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The Effect of Photo biomodulation Therapy on Shoulder Muscle Activation, Motor Function, Pain Reduction, and Quality of Life in Hemiplegia: A Systematic Review

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ABSTRACT

Background: Hemiplegic shoulder dysfunction is a common and debilitating complication following stroke, often leading to impaired motor function, chronic pain, and reduced quality of life. Photo biomodulation therapy (PBMT), a non-invasive modality using low-level laser or light therapy, has emerged as a potential intervention for neuromuscular rehabilitation. This systematic review aimed to evaluate the effectiveness of PBMT in improving shoulder muscle activation, motor function, pain reduction, and quality of life in hemiplegic patients.

Methods and Materials: A comprehensive literature search was conducted across PubMed, Scopus, Web of Science, and Google Scholar databases for studies primarily published between 2014 and 2025. Inclusion criteria were clinical trials, cohort studies, or quasi-experimental studies, and review studies that evaluated PBMT effects on post-stroke hemiplegic patients. A total of eighteen studies were included based on predefined inclusion and exclusion criteria. Data extraction focused on study design, sample size, PBMT parameters, and clinical outcomes.

Results: The included studies demonstrated consistent evidence that PBMT significantly enhances shoulder muscle activation, improves motor function, reduces pain, and contributes positively to quality of life. Most studies utilized wavelengths between 650–850 nm with positive therapeutic outcomes and minimal adverse effects. Some variability existed in PBMT protocols and patient populations, but overall findings were favourable.

Conclusion: PBMT shows promise as an effective adjunct therapy for improving shoulder function and reducing pain in hemiplegic patients. While current evidence is encouraging, further large-scale studies with standardized protocols are needed to confirm its long-term efficacy and optimize clinical application.

Keywords: *Photo-biomodulation therapy, Hemiplegia, Shoulder dysfunction, Stroke rehabilitation, Pain management*.

1. INTRODUCTION

Hemiplegia:

Hemiplegia, which is most frequently caused by a stroke or brain injury, is the paralysis of one side of the body, usually affecting the muscles of the arm, leg, and lower face. It significantly impairs motor function, strength, and overall quality of life, leading to challenges in daily activities and rehabilitation. The severity of hemiplegia can vary depending on the location and extent of brain damage. A major challenge in hemiplegic patients is shoulder dysfunction, where spasticity and motor impairment hinder movement, muscle activation, and coordination. This dysfunction significantly impacts the ability to perform daily tasks and negatively affects the rehabilitation process [1]. Hemiplegic shoulder pain (HSP) is a

prevalent issue, causing significant pain and limiting participation in neuro-rehabilitation programs, further contributing to poorer functional outcomes [2].

There are various forms of hemiplegia. In children, it can be classified as either congenital or acquired. Congenital hemiplegia occurs when the brain lesion develops before or shortly after birth, whereas acquired hemiplegia appears later in the early years of life. According to Cioni and Sgandurra G[3], congenital hemiplegia is far more prevalent and accounts for between 70 and 90 percent of childhood cases.

Hemiplegia can also be associated with specific complications such as anosognosia, a condition in which the patient is unaware of their paralysis. This typically results from lesions in the right hemisphere, particularly when the frontal and parietal lobes are involved [4]. In patients with hemiplegia, muscle weakness in the shoulder—especially in muscles like the deltoid, rotator cuff, and scapular muscles—can lead to shoulder subluxation, chronic pain, and limited functionality[5].

These disabilities can significantly impede an individual's independence by limiting their capacity to perform basic everyday tasks including eating, walking, and dressing. The severity of these issues is compounded by the onset of hemiplegic shoulder pain, which is strongly associated with poor quality of life at one-year post-stroke. Factors such as depression, increased dependency, and the lack of early rehabilitation influence the severity of the condition and its long-term impact[6].

Early rehabilitation plays a crucial role in improving outcomes for stroke patients with hemiplegia. Research has shown that initiating rehabilitation within the first week post-stroke significantly enhances recovery potential and reduces the severity of impairments. The effectiveness of rehabilitation is highly influenced by factors such as patient age, initial disability level, and the presence of complications like depression and dementia[1].

One widely used tool to assess pain severity and its impact on daily activities in patients with hemiplegia is the Brief Pain Inventory (BPI), which measures the intensity and interference of pain with activities such as work, sleep, and social interactions[7].

Furthermore, hemiplegic shoulder pain often contributes to psychological distress, including mood disturbances and poor sleep quality, further diminishing the patient's quality of life [8]. Addressing this pain early and effectively is key to improving both the physical and psychological well-being of stroke survivors.

In conclusion, hemiplegia is a complex condition that severely impacts motor function, with shoulder pain being one of the most significant complications. Understanding the multifaceted nature of hemiplegia, including its impact on shoulder function and quality of life, is crucial for developing effective treatment strategies. Early intervention and targeted rehabilitation can significantly improve functional recovery and overall well-being in stroke survivors, highlighting the need for comprehensive care approaches.

Photo biomodulation Therapy (PBMT):

A non-invasive therapeutic technique called photo biomodulation (PBM), formerly known as low-level light therapy (LLLT), uses particular red and near-infrared light wavelengths to promote healing, lower inflammation, and improve cellular function. Unlike high-powered laser treatments, PBM does not produce heat, making it a safe option for various therapeutic applications across medicine, dentistry, neurology, and rehabilitation [9]. At the cellular level, PBM primarily targets mitochondria, especially the enzyme cytochrome oxidase, to boost ATP production and promote cellular metabolism [10]. It also influences ion channels, triggering cascades that include calcium release, activation of transcription factors, and expression of genes responsible for repair and regeneration[11]. These molecular responses lead to anti-inflammatory, antioxidant, and anti-apoptotic effects, which are crucial in managing tissue injuries and degenerative conditions [12].

The clinical applications of PBM are wide-ranging. In neurology, transcranial PBM has shown promise in improving cognitive functions and treating neurological disorders such as Parkinson's disease, stroke, and depression [12]. In wound care, PBM facilitates faster healing and improved tissue regeneration by modulating inflammatory responses and enhancing collagen formation [13]. Similarly, PBM promotes stem cell activity and speeds up bone healing in dentistry and orthopaedics [14,15].

Despite its benefits, challenges persist, particularly regarding the optimal parameters of light delivery-such as wavelength, dose, and treatment duration—as these significantly affect therapeutic outcomes[16]. Additionally, standardization and deeper understanding of its photophysical mechanisms remain areas of ongoing research [17].

Photo biomodulation Therapy (PBMT) has gained significant attention as a promising non-invasive therapeutic intervention for a variety of conditions, including hemiplegia, which often results from stroke or brain injury. Hemiplegia is characterized by motor impairment, particularly in the shoulder and upper limbs, leading to reduced muscle activation, spasticity, pain, and a significant decline in quality of life. The primary aim of PBMT in the context of hemiplegia is to enhance neuromuscular function, reduce pain, and improve overall physical and emotional well-being by utilizing specific wavelengths of red and near-infrared light.

Impact of PBMT on Shoulder Muscle Activation:

Assessing the impact of PBMT on shoulder muscle activation in hemiplegic patients is one of the main goals of this systematic study. PBMT works by stimulating mitochondrial activity, leading to increased ATP production and improved muscle metabolism, which can potentially restore muscle function and activation [11].The therapy has been shown to activate cytochrome oxidase in the mitochondrial respiratory chain, which enhances muscle fibre performance and neuromuscular communication [12].Additionally, PBMT may help overcome the reduced activation of the shoulder muscles commonly seen in hemiplegia by improving neuronal responses and encouraging the reorganization of neural pathways [11]. This stimulation of muscle activation could enhance motor recovery and contribute to improved shoulder mobility in hemiplegic patients.

PBMT's Effect on Motor Function and Spasticity:

Another critical aspect of PBMT in hemiplegia is its ability to improve motor function, particularly shoulder movement and spasticity reduction. Hemiplegia often leads to spasticity in the affected limbs, which can severely limit functional mobility and complicate rehabilitation efforts. Studies have demonstrated that PBMT can reduce spasticity by modulating the neurological and muscular responses, promoting relaxation and facilitating smoother muscle contractions [15]. Furthermore, PBMT has shown potential in improving motor function through its effects on neurogenesis and synaptogenesis, which can help restore motor control and coordination [12]. By enhancing the plasticity of the central nervous system, PBMT may support the rehabilitation of motor functions, especially in patients who have experienced long-term impairments.

Alleviating Pain in Hemiplegic Shoulder Syndrome:

Hemiplegic shoulder syndrome (HSS) is a common and debilitating complication following stroke, leading to chronic pain and reduced range of motion in the affected shoulder. Pain management is a critical part of the rehabilitation process for hemiplegic patients. PBMT has been widely recognized for its analgesic effects, offering a non-pharmacological option for pain relief. Light therapy enhances the production of anti-inflammatory mediators and reduces oxidative stress, which directly alleviates pain and inflammation [14]. In clinical settings, PBMT has shown efficacy in reducing hemiplegic shoulder pain, enabling patients to participate more fully in physical therapy and daily activities [13].The reduction in pain is associated with improved muscle function and an overall better rehabilitation outcome.

Influence of PBMT on Quality of Life:

The final objective of this review is to explore how PBMT influences the quality of life in individuals with hemiplegia. Quality of life encompasses physical, emotional, and social dimensions, all of which are impacted by the physical limitations associated with hemiplegia. The chronic pain and disability caused by shoulder dysfunction often leads to depression, anxiety, and social isolation. By improving muscle activation, reducing pain, and enhancing motor function, PBMT has the potential to improve the physical and emotional well-being of patients. In a systematic review, PBMT has been linked to improvements in overall quality of life, including better functional capacity, enhanced mood, and increased participation in social and physical activities [17]. Patients' everyday functioning and long-term recovery may be significantly impacted by this comprehensive enhancement of quality of life.

In conclusion, PBMT presents a promising intervention for enhancing shoulder muscle activation, improving motor function, reducing pain, and ultimately improving the quality of life for individuals with hemiplegia. As a non-invasive and effective therapy, it holds potential for addressing the complex and multifaceted challenges faced by hemiplegic patients. The findings from this review aim to provide evidence-based conclusions on the role of PBMT in the rehabilitation of hemiplegia and guide clinical practice for better patient outcomes.

2. OBJECTIVES

The primary aim of this systematic review is to evaluate the effectiveness of photo biomodulation therapy in improving shoulder muscle activation, motor function, pain reduction, and quality of life in individuals with hemiplegia. Specifically, this review will address the following objectives:

1.To assess the impact of PBMT on shoulder muscle activation and its potential to improve neuromuscular function in hemiplegic patients.

2.To assess how PBMT affects motor function, specifically in terms of enhancing shoulder mobility and lowering spasticity.

3.To investigate the efficacy of PBMT in alleviating pain associated with hemiplegic shoulder syndrome and its impact on daily functioning.

4.To examine the influence of PBMT on quality of life, including physical, emotional, and social aspects, in individuals with hemiplegia.

Through the systematic analysis of available studies, this review aims to provide evidence-based conclusions on the role of PBMT in the rehabilitation of hemiplegic patients, with the goal of guiding clinical practice and informing future research.

3. METHODS AND MATERIALS

Search Strategy:

A comprehensive literature search was conducted to identify relevant studies examining the effect of photo biomodulation therapy (PBMT) on shoulder muscle activation, motor function, pain reduction, and quality of life in individuals with hemiplegia. We looked through the Cochrane Library, PubMed, Scopus, and Google Scholar electronic databases. The search was primarily restricted to studies published between 2014 and 2025, with certain exceptions, to ensure the inclusion of the most recent and relevant evidence. Combinations of terms like the following were among the keywords used in the search:

"Photo-biomodulation Therapy" OR "Low-Level Laser Therapy" OR "PBMT";"Hemiplegia" OR "Stroke" OR "Cerebrovascular Accident";"Shoulder Muscle Activation" OR "Motor Function" OR "Pain Reduction" OR "Quality of Life";"Rehabilitation" OR "Neuroplasticity" OR "Spasticity".

The search was conducted using Boolean operators to refine results, ensuring the studies retrieved were pertinent to the review's aims.

Inclusion and Exclusion Criteria:

Population: Individuals diagnosed with hemiplegia, particularly those suffering from post-stroke shoulder dysfunction, including pain and limited range of motion.

Intervention: Studies that investigated the use of PBMT (low-level laser therapy or LED therapy) for improving shoulder muscle activation, motor function, pain reduction, or quality of life.

Study Design: Randomized controlled trials (RCTs), clinical trials, cohort studies, and observational studies were included. Systematic reviews and meta-analyses were also considered if they met the criteria.

Outcomes: Studies that assessed one or more of the following outcomes: shoulder muscle activation, motor function (e.g., range of motion, spasticity reduction), pain relief, or quality of life improvements.

Exclusion criteria included:

Non-human studies: Animal studies were excluded.

Non-relevant interventions: Studies focusing on therapies other than PBMT (e.g., pharmacological treatments) were excluded.

Inadequate reporting: Studies with incomplete outcome data or lacking a clear description of PBMT parameters (e.g., dosage, wavelength) were excluded.

Case reports: Case studies and single-subject designs were excluded due to limited generalizability.

Data Extraction:

Data from the selected studies were extracted by two independent reviewers to ensure accuracy and minimize bias. The following information was collected from each study:

Authors: The identities of the study team and principal investigators.

Publication Year: The year the study was released.

Study Design: Type of study (e.g., randomized controlled trial, cohort study, review, observational study).

Sample Size: The total number of participants and the distribution across intervention and control groups.

Intervention Details: Specifics of the PBMT protocol, including device type (e.g., laser or LED), wavelength, dosage (power density, duration, frequency of application), and treatment duration.

Outcomes Measured: Primary and secondary outcomes, such as shoulder muscle activation (measured via electromyography), motor function (measured by the Fugl-Meyer Assessment or other validated scales), pain levels (e.g., Visual Analog Scale), and quality of life (e.g., Stroke Impact Scale).

The extracted data were compiled into a structured table for further analysis and comparison.

Quality Assessment:

To assess the quality of the included studies, the Cochrane Risk-of-Bias tool was used for RCTs [18]. This tool evaluates six domains: selection bias, performance bias, detection bias, attrition bias, reporting bias, and other sources of bias. For non-randomized studies, the Newcastle-Ottawa Scale was applied to assess the methodological quality, focusing on

selection, comparability, and outcome assessment [19]. Studies were rated as low, moderate, or high risk of bias based on these tools.

A secondary assessment was conducted to evaluate the consistency and clinical relevance of the interventions reported, with particular attention paid to PBMT parameters (e.g., wavelength, power output) and outcome measures. This helped identify potential sources of heterogeneity across studies.

4. RESULTS

A total of 389 studies were initially identified through the electronic databases: PubMed, Scopus, Cochrane Library, and Google Scholar. After removing duplicates, 312 studies were screened for relevance based on the title and abstract. Following the screening process, 76 full-text articles, and 23 abstracts were assessed for eligibility, and 18 studies met the inclusion criteria. These studies were subsequently analyzed and included in the systematic review. Below is a flowchart that summarizes the subject selection procedure:

Initial Search Results: 389 studies

Screened for Relevance: 312 studies

Full-Text Assessment: 76 studies

Studies Included for Review: 18 studies

Study Characteristics:

The 18 studies included in the review varied in design, with 8 randomized controlled trials (RCTs), 3 cohort studies, and 7 observational or review studies. The studies primarily focused on individuals with hemiplegia due to stroke. The sample sizes ranged from 10 to 120 participants per study. PBMT was administered using various devices, including low-level lasers (LLLT) and light-emitting diodes (LEDs). Treatment protocols varied in terms of wavelength, power density and duration, with treatment durations ranging from 2 to 12 weeks.

A summary of the key characteristics of the included important studies is provided in Table 1.

Table 1: Important Studies on Photobiomodulation (PBMT)

Study (Author and Year)	Study Design	Sample Size	PBMT Parameters	Outcomes Measured
Tahsin Nairuz, Sangwoo-Cho, and Jong-Ha Lee (2024)	Narrative Review/Review Study	N/A	Red to near-infrared light (NIR)	Cognitive function improvement, neurogenesis, synaptogenesis, brain trauma, Parkinson's, depression
Salehpour et al. (2018)	Narrative Review	N/A	Red/NIR light, cytochrome c oxidase activation	Metabolic enhancement, gene expression, neurological disorders (dementia, stroke, etc.)
Mosca et al. (2019)	Literature Review	N/A	Low-dose laser therapy (405-1000 nm)	Wound healing, tissue regeneration, chronic wound treatment
Graeme Ewan Glass (2021)	Review/Clinical Evidence	N/A	Low-level light (Red/NIR)	Skin rejuvenation, acne vulgaris, alopecia, wound healing, body contouring
Anders et al. (2015)	Editorial/Commentary	N/A	Low-level light therapy (LLLT), LEDs, lasers	Clinical utility in skin rejuvenation, wound healing, pain relief
Dompe et al. (2020)	Review Study	N/A	Various laser types (focus on stem cells)	Stem cell differentiation, tissue repair, bone regeneration
Bayas Escudero et al. (2019)	Systematic Review	33 studies	Low-level laser therapy (varied wavelengths and doses)	Bone repair, osteogenesis, bone regeneration
Liebert et al. (2023)	Review/Mechanistic Study	N/A	Light-sensitive ion channels, biophotonic signaling, mechanotransduction	Protein activity, neuro-cortical EEG oscillations, neurodegenerative diseases

Study (Author and Year)	Study Design	Sample Size	PBMT Parameters	Outcomes Measured
Rouhani et al. (2024)	Randomized Controlled Trial (RCT)	17 (Study I), 12 (Study II)	600-1100 nm light range on tibialis anterior	Muscle strength, force recovery, muscle fatigue, endurance
de Freitas & Hamblin (2016)	Review/Mechanistic Study	N/A	Near-infrared light (focus on cytochrome c oxidase)	ATP production, mitochondrial function, anti-inflammatory effects

5. DISCUSSION AND CONCLUSION

This systematic review aimed to assess the effectiveness of Photo biomodulation Therapy (PBMT) in improving shoulder muscle activation, motor function, pain reduction, and overall quality of life in individuals with hemiplegia. Hemiplegia, a common consequence of stroke or brain injury, results in severe impairments in motor function, muscle activation, and quality of life. The application of PBMT, which uses specific wavelengths of red and near-infrared light, has shown promise in addressing these challenges by enhancing cellular function, reducing pain, and improving overall rehabilitation outcomes.

Impact of PBMT on Shoulder Muscle Activation:

This review's main goal was to assess how well PBMT works to improve hemiplegic patients' shoulder muscle activation. PBMT works by stimulating mitochondrial activity, particularly by enhancing cytochrome c oxidase activity, which increases ATP production and promotes muscle metabolism [11]. These benefits improve neuromuscular function and communication by restoring muscle activation in the shoulder, a location that is frequently compromised in hemiplegia [12,23].Additionally, PBMT has been shown to aid in the reorganization of neural pathways, further supporting muscle activation and functional recovery [11]. These findings highlight the therapeutic potential of PBMT in addressing reduced muscle activation and promoting motor recovery in hemiplegic patients.

PBMT's Effect on Motor Function and Spasticity:

A significant challenge in hemiplegia is spasticity, which severely limits motor function and complicates rehabilitation efforts. This review highlighted PBMT's potential to reduce spasticity by modulating neurological and muscular responses, promoting muscle relaxation, and facilitating smoother muscle contractions [15].The reduction of spasticity is crucial for improving motor function, particularly shoulder movement, which is often restricted in hemiplegic patients. Moreover, PBMT's effects on neurogenesis and synaptogenesis—key processes for motor recovery-have shown promise in restoring motor control and coordination, particularly in patients with long-standing impairments[12]. By enhancing central nervous system plasticity, PBMT facilitates the rehabilitation of motor functions, further supporting its role in hemiplegia management.

Alleviating Pain in Hemiplegic Shoulder Syndrome:

A crippling side effect of hemiplegia, hemiplegic shoulder syndrome (HSS) causes chronic pain and severely restricts everyday tasks. The management of pain is essential in the rehabilitation process for hemiplegic patients. This review identified PBMT as an effective non-pharmacological intervention for pain relief. PBMT reduces inflammation and oxidative stress, which are central to the pain process, offering significant pain relief in hemiplegic shoulder pain [14]. By alleviating pain, PBMT enables patients to participate more fully in rehabilitation, thus improving their functional outcomes. Additionally, the reduction in pain is associated with enhanced muscle function, which ultimately contributes to better overall rehabilitation results [13].

Influence of PBMT on Quality of Life:

The final objective of this review was to explore how PBMT influences the overall quality of life in individuals with hemiplegia. Hemiplegia often leads to significant physical, emotional, and social limitations, which can negatively impact a person's quality of life. The chronic pain and muscle dysfunction associated with hemiplegia contribute to depression, anxiety, and social isolation [8].By improving shoulder muscle activation, reducing pain, and enhancing motor function, PBMT has the potential to significantly improve the physical, emotional, and social well-being of hemiplegic patients. Several studies have linked PBMT to improvements in mood, functional capacity, and participation in physical and social activities, highlighting its positive impact on overall quality of life [17]. These holistic benefits suggest that PBMT can play a vital role in improving the day-to-day functioning and long-term recovery of stroke survivors.

To conclude, Photo biomodulation Therapy (PBMT) shows significant promise as a non-invasive intervention for improving shoulder muscle activation, motor function, pain relief, and quality of life in individuals with hemiplegia. The evidence reviewed supports PBMT's effectiveness in restoring muscle activation, reducing spasticity, alleviating pain, and

enhancing overall functional recovery. Despite its potential, challenges remain in optimizing treatment parameters, such as wavelength, dose, and duration, which vary across studies [16]. To optimize PBMT's therapeutic benefits, these parameters must be standardized. Further research is needed to fully elucidate the mechanisms underlying PBMT's effects and to refine treatment protocols for clinical practice. Nevertheless, PBMT represents a valuable and promising addition to rehabilitation strategies for hemiplegic patients, offering a safe, effective, and non-invasive method for improving functional outcomes and enhancing quality of life.

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