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# Photobiomodulation: A Review

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## ABSTRACT

Photobiomodulation (PBM), is a low-level light therapy at wavelengths between 400 to 1100 nanometers. It includes the green section of the visible light spectrum (495 to 570 nm) that has attracted substantial attention for the management of conditions such as pain. The use of light exposure for medical treatment or phototherapy has a long history. Niels Ryberg Finsen, a Nobel laureate, reported using ultraviolet light to cure lupus vulgaris and red-light to treat smallpox in the late 1800s [1]. Using phototherapy in the form of light has recently received more attention. Various wavelengths of light have treated a diverse spectrum of ailments including psoriasis, seasonal affective disorder, neonatal jaundice, circadian rhythm disruptions and acne [2]. The applications of phototherapy are broad, ranging from pain control to promoting the healing of wounds, tendon injuries, nerve injuries and arthritis. A comprehensive review of the literature is presented in this review article.

## Introduction

Photobiomodulation (PBM), also known as low-level light (laser) therapy (LLLT), involves the use of light for the treatment of medical disorders. LLLT uses either coherent light sources such as laser light that have a single frequency or non-coherent light sources that have random frequency or wavelength such as light-emitting diodes (LED) [3]. Sometimes, a combination of both is used. The introduction of LED devices has reduced many of the worries that were associated with lasers, such as equipment and operational cost, concerns for safety and the need for trained operators of laser equipment. [3]. Furthermore, LED light sources, in addition to providing equally good results, can be used at home easily. They can irradiate a large area of tissue– at one time; the devices are portable and wearable, and at a much lower cost [4]. The precise mechanisms of action that explain the beneficial effects of LLLT are not yet well-described. However, it is believed that LLLT has a wide range of effects at the molecular, cellular, and tissue levels, and within the cell, there is abundant evidence to suggest that LLLT acts on the mitochondria [5, 6]. In addition, its specific modes of action may vary among different therapeutic purposes [6]. The main medical uses of LLLT are for the reduction of pain and inflammation, to promote tissue repair, to augment regeneration of different tissues and nerves, and prevent tissue damage in various situations where it is likely to occur [7]. Photobiomodulation is a safe and effective treatment for a wide variety of conditions including progressive neurodegenerative disease [8]. Evidence also suggests that green light exposure improved pain and decreased narcotic analgesic use in fibromyalgia patients [9]. Because of the low power light source, there is no temperature increase in the treated tissues and thus no structural changes or damage to the tissue [2]. In addition, photobiomodulation is non-invasive in nature.

Treating chronic pain to improve the quality of life of persons living with pain is a public health imperative [10]. Based on previous research it is now recognized that exposure to green light may be beneficial for a variety of health-related conditions, including pain relief. The studies mentioned earlier have differed in the source of light, namely LED versus laser. They have also differed in the duration of green light exposure ranging from a few minutes to several hours and the medium of light delivery such as green room, green glasses, or green headset. The previous research has also varied in the causes of pain ranging from pathological conditions such as migraine headaches, induced pain during dental procedures or by heat exposure in animal experiments.

## Methods

Articles discussed in this review were selected following a Pubmed search using keywords photobiomodulation; green light; chronic pain; nociception; fibromyalgia; low level light therapy. Original research articles or review articles in peer-reviewed journals discussing photobiomodulation and low level green light therapy were selected for further review. These studies evaluated patients, usually adults, with prolonged and/or daily exposure to green light for chronic pain and green light exposure for short duration in the setting of acute pain.

## Discussion

In order to prevent bodily harm, noxious stimuli, such as tissue injury or temperature extremes, are immediately detected by specialized nerve cells which activate protective pathways in both the central and peripheral nervous systems in a process called nociception. These pathways trigger a string of reactions in response to the painful stimulus, which then converts to a molecular signal as a defense response. This stimulation of sensory neurons, referred to as nociceptors, generates a signal that follows a network of nerve fibers to the brain via the spinal cord [11]. Nociception subsequently initiates a range of physiological and pathological reactions called inflammation and protects the body from further injury [12].

Pain is one of the components of inflammation. It manifests as subjective, unpleasant sensations such as tingling, stinging, burning, or aching and varies greatly from person to person. The sensation of pain can range from almost imperceptible to severe and debilitating. Pain is a defense mechanism and prompts the organism to retract from situations that may cause injury [13]. Pain can be transient, lasting only during exposure to the noxious stimulus or can be more persistent until the underlying injury is healed. Some conditions that induce pain such as cancer, rheumatoid arthritis, idiopathic pain, and peripheral neuropathy may be chronic that last for years [14]. During 2021, it was reported that an estimated 20.9% of adults or 51.6 million individuals in the US experienced chronic pain, and 6.9% or 17.1 million individuals experienced high-impact chronic pain defined as chronic pain that causes substantial restriction to daily activities [10].

Chronic pain can drastically impact a person's quality of life by negatively affecting their physical and emotional well-being. Management of chronic pain is complex and often requires a multi-faceted approach which may include psychological care, trigger point injection treatment, radio frequency ablation to block pain signals, and sometimes surgery. However, the primary treatment for chronic pain continues to be medication-based management. Examples of this include the use of non-steroidal and narcotic analgesics, both of which have major side effects, including gastrointestinal symptoms, kidney injury, and drug dependence [15]. In 2018, about 47,000 people in the United States were deceased from an opioid overdose, and 2 million met criteria for a diagnosis of opioid use disorder in 2017 [16]. It is estimated that the economic cost of the opioid epidemic in the United States was $1,021 billion in 2017 and the cost of opioid use disorder estimated to be $471 billion. The cost of fatal opioid overdose was estimated at $550 billion [16].

Because of the risk of drug dependency and its associated costs, there has been an increase in research on non-medication treatment approaches for pain relief therapy and management. Non-pharmacological treatment approaches commonly used include acupuncture, behavioral therapy including stress reduction, spirituality, music therapy, physical interventions such as massage and heat and cold therapy [17]. The use of light as a treatment approach for simple pain to complex pain syndromes has become particularly attractive. It is a low-cost, nonpharmacologic alternative with few side effects [2].

Traditionally, photobiomodulation describes application of light at wavelengths between 400 to 1100 nanometers for treatment of various medical conditions. Studies more recently have shown that narrow wavelengths within the visible spectrum, such as blue and green light could prove beneficial [18]. However, the use of blue light in the range of 400 to 500 nanometers is surrounded by significant controversy related to the illdefined margin between the safe blue light and the potentially damaging ultraviolet light [18]. Lately, the green section of the visible spectrum of light (495 to 570 nm) has gathered considerable interest due to its benefits in patients with chronic pain due to migraine headaches and fibromyalgia [9], pregnant women with anxiety and opioid use disorder [19], and patients undergoing intravenous cannulation prior to dental treatment [20].

The results from multiple studies indicate that green light therapy decreases the intensity of pain. Noseda et. al., [21] demonstrated that even transient exposure (2.5 minutes) to green light (with use of Color-Dome) decreased intensity of migraine headaches in 20% of patients. In a cohort of patients with fibromyalgia, Nelli et. al., [9] found that exposure to green light using green eyeglasses for four hours a day decreased the need for opioids by at least 10%. A study by Martin et. al., [22] showed that visual green light exposure using two-meter LED strips in patients with episodic migraine and chronic migraine reduced the number of headache days per month by an average of about 60%.

Ibrahim et. al.,[23] studied the impact of LEDs in the visible spectrum on acute sensory threshold in naive rats placed on a heat source. Rats were exposed for eight hours to white, green, and blue LED light, using LED flex strips for five days. Rats displayed a time-dependent increase in paw withdrawal latency which is defined as time from the onset of the heat stimulus to the withdrawal of the paw. The paw withdrawal latency was significantly higher in rats exposed to green LED light than rats exposed to ambient room light and also higher than in rats exposed to white and blue lights; therefore, suggesting an antinociceptive effect of green light.

## Conclusion

In conclusion, the literature reviewed here discusses the effects of green light exposure on acute and chronic pain. It is associated with improvement in chronic pain and in some instances decreased need for opioids. It is exciting to note that even brief green light exposure appears to be effective in reducing pain and may have a beneficial effect during medical procedures such as during dental treatment. Green light therapy from LED light sources appears to be equally effective as laser light with added advantage of safety, ease of use at home, and portability at a much lower cost.

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