Red light therapy

-more precisely termed **photobiomodulation (PBM)** — uses red (620–700 nm) and near-infrared (700–1100 nm) light at low, non-thermal doses. The evidence base spans several clinical domains, with the strongest data in **oral mucositis prevention**, **musculoskeletal pain**, **muscle recovery**, **skin rejuvenation**, and emerging **neurological applications**.

Mechanism of Action

PBM works primarily through absorption by **cytochrome c oxidase** in mitochondria, displacing inhibitory nitric oxide and restoring ATP production, reducing oxidative stress, and activating downstream signaling cascades (ROS, cAMP, Ca^{2+}) that promote cell proliferation, migration, anti-inflammatory signaling, and tissue repair.

Oral Mucositis Prevention — The Strongest Evidence

This is the most guideline-supported application of PBM, now recommended by MASCC/ISOO:

- A meta-analysis of 30 RCTs (n = 1,748) found PBM **reduced severe oral mucositis risk by 54%** (RR 0.46, 95% CI 0.29–0.71) and **severe oral pain by 65%** (RR 0.35, 95% CI 0.23–0.53) in head and neck cancer patients.
- A 2026 sham-controlled RCT (n = 85) confirmed that daily intraoral LED-based PBM **reduced severe OM from 57% to 37%** during IMRT ($p = 0.046$), with fewer feeding tube placements and better taste preservation.
- In a clinical cohort (n = 132), severe mucositis **dropped from 57% to 2%** over 8 weeks with PBM, with opioid reliance falling from 85% to 57% ($p < 0.01$).

Musculoskeletal Pain

- A meta-analysis of 22 RCTs (n = 1,063) in **knee osteoarthritis** found PBM at recommended doses reduced pain by **~32 mm on VAS** at 2–4 weeks post-treatment (95% CI 18.18–45.56), with significant disability reduction and no adverse events.

- A more recent meta-analysis (10 RCTs, n = 542) confirmed a **moderate effect on pain at rest** (−0.7 on VAS, 95% CI −1.1 to −0.2), though evidence certainty was very low.
- In a sham-controlled RCT of combat soldiers with anterior knee pain, PBM added to physiotherapy produced additional pain reduction, with PBM previously shown to be **not inferior or superior to NSAIDs** for musculoskeletal pain relief.
- In **rheumatoid arthritis and ankylosing spondylitis**, LED PBM has shown analgesic and anti-inflammatory effects in preclinical models, decreasing edema, hyperalgesia, and proinflammatory cytokines, though clinical trials remain limited.

Muscle Recovery

- A meta-analysis of 21 RCTs found near-infrared preirradiation **preserved peak torque** (SMD 1.33), **reduced creatine kinase by ~160 U/L**, decreased blood lactate, and **reduced DOMS** (all $p < 0.001$).
- A head-to-head comparison meta-analysis (4 RCTs) found PBM **superior to cryotherapy** for muscle strength recovery (SMD 1.73, $p < 0.00001$), DOMS reduction (−25.69%, $p < 0.00001$), and muscle damage biomarkers (SMD −1.48, $p < 0.001$).
- In a sham-controlled RCT, PBM alone achieved **complete recovery to baseline MVC by 24 hours** after eccentric exercise, while cryotherapy and placebo did not ($p < 0.05$). Notably, applying cryotherapy after PBM **attenuated** PBM's benefits.

Skin Rejuvenation

- A placebo-controlled RCT (n = 76) showed red LED, NIR, or combined red/NIR treatment for 4 weeks improved wrinkles by **26%, 33%, and 36%**, respectively.
- A meta-analysis confirmed a **large effect size for wrinkle reduction** (SMD = 3.54, $I^2 = 33\%$) with LED therapy, driven by increased collagen synthesis and MMP downregulation.
- Both LED and laser devices upregulate **collagen I expression** and downregulate **MMP-1**, with effects persisting at least 21 days after a single treatment session.

Neurological Applications — Emerging

- In **traumatic brain injury**, a meta-analysis of 17 preclinical studies found PBM significantly improved neurological severity scores and reduced lesion size, with optimal wavelengths at 665 nm and 810 nm.
- A 2025 sham-controlled RCT (n = 17) in mild TBI showed transcranial PBM **significantly improved cognitive efficiency, working memory, sleep quality, and reduced PTSD symptoms** compared to sham, with improvements reaching minimal clinically important difference thresholds.
- A scoping review identified clinical evidence for tPBM across stroke, Alzheimer's disease, Parkinson's disease, depression, anxiety, insomnia, and autism spectrum disorder, though most studies remain small.

Wound Healing

Both LED and laser PBM accelerate tissue repair through enhanced cell proliferation, collagen deposition, angiogenesis, and anti-inflammatory signaling. Clinical trials in diabetic foot ulcers have shown complete healing with both 620 nm and 904 nm LED protocols.

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