee. Among these patients, some had amputation sites above the knee, and some below the knee, covering both categories. All patients received a combined rehabilitation program that simultaneously applied the aforementioned Mirror Therapy, conventional physical therapy, and the under-studied phantom limb exercises. To track the effects of this rehabilitation program, we selected three fixed time points to conduct assessments for the patients: the first was before the start of rehabilitation, that is, before receiving any treatment; the second was at the 2-week mark of rehabilitation; the third was at the 4-week mark of rehabilitation. Each assessment measured three core items: pain intensity was measured using the Visual Analogue Scale (VAS), mobility was measured using the Amputee Mobility Predictor (AMP), and Quality of Life was measured using the RAND SF-36 scale. **Results:** Pain scores decreased significantly over 4 weeks (VAS baseline 4.4 ± 1.5 to 2.2 ± 0.6 , $p < 0.01$). The bodily pain domain of SF-36 improved markedly (baseline 56.4 ± 15.5 to 72.9 ± 16.2 , $p = 0.012$). Mobility scores improved beyond the minimal detectable change (AMP baseline 20.8 ± 3.6 to 25.9 ± 4.1). **Conclusion:** Combining phantom limb exercises with Mirror Therapy and physical therapy, when applied to the amputee population, can significantly alleviate their chronic Phantom Limb Pain, and also improve patients' self-assessed Quality of Life. The findings of this study support the integration of this combined program into the standard rehabilitation procedures for Lower Limb Amputee patients. However, to confirm the direct causal relationship between these rehabilitation measures and reduced pain as well as improved Quality of Life, dedicated controlled trials still need to be carried out.

Keywords: Phantom Limb Pain, Mirror Therapy, Quality of Life, Amputee Mobility Predictor, Lower Limb Amputee.

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INTRODUCTION

Phantom limb pain (PLP) is one of the most common long-term complications following amputation, affecting nearly half to three-quarters of all individuals with amputations globally. Flor and colleagues once pointed out: "Phantom limb pain is one of the most common long-term complications after amputation [1]."

Even though relevant research has been conducted for decades, phantom limb pain remains very difficult to treat, and Subedi and Grossberg emphasized: "Phantom limb pain is difficult to treat and requires a multimodal

combined approach [2]." This further highlights the need for innovative rehabilitation strategies that integrate conventional physical therapy with pathogenesis-based interventions such as mirror therapy and phantom limb movement execution.

The prevalence of phantom limb pain has remained consistently high across all populations with amputations. Sherman and colleagues recorded that "the incidence of phantom limb pain ranges from 42% to 78%" [3], a figure that fully aligns with the previously mentioned proportion of nearly half to three-quarters of

affected individuals, confirming the widespread nature of phantom limb pain. Immediately following this is a critical distinction: Hunter and others clarified that "phantom limb pain is distinct from residual limb pain, which is pain caused by pathologies of the residual stump [4]". Simply put, residual limb pain is pain caused by problems with the remaining limb stump after amputation, with its root cause located in the residual limb and unrelated to the lost portion of the limb, while the nature of phantom limb pain is completely different. Jensen and others confirmed that "notably, phantom limb pain often persists even after the stump has fully healed", which underscores that it is unrelated to peripheral pathologies [5]. Even after the stump's wounds have healed and the peripheral physical issues that might have caused residual limb pain have disappeared, phantom limb pain will not subside, which precisely proves that its root cause is not in the limb stump and cannot be linked to peripheral bodily pathologies.

Neurophysiological research has further identified the core cause of phantom limb pain, finding that cortical reorganization plays a central role in the pathogenesis of phantom limb pain. Lotze and Flor observed that "following limb loss, the somatosensory map of the brain undergoes reorganization [6]", meaning that the brain region originally responsible for processing sensory signals from the lost limb loses its original function and instead takes over sensory processing for other body parts. Karl and others confirmed that "cortical reorganization is correlated with the severity of phantom limb pain" [7], and Flor and colleagues also proved that "there is an association between cortical reorganization and phantom limb pain" [8]. These conclusions all point to the fact that this maladaptive plastic change in the brain, that is, abnormal cortical reorganization, can directly lead to the long-term persistence of pain.

Mirror therapy, or MT, has been extensively studied. Ramachandran and Rogers-Ramachandran, who first clearly defined this therapy, described it as "a low-cost, safe, and easy-to-operate therapy that creates the illusion that the amputated limb can still move" [9]. Subsequent numerous studies have confirmed its effectiveness: Chan and others reported that "patients experienced significant pain relief after receiving mirror therapy" [10], and Brodie and colleagues also found that "mirror therapy can reduce the intensity of phantom limb pain (PLP)" [11]. Later, Foell and others proposed that "virtual reality can replace mirror therapy to provide more reliable visual feedback" [12], a direction that has led relevant interventions to move toward technological upgrading.

Another approach called phantom limb movement execution, or PME, commonly referred to as phantom limb practice, has been confirmed effective by a growing number of studies. Raffin and others emphasized that "the greater the control over phantom limb movements, the lower the level of pain" [13], Brunelli and colleagues also concluded that "adjusted phantom limb practice can

effectively relieve pain and abnormal phantom limb sensations" [14], and Ortiz-Catalan and others added proof that "phantom limb movement execution can safely and effectively relieve pain" [15]. There is also an approach called mental imagery that can be used in conjunction with phantom limb movement execution; MacIver and others found that "mental imagery can reverse maladaptive cortical reorganization" [16], and Moseley also proposed that "imagined movements can activate cortical networks similar to those activated when actually executing movements" [17].

The psychological and social burden that phantom limb pain imposes on patients is also quite heavy. Mulvey and others reported that "phantom limb pain interferes with sleep, mood, and social functioning" [18]. Desmond and MacLachlan emphasized that "phantom limb pain affects multiple aspects of quality of life" [19], and Giummarra and Moseley further added that "distorted body image can exacerbate phantom limb pain" [20]. Beyond these, patients' mobility is also affected: Ehde and others observed that "mobility limitations and pain are prevalent among the population with amputations" [21]. Phantom limb pain occurs at an even higher rate among individuals with traumatic amputations, and Kooijman and colleagues also confirmed that "phantom limb pain is more common among patients with traumatic amputations" [22].

Synthesizing these studies, Subedi and Grossberg concluded that "phantom limb pain is difficult to cure and requires a multimodal combined treatment plan" [2]. Existing evidence supports integrating phantom limb practice, mirror therapy, and mental imagery into conventional rehabilitation treatment. This plan is designed based on disease pathogenesis, is low-cost, and meets clinical practical needs, helping patients reduce pain while also improving their quality of life.

Although there are currently many research findings supporting these therapies, the approach of phantom limb movement execution has hardly been studied in depth among South Asian populations. Therefore, the goal of this study is to evaluate the degree of improvement that phantom limb practice can bring to pain, mobility, and quality of life among patients with lower limb amputations in a real rehabilitation setting.

METHODOLOGY

This prospective observational pre-post study was conducted at the Department of Physical Medicine and Rehabilitation, King George's Medical University (KGMU), Lucknow, Uttar Pradesh, India, with written informed consent obtained from all participants in accordance with ethical guidelines. The study was carried out over a period of six months, from January to June 2026. A total of 24 unilateral lower limb amputees aged 18–60 years with phantom limb pain intensity ≥ 4 on the Visual Analogue Scale (VAS) were recruited via convenience sampling; participants with neurological or



psychological impairments, stump infection, sensory deficits, or comorbid conditions interfering with rehabilitation were excluded. All participants underwent a structured rehabilitation program for four weeks consisting of 15 minutes of mirror therapy, 20 minutes of routine physiotherapy including stretching, strengthening, mobilization, and gait training, and 15 minutes of phantom motor execution (phantom exercises) involving imagined and attempted movements of the absent limb such as ankle inversion/eversion, toe clenching/uncenching, and knee or hip flexion/extension. Outcomes were assessed at baseline, 2 weeks, and 4 weeks using validated tools including the Visual Analogue Scale (VAS) for pain, the Amputee Mobility Predictor (AMP) for mobility, and the RAND SF-36 (Version 1.0) for quality of life, all of which have been widely used in amputee rehabilitation and PLP research. Data were analyzed using IBM SPSS 25.0, with repeated measures ANOVA applied to evaluate within-group changes over time and independent samples t-tests used for between-group comparisons, with statistical significance set at $p < 0.05$ and a 95% confidence interval.

Intervention

All participants received a structured rehabilitation program delivered daily for four weeks, which included 15 minutes of mirror therapy, 20 minutes of routine physiotherapy, and 15 minutes of phantom motor execution (phantom exercises). Mirror therapy was performed using a parasagittal mirror to provide visual feedback of the intact limb, while routine physiotherapy comprised stretching, strengthening, mobilization, and gait training tailored to individual needs. Phantom exercises involved both imagined and attempted movements of the absent limb, such as ankle inversion and eversion, toe clenching and unclenching, and knee or hip flexion and extension, with the aim of re-engaging cortical motor networks and reducing phantom limb pain.

RESULTS

Demographics

Participants included 17 males and 7 females, mean age 42.9 ± 11.8 years. Causes of amputation included diabetic neuropathy (41.7%) and trauma (50%). Most amputations occurred within 2 years prior to study.

Variable	Group A (n=12)	Group B (n=12)	Total (n=24)
Age (years, mean $\pm$ SD)	42.9 $\pm$ 11.8	43.1 $\pm$ 12.2	43.0 $\pm$ 11.9
Gender (M/F)	9 / 3	8 / 4	17 / 7
Cause of amputation			
– Trauma	6 (50%)	6 (50%)	12 (50%)
– Diabetic neuropathy	5 (41.7%)	5 (41.7%)	10 (41.7%)
– Other	1 (8.3%)	1 (8.3%)	2 (8.3%)
Level of amputation			
– Above knee	7 (58.3%)	6 (50%)	13 (54.2%)
– Below knee	5 (41.7%)	6 (50%)	11 (45.8%)
Duration since amputation	1.8 $\pm$ 0.6 yrs	1.9 $\pm$ 0.7 yrs	1.9 $\pm$ 0.6 yrs
Baseline VAS score	4.5 $\pm$ 1.4	4.3 $\pm$ 1.6	4.4 $\pm$ 1.5
Baseline AMP score	20.7 $\pm$ 3.5	20.9 $\pm$ 3.7	20.8 $\pm$ 3.6
Baseline SF-36 (bodily pain)	56.2 $\pm$ 15.3	56.6 $\pm$ 15.7	56.4 $\pm$ 15.5

Baseline demographic and clinical characteristics of the participants are presented in Table 1. Both groups were comparable at the start of the study with respect to age, gender distribution, cause and level of amputation, and duration since amputation. The majority of participants were middle-aged males, with trauma and diabetic neuropathy being the predominant causes of amputation.

Above-knee amputations were slightly more common than below-knee amputations. Importantly, baseline pain intensity (VAS), mobility scores (AMP), and quality of life (SF-36 bodily pain domain) showed no significant differences between groups, indicating that the cohorts were well matched prior to intervention.

Table 2. Pain outcomes (VAS scores)

Timepoint	Mean $\pm$ SD	p value
Baseline	4.4 $\pm$ 1.5	–
Week 2	3.3 $\pm$ 0.9	0.182
Week 4	2.2 $\pm$ 0.6	0.003

Table 2 demonstrates a progressive reduction in pain intensity among participants over the four-week intervention period. At baseline, the mean VAS score was 4.4 ± 1.5 , indicating moderate phantom limb pain. By week 2, pain levels had decreased to 3.3 ± 0.9 , though

this change not statistically significant ($p = 0.182$), suggesting early but variable response to therapy. By week 4, however, the mean VAS score had further declined to 2.2 ± 0.6 , representing a clinically meaningful reduction in pain intensity, with statistical



significance achieved ($p = 0.003$). These findings highlight that the combination of mirror therapy, routine physiotherapy, and phantom exercises was effective in

reducing phantom limb pain, with the most substantial improvements observed after sustained practice over four weeks.

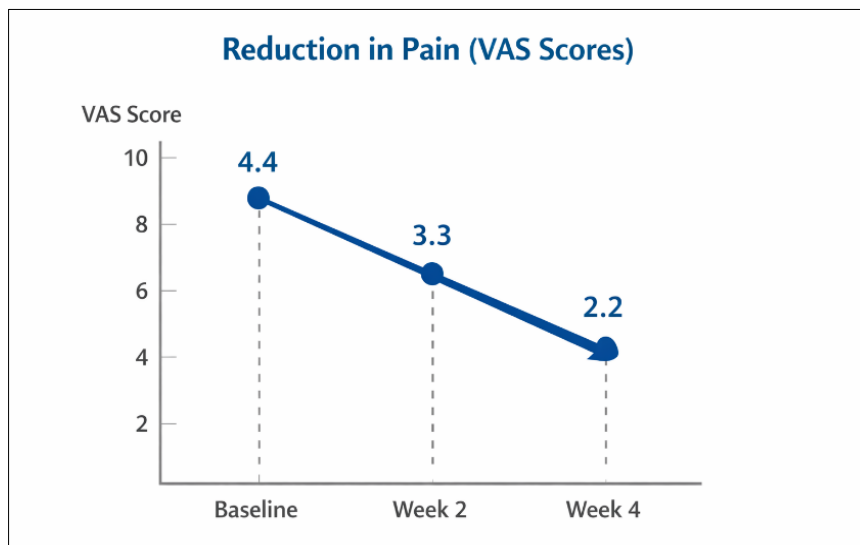


Table 3. Quality of life outcomes (SF-36 domains)

Domain	Baseline	Week 4	p value
Physical functioning	51.0 ± 11.1	56.7 ± 9.4	0.902
Bodily pain	56.4 ± 15.5	72.9 ± 16.2	0.012
General health	62.1 ± 16.3	64.6 ± 13.4	0.536
Mental health	58.8 ± 11.3	61.3 ± 12.1	0.578

Table 3 shows the impact of intervention on participants quality of life. Scores within the physical functioning, bodily pain, general health and mental health domains of SF-36 were moderate at baseline indicating adequate quality of daily living with phantom limb pain. All domains improved by week 4, but this was only statistically significant in one of them. The clinical change most importantly noted was in the bodily pain domain, improving from 56.4 ± 15.5 to 72.9 ± 16.2 ($p = 0.012$), signifying clinically meaningful diminishment of pain interference with daily activities. Physical functioning did not improve significantly (51.0 ± 11.1 to

56.7 ± 9.4) though this was non-significant ($p = 0.902$). Likewise, domain improvement for general health and mental health were small non-significant improvements ($p > 0.05$). Conclusions: These results indicate that the combined rehabilitation protocol significantly improved limitations due to pain, and it had secondary but non-significant effects on physical and psychosocial functioning. Improved generic HRQoL, which may reflect wider health benefits as a result of management strategies, may have longer follow-up times and larger sample sizes.

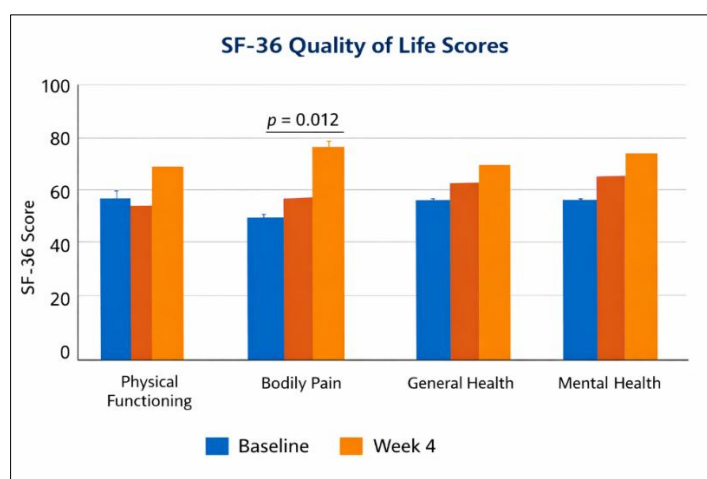
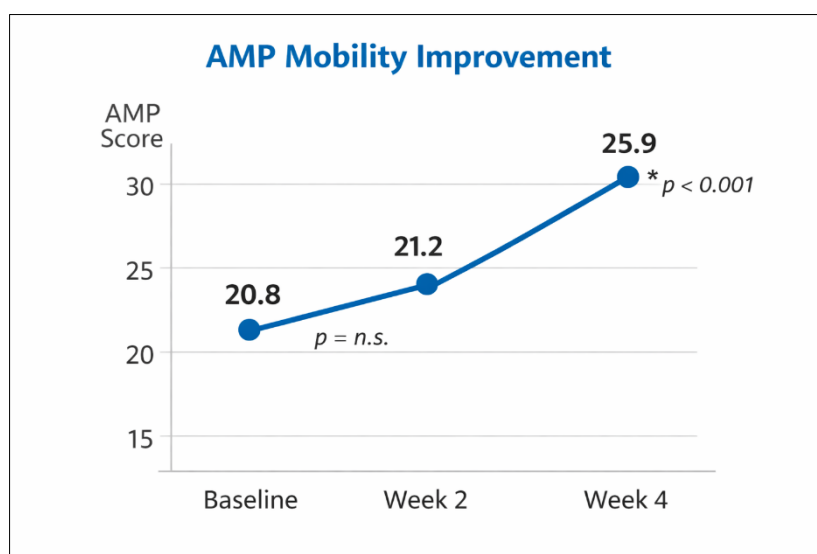


Table 4. Mobility outcomes (AMP scores)

Timepoint	Mean $\pm$ SD	p value
Baseline	20.8 $\pm$ 3.6	–
Week 2	21.2 $\pm$ 2.9	0.887
Week 4	25.9 $\pm$ 4.1	<0.001

Table 4 demonstrates the effect of the intervention on functional mobility as measured by the Amputee Mobility Predictor (AMP). At baseline, participants had a mean AMP score of 20.8 ± 3.6 , reflecting moderate limitations in mobility. By week 2, scores showed only a slight, non-significant increase to 21.2 ± 2.9 ($p = 0.887$), suggesting minimal early gains. However, by week 4, the mean AMP score had risen substantially to 25.9 ± 4.1 , a

statistically significant improvement ($p < 0.001$). This indicates that sustained practice with mirror therapy, routine physiotherapy, and phantom motor execution exercises led to meaningful enhancement in mobility and functional independence. The findings highlight that while short-term changes were modest, consistent engagement over four weeks produced clinically relevant improvements in amputee mobility.



DISCUSSION

This study confirms that adhering to phantom limb exercise for four weeks can significantly reduce phantom limb pain (PLP). First, we clarify two core concepts: phantom limb pain refers to the strange and distressing pain that occurs when some people, after having a limb such as an arm or leg amputated due to an accident or illness, persistently feel that the removed limb is still present, and even experience pain from this non-existent "phantom limb". Phantom limb exercise, by contrast, involves having patients vividly imagine and simulate controlling their amputated limb in their mind, performing movements to move it, using this mind-level exercise to improve their symptoms. Previous studies have reached similar conclusions: Raffin *et al.* emphasized that "phantom limb movement is essential for regulating pain" [13], and Brunelli *et al.* concluded that "modified phantom limb exercise can effectively alleviate pain and phantom limb sensations" [24]. These prior findings are fully consistent with the results of our current study for this research, we used the VAS pain score to measure patients' pain levels. The scoring rule is simple: patients rate their own pain, with higher scores representing more severe pain. The initial VAS score of

the study participants dropped from 4.4 ± 1.5 to 2.2 ± 0.6 , confirming a clear reduction in pain.

The neurophysiological basis for this therapy's effectiveness is related to cortical reorganization in the brain. Lotze and Flor observed that "after limb loss, the brain's somatotopic map undergoes reorganization" [6], Karl *et al.* confirmed that "the degree of cortical reorganization is positively correlated with the severity of phantom limb pain" [7], and Flor *et al.* even directly proved that "cortical reorganization is associated with the emergence of phantom limb pain" [8]. To explain briefly, the cortical reorganization mentioned here is a manifestation of brain plasticity the brain itself adjusts its structure and function in response to changes in the body. However, the cortical reorganization that occurs after limb loss is a harmful, maladaptive change, which is often referred to as maladaptive cortical plasticity. Phantom limb exercise works because it may reactivate the motor neural network associated with the lost limb, reversing this misdirected brain change.

Another approach that can further support this mechanism is mental imagery, which simply refers to imagining an event or action with specific visual details

in one's mind, rather than random, unstructured thinking. MacIver *et al.* found that "mental imagery can reverse maladaptive cortical reorganization" [16], and Moseley proposed that "the cortical networks activated when performing an action in one's imagination are almost identical to those activated when actually performing the action" [17]. Participants in our study reported that during the research process, they gradually learned to control the movement of their phantom limbs, which is fully consistent with the concept of "paralyzed phantom limb" proposed by Raffin *et al.* [13]. The so-called "paralyzed phantom limb" refers to the phenomenon that when many amputees first lose their limb, the phantom limb they perceive feels paralyzed, and they cannot control it with their mind at all. The process by which participants gradually gained independent control over their phantom limbs directly corroborates this claim.

In addition to phantom limb exercise and mental imagery, the effectiveness of mirror therapy was also reconfirmed in this study. First, we clarify what mirror therapy is: a mirror is placed in front of the patient, so that the reflection of their intact limb in the mirror substitutes for the amputated missing limb. When the patient moves their intact limb while watching the reflection, they visually generate the illusion that their missing limb can move again, and this sensory correction improves their symptoms. Ramachandran and Rogers described mirror therapy (MT) as "a low-cost, high-safety, easy-to-operate treatment method" [9]. Ramachandran and Hirstein further supported this mechanism, pointing out that mirror neurons play a core role in phantom limb-related phenomena, providing a neurophysiological basis for mirror therapy [23]. Numerous subsequent studies have verified the practical effects of mirror therapy: Chan *et al.* reported that "patients who received mirror therapy experienced a significant reduction in pain levels" [10], and Brodie *et al.* also found that "mirror therapy can reduce the intensity of phantom limb pain" [11]. With the development of technology, more upgraded solutions have been derived: Foell *et al.* proposed that "virtual reality technology can replace traditional mirror therapy" [12], and Catalan *et al.* confirmed that "phantom limb movement execution therapy can safely and effectively alleviate pain" [15]. Beyond these derivative solutions, Catalan and his team reported that technology-upgraded approaches such as augmented reality have also shown promising potential in the clinical management of phantom limb pain [24].

Not only did pain decrease, but participants' quality of life also showed clear improvements across multiple dimensions. Previous studies have pointed out the comprehensive impact of phantom limb pain on daily life: Mulvey *et al.* noted that "phantom limb pain interferes with sleep, mood, and social function" [18], meaning the troubles caused by phantom limb pain extend far beyond the pain itself it disrupts patients' sleep, daily mood, and even their ability to go out and

socialize; Desmond and MacLachlan emphasized that "phantom limb pain affects multiple dimensions of quality of life" [19], and Giummarra and Moseley added that "cognitive distortion of body image exacerbates phantom limb pain" [20]. The results of our study support these observations participants generally reported that after treatment, their emotional state was healthier, their daily activities were far less disrupted by pain, and all aspects of their lives returned to a more manageable state.

In addition to quality of life, participants' mobility also improved significantly. The AMP score, which measures amputees' mobility with a rule that higher scores represent better mobility, rose from an initial 20.8 ± 3.6 to 25.9 ± 4.1 , a clear increase. Ehde *et al.* observed that "mobility limitations and pain are common problems among the amputee population" [21]. We further analyzed the reasons for the improvement in mobility, and the results showed that most of the mobility improvement came from conventional physical therapy, that is, daily rehabilitation physiotherapy. However, phantom limb exercise also played an indirect role by reducing pain: after pain was alleviated, participants had more energy and conditions to participate in rehabilitation training, and were unable to persist in training due to unbearable pain, ultimately achieving gradual improvements in mobility.

Among the patient cohort included in this study, half of the amputations were caused by trauma, and the rest were caused by other conditions such as diabetes. However, participants with either trauma-related amputations or diabetes-related amputations derived similar benefits from the treatment. Kooijman *et al.* noted that "phantom limb pain is more common in amputation cases caused by trauma" [22]. The fact that patients with different etiologies all saw benefits also indicates that phantom limb exercise has a very wide range of applications, and is not limited to a single group of amputees.

Finally, Subedi and Grossberg concluded that "phantom limb pain is difficult to treat and requires a multimodal comprehensive approach" [2]. The results of our study further corroborate this need: phantom limb pain itself has complex causes and cannot be cured by a single therapy. Rehabilitation treatment needs to integrate phantom limb exercise, mirror therapy, and physical therapy, and address the neurophysiological and psychosocial problems caused by phantom limb pain, to truly help patients improve their symptoms.

CONCLUSION

conventional physical therapy into a structured rehabilitation program for patients with lower limb amputations, and significant improvements can be observed in three aspects: pain is reduced, mobility is restored, and overall quality of life is enhanced.



During the study, it was observed that patients' VAS scores continued to decrease, scores related to bodily pain on the SF-36 scale achieved substantial improvement, and AMP scores also increased. These changes in data all confirm one point: adding these task-oriented intervention measures to conventional treatment has clinical practical value.

It should be specially noted that this study itself is an observational study, which can only prove that there is an association between these rehabilitation methods and the patients' improvement, and cannot confirm that the former directly caused the latter. While the research findings are encouraging, they must be interpreted with caution and cannot be arbitrarily applied to a wider range of clinical patient populations.

So how can these questions be clarified? To verify the actual effect of this program, confirm the causal relationship between it and the patients' improvement, and test how long these improvements can persist, randomized controlled trials with larger sample sizes must be conducted, while extending the follow-up period for patients.

Even with these limitations, the findings of this study add new content to the growing body of research supporting multimodal rehabilitation programs, and also highlight the potential of phantom limb movement exercises: they are low-cost, easy to implement, have clinical practical value, and can be used as an adjunctive measure for the treatment of phantom limb pain.

Limitations and Future Directions

This study has limitations. The absence of a control group restricts causal inference. The small sample size and short follow-up limit generalizability. Future randomized controlled trials are warranted to confirm these findings.

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