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The Effectiveness of Home-Based Mirror Therapy in Reduction of Phantom Limb Pain in Unilateral Below-Knee Amputees

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Phantom limb pain; Mirror therapy; Below knee amputation; Prosthesis

1. Abstract

1.1. Introduction: Phantom limb pain (PLP), a prevalent condition among amputees, causes many challenges and long-term complications for those affected. One treatment that offers a low-risk and cost-effective solution is mirror therapy, which can be conducted at home. This study aims to determin the effect of home-based mirror therapy for unilateral below-knee amputees suffering from PLP.

1.2. Methods: This study enrolled 16 male participants, aged 18 and above, who were randomly assigned to either the intervention (mirror therapy) or control (prosthesis use) group. The mirror therapy group received a single training session, lasting between 15 to 30 minutes, after which they performed the exercises independently at home for at least 15 minutes each day over four weeks and they were required to use their prosthesis for at least three hours daily. Weekly phone or online check-ins were conducted to record pain levels. Participants in the control group were required to use their prosthesis for at least three hours daily and report their PLP pain weekly. Pain was measured using the Visual Analogue Scale (VAS).

1.3. Results: The mean age of the participants was 45.12 years. The initial VAS pain score ranged from 3 to 10. Following four weeks of intervention, the mirror therapy group exhibited a 37.5% reduction in pain (Pvalue<0.05), unlike the control group, which did not experience a significant change (Pvalue>0.05).

1.4. Conclusion: Mirror therapy appears to be a viable option for managing phantom limb pain, offering the benefits telehealth and home-based exercises, thus eliminating the need for face-to-face consultations.

2. Introduction

Phantom limb pain is characterized as a painful sensation perceived in an amputated limb [1-3]. It is a significant factor affecting the decline in quality of life among amputees [4].

Phantom limb syndrome is experienced by 80% of individuals who have undergone limb amputation [5]. The etiology of this syndrome is influenced by physiological, environmental, and psychological factors [3, 6-8]. The experience of phantom limb pain varies considerably among individuals, ranging from transient, short-term discomfort to persistent pain. This pain can manifest in several forms, including muscle cramping, burning, and shooting pain [9].

The pathophysiology of phantom limb pain remains elusive, though it is hypothesized that the peripheral and central nervous systems significantly contribute to the syndrome's development. The primary mechanism behind this pain is not fully understood, but prevailing theories suggest that alterations in the brain's cortical map following amputation could be the syndrome's origin [2, 8, 10].

At present, there are various treatments for phantom limb pain and their effects are often unpredictable. These treatments include

medication like analgesics and antidepressants, psychological distractions such as reading or exercise, acupuncture, transcutaneous electrical nerve stimulation (TENS), hypnosis, and mirror therapy. Despite these options, no single method has proven fully effective at relieving this type of pain on its own, leading to the common use of combination treatments [2, 3, 6]. The development of a non-invasive treatment option that does not require surgery or medications with potential side effects would be a significant advancement in improving the quality of life for patients experiencing phantom limb pain.

Recognizing these challenges, Ramachandran pioneered a simple, cost-effective approach to treating this syndrome, known as mirror therapy [11]. This method has attracted significant interest in the therapeutic community. In mirror therapy, a mirror is placed between the patient's sound limb and their amputated limb. The patient executes a series of movements with the intact limb while trying to mimic the same movements with the amputated limb. This generates an illusion for the patient, making them perceive the presence of the missing limb [7-9, 12, 13]. This allows individuals, who previously had the experience of using both limbs, to regain the sensation of having two sound limbs, thus helping correct erroneous signals from the motor and sensory parts of the brain when trying to control a non-existent limb.

This treatment doesn't necessitate specific procedures or additional medication and can be implemented wherever a mirror is available, resulting in significant cost reduction. If more evidence is provided on its effectiveness, patients will no longer require frequent consultations or additional medications. With the emphasis on reducing clinic visits growing in the wake of the COVID-19 pandemic [14], it's possible that an individual can manage or even eliminate their phantom limb pain independently with telehealth, rendering this treatment the most accessible and cost-effective for phantom limb syndrome.

The aim of this study is to investigate and evaluate home-based mirror therapy as an effective treatment for reducing pain in unilateral below-knee phantom limb syndrome. This will be done in a manner that involves daily and weekly online consultations, allowing for a review of treatment progress without necessitating frequent patient visits.

3. Materials and Methods

This study is a clinical trial of the "before and after study" type. Prior to initiation, approval was obtained from the Research Committee of the Isfahan University of Medical Sciences. Participants were made aware of their rights, the study's objectives, and the fact that they were free to withdraw from the study at any time. After becoming familiar with the training environment and test procedures, all participants gave full consent to partake in the study and signed the relevant consent form. A questionnaire was used to collect individual demographic characteristics, such as sex, age, height, weight, body mass index, side of amputation, time since amputation, occupation, and the duration of prosthesis use each day.

Sampling was carried out using the convenience sampling method. The majority of participants were from the Iranian Red Crescent Society in Tehran, which was chosen due to the high daily influx of patients, thereby facilitating participant selection. Prior to beginning the study, participants were informed that this type of treatment has no known side effects. After completing the ethical consent form, they agreed to participate in the study.

Mirrors used in the study were 50 by 30 centimeters in size, with a plastic frame and metal wires attached to the back for easier balancing. A 15 to 30-minute in-person session was conducted to teach participants the safe usage of the mirror. Once it was confirmed that participants could perform the exercises independently at home, and could commit to daily exercises for 4 weeks, they were gifted a mirror to conduct exercises at home per the given instructions, and to send weekly reports via online messaging.

Participants were instructed to contact the researcher if they encountered any problems. In addition, each individual in the mirror therapy group was provided a sheet outlining the exercises to be performed and 12 key points to remember about these exercises.

Daily exercises, which lasted for 15 minutes, included foot rotation from heel to toe, forefoot rotation, finger bending and straightening, foot tapping on a carpet or object below, writing numbers in the air with the foot, and arranging different objects.

This study enrolled sixteen male patients aged 18 and above who had undergone a unilateral below-knee amputation at least a year prior and wore a prosthesis for a minimum of 3 hours per day. Eligible participants had never undergone mirror therapy before and had a pain score of at least 3 on the visual analog scale (VAS). The VAS has been demonstrated to have high reliability and validity [15]. Pain severity was classified as mild (score 1-3), moderate (score 4-5), or severe (score 6-10). Individuals were excluded from the study if they had severe infections or soft tissue deformities in the stump, substance addiction, vision problems, brain damage, or were on painkillers or sedatives. The amputees were randomly divided into two groups: intervention (mirror therapy) and control (prosthesis use), each comprising 8 individuals.

The intervention group learned mirror work in an in-person session and practiced with the mirror daily for 15 minutes over a period of 4 weeks. The control group, which consisted of prosthetic users, continued their daily activities with full contact with the prosthesis for at least 4 hours per day. Pain was assessed using the visual analog scale, with participants asked to report their average pain intensity over the past week using an 11-point numerical rating scale (0-10), where 0 equals no pain and 10 equals the worst possible pain. Both groups were required to complete the pain questionnaire on a weekly basis and share it with the researchers.

The Shapiro-Wilk test and the two-sample t-test were used for statistical analysis. The paired t-test and Pearson's tests were employed for statistical comparison. The significance level for all tests was set at 0.05, and statistical analysis was conducted using SPSS 22 software.

4. Results

The average age of participants in the study was 45.12 years. The average time that had passed since the amputation was 10 years. Before starting the study, the mirror therapy group's severity of pain, as assessed using the Visual Analog Scale (VAS), was categorized as follows: none of the participants experienced mild pain, two experienced moderate pain, and six experienced severe pain. After the intervention, these numbers changed, with three participants experiencing mild pain, two continuing to experience moderate pain, and three experiencing severe pain. At the end of the study, the pain level of three participants in the intervention group was reduced to the mild category.

The average daily prosthesis use among all participants was 7.5 hours. Within the mirror therapy group, only one individual reported no changes in their phantom pain, while another experienced a one-point increase on the visual analog scale. The remaining participants reported a decrease in pain after the conclusion of the course. The average pain score of the mirror therapy group according to the visual analog scale declined from an initial average of 7.25 (SD 2.12) to an average of 4.62 (SD 1.92) (P-value: 0.029). No significant decrease in phantom pain was observed in the control group, with the average pain and standard deviation reaching 4.6 and 2.19, down from 5.7 and 2.31, respectively (P-value: 0.051). Although we did not see a significant pain reduction in the control group, there was a noticeable 4-point decrease in pain in one of the individuals in this group by the end of the fourth week.

Table 1 outlines the statistics for demographic variables such as age, weight, height, and body mass index of the study's participants, with a maximum and minimum limit defined for each variable.

Figures 1 and 2 illustrate the perceived pain alterations in both the intervention and control groups. As per these figures, participants' pain diminished to a lower level after four weeks of exercise, but this pain remained largely unchanged in the control group's participants.

Table 2 displays the mean and standard deviation of perceived pain before and after the study for both the mirror therapy and control groups. The average pain intensity reduction in the mirror group was more significant (P-value: 0.029), but it was not significant in the control group (P-value: 0.051). Statistical analysis results show that one-month exercise with a mirror could have a significant effect on reducing perceived pain (P=0.029). The perceived pain did not significantly decrease for the control group (P=0.051).

When comparing perceived pain before and after mirror therapy in pairs, the mean was 2.62, with a standard deviation of 2.72 and a P-value of 0.29. The corresponding figures for the control group were 1.12, 1.35, and 0.051, respectively.

There was a moderate positive correlation (0.464) between the duration since amputation and pain reduction, even though this correlation was not statistically significant (P-value = 0.070). A moderate positive correlation signifies that as the duration since amputation increases, the pain reduction also increases.

The correlation between prosthetic use and pain reduction was assessed. According to the obtained data, there was a moderate negative correlation (-0.330) between these two variables, which was not statistically significant (P-value = 0.212). A moderate negative correlation means that wearing the prosthesis more does not result in greater pain reduction.

We also examined the correlation between the level of pain discomfort and pain reduction. A moderate negative correlation (-0.430) was found between these variables; however, this correlation was not statistically significant (P-value = 0.096). This finding implies that an increase in the level of phantom pain discomfort does not correspond to a greater reduction in pain.

Figure 1: Mirror Exercise Technique

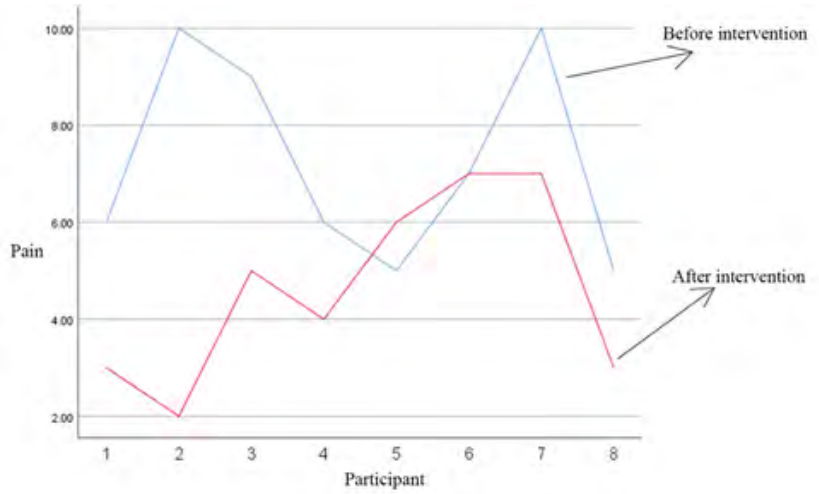

Figure 2: Pain before and after a four-week period in the mirror group.

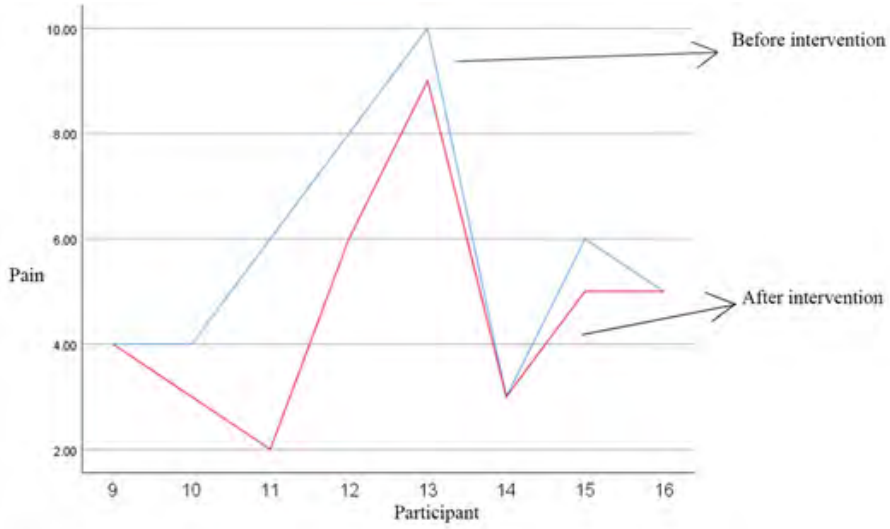

Figure 3: Pain before and after a four-week period in the control group.

Table 1: Demographic information of participants in the study.

Variable	Minimum	Maximum	Mean	St. Deviation
Age	19	68	45.12	14.54
Height	161	190	176.93	7.67
Weight	65	110	83.12	12.02
BMI	20.06	36.96	26.7	4.62

Table 2: Pain before and after intervention in each group.

Group	Before	After	P.value
Mirror Therapy	Mean: 7.25 St. Deviation: 2.12	Mean: 4.62 St. Deviation: 1.92	0.029
Control	Mean: 5.75 St. Deviation: 2.31	Mean: 4.62 St. Deviation: 2.19	0.051

5. Discussion

Mirror therapy has emerged as a promising approach for the treatment of phantom limb pain over the past two decades. It is a non-surgical method that requires no hospitalization and is devoid of side effects typically associated with medications. Moreover, it enables patients to manage their phantom limb pain independently, allowing them to conduct the exercises at home without frequent therapist visits. Our study was undertaken with this objective, to evaluate the efficacy of mirror therapy.

Our findings suggest that mirror therapy significantly alleviates phantom limb pain. To our knowledge, this study is the first of its kind conducted in Iran that investigates the impact of mirror therapy on phantom limb pain in individuals with below-knee amputations. The results affirm the hypothesis that mirror therapy can effectively reduce phantom limb pain in these individuals. This stands in contrast to the use of a prosthesis, which our study found to not positively influence the reduction of phantom limb pain.

Furthermore, patient feedback at the one-week marks mirrored feedback received in the fourth week. This implies that the success or failure of this method in mitigating phantom limb pain can be gauged as early as the first week, thereby facilitating decisions on whether to continue or discontinue the exercises.

In our study, participants engaged in 15-minute daily mirror therapy sessions at home over a four-week period. Our findings showed that after four weeks, patients gained better control of their phantom limb pain, experiencing a 37.5% reduction. These findings align with those of Foell et al. who reported significant effects of mirror therapy in reducing phantom limb pain, with an average decrease of 27% in a similar four-week daily exercise study involving 13 participants [16]. However, our study focused on lower limb amputees, whereas their study involved upper limb amputees.

Our research corroborates recent studies on mirror therapy's efficacy in reducing phantom limb pain in individuals with lower limb amputation [17-20]. However, it contradicts the results of a study by Brodie et al., which examined 80 individuals divided into two groups: one engaged in mirror exercises and a control group that merely observed movements of their healthy leg. No significant difference was noted between the two groups in terms of changes and reduction in phantom limb pain. Importantly, in their study, only a single exercise session was conducted [21].

Although the number of studies directly investigating the effect of mirror therapy on phantom limb pain is limited, and most have a small sample size, the majority have reported positive results regarding mirror therapy as an effective method for reducing phantom limb pain. Completion of the mirror therapy regimen is considered key, with most studies advocating a 10 to 30-minute session duration [16, 19, 22-26]. In a case study by Darnall et al., it was noted that phantom limb pain returned within one or two days following the discontinuation of mirror therapy. The patient had practiced exercises for at least 20 minutes daily. No significant correlation was found between the success of mirror therapy and the number of exercise repetitions per day or the exercise duration. In other words, consistent daily exercise plays a crucial role in mirror therapy. However, increasing the frequency of exercises or extending their duration did not significantly impact mirror therapy's success [13]. Therefore, in our study, participants in the mirror group were advised to commit to at least 15 minutes of mirror therapy exercises daily, avoid excessive daily exercise, and not miss a day of exercise.

Yildirim et al. explored the effects of a four-week mirror therapy program on 15 individuals with upper or lower limb amputations, who were divided into two groups: prosthetic and non-prosthetic. While they found no specific correlation between demographic characteristics and mirror therapy, the treatment proved more effective for patients not using a prosthesis [26]. In our study, we examined the effect of using a prosthesis alone versus combining mirror therapy with a prosthesis. Our findings indicated that incorporating mirror therapy with a prosthesis led to a significant reduction in phantom limb pain for most participants. Conversely, the group using only a prosthesis showed no significant reduction, with some cases even reporting an increase in pain over a month. All treatment group participants were from a single rehabilitation center, using patellar tendon-bearing (PTB) prostheses to avoid discrepancies in prosthetic construction potentially affecting the intervention results. Yildirim et al. hypothesized that using a prosthesis alone might exacerbate phantom limb pain, as it could be perceived as a defect compared to mirror therapy, which redirects attention towards the perceived healthiness of the amputated limb. This theory may explain our prosthetic group's absence of pain reduction, or even pain increase. Our results align with Yildirim et al.'s study, although our research specifically included individuals with below-knee amputations.

Föll et al.'s case study, involving a 53-year-old woman with a left leg amputation, showed a mean reduction of 3.92 in phantom limb pain and a 48% decrease in average pain intensity over a two-year follow-up [19]. In our study, despite the one-month treatment duration, we observed a 2.63 reduction in phantom limb pain scores, translating to a 37.5% decrease. Föll et al.'s findings could suggest the long-term potential of mirror therapy to achieve maximum pain reduction.

Telehealth, conducted via email, messaging applications, forums, etc., could be considered a strength of home-based mirror therapy. Telehealth encourages individuals to engage in and maintain their exercises, potentially leading to more reliable results than in-person visits, due to increased motivation to perform daily exercises. Of the eight participants in our mirror therapy group, only one reported an increase in phantom pain after treatment, while one experienced no change, and the remainder reported pain reduction. Some participants also reported improved mental well-being and

quality of life due to the mirror exercises and weekly follow-ups, though this aspect could not be analyzed.

The participants who reported weekly phantom pain reductions had a positive perception of mirror therapy, attributing their improved mental states to the physical activity associated with mirror exercises and pain reduction. Interestingly, they maintained this positive view even during weeks of little pain decrease. The combination of in-person and online exercises seems to have contributed to participant satisfaction. Additionally, online follow-ups can help the treatment team identify psychological and physical issues during the course, allowing early intervention and preventing disruption of their phantom pain reduction, thereby increasing the likelihood of successful treatment.

Our study is unique in focusing solely on individuals with below-knee amputations. This specific demographic had not been previously explored in the studies we reviewed. Furthermore, the use of home-based and telehealth treatment methodologies represents an innovative approach to managing phantom limb pain.

Given the clinically significant 37.5% average pain reduction within the mirror therapy group (8 participants), we recommend future studies with larger sample sizes and extended follow-up periods of over six months, inclusive of various amputation levels and both genders. This would provide more substantial evidence on the long-term effects of exercises for individuals with phantom pain. Further exploration of factors such as stress, depression, and living conditions in larger samples may illuminate this.

6. Conclusion

Mirror therapy can be regarded as a viable method for reducing phantom limb pain, aiding individuals in managing their discomfort. This method is easily adaptable for home implementation, and telehealth between the therapist and the individual can act as a catalyst for maintaining consistency in mirror therapy exercises, thereby enhancing its efficacy.

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