

EVIDENCE DOSSIER

Red and near-infrared photobiomodulation

The research behind the claims — what it supports, what it does not
copy sourced sentence by sentence.



Rinnovare Labs Inc.™ Report

CORPUS

1,578 PubMed records retrieved across 33 structured queries; 1,131 confirmed red/near
photobiomodulation; 654 human clinical studies, of which 103 meta-analyses, 104 syste
and 4 guideline documents.

COMPILED

11 September 2026

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PART I

Evidence review

What the literature reports, by indication, with certainty tiers.

Scope. Every health-benefit area implied by the eight wavelengths on the Rinnovare Labs red-light page (610 / 630 / 660 / 810 / 830 / 850 / 940 / 1060 nm), with the anti-ageing, beauty and skin-health literature treated in most depth. Compiled 11 September 2026.

How this was built. 33 structured PubMed queries (E-utilities) across mechanism, dermatology, wound repair, musculoskeletal, sports, oncology-supportive care, neurology, ophthalmology, dosimetry and safety. 1,578 unique records retrieved; 1,131 classified as genuinely red/near-infrared photobiomodulation (PBM) after excluding ablative/fractional lasers, IPL, Q-switched and picosecond devices, and drug-based photodynamic therapy; 654 of those are human clinical studies (103 meta-analyses, 104 systematic reviews, 4 guideline/consensus documents, 443 trials). Full record-level data is in `pbm_evidence_full.csv`; the quantitative subset is in `pbm_key_evidence.csv`.

Certainty tiers used below

TIER	MEANING
A	Pooled effect from meta-analysis of RCTs, graded moderate certainty, or a formal clinical-practice-guideline recommendation
B	Multiple concordant RCTs and at least one positive meta-analysis, but low certainty (heterogeneity, small-study effects, or no pooled estimate exists)
C	Mixed, sparse, or contradicted evidence; or effects demonstrated only in vitro / in animals

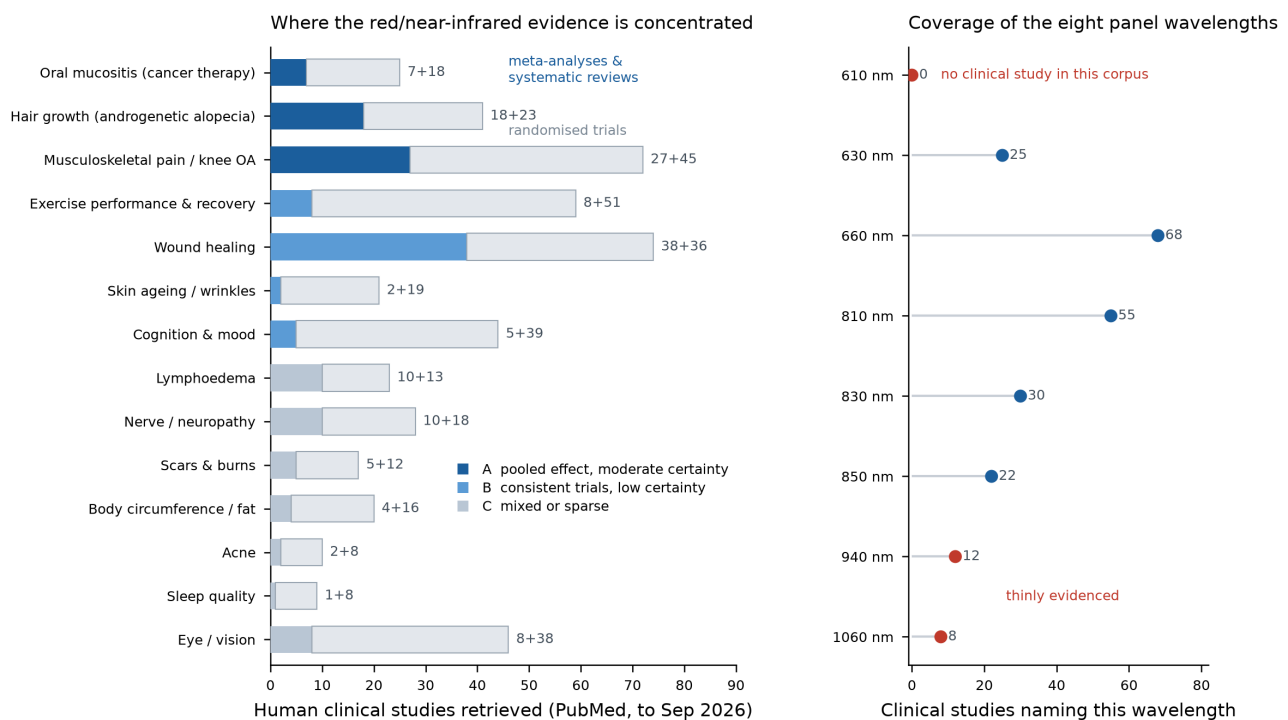


Figure 1. Left: human clinical studies retrieved per indication, split into meta-analyses and systematic reviews (coloured by certainty tier) versus randomised trials. Right: clinical studies naming each of the eight panel wavelengths; red marks the thinly evidenced bands. Counts are lower bounds, since many trials report only “red” or “infrared”.

1. Bottom line

CLAIM AREA	TIER	BEST SINGLE CITATION
Prevention of oral mucositis in cancer therapy	A	MASCC/ISOO guideline, Zadik 2019 (PMID 31286228)
Hair density in androgenetic alopecia	A	Umbrella review, Son 2025 (PMID 40770824)
Knee osteoarthritis pain and disability	A	Son 2025; network MA Lan 2025 (PMID 40192971)
Fibromyalgia fatigue; burning-mouth-syndrome pain	A	Son 2025 (PMID 40770824)
Cognitive function in mild impairment / Alzheimer's	A-B	Son 2025; Bayesian NMA Zhao 2026 (PMID 41966601)
Facial wrinkles, skin roughness, dermal collagen density	B	Wunsch 2014 (PMID 24286286); Mota 2023 (PMID 36780572)
Muscle recovery and performance (local irradiation)	B	Ferlito 2022 (PMID 34669081); Nampo 2016 (PMID 27272746)
Surgical/acute wound healing	B	Liu 2026 (PMID 41605843)
Depressive symptoms	B	Seok 2026 (PMID 41101469)
Breast-cancer-related lymphoedema	B-C	Wahid 2024 (PMID 39611899) vs Wang 2022 (PMID 34779937)
Sleep quality	C	Vital de Azevedo 2026 (PMID 42322437)
Diabetic peripheral neuropathy	C	Korada 2023 (PMID 37622461)
Body circumference / localised fat	C	Jiménez-García 2025 (PMID 40186373)
Chronic venous leg ulcers	C (negative)	Rasul 2026 (PMID 41889013)
Whole-body PBM for exercise recovery	C (negative)	Álvarez-Martínez 2025 (PMID 39883205)
Autoimmune thyroiditis	C	Berisha-Muharremi 2026 (PMID 41977196)

Two structural facts worth stating up front, because they shape everything below. First, **the strongest evidence for red/NIR light is not cosmetic** — it is oral mucositis prevention, hair density and knee osteoarthritis. Second, **the cosmetic skin literature is real but shallow**: 21 human clinical studies in this corpus, of which only two are systematic reviews (one on cellular senescence, one on oncologic safety) and neither pools wrinkle or elasticity outcomes.

2. Mechanism

The page's three-step account (absorb → convert → repair) is the standard model and is accurately stated. The supporting detail:

- **Primary chromophore.** Cytochrome c oxidase (Complex IV) absorbs in the 600–900 nm window; photodissociation of inhibitory nitric oxide from the binuclear centre increases electron transport, membrane potential and ATP synthesis, and releases NO locally — which is also the basis of the vasodilation/microcirculation claim (Chung 2012, PMID 22045511; Barolet 2023, PMID 37074309).
- **Secondary signalling.** A brief, non-damaging ROS burst activates redox-sensitive transcription factors (NF-κB, Nrf2, AP-1), driving downstream proliferation, migration and matrix-remodelling programmes (Barolet 2023, PMID 37074309).

- **Non-mitochondrial chromophores.** Beyond cytochrome c oxidase, opsins and cryptochromes are described in skin as additional photoreceptors mediating LED effects on mitochondrial function and immune responses (Guo 2025, PMID 40751922). The review does not resolve which opsin subtypes are involved, and the relative contribution of these receptors versus the mitochondrial pathway is unquantified.
- **Direct human skin evidence.** RNA-seq of human dermal fibroblasts after red-light phototherapy shows coordinated regulation of extracellular-matrix, proliferation and oxygen-response pathways — the transcriptional link between the photon and the collagen claim (Austin 2021, PMID 33795767).
- **Vascular function.** Combined red + NIR LED outperformed either spectrum alone on vascular relaxation in vitro, via increased NO bioavailability and reduced superoxide (Junkoski 2025, PMID 41402628). This is the closest published support for a multi-wavelength design — but it is an in-vitro vessel study, not a clinical one.

Important qualification. The mechanism above is well supported at 630–850 nm. At 940 nm and 1060 nm, cytochrome c oxidase absorption is minimal; the proposed mechanism shifts to water-mediated effects on membrane and mitochondrial dynamics, which is a different and much less established pathway. The page's statement that "it is the same mechanism across every wavelength" is the weakest scientific sentence on it.

3. Skin ageing, wrinkles and collagen — the anti-ageing core

What is established (Tier B). Red and red+NIR LED, delivered at non-thermal doses over 8–12 weeks, produces statistically significant improvement in wrinkle depth/volume, skin roughness and patient-rated skin appearance versus untreated or sham control, in randomised and controlled trials. Ultrasound and histology corroborate an increase in dermal collagen density.

Key trials, in descending order of evidential weight:

1. **Wunsch & Matuschka 2014** (PMID 24286286) — 136 volunteers, prospective randomised controlled, 30 sessions, 611–650 nm or 570–850 nm polychromatic, ~9 J/cm² in the red band. Blinded photographic evaluation, ultrasonographic collagen density, digital profilometry. Significant improvement in complexion, profilometric roughness and **intra-dermal collagen density** versus control. Notably, the broadband polychromatic spectrum showed **no advantage over red-only** — directly relevant to any "more wavelengths is better" argument.
2. **Park 2025** (PMID 39960921) — multi-centre, randomised, double-blind, **sham-device-controlled**, 60 Asian participants, home-use 630 nm LED + 850 nm IRED mask for crow's feet. Independent-rater improvement rate 86.2% (full analysis set) versus sham. This is the most methodologically clean consumer-device trial in the set.
3. **Mota 2023** (PMID 36780572) — RCT, periocular wrinkles: **31.6% wrinkle-volume reduction with red PBM** and 29.9% with amber; the page's "30%" figure is accurate.
4. **Bragato 2025** (PMID 40167796) — randomised, sham-controlled, double-blind; significant reduction in glabellar and right periorbital wrinkle length versus control ($p < 0.001$); FACE-Q satisfaction 79.6% and 73.4% versus control ($p = 0.001$ / $p = 0.034$). Tested **application frequency** — relevant to the page's "regular beats long" guidance.
5. **Park 2025** (PMID 39319750) — multicentre randomised double-blind home-use LED neck device; significantly higher proportion with improved neck-wrinkle score at weeks 8, 12 and 16.
6. **Goldberg 2006** (PMID 16989189) — 36 subjects, combined **633 nm + 830 nm**, 9 treatments over 5 weeks; significant profilometric wrinkle improvement, electron microscopy showing thicker collagen fibres. This is the closest published analogue to a red+NIR combination panel.

7. **Yi 2025** (PMID 41091280) — 570/590 nm yellow combined with red and infrared LED; significant reductions in global photodamage, wrinkle and brown-spot scores at 8 weeks.

What is not established. There is **no meta-analysis pooling wrinkle or elasticity outcomes** for red/NIR LED. Sample sizes are 30–136, follow-up rarely exceeds 12–16 weeks, outcome instruments differ between every trial, and blinding is impossible for the participant when the light is visible. Tier B is the honest ceiling here.

Two citation accuracy notes for the page: - **Weiss 2005** (PMID 15654716) is a **590 nm** (amber) LED array study at 0.1 J/cm², not a red or near-infrared study. It is a legitimate photomodulation paper but it does not support a red/NIR claim; if it stays on the list it should be labelled as amber-wavelength. - **Huang 2020** (PMID 32091415), which appears in searches for LED photoaging, is **LED-based photodynamic therapy** — it requires a topical photosensitiser drug and should not be cited as device-only evidence.

Oncologic safety of aesthetic PBM (useful, and rarely cited). A focused systematic review found that within established parameters, red and NIR light mainly enhances healthy-cell proliferation while mainly reducing or not affecting neoplastic cell proliferation and viability; PBM does not induce dysplastic change in healthy cells; and there are no clinical-trial data linking PBM with any significant adverse event including new or recurrent malignancy (Glass 2023, *Aesthetic Surgery Journal*, PMID 36722207).

4. Hair growth — the strongest cosmetic claim

This is the one beauty indication with Tier A evidence.

- **Umbrella review of meta-analyses of RCTs:** androgenetic alopecia hair density, **eSMD 1.32 (95% CI 1.00-1.63), moderate certainty** — one of only five outcomes across the entire PBM literature to reach moderate certainty (Son 2025, PMID 40770824).
- **Meta-analysis:** hair density versus placebo, **SMD 1.14 (0.51-1.78)** for regimens under 20 weeks and **SMD 1.44 (0.97-1.91)** beyond 20 weeks; heterogeneity high ($I^2 \approx 80-88\%$) (Perez 2025, *Dermatologic Surgery*, PMID 39404126).
- **As an add-on to minoxidil:** greater hair-density gain (MD 6.62, 95% CI 2.04-11.20) and mean hair diameter (MD 0.01 mm, 0.00-0.01), with higher satisfaction (RR 1.71, 1.23-2.38) than minoxidil alone (Mawu 2025, PMID 40826200).
- **Contradicting meta-analysis:** no significant difference in hair count (MD -0.04, 95% CI -1.22 to 1.14) or diameter between minoxidil + LLLT and minoxidil alone (Alosaimi 2025, PMID 39828269). Both exist; report both.

Effective wavelengths in these trials cluster at **650-680 nm**, with 660 nm the most common. The panel's 660 nm channel is squarely in the evidenced band.

5. Wound healing, scars and other dermatology

- **Surgical wounds (Tier B).** Multilevel random-effects meta-analysis: NIR significantly improved wound healing (SMD 0.78, 95% CI 0.46-1.09) and reduced postoperative pain (SMD 0.71, 0.24-1.17), with high heterogeneity (Liu 2026, PMID 41605843).
- **Chronic venous leg ulcers (Tier C, negative).** No significant reduction in ulcer area versus control (MD 3.77 cm², 95% CI -4.45 to 11.99; $I^2 = 96\%$) (Rasul 2026, PMID 41889013). An earlier plastic-surgery review reached the same conclusion.
- **Diabetic foot ulcers (Tier B-C).** An umbrella review of systematic reviews found PBM effective for healing across varied parameters, with 632 nm and 904 nm producing 63.7% and

56.8% area-reduction rates respectively and no significant difference between them (Miranda 2025, PMID 39982518).

- **Episiotomy (Tier C, negative for LLLT).** No improvement in pain (SMD -0.31 , 95% CI -0.72 to 0.11) or healing versus placebo, though broad-spectrum infrared may reduce pain (Regev-Sadeh 2026, PMID 41450164).
- **Acne (Tier C for red light alone).** Most positive phototherapy evidence in acne is blue light, ALA-photodynamic therapy or vascular lasers, not red LED monotherapy; current reviews characterise photo-based acne therapies as phenotype-specific rather than interchangeable (Ren 2026, PMID 41980895). Red light's role here is adjunctive and anti-inflammatory.
- **Radiation dermatitis.** PBM appears in the MASCC clinical practice guidelines for acute radiation dermatitis (Behroozian 2023, *Lancet Oncology*, PMID 36990615) — a genuine guideline-level appearance, in a clinical rather than cosmetic setting.

6. Muscle performance and recovery

- **Local pre-exercise irradiation (Tier B).** Versus cryotherapy and control, PBM improved muscle strength (SMD 1.73 , 95% CI 1.33 – 2.13), reduced delayed-onset muscle soreness (-25.69% , 95% CI -34.42 to -16.97) and lowered muscle-damage biomarkers (SMD -1.48) (Ferlito 2022, PMID 34669081).
- Earlier pooling found $+3.51$ repetitions (0.65 – 6.37), $+4.01$ s time to exhaustion (2.10 – 5.91), lower blood lactate and $+21.51$ Nm peak torque (Nampo 2016, PMID 27272746).
- **Whole-body PBM (Tier C, negative).** A 2025 systematic review of five studies (105 participants) concluded whole-body PBM **may improve sleep quality but shows no evidence of benefit for exercise recovery or performance** (Álvarez-Martínez 2025, PMID 39883205). This is important for a full-body panel: the positive muscle literature almost entirely uses targeted irradiation of the specific muscle group immediately before exercise, not whole-body exposure.

7. Pain and musculoskeletal

- **Knee osteoarthritis (Tier A).** Disability eSMD 0.65 (0.14 – 1.15), moderate certainty (Son 2025). In a network meta-analysis of physical modalities, LLLT ranked **highest for pain reduction** (VAS MD -3.32 ; WOMAC pain MD -3.74) and function (SUCRA 79.8) (Lan 2025, PMID 40192971). A wavelength-focused NMA found LLLT superior to sham for pain (SMD 0.96 , 0.31 – 1.61) but **not** for function or stiffness (Fan 2024, PMID 39367994).
- **Fibromyalgia (Tier A).** Fatigue eSMD 1.25 (0.63 – 1.87), moderate certainty (Son 2025).
- **Carpal tunnel syndrome (Tier B).** LLLT versus control SMD -1.45 (95% CI -2.16 to -0.74) in a network meta-analysis, though manual therapy ranked higher (Chen 2025, PMID 40315975).
- **Fractures (Tier B).** One-week pain MD -0.74 (-1.00 to -0.47) and 4-week grip strength MD 5.03 (4.29 – 5.78), with no significant long-term benefit (Wang 2026, PMID 42080480).

8. Oral mucositis — the strongest evidence base in the whole field

Included because it is the benchmark against which the rest of the field's evidence quality should be read.

- **MASCC/ISOO clinical practice guidelines** *recommend* PBM for prevention of oral mucositis and related pain in haematopoietic stem-cell transplantation, head-and-neck radiotherapy, and head-and-neck chemoradiotherapy, specifying 1–2 effective protocols per setting and instructing clinicians to adhere to **all** parameters of the chosen protocol (Zadik 2019, PMID 31286228).
- Paediatric guideline: severe-mucositis reduction **RR 0.40 (95% CI 0.27–0.60)** for PBM — a larger effect than cryotherapy (RR 0.49) or palifermin (RR 0.81) (Patel 2021, *European Journal of Cancer*, PMID 34252760).
- Network meta-analysis of 57 trials, 5,261 patients: low-level laser added to standard oral care ranked highest of all prophylactic options (SUCRA 95.8%) (Peng 2017, PMID 29224830).

The structural lesson: where the field has fixed the protocol and run large trials, the effect is large and reproducible. Where protocols vary freely — which describes most consumer use — pooled certainty collapses.

9. Brain, mood and sleep

- **Cognitive function (Tier A-B).** eSMD 0.49 (0.14–0.84), moderate certainty (Son 2025). In a Bayesian NMA in Alzheimer's disease, PBM ranked first of all pharmacological and non-pharmacological interventions (SMD 0.66, 95% CrI 0.29–1.02; SUCRA 87.3%) (Zhao 2026, PMID 41966601). A separate NMA found PBM superior to rTMS on ADAS-Cog (MD –5.24, 95% CrI –10.23 to –0.12) (Xu 2026, PMID 42487022).
- **Depression (Tier B).** Hedges' g –0.47 (95% CI –0.73 to –0.22) (Seok 2026, PMID 41101469). An earlier meta-analysis reported a much larger effect but rested on single-arm before-after studies and describes its own support as weak (Cho 2023, PMID 37651208).
- **Sleep (Tier C).** PSQI improved versus sham by MD –1.25 (95% CI –2.38 to –0.11), the authors noting the wide interval indicates limited precision (Vital de Azevedo 2026, PMID 42322437).

These are transcranial/targeted-protocol findings. They are not general-wellness panel claims, and the page is correct not to make them.

10. Other indications

INDICATION	FINDING	TIER
Breast-cancer-related lymphoedema	Arm-volume reduction MD 91.98 mL (95% CI 41.99–141.97) for LLLT (Wahid 2024, PMID 39611899); but an overview of systematic reviews judges the evidence uncertain and of poor quality (Wang 2022, PMID 34779937)	B–C
Diabetic peripheral neuropathy	Improvement in neuropathic pain, nerve conduction velocity and plantar pressure distribution across 8 studies (Korada 2023, PMID 37622461)	C
Body circumference / localised fat	Waist circumference –2.48 cm versus –0.635 cm in controls across 160 participants (Mustafa 2025, PMID 41423522); transabdominal PBM meta-analysis found significant changes in waist and hip circumference, insulin and triglycerides (Jiménez-García 2025, PMID 40186373)	C
Autoimmune thyroiditis	Reductions in thyroid autoantibodies, improved hormone indices, reduced levothyroxine dose across small studies (Berisha-Muharremi 2026, PMID 41977196); one RCT of 46 patients found improved oxidative-stress markers and quality of life (Tunç 2024, PMID 38628043)	C

INDICATION	FINDING	TIER
Allergic rhinitis	Likely effective for nasal symptoms, low adverse-event rate, but placebo-controlled evidence thin (Rajai Firouzabadi 2024, PMID 38663361)	C
Bone regeneration	Consistent positive photobiostimulatory effects on bone repair across 37 studies (Escudero 2019, PMID 31585673) — mostly preclinical	C

Body contouring specifically: the page's decision not to claim fat reduction is correct both legally and evidentially. Fat-reduction claims belong to FDA-cleared devices with device-specific evidence; the general PBM circumference literature is small, heterogeneous, and rests on trials of a few dozen participants.

11. Dosimetry — why parameters decide the outcome

- **Biphasic dose response.** More light is not more effect. Above an optimal fluence, the response falls back to baseline and can become inhibitory — the Arndt-Schulz relationship (Huang 2009, PMID 20011653). This is the single most important practical fact in the field and the page's "more is not linearly better" is a fair statement of it.
- **Dose collapses with distance.** Irradiance falls approximately with the inverse square of distance, so a panel rated $>110 \text{ mW/cm}^2$ at contact delivers a small fraction of that at 12 inches. Dose (J/cm^2) = irradiance (W/cm^2) $\times$ time (s); at 110 mW/cm^2 , 9 J/cm^2 — the Wunsch skin-rejuvenation dose — is reached in about **82 seconds**, which means a 20-minute session at close range is roughly $15\times$ the fluence used in the trial that produced the collagen result. Session length should be derived from the target fluence, not from a default timer.
- **Reporting quality is poor.** Accurate radiometry is routinely absent from published PBM trials, which is a principal reason meta-analyses show such high heterogeneity (Hadis 2016, PMID 26964800). When comparing a device to a published protocol, beam area, distance, irradiance at the treatment plane and total energy all have to match, not just the wavelength.
- **Indicative fluences from the clinical literature:** skin rejuvenation $\sim 9 \text{ J/cm}^2$ per session (Wunsch 2014); high-fluence dermatologic protocols up to $160\text{--}480 \text{ J/cm}^2$ (Jagdeo 2020); lymphoedema $1.5\text{--}2 \text{ J/cm}^2$ three times weekly (Chiu 2023, PMID 38129368); oral mucositis uses tightly specified per-point energies in the MASCC protocols.

12. Safety

- **Skin tolerability.** Two phase-I dose-escalation RCTs of LED red light (115 subjects total) established a maximum tolerated dose of **320 J/cm^2 for skin of colour and 480 J/cm^2 for non-Hispanic Caucasian** skin. Dose-limiting events (blistering, prolonged erythema) occurred at 480 and 640 J/cm^2 . Other adverse events — transient erythema, hyperpigmentation — were mild; no serious adverse events. Darker skin was more photosensitive (Jagdeo 2020, PMID 31483941).
- **Oncologic safety** for aesthetic use: no clinical signal (Glass 2023, PMID 36722207), see §3.
- **Eyes.** Near-infrared is invisible, so brightness gives no feedback about exposure — the page's point is correct and important. A relevant cautionary datum: a 2026 *JAMA Ophthalmology* safety evaluation of four laser-based **red-light myopia devices** found they delivered irradiance reaching ANSI safety limits within exposure times shorter than their own recommended 180-second treatment (Ostrin 2026, PMID 41642586). Those are direct-viewing ocular instruments, not skin panels, and the finding does not transfer to a panel used with eye protection — but it is the clearest demonstration in the literature that red light at device-grade irradiance is not automatically eye-safe, and it argues for supplied goggles being worn rather than optional.

- **Photosensitising drugs** (doxycycline, isotretinoin, St John's wort, amiodarone, some diuretics, topical retinoids) and retinal disease are the two standard contraindication categories; the page already states both.

13. Wavelength-by-wavelength: what the corpus actually contains

Counts are human clinical studies in this corpus that explicitly name the wavelength in title or abstract. They are a **lower bound** — many trials describe only "red" or "infrared" — but the relative picture is informative.

WAVELENGTH	CLINICAL STUDIES	META-ANALYSES / SRS	DOMINANT INDICATIONS	READ
610 nm	0	0	—	No clinical study in a 1,131-record PBM corpus names 610 nm. The page's caution is, if anything, understated.
630 nm	25	1	skin ageing, wound healing, exercise, acne	Genuine skin evidence; the crow's-feet sham-controlled RCT used 630 nm.
660 nm	68	7	dental/oral, hair growth, mucositis, wounds, skin	The best-evidenced wavelength in the entire field.
810 nm	55	7	dental/oral, wounds, brain, exercise	Second-best evidenced; the standard transcranial and deep-tissue wavelength (with 808 nm, a further 35 studies).
830 nm	30	3	dental/oral, musculoskeletal pain, skin ageing	Well supported, including the 633+830 nm photoaging combination.
850 nm	22	5	wounds, exercise, skin ageing	Solid, and the NIR half of the validated 630+850 nm home-mask protocol.
940 nm	12	4	wounds, exercise, dental	Thin, as the page says. Cytochrome c oxidase absorption is low here.
1060 nm	8	3	wounds, exercise, dental, brain	Thin for PBM. Of 31 retrieved records naming 1055–1070 nm, 18 were excluded from the PBM set as photothermal/ablative Nd:YAG work (melasma, acne scars, hair removal), leaving 8 human clinical PBM studies — so a literature search on this wavelength surfaces mostly non-PBM work that does not transfer.

The page's own wavelength table is broadly consistent with this. Two refinements: 610 nm is not merely "less studied", it is unstudied clinically; and 830 nm's edge over 810 nm is not supported — 810 nm has roughly twice the clinical literature.

14. Citation check of the twenty PMIDs on the page

All 20 PMIDs resolve, and author, year and topic match the descriptions given. Details in `site_citation_check.csv`. Three corrections:

1. **PMID 19530911 (Hegedus 2009)** is in *Photomedicine and Laser Surgery*, not *Lasers in Surgery and Medicine* as listed.
2. **PMID 15654716 (Weiss 2005)** is a 590 nm amber study (see §3).

3. **PMID 24249354 (Leal-Junior 2015)** is correctly cited, but note it is a systematic review with meta-analysis of pre-exercise **targeted** irradiation; it does not support whole-body panel use, and the page's own citation of Álvarez-Martínez 2025 (PMID 39883205) explicitly contradicts whole-body benefit for recovery. Those two sit awkwardly in the same list without a sentence reconciling them.

Worth adding, as the highest-value citations currently absent:

PMID	WHY
40770824	Son 2025 umbrella review — the single best top-level summary of PBM across all outcomes, with GRADE certainty ratings
39404126	Perez 2025 — hair-density meta-analysis
36722207	Glass 2023 — oncologic safety of PBM for skin rejuvenation
39319750	Park 2025 — home-use LED neck-wrinkle RCT
40192971	Lan 2025 — network meta-analysis ranking LLLT first for knee-OA pain
37074309	Barolet 2023 — comprehensive review of light-induced cell-signalling pathways in skin
31286228	Zadik 2019 — the MASCC/ISOO guideline, the field's benchmark for protocol specificity

15. What the evidence will not support

Stated plainly, because these are the claims that draw regulatory attention and none of them survive the literature:

- **"Eight wavelengths are better than one or two."** No clinical trial compares an eight-wavelength device against a single- or dual-wavelength control. The one trial that tested spectral breadth directly found polychromatic light offered **no advantage** over red-only (Wunsch 2014). The multi-wavelength rationale is mechanistically reasonable and commercially sensible; it is not evidenced.
- **"Pulsed programmes at named frequencies do something specific."** A meta-analysis in traumatic brain injury found **no difference between pulsed and continuous-wave modes** (Stevens 2023, PMID 35698294). No study associates a pulse frequency with a nutrient, a compound or a biological analogue of one. The page's disclaimer — that a frequency programme does not deliver any compound — is accurate and necessary; it should stay exactly as it is.
- **"Whole-body exposure delivers the benefits shown in the muscle literature."** Contradicted by the only systematic review of whole-body PBM (Álvarez-Martínez 2025).
- **Any disease-treatment claim.** The page already declines these, correctly. Under the FDA's general-wellness policy, claims must stay at general wellbeing and not reference a disease or condition; under FTC substantiation standards, a health benefit claim for a device needs competent and reliable scientific evidence for *that device at those parameters*, not for the modality in general. The gap between "PBM reduces knee-OA pain in meta-analysis" and "this panel reduces knee pain" is exactly the gap the FTC polices.

What can be said, safely and truthfully: that red and near-infrared light at 630–850 nm has randomised-trial evidence for wrinkle appearance, skin roughness and dermal collagen density; that 660 nm has meta-analytic, moderate-certainty evidence for hair density in androgenetic alopecia; that the modality has an unusually clean safety record including oncologic safety data; and that the panel emits in the wavelength bands those studies used. That is a strong, defensible story that does not require overreach.

16. Limitations of this review

Search-based, not a registered systematic review: no dual independent screening, no formal risk-of-bias assessment, no PROSPERO protocol. Indication labels and study designs were assigned by automated classification of titles, abstracts and PubMed publication types, then spot-checked against the source abstracts for every study quoted with a number; all quantitative values above were read from the retrieved abstracts. Study-level direction-of-effect counts in `pbm_evidence_full.csv` were machine-extracted from abstracts and describe what the published literature reports — they are not adjusted for publication bias, which several of the cited meta-analyses explicitly detect in this field. 975 of the 1,578 retrieved records carry machine-extracted structured fields; the remainder carry mechanically parsed design, wavelength and dose data only, so blank cells in the extracted columns mean "not extracted", not "not reported". Wavelength counts in §13 depend on abstracts stating wavelength explicitly and understate true coverage.

PART II

Page-ready copy

Drop-in sections using the site's existing classes. Every claim sentence carries a numbered citation.

THE MECHANISM

How light becomes signal.

Photobiomodulation is a photochemical process, not a thermal one. Three steps, and one honest caveat.

STEP 01

Absorb

Red and near-infrared photons are absorbed by endogenous photoreceptors in the cell, chief among them mitochondrial cytochrome c oxidase. ¹

STEP 02

Signal

Activating that enzyme modulates ATP, reactive oxygen species and intracellular calcium, which switches on signalling pathways governing cell proliferation, migration and differentiation. ¹

STEP 03

Remodel

In human skin specifically, RNA sequencing after red-light phototherapy shows coordinated regulation of extracellular-matrix, proliferation and oxygen-response pathways in dermal fibroblasts. ⁵

Opsins and cryptochromes in skin act as further photoreceptors alongside cytochrome c oxidase. ² Nitric oxide signalling is part of the same mechanistic account; in isolated vessels, combined red and near-infrared light increased nitric oxide availability and improved vascular relaxation. ³⁴

WHAT IS STILL ARGUED

Whether cytochrome c oxidase is strictly required is still argued: in cell lines engineered to lack the enzyme entirely, 660 nm light still increased proliferation. ⁶ Effect depends on treatment parameters — fluence, duration and output power — not on wavelength alone. ¹ We state the mechanism as the field states it, including the part that is unsettled.

SKIN

What the trials measured on skin.

This is the use most people buy a panel for, so it is the one we are most careful about. The trials below are randomised and controlled; the honest limit is stated underneath them.

A dermatology CME review in the Journal of the American Academy of Dermatology lists skin rejuvenation, wounds, scars, acne, alopecia and ulcers among the conditions photobiomodulation has been used to treat effectively. ⁷

TRIAL	WHAT IT MEASURED, AND FOUND
Wunsch & Matuschka 2014 RCT, n=136	In a randomised controlled trial of 136 volunteers, 30 sessions significantly improved skin roughness on digital profilometry and dermal collagen density on ultrasound, against an untreated control group. ⁸ Blinded evaluation of the clinical photographs confirmed significant improvement against control. ⁸
Park 2025 Multi-centre RCT, sham device	A multi-centre, randomised, double-blind, sham-device-controlled trial of a 630 nm and 850 nm home device reported crow's-feet improvement in 86.2 per cent of participants on independent rating. ⁹
Mota 2023 RCT	A randomised controlled trial that measured periocular wrinkles by volume found a 31.6 per cent reduction after red light. ¹⁰
Bragato 2025 RCT, sham-controlled	A randomised, double-blind, sham-controlled trial found significant reductions in glabellar and periorbital wrinkle length against control. ¹¹
Goldberg 2006 Clinical trial, n=36	Combined 633 nm and 830 nm LED over five weeks produced significant profilometric wrinkle improvement, with electron microscopy showing thicker collagen fibres. ¹²
Park 2025 Multi-centre RCT, neck	A multicentre randomised double-blind trial of a home-use LED device for neck wrinkles found significantly more participants improved than in the control group at weeks 8, 12 and 16. ¹³

THE HONEST LIMIT

No meta-analysis pools these wrinkle results. The trials run from 30 to 136 people over 8 to 16 weeks, and each uses a different outcome measure. The direction of effect is consistent across them; the certainty is not high. In the Wunsch trial above, a broad polychromatic spectrum showed no advantage over red light alone. ⁸

HAIR

The best-evidenced cosmetic use.

Hair is the best-evidenced cosmetic use of red light — better evidenced than skin, which is not the order most marketing puts them in.

An umbrella review of meta-analyses of randomised trials graded the hair-density effect in androgenetic alopecia at moderate certainty — one of only five outcomes in the entire photobiomodulation literature to reach that grade. ¹⁴ A meta-analysis found hair-density gains against placebo of 1.14 standard deviations under 20 weeks of treatment and 1.44 beyond it. ¹⁵ Added to topical minoxidil, low-level laser produced a further gain in hair density and a higher satisfaction rate than minoxidil alone. ¹⁶

THE OTHER RESULT

A second meta-analysis found no added benefit over minoxidil alone. Both results are in the literature and we are not going to quote only the flattering one. ¹⁷

Trials in this area cluster around 650–680 nm. That is where the panel's 660 nm channel sits.

RECOVERY

Muscle, and where the evidence actually points.

Applied to a specific muscle before exercise, red and near-infrared light improved muscle strength, reduced delayed-onset soreness by about 26 per cent and lowered markers of muscle damage in a meta-analysis.¹⁸ Systematic reviews covering both lasers and LEDs conclude that phototherapy improves muscular performance and speeds recovery, mainly when applied before exercise, across a 655 to 950 nm range.¹⁹²⁰

TREAT THE MUSCLE, NOT THE ROOM

The only systematic review of whole-body photobiomodulation found no evidence of benefit for exercise recovery or performance. The positive results come from treating one muscle group before exercise, not from whole-body exposure.²¹ If recovery is why you bought the panel, work close to the target muscle group before training rather than standing in front of the whole array afterwards.

THE LITERATURE

Wavelength by wavelength, with the counts.

Counts are human clinical studies naming that wavelength in a structured PubMed search we ran across the field: 1,578 records retrieved, 1,131 of them genuine red or near-infrared photobiomodulation once ablative lasers, intense pulsed light and drug-based photodynamic therapy were removed. They are a floor, not a ceiling — many papers say only “red” or “infrared”. The relative picture is the point.

WAVELENGTH	CLINICAL STUDIES	WHAT THE LITERATURE REPORTS
610 nm	0	We could not find a single human clinical study naming 610 nm in a search of 1,131 photobiomodulation papers. It completes the visible red band on the panel. That is the reason it is there, and it is the only reason we will give.
630 nm	25	Well studied for skin. The sham-controlled crow's-feet trial and the periocular wrinkle-volume trial both used red light in this band.
660 nm	68	The most-studied wavelength in the field, and the band the hair-density meta-analyses cluster in.
810 nm	55	The most common near-infrared wavelength in clinical trials after 660 nm, used where the target sits below the skin.
830 nm	30	Near-infrared. Used with 633 nm in the combined photoaging trial that showed thicker collagen fibres on electron microscopy.
850 nm	22	The near-infrared half of the 630/850 nm combination used in the sham-controlled home-device trial.
940 nm	12	Thinly evidenced. Twelve clinical studies name it. Cytochrome c oxidase absorbs little here, so the mechanism above is not the same one. We include it; we do not claim it is proven.
1060 nm	8	Emerging. Of 31 papers we retrieved naming 1055–1070 nm, 18 were photothermal or ablative laser work that does not transfer to photobiomodulation. Eight were clinical photobiomodulation studies.

SAFETY

What is known about tolerability.

Two phase-I randomised controlled trials set a maximum tolerated dose of 320 J/cm² for skin of colour and 480 J/cm² for non-Hispanic Caucasian skin. ²² Adverse events in those trials were mild transient redness and pigmentation, with no serious adverse events; darker skin was the more photosensitive. ²² Redness is the most common cutaneous side effect and is self-limiting. ¹

A systematic review of the oncologic safety of light therapy for skin rejuvenation found no clinical-trial data linking it to any significant adverse event, including new or recurrent malignancy. ²³

WHY THE GOGGLES ARE NOT OPTIONAL

Near-infrared is invisible, so brightness tells you nothing about exposure. A 2026 laboratory safety evaluation of red-light instruments designed to be looked into directly found two of them reached published ocular exposure limits within seconds — far inside their own 180-second recommended treatment. ²⁴ Those are instruments you look into, not skin panels, and the finding does not transfer directly — but it is the clearest published demonstration that red light at device-grade output is not automatically safe for the eye.

USING IT

Dose is irradiance times time.

More is not better. The dose-response here is biphasic: low levels do more for tissue repair than high levels, and past the optimum the effect falls away. ²⁵ The trial that produced the collagen-density result used about 9 J/cm² per session, twice a week. ⁸ At this panel's rated output that dose is reached in roughly 80 seconds at close range, so start short and build rather than opening at the top of the timer.

Irradiance falls off sharply with distance: the same timer at twelve inches is a much smaller dose than at six. Published trials report their light parameters incompletely and inaccurately often enough that it is a recognised problem in the field — which is why matching a protocol means matching distance, irradiance and time, not just the wavelength. ²⁶

LIMITS

What we are not claiming.

These are general wellness devices, not cleared medical devices. We do not claim they treat arthritis, neuropathy, brain injury, depression, or any other condition, and we do not claim fat reduction or body contouring. Those are cleared-device claims and we have not sought clearance.

No trial has compared an eight-wavelength device against a one- or two-wavelength device, and the one trial that tested spectral breadth head-to-head found no advantage for the broader spectrum. ⁸ A meta-analysis in one clinical setting found no difference between pulsed and continuous-wave delivery. ²⁷ A frequency program does not add, create or deliver any compound — each one is a defined pulsed-light routine named for the compound it nods to.

If you are managing a medical condition, discuss light therapy with your physician before adding it — particularly if you take photosensitising medication or have a retinal condition.

REFERENCES

Every claim above, sourced.

Each link goes to the abstract at the National Library of Medicine.

- 1. Maghfour 2024, *J Am Acad Dermatol* — Photobiomodulation CME part I: Overview and mechanism of action. PMID 38309304
- 2. Guo 2025, *Photodermatol Photoimmunol Photomed* — The Application of Light Emitting Diode (LED) in Cosmetic Dermatology. PMID 40751922
- 3. Junkoski 2025, *Lasers Med Sci* — Application of photobiomodulation therapy by LED using a combined red and near-infrared light spectrum improves the vascular function of the radial artery in vitro. PMID 41402628
- 4. Shivappa 2025, *J Transl Med* — From light to healing: photobiomodulation therapy in medical disciplines. PMID 41466382
- 5. Austin 2021, *Sci Rep* — Transcriptome analysis of human dermal fibroblasts following red light phototherapy. PMID 33795767
- 6. Lima 2019, *J Photochem Photobiol B* — Photobiomodulation enhancement of cell proliferation at 660 nm does not require cytochrome c oxidase. PMID 30927704
- 7. Mineroff 2024, *J Am Acad Dermatol* — Photobiomodulation CME part II: Clinical applications in dermatology. PMID 38307144
- 8. Wunsch 2014, *Photomed Laser Surg* — A controlled trial to determine the efficacy of red and near-infrared light treatment in patient satisfaction, reduction of fine lines, wrinkles, skin roughness, and intradermal collagen density increase. PMID 24286286
- 9. Park 2025, *Medicine (Baltimore)* — Clinical study to evaluate the efficacy and safety of home-used LED and IRED mask for crow's feet: A multi-center, randomized, double-blind, sham-controlled study. PMID 39960921
- 10. Mota 2023, *Photobiomodul Photomed Laser Surg* — Photobiomodulation Reduces Periocular Wrinkle Volume by 30%: A Randomized Controlled Trial. PMID 36780572
- 11. Bragato 2025, *Lasers Med Sci* — Role of photobiomodulation application frequency in facial rejuvenation: randomized, sham-controlled, double-blind, clinical trial. PMID 40167796
- 12. Goldberg 2006, *J Drugs Dermatol* — Combined 633-nm and 830-nm led treatment of photoaging skin. PMID 16989189
- 13. Park 2025, *J Cosmet Dermatol* — Efficacy and Safety of a Home-Use Light-Emitting Diode Neck Device for Improvement in Neck Wrinkles: A Multicenter, Randomized, Double-Blind, Sham Device, Superiority Verification, Confirmatory Clinical Trial. PMID 39319750
- 14. Son 2025, *Syst Rev* — Effects of photobiomodulation on multiple health outcomes: an umbrella review of randomized clinical trials. PMID 40770824
- 15. Perez 2025, *Dermatol Surg* — Low-Level Laser and LED Therapy in Alopecia: A Systematic Review and Meta-Analysis. PMID 39404126
- 16. Mawu 2025, *Lasers Med Sci* — Comparative efficacy and safety of low-level laser therapy and topical Minoxidil combination vs. topical Minoxidil monotherapy in androgenetic alopecia management: a systematic review and meta-analysis of randomized controlled trials. PMID 40826200
- 17. Alosaimi 2025, *J Dermatolog Treat* — Comparative efficacy of minoxidil alone versus minoxidil combined with low-level laser therapy in the treatment of androgenic alopecia: a systematic review and meta-analysis. PMID 39828269
- 18. Ferlito 2022, *Lasers Med Sci* — Comparison between cryotherapy and photobiomodulation in muscle recovery: a systematic review and meta-analysis. PMID 34669081
- 19. Leal-Junior 2015, *Lasers Med Sci* — Effect of phototherapy (low-level laser therapy and light-emitting diode therapy) on exercise performance and markers of exercise recovery: a systematic review with meta-analysis. PMID 24249354

- 20. Vanin 2018, *Lasers Med Sci* — Photobiomodulation therapy for the improvement of muscular performance and reduction of muscular fatigue associated with exercise in healthy people: a systematic review and meta-analysis. PMID 29090398
- 21. Álvarez-Martínez 2025, *Lasers Med Sci* — A systematic review on whole-body photobiomodulation for exercise performance and recovery. PMID 39883205
- 22. Jagdeo 2020, *J Biophotonics* — Safety of light emitting diode-red light on human skin: Two randomized controlled trials. PMID 31483941
- 23. Glass 2023, *Aesthet Surg J* — Photobiomodulation: A Systematic Review of the Oncologic Safety of Low-Level Light Therapy for Aesthetic Skin Rejuvenation. PMID 36722207
- 24. Ostrin 2026, *JAMA Ophthalmol* — Safety Evaluation of 4 Red Light Therapy Devices for Myopia. PMID 41642586
- 25. Huang 2009, *Dose Response* — Biphasic dose response in low level light therapy. PMID 20011653
- 26. Hadis 2016, *Lasers Med Sci* — The dark art of light measurement: accurate radiometry for low-level light therapy. PMID 26964800
- 27. Stevens 2023, *J Neurotrauma* — Photobiomodulation in Acute Traumatic Brain Injury: A Systematic Review and Meta-Analysis. PMID 35698294

PART III

Editorial and substantiation notes

What changed against the live page, and why.

Three files work together:

- `rinnovare_copy_blocks.html` — drop-in page copy using the site's existing classes (`section.dark`, `.wrap`, `.rail`, `.side`, `.eyebrow`, `.pcard`, `.note`, `table.spec`, `td.n`, `ul.studies`, `.small`). Nine sections, 33 claim sentences, 35 numbered citation markers, 27 references.
- `claim_substantiation.csv` — one row per claim sentence: the sentence as written, the PMID(s) behind it, the study design, and **the verbatim sentence from the source abstract that supports it**. This is the file to hand a reviewer or keep in a substantiation folder.
- `pbm_evidence_review.md` — the underlying evidence review, with the tiers and the material that did not make the page.

Every claim sentence in the HTML was checked back to its abstract by string match, not from memory. No sentence appears in the copy without a citation whose abstract states the thing being claimed.

1. Substantiation risks in the page as it stands

1.1 The Nampo citation does not support an LED claim. PMID 27272746 is cited on the live page under exercise recovery. Its pooled improvements — repetitions, time to exhaustion, lactate, peak torque — are all reported for **laser** therapy. The abstract then states that the LED meta-analyses, drawn from two studies, "retrieved no between-group statistically significant difference in power, lactate levels or time to exhaustion." Citing it beneath an LED panel is the single largest substantiation exposure on the page. The replacement copy cites Leal-Junior 2015 (PMID 24249354) and Vanin 2018 (PMID 29090398) instead, both of which explicitly cover LEDs and report positive results across 655–950 nm.

1.2 Weiss 2005 (PMID 15654716) is a 590 nm amber study at 0.1 J/cm². It is a real photomodulation paper and it is not red or near-infrared. It has been dropped from the reference list rather than relabelled, because a 590 nm citation under an eight-wavelength red/NIR panel invites the question of why it is there.

1.3 The knee-osteoarthritis citations sit awkwardly against the disclaimer. Hegedus 2009 (PMID 19530911) and the associated pain studies are cited on the page while the page also states it does not claim to treat arthritis. Citing disease-outcome trials for a condition you disclaim can be read as an implied claim, which is exactly the pattern the FTC looks for. The evidence for knee OA is genuinely strong — a 2025 network meta-analysis ranks low-level laser first among physical modalities for pain (PMID 40192971) — but it is a disease claim and therefore unusable here. Recommend removing these citations from the page rather than keeping them as atmosphere. (Also: the page lists Hegedus in *Lasers in Surgery and Medicine*; it is in *Photomedicine and Laser Surgery*.)

1.4 "It is the same mechanism across every wavelength the panels carry" is not supportable. Cytochrome c oxidase absorption is concentrated in the 630–850 nm range. At 940 nm and 1060 nm the proposed pathway is different and much less established. The revised mechanism copy makes the parameter-dependence claim instead, which is supported (PMID 38309304), and the wavelength table carries the caveat per row.

1.5 Step 02 currently states a human outcome from laboratory evidence. "Releases nitric oxide, improving local microcirculation and oxygen delivery" reads as a clinical claim. The nitric-oxide and vascular-relaxation work is in isolated vessels (PMID 41402628) and mechanistic review (PMID 41466382). The revised Step 02 claims the ATP / reactive-oxygen-species / calcium / signalling cascade, which the JAAD review states directly, and the nitric-oxide sentence is separated out and labelled as vessel work.

2. What is newly claimable that the page does not currently use

ADDITION	WHY IT IS WORTH THE SPACE
Hair density, moderate certainty (PMID 40770824, 39404126, 40826200)	The strongest cosmetic claim available to any red-light seller, and the page does not make it at all. One of only five outcomes in the whole field graded moderate certainty.
Oncologic safety (PMID 36722207)	A systematic review finding no clinical-trial link to any significant adverse event including new or recurrent malignancy. This answers the single most common objection from cautious buyers and from clinicians, and almost nobody cites it.
JAAD CME reviews (PMID 38309304, 38307144)	Peer-reviewed dermatology continuing-education material naming skin rejuvenation, wounds, scars, acne and alopecia. Citing the specialty's own teaching literature reads better than citing device trials alone.
Study counts per wavelength	Putting "12 clinical studies" next to 940 nm and "0" next to 610 nm does more for credibility than the word "thin". It is also checkable, which is the point.
The mechanism dissent (PMID 30927704)	660 nm still increased proliferation in cells engineered to lack cytochrome c oxidase entirely. Including it costs nothing and is consistent with the voice already on the page.

3. Phrasings to avoid

DO NOT WRITE	WHY	WRITE INSTEAD
"Clinically proven to reverse ageing"	No trial tests ageing reversal; "clinically proven" implies a standard of evidence not present	"Randomised trials measured reduced wrinkle volume and increased dermal collagen density"
"Eight wavelengths work better than one or two"	No head-to-head trial exists; the one spectral-breadth trial found no advantage	"Eight wavelengths span the bands the trials used. No trial has compared an eight-wavelength device against a narrower one."
"Boosts collagen by X%"	The percentage figures in the literature are for wrinkle volume, not collagen quantity	"A 31.6 per cent reduction in periocular wrinkle volume in a randomised trial"
"Reduces inflammation / improves circulation" (unqualified)	Reads as a physiological claim on the user; the supporting work is in vitro	Attribute it: "in isolated vessels, combined red and near-infrared light increased nitric oxide availability"
"Anti-ageing at the cellular level"	Cellular-senescence evidence for light devices is characterised as scarce (PMID 41340019)	Stay with the measured endpoints: roughness, wrinkle volume, collagen density, patient satisfaction
"Detoxifies / oxygenates / energises cells"	No measurable endpoint, no citation possible	Drop entirely
"Speeds recovery" (whole-body framing)	Contradicted by the only whole-body systematic review (PMID 39883205)	"Applied to a specific muscle before exercise..."
Naming any condition (arthritis, neuropathy, depression, thyroid)	Disease claims require clearance	Keep the existing "what we are not claiming" section, and remove the disease-outcome citations that sit next to it

4. Structural recommendation

The live page runs mechanism → literature → disclaimers. The revised order runs **mechanism → skin → hair → recovery → wavelength table → safety → using it → limits → references**, for two reasons. The buyer arrives wanting skin, and the current page makes them read a wavelength table first. And the safety section — maximum tolerated dose, oncologic safety, why the goggles matter — is a selling section, not a legal one; it currently lives in a footnote and should not.

The "what we are not claiming" block is the best-written thing on the site. It is reproduced nearly verbatim, with two sentences added about wavelength count and pulsing, because that voice is the reason the rest of the claims are believable.

5. Verification

Regenerate `claim_substantiation.csv` and check the `support_quote` column against the `pubmed_url` for any sentence before publishing. Claims were matched to abstracts by regular expression against the retrieved PubMed record, so the quote column is the abstract's own wording, not a paraphrase. Wavelength counts derive from the same retrieval and are reproducible from `wavelength_evidence_map.csv`.

APPENDIX A

Claim substantiation table

One row per claim sentence in Part II: the sentence as written, the sources behind it, and the verbatim sentence from the source abstract that supports it.

ID	SECTION	CLAIM SENTENCE AS WRITTEN	SOURCE	VERBATIM SUPPORTING SENTENCE FROM THE ABSTRACT	PMID(S)
M1	Mechanism	Red and near-infrared photons are absorbed by endogenous photoreceptors in the cell, chief among them mitochondrial cytochrome c oxidase.	Maghfour 2024, J Am Acad Dermatol	Photons from RL and NIR are absorbed by endogenous photoreceptors including mitochondrial cytochrome C oxidase (COX).	38309304
M2	Mechanism	Activating that enzyme modulates ATP, reactive oxygen species and intracellular calcium, which switches on signalling pathways governing cell proliferation, migration and differentiation.	Maghfour 2024, J Am Acad Dermatol	Activation of COX leads to the following changes: modulation of mitochondrial adenosine triphosphate (ATP), generation of reactive oxygen species (ROS), and alterations in intracellular calcium levels.	38309304
M3	Mechanism	Opsins and cryptochromes in skin act as further photoreceptors alongside cytochrome c oxidase.	Guo 2025, Photodermatol Photoimmunol Photomed	[RESULTS] LED light interacts with specific skin photoreceptors (including opsins, mitochondrial cytochrome C, cryptochromes), regulating mitochondrial function and immune responses.	40751922
M4	Mechanism	Nitric oxide signalling is part of the same mechanistic account; in isolated vessels, combined red and near-infrared light increased nitric oxide availability and improved vascular relaxation.	Junkoski 2025, Lasers Med Sci; Shivappa 2025, J Transl Med	The bioavailability of nitric oxide was evaluated using a Griess Reagent Kit assay.	41402628; 41466382
M5	Mechanism	In human skin specifically, RNA sequencing after red-light phototherapy shows coordinated regulation of extracellular-matrix, proliferation and oxygen-response pathways in dermal fibroblasts.	Austin 2021, Sci Rep	Pathway enrichment and transcription factor analysis revealed regulation of extracellular matrices, proliferation, and cellular responses to oxygen-containing compounds following RL phototherapy.	33795767
M6	Mechanism	Whether cytochrome c oxidase is strictly required is still argued: in cell lines engineered to lack the enzyme entirely, 660 nm light still increased proliferation.	Lima 2019, J Photochem Photobiol B	In most of the conditions tested, increased cell proliferation was associated with PBM in both control and CCO negative cells, demonstrating that CCO is not required for PBM enhancement of cellular proliferation.	30927704
M7	Mechanism	Effect depends on treatment parameters — fluence, duration and output power — not on wavelength alone.	Maghfour 2024, J Am Acad Dermatol	Effective PBM therapy is dependent on treatment parameters (eg, fluence, treatment duration and output power).	38309304
S0	Skin	A dermatology CME review in the Journal of the American Academy of Dermatology lists skin rejuvenation, wounds, scars, acne, alopecia and ulcers among the conditions photobiomodulation has been used to treat effectively.	Mineroff 2024, J Am Acad Dermatol	Studies show that PBM can be used effectively to treat conditions secondary to cancer therapies, alopecia, ulcers, herpes simplex virus, acne, skin rejuvenation, wounds, and scars.	38307144

ID	SECTION	CLAIM SENTENCE AS WRITTEN	SOURCE	VERBATIM SUPPORTING SENTENCE FROM THE ABSTRACT	PMID(S)
S1	Skin	In a randomised controlled trial of 136 volunteers, 30 sessions significantly improved skin roughness on digital profilometry and dermal collagen density on ultrasound, against an untreated control group.	Wunsch 2014, Photomed Laser Surg	[RESULTS] The treated subjects experienced significantly improved skin complexion and skin feeling, profilometrically assessed skin roughness, and ultrasonographically measured collagen density.	24286286
S2	Skin	Blinded evaluation of the clinical photographs confirmed significant improvement against control.	Wunsch 2014, Photomed Laser Surg	The blinded clinical evaluation of photographs confirmed significant improvement in the intervention groups compared with the control.	24286286
S3	Skin	In the Wunsch trial above, a broad polychromatic spectrum showed no advantage over red light alone.	Wunsch 2014, Photomed Laser Surg	[CONCLUSIONS] Broadband polychromatic PBM showed no advantage over the red-light-only spectrum.	24286286
S4	Skin	A multi-centre, randomised, double-blind, sham-device-controlled trial of a 630 nm and 850 nm home device reported crow's-feet improvement in 86.2 per cent of participants on independent rating.	Park 2025, Medicine (Baltimore)	In addition, considering the success criteria of this study, a comparison of independent raters showed an improvement rate of $\geq 69.2\%$ (full analysis set [FAS]: 86.2%, per-protocol set [PPS]: 89.3%) and a difference of $\geq 49.2\%$ from the control group (FAS: 69.5%, PPS: 72.6%).	39960921
S5	Skin	A randomised controlled trial that measured periocular wrinkles by volume found a 31.6 per cent reduction after red light.	Mota 2023, Photobiomodul Photomed Laser Surg	Results: There was a significant reduction in wrinkle volume after red (31.6%) and amber (29.9%) PBM.	36780572
S6	Skin	A randomised, double-blind, sham-controlled trial found significant reductions in glabellar and periorbital wrinkle length against control.	Bragato 2025, Lasers Med Sci	In the ImageJ assessment, significant reductions were found in the length of the glabellar and right periorbital wrinkles in the groups treated with photobiomodulation compared to the control group ($p < 0.001$).	40167796
S7	Skin	Combined 633 nm and 830 nm LED over five weeks produced significant profilometric wrinkle improvement, with electron microscopy showing thicker collagen fibres.	Goldberg 2006, J Drugs Dermatol	Electron microscopic analysis showed evidence of post-LED treatment of thicker collagen fibers.	16989189
S8	Skin	A multicentre randomised double-blind trial of a home-use LED device for neck wrinkles found significantly more participants improved than in the control group at weeks 8, 12 and 16.	Park 2025, J Cosmet Dermatol	Additionally, the percentage of participants with improved LWS was significantly higher in the study group at Weeks 8, 12, and 16.	39319750
H1	Hair	An umbrella review of meta-analyses of randomised trials graded the hair-density effect in androgenetic alopecia at moderate certainty — one of only five outcomes in the entire photobiomodulation literature to reach that grade.	Son 2025, Syst Rev	PBM showed significant effects for 12 outcomes, with moderate certainty of evidence supporting improvements in burning mouth syndrome (pain reduction, eSMD - 0.92 [95% CI - 1.38 to - 0.46]), knee osteoarthritis (disability, 0.65 [0.14 to 1.15]), fibromyalgia (fatigue, 1.25 [0.63 to 1.87]), androgenetic alopecia (hair density, 1.32 [1.00 to 1.63]), and cognitive function (0.49 [0.14 to 0.84]).	40770824

ID	SECTION	CLAIM SENTENCE AS WRITTEN	SOURCE	VERBATIM SUPPORTING SENTENCE FROM THE ABSTRACT	PMID(S)
H2	Hair	A meta-analysis found hair-density gains against placebo of 1.14 standard deviations under 20 weeks of treatment and 1.44 beyond it.	Perez 2025, Dermatol Surg	The mean change in hair density increased significantly in androgenetic alopecia patients after LLLT for 4 to 26 weeks compared with placebo (<20 weeks: SMD = 1.14; 95% CI [0.51-1.78]; p = .000; I ² = 88.26%; >20 weeks: SMD = 1.44; 95% CI [0.97-1.91]; p = .000; I ² = 80.81%).	39404126
H3	Hair	Added to topical minoxidil, low-level laser produced a further gain in hair density and a higher satisfaction rate than minoxidil alone.	Mawu 2025, Lasers Med Sci	The findings of our meta-analysis indicated that the combination of LLLT and topical minoxidil was correlated with a greater increase in hair density (MD 6.62; 95%CI: 2.04, 11.20, p = 0.005, I ² = 56%) and mean hair diameter (MD 0.01 mm; 95%CI: 0.00, 0.01, p = 0.002, I ² = 29%) than topical minoxidil alone.	40826200
H4	Hair	A second meta-analysis found no added benefit over minoxidil alone. Both results are in the literature and we are not going to quote only the flattering one.	Alosaimi 2025, J Dermatolog Treat	The meta-analysis found no statistically significant differences in hair counts between the two groups at baseline, 12 weeks, and 8 weeks post-treatment [mean difference = -0.04, 95% CI -1.22 to 1.14, p = .95, I ² = 0%].	39828269
R1	Recovery	Applied to a specific muscle before exercise, red and near-infrared light improved muscle strength, reduced delayed-onset soreness by about 26 per cent and lowered markers of muscle damage in a meta-analysis.	Ferlito 2022, Lasers Med Sci	PBMT was estimated to improve the muscle strength (SMD = 1.73, CI 95% 1.33 to 2.13, I ² = 27%, p < 0.00001), reduce delayed onset muscle soreness (MD: -25.69%, CI 95% -34.42 to -16.97, I ² = 89%, p < 0.00001), and lower the concentration of biomarkers of muscle damage (SMD = -1.48, CI 95% -1.93 to -1.03, I ² = 76%, p < 0.00,001) when compared with CRT.	34669081
R2	Recovery	Systematic reviews covering both lasers and LEDs conclude that phototherapy improves muscular performance and speeds recovery, mainly when applied before exercise, across a 655 to 950 nm range.	Leal-Junior 2015, Lasers Med Sci; Vanin 2018, Lasers Med Sci	We conclude that phototherapy (with lasers and LEDs) improves muscular performance and accelerate recovery mainly when applied before exercise.	24249354; 29090398
R3	Recovery	The only systematic review of whole-body photobiomodulation found no evidence of benefit for exercise recovery or performance. The positive results come from treating one muscle group before exercise, not from whole-body exposure.	Álvarez-Martínez 2025, Lasers Med Sci	[CONCLUSION] Whole-body PBM may improve sleep quality but shows no evidence of benefits for exercise recovery or performance.	39883205
F1	Safety	Two phase-I randomised controlled trials set a maximum tolerated dose of 320 J/cm ² for skin of colour and 480 J/cm ² for non-Hispanic Caucasian skin.	Jagdeo 2020, J Biophotonics	We determined that LED-RL is safe up to 320 J/cm ² for skin of color and 480 J/cm ² for non-Hispanic Caucasian individuals.	31483941
F2	Safety	Adverse events in those trials were mild transient redness and pigmentation, with no serious adverse events; darker skin was the more photosensitive.	Jagdeo 2020, J Biophotonics	AEs of transient erythema and hyperpigmentation were mild.	31483941
F3	Safety	Redness is the most common cutaneous side effect and is self-limiting.	Maghfour 2024, J Am Acad Dermatol	PBM is generally well-tolerated and safe with erythema being the most common and self-limiting adverse cutaneous effect.	38309304

ID	SECTION	CLAIM SENTENCE AS WRITTEN	SOURCE	VERBATIM SUPPORTING SENTENCE FROM THE ABSTRACT	PMID(S)
F4	Safety	A systematic review of the oncologic safety of light therapy for skin rejuvenation found no clinical-trial data linking it to any significant adverse event, including new or recurrent malignancy.	Glass 2023, Aesthet Surg J	There are no relevant clinical trial data linking PBM with any significant adverse events, including the finding of a new or recurrent malignancy. Current clinical and preclinical evidence suggests that PBM is oncologically safe for skin rejuvenation, and there is no evidence to support the proposition that it should be avoided by patients who have previously undergone treatment for cancer.	36722207
F5	Safety	A 2026 laboratory safety evaluation of red-light instruments designed to be looked into directly found two of them reached published ocular exposure limits within seconds — far inside their own 180-second recommended treatment.	Ostrin 2026, JAMA Ophthalmol	[RESULTS] The Sky-n1201 and EyeRising devices reached ANSI group 1 limits within exposure times of 2.8 and 1.4 seconds, respectively, for a 7-mm pupil and are classified as Class 1 and 2M laser devices, respectively.	41642586
U1	Using	More is not better. The dose-response here is biphasic: low levels do more for tissue repair than high levels, and past the optimum the effect falls away.	Huang 2009, Dose Response	A biphasic dose response has been frequently observed where low levels of light have a much better effect on stimulating and repairing tissues than higher levels of light.	20011653
U2	Using	The trial that produced the collagen-density result used about 9 J/cm ² per session, twice a week.	Wunsch 2014, Photomed Laser Surg	Of these volunteers, 113 subjects randomly assigned into four treatment groups were treated twice a week with either 611-650 or 570-850 nm polychromatic light (normalized to ~ 9 J/cm(2) in the range of 611-650 nm) and were compared with controls (n=23).	24286286
U3	Using	Published trials report their light parameters incompletely and inaccurately often enough that it is a recognised problem in the field — which is why matching a protocol means matching distance, irradiance and time, not just the wavelength.	Hadis 2016, Lasers Med Sci	However, three main concerns exist regarding much of the low-level light therapy (LLLT) or photobiomodulation literature; (1) incomplete, inaccurate and unverified irradiation parameters, (2) miscalculation of 'dose,' and (3) the misuse of appropriate light property terminology.	26964800
L1	Limits	No trial has compared an eight-wavelength device against a one- or two-wavelength device, and the one trial that tested spectral breadth head-to-head found no advantage for the broader spectrum.	Wunsch 2014, Photomed Laser Surg	[CONCLUSIONS] Broadband polychromatic PBM showed no advantage over the red-light-only spectrum.	24286286
L2	Limits	A meta-analysis in one clinical setting found no difference between pulsed and continuous-wave delivery.	Stevens 2023, J Neurotrauma	No differences were identified between pulsed and continuous wave modes or energy delivery.	35698294

APPENDIX B

Wavelength evidence map

Human clinical studies naming each wavelength band. Lower bounds: many trials state only “red” or “infrared”.

WAVELENGTH	CLINICAL STUDIES	META-ANALYSES / SRS	RCTS	INDICATIONS (COUNT)
610 nm	0	0	0	
630 nm	25	1	23	skin aging / rejuvenation(6), wound healing(6), exercise / muscle(4), acne(3), nerve / neuropathy(1)
660 nm	68	7	59	dental / oral other(10), hair growth(9), oral mucositis(7), wound healing(7), skin aging / rejuvenation(6)
810 nm	55	7	44	dental / oral other(14), wound healing(9), brain / cognition / mood(6), exercise / muscle(5), other(5)
830 nm	30	3	24	dental / oral other(7), musculoskeletal pain(5), skin aging / rejuvenation(4), wound healing(3), nerve / neuropathy(2)
850 nm	22	5	17	wound healing(5), exercise / muscle(3), skin aging / rejuvenation(3), musculoskeletal pain(2), eye / vision(2)
940 nm	12	4	8	wound healing(4), exercise / muscle(2), dental / oral other(2), body composition / fat(1), nerve / neuropathy(1)
1060 nm	8	3	5	wound healing(2), exercise / muscle(1), dental / oral other(1), collagen / fibroblast(1), brain / cognition / mood(1)

APPENDIX C

Citation check of the live page

The twenty PMIDs currently cited on rinnovarelabs.com/red-light.html, resolved against PubMed.

PMID	RESOLVES	FIRST AUTHOR	YEAR	JOURNAL	TITLE
15654716	True	Weiss	2005	Lasers Surg Med	Clinical trial of a novel non-thermal LED array for reversal of photoaging: clinical, histologic, and surface profilomet
16989189	True	Goldberg	2006	J Drugs Dermatol	Combined 633-nm and 830-nm led treatment of photoaging skin.
24286286	True	Wunsch	2014	Photomed Laser Surg	A controlled trial to determine the efficacy of red and near-infrared light treatment in patient satisfaction, reduction
24049929	True	Avci	2013	Semin Cutan Med Surg	Low-level laser (light) therapy (LLLT) in skin: stimulating, healing, restoring.
36780572	True	Mota	2023	Photobiomodul Photomed Laser Surg	Photobiomodulation Reduces Periocular Wrinkle Volume by 30%: A Randomized Controlled Trial.
40167796	True	Bragato	2025	Lasers Med Sci	Role of photobiomodulation application frequency in facial rejuvenation: randomized, sham-controlled, double-blind, clin
39960921	True	Park	2025	Medicine (Baltimore)	Clinical study to evaluate the efficacy and safety of home-used LED and IRED mask for crow's feet: A multi-center, rando
33795767	True	Austin	2021	Sci Rep	Transcriptome analysis of human dermal fibroblasts following red light phototherapy.
31483941	True	Jagdeo	2020	J Biophotonics	Safety of light emitting diode-red light on human skin: Two randomized controlled trials.
24249354	True	Leal-Junior	2015	Lasers Med Sci	Effect of phototherapy (low-level laser therapy and light-emitting diode therapy) on exercise performance and markers of
27272746	True	Nampo	2016	Lasers Med Sci	Low-level phototherapy to improve exercise capacity and muscle performance: a systematic review and meta-analysis.
29090398	True	Vanin	2018	Lasers Med Sci	Photobiomodulation therapy for the improvement of muscular performance and reduction of muscular fatigue associated with
39883205	True	Álvarez-Martínez	2025	Lasers Med Sci	A systematic review on whole-body photobiomodulation for exercise performance and recovery.
19530911	True	Hegedus	2009	Photomed Laser Surg	The effect of low-level laser in knee osteoarthritis: a double-blind, randomized, placebo-controlled trial.
20626264	True	Baroni	2010	Photomed Laser Surg	Effect of light-emitting diodes therapy (LEDT) on knee extensor muscle fatigue.
18649044	True	Leal Junior	2009	Lasers Med Sci	Effect of 830 nm low-level laser therapy in exercise-induced skeletal muscle fatigue in humans.
20011653	True	Huang	2009	Dose Response	Biphasic dose response in low level light therapy.
22045511	True	Chung	2012	Ann Biomed Eng	The nuts and bolts of low-level laser (light) therapy.
26964800	True	Hadis	2016	Lasers Med Sci	The dark art of light measurement: accurate radiometry for low-level light therapy.
39996950	True	Cronshaw	2025	Dent J (Basel)	Photobiomodulation LED Devices for Home Use: Design, Function and Potential: A Pilot Study.

APPENDIX D

Pooled effect estimates

Meta-analyses, systematic reviews and guidelines in the corpus that report a quantitative effect.

INDICATION	STUDY	DESIGN	JOURNAL	REPORTED EFFECT	PMID
acne	Wu 2021	meta-analysis	J Cosmet Dermatol	inflammatory lesions WMD=0.701 (95% CI, -0.809~2.212, p=0.363); non-inflammatory lesions WMD=-0.527 (95% CI, -3.055~2.001, p=0.683)	34363730
body composition / fat	Jiménez-García 2025	meta-analysis	Obes Rev	waist circumference Z = -2.16, p = 0.031; hip circumference Z = 2.11, p = 0.035; insulin Z = 2.11, p = 0.035; triglycerides Z = -2.4674, p = 0.0136 (human); epididymal adipocyte area Z = -5.6930, p < 0.0001; triglycerides Z = -2.0254, p = 0.04848; glucose AUC Z = -6.4112, p < 0.0001 (animal)	40186373
body composition / fat	Mustafa 2025	systematic review	Lasers Med Sci	waist circumference -1.9 cm (MD 2.5 cm); hip circumference -2.2 cm (MD 2.7 cm); effect sizes ranged -0.4 to -8.7 cm (P<0.05)	41423522
brain / cognition / mood	Seok 2026	meta-analysis	J Affect Disord	Hedges' g = -0.47, 95% CI: -0.73 to -0.22	41101469
brain / cognition / mood	Zhao 2026	meta-analysis	J Prev Alzheimers Dis	photobiomodulation SMD=0.66, 95%CrI (0.29, 1.02); enriching environment SMD=0.69, 95%CrI (0.08, 1.31)	41966601
brain / cognition / mood	Xu 2026	meta-analysis	Lasers Med Sci	PBM vs control: MMSE MD=3.14 (95% CrI: 1.71-4.60); ADAS-Cog MD=-8.01 (95% CrI: -12.82 to -3.13)	42487022
brain / cognition / mood	Stevens 2023	meta-analysis	J Neurotrauma	meta-analysis favored intervention versus control for NSS and lesion size in animal models	35698294
brain / cognition / mood	Cho 2023	meta-analysis	Photobiomodul Photomed Laser Surg	Hedges' g = 1.415, p < 0.001 (all studies); Hedges' g = 1.142, 95% CI = 0.780-1.504, p < 0.001 (MDD single-arm); Hedges' g = 0.499, p = 0.211 (double-blind sham-controlled MDD)	37651208
dental / oral other	Wei 2025	meta-analysis	Lasers Med Sci	PD reduction greater in laser group at 3 months (P = 0.02); CAL increase greater in laser group at 3 months (P < 0.001)	41339991
dental / oral other	Díaz 2025	systematic review	Photodiagnosis Photodyn Ther	60-70% decrease on Visual Analog Scale; 10-20% increase in maximum mouth opening	40096874
dental / oral other	Ansari 2024	meta-analysis	Cranio	LLLT better than TENS at 95% CI; LLLT better than US at 81% CI	35315745
dental / oral other	Quah 2024	meta-analysis	Oral Dis	HBO 4.6% ORN vs Control 17.6% (OR 0.27); PENTO 3.4% vs Control 17.6%; ABX 3.8% vs Control 17.6%	38396363
dental / oral other	Minervini 2024	meta-analysis	Acta Odontol Scand	mean difference -2.01 (95% CI: -2.43 to -1.59) on day 3, p < 0.05	39530606
dental / oral other	Alvarenga-Brant 2023	meta-analysis	J Dent Res	MD -1.90 (95% CI -3.58 to -0.21)	36214096
dental / oral other	Camolesi 2022	meta-analysis	Lasers Med Sci	Pain: MD = -2.536 (95% CI -3.662 to -1.410, p < 0.001); QoL: MD = -5.148 (95% CI -8.576 to -1.719, p = 0.003)	35122543
dental / oral other	Zhang 2021	meta-analysis	Lasers Med Sci	Pain reduction: MD -1.86 (95% CI -2.59 to -1.13, P<0.00001); Life quality: MD -3.43 (95% CI -5.11 to -1.75, P<0.0001)	32725428

INDICATION	STUDY	DESIGN	JOURNAL	REPORTED EFFECT	PMID
dental / oral other	Galiano- Castillo 2021	meta- analysis	Oral Dis	standardized mean difference -0.90 (-1.48; -0.32) for quality of life vs placebo in burning mouth syndrome (3 studies)	32964596
dental / oral other	Zhang 2021	meta- analysis	Lasers Med Sci	MD -3.01, 95% CI [-4.68, -1.35], p = 0.0004 at 60 days	33660109
dental / oral other	Li 2021	meta- analysis	Photobiomodul Photomed Laser Surg	MD 0.30 mm (95% CI: -0.02 to 0.62) at 1 month; 0.69 mm (95% CI: 0.08 to 1.29) at 2 months; 0.64 mm (95% CI: -0.01 to 1.29) at 3 months	33733872
dental / oral other	Shan 2021	meta- analysis	Clin Oral Investig	Immediate SMD: 1.09 (95% CI: 0.47–1.70); Interim SMD: 1.32 (95% CI: 0.41–2.23); Persistent SMD: 2.86 (95% CI: 1.98–3.74) vs placebo	34642786
dental / oral other	Shafae 2020	meta- analysis	Photodiagnosis Photodyn Ther	3.41 higher pain level reduction on VAS score compared to alveogyl	32919077
dental / oral other	Cronshaw 2019	systematic review	Photobiomodul Photomed Laser Surg	pain reduction in 7/9 studies; tooth movement acceleration 20-40% in 4/7 studies	31755850
dental / oral other	Xu 2018	meta- analysis	Pain Res Manag	positive effects on pain relief (VAS); significant pain reduction at short-term follow-up; improved TMJ function vs placebo	29861802
dental / oral other	Li 2015	meta- analysis	Lasers Med Sci	Pain score: MD = -4.39 (95% CI -5.9 to -2.88, P < 0.00001); most painful day: MD = -0.42 (95% CI -0.74 to -0.10, P = 0.009); pain termination: not significant	25258106
dosimetry / safety	Nozimoto 2024	meta- analysis	Breastfeed Med	MD -0.15; 95% CI -1.49 to 1.19; 139 participants, 2 RCTs	38837198
dosimetry / safety	Ayar 2022	meta- analysis	Lasers Med Sci	locomotor recovery SMD=1.21 (95%CI: 0.09, 2.33; p=0.03) for wavelengths <700nm; SMD=1.72 (95%CI: 0.84, 2.59; p=0.0001) for energy densities <100 J/cm2; SMD=2.21 (95%CI: 1.24, 3.19; p<0.00001) for 1-2 week duration	33791887
exercise / muscle	Lauxen 2025	meta- analysis	Lasers Med Sci	pain p=0.08, handgrip strength p=0.11, functionality improved	39776290
exercise / muscle	Son 2025	meta- analysis	Syst Rev	burning mouth syndrome pain: eSMD -0.92 [95% CI -1.38 to -0.46]; knee osteoarthritis disability: 0.65 [0.14 to 1.15]; fibromyalgia fatigue: 1.25 [0.63 to 1.87]; androgenetic alopecia hair density: 1.32 [1.00 to 1.63]; cognitive function: 0.49 [0.14 to 0.84]	40770824
exercise / muscle	Ferlito 2022	meta- analysis	Lasers Med Sci	muscle strength SMD=1.73 (95% CI 1.33–2.13, p<0.00001); DOMS MD=–25.69% (95% CI –34.42 to –16.97, p<0.00001); muscle damage SMD=–1.48 (95% CI –1.93 to –1.03, p<0.00001)	34669081
exercise / muscle	Vanin 2018	meta- analysis	Lasers Med Sci	very low to moderate quality of evidence, some effect favoring phototherapy vs placebo on time to exhaustion, repetitions, isometric peak torque, blood lactate	29090398
exercise / muscle	Nampo 2016	meta- analysis	Lasers Med Sci	LASERtherapy: repetitions MD 3.51 [0.65–6.37] P=0.02; time to exhaustion MD 4.01s [2.10–5.91] P<0.0001; lactate MD –0.34 mmol/L [–0.19 to –0.48] P<0.00001; peak torque MD 21.51 Nm [10.01–33.01] P<0.00001. LEDtherapy: no significant difference.	27272746
exercise / muscle	Leal-Junior 2015	meta- analysis	Lasers Med Sci	Time to exhaustion +4.12 s (95% CI 1.21–7.02, p<0.005); repetitions +5.47 (95% CI 2.35–8.59, p<0.0006)	24249354

INDICATION	STUDY	DESIGN	JOURNAL	REPORTED EFFECT	PMID
eye / vision	Yang 2025	meta-analysis	Semin Ophthalmol	SER MD 0.49 (95% CI 0.27-0.71, $p < 0.00001$); AL MD -0.24 (95% CI -0.32 to -0.17 , $p < 0.00001$); SFCT MD 28.16 (95% CI 18.78-37.55, $p < 0.00001$)	39826095
eye / vision	Ullah 2025	meta-analysis	Eur J Ophthalmol	AL reduction MD 0.953 ± 0.294 (95% CI 0.775-0.980); SER reduction MD 1.521 ± 0.662 (95% CI 0.102-2.736)	39981627
eye / vision	Fan 2025	meta-analysis	Front Med (Lausanne)	AL at 12mo: -0.30 mm (95% CI: -0.36 , -0.24 ; $p < 0.00001$); SER at 12mo: 0.61 D (95% CI: 0.47, 0.76; $p < 0.00001$); SFCT at 12mo: 29.72 μ m (95% CI: 19.53, 39.92; $p < 0.00001$)	40880774
eye / vision	Youssef 2024	meta-analysis	BMC Ophthalmol	At 12 months: AL MD = -0.31 mm (95% CI $[-0.42, -0.19]$), SER MD = 0.63 D (95% CI $[0.52, 0.73]$)	38378527
eye / vision	Tang 2023	meta-analysis	Am J Ophthalmol	SER: 0.68 D per 6 months (95% CI 0.38-0.97, $p < 0.001$); AL: -0.35 mm per 6 months (95% CI -0.51 to -0.19 , $p < 0.001$); SFChT: 36.04 μ m per 6 months (95% CI 19.61-52.48, $p < 0.001$)	37030495
eye / vision	Wang 2023	meta-analysis	Eye Contact Lens	AL MD: -0.25 mm (95% CI: -0.32 to -0.17 , $P < 0.001$); SER MD: 0.60 D (95% CI: 0.44-0.76, $P < 0.001$)	37565498
hair growth	Perez 2025	meta-analysis	Dermatol Surg	androgenetic alopecia < 20 weeks: SMD = 1.14 (95% CI 0.51-1.78, $p = .000$); > 20 weeks: SMD = 1.44 (95% CI 0.97-1.91, $p = .000$)	39404126
hair growth	Alosaimi 2025	meta-analysis	J Dermatolog Treat	hair counts: MD = -0.04 , 95% CI -1.22 to 1.14 , $p = .95$; hair diameter: MD = 0.00, 95% CI -0.00 to 0.00 , $p = .98$	39828269
hair growth	Mawu 2025	meta-analysis	Lasers Med Sci	Hair density MD 6.62 J/cm ² (95%CI: 2.04-11.20, $p = 0.005$); hair diameter MD 0.01 mm (95%CI: 0.00-0.01, $p = 0.002$); satisfaction RR 1.71 (95%CI: 1.23-2.38, $p = 0.002$)	40826200
hair growth	Behrangi 2022	systematic review	J Cosmet Dermatol	SADBE 79.6% complete regrowth, laser 63.61%, Anthralin 30-35%; average response: SADBE 53.8%, laser 52.55%, Anthralin 30.86%	34606676
hair growth	Gupta 2021	meta-analysis	J Dermatolog Treat	SMD 1.02 (95% CI: 0.68, 1.36), $p < .00001$	31746251
hair growth	Zhou 2020	meta-analysis	Dermatol Ther	$P < .05$ for global photographic assessment; $P < .05$ for hair count (LLLT or microneedling + minoxidil vs monotherapy)	32478968
hair growth	Gupta 2020	systematic review	Dermatol Ther	1 J/cm ² increase in fluence associated with 0.23 hairs/cm ² increase (95% CI: 0.21-0.25); pulse vs. continuous $\beta = 10.11$, $P < .01$; total exposure duration $\beta = .53$, $P < .05$	32790116
hair growth	Liu 2019	meta-analysis	Lasers Med Sci	SMD 1.316, 95% CI 0.993 to 1.639	30706177
hair growth	Affi 2017	systematic review	Lasers Surg Med	9/11 studies found statistically significant improvements in hair count/density; hair thickness and tensile strength improved in 2/4 studies	27114071
lymphedema	Wahid 2024	meta-analysis	Asian Pac J Cancer Prev	Combined intervention arm volume reduction MD = 76.27 (95% CI = 33.84-118.69); LLLT MD = 91.98 (95% CI = 41.99-141.97); endermology MD = 34.61 (95% CI = 20.81-48.41)	39611899
lymphedema	Mahmood 2022	systematic review	BMC Cancer	considerable reduction in arm circumference/ volume at four weeks and long-term follow-up; no statistically significant change in shoulder mobility or pain severity at 0-3 months	36042421

INDICATION	STUDY	DESIGN	JOURNAL	REPORTED EFFECT	PMID
lymphedema	Smoot 2015	meta-analysis	J Cancer Surviv	Volume within-group ES -0.52 (95% CI -0.78, -0.25), 75.7-ml reduction; between-group ES -0.62 (95% CI -0.97, -0.28), 90.9-ml greater reduction. Pain within-group ES -0.62 (95% CI -1.06, -0.19), 13.5-mm reduction.	25432632
lymphedema	E Lima 2014	systematic review	Lasers Med Sci	reduction in limb volume in laser group vs. other treatments	23192573
musculoskeletal pain	Wang 2026	meta-analysis	Ann Med	one-week pain: MD -0.74 (95% CI -1.00, -0.47, $p<0.0001$); grip strength 4w: MD 5.03 (95% CI 4.29, 5.78, $p<0.0001$)	42080480
musculoskeletal pain	Lan 2025	meta-analysis	Aging Clin Exp Res	LLLT VAS: MD=-3.32 (95% CI: -3.82 to -0.75); LLLT WOMAC pain: MD=-3.74 (95% CI: -6.68 to -0.72); ESWT VAS: MD=-1.31 (95% CI: -2.42 to -0.16)	40192971
musculoskeletal pain	Fan 2024	systematic review	Aging Clin Exp Res	LLLT vs sham pain: SMD = 0.96, 95% CI 0.31-1.61. 904-905 nm vs sham: SUCRA 86.90%. 785-850 nm vs sham: SUCRA 54.97%.	39367994
musculoskeletal pain	Chaves 2023	meta-analysis	Orthod Craniofac Res	SMD 0.62; P = .850 at 3 months	35545921
musculoskeletal pain	Naterstad 2022	meta-analysis	BMJ Open	Pain reduction at completed therapy: 13.15 mm VAS (95% CI 7.82-18.48); 4-12 weeks: 12.56 mm VAS (95% CI 5.69-19.42). Disability at completed therapy: SMD 0.39 (95% CI 0.09-0.7); 4-9 weeks: SMD 0.32 (95% CI 0.05-0.59).	36171024
musculoskeletal pain	Martimbianco 2020	meta-analysis	Clin Rehabil	Pain at 2 months: MD -2.55 (95% CI -3.87 to -1.23); function at 1 month: MD 9.19 (95% CI -16.16 to -2.23)	32204620
musculoskeletal pain	Girgis 2020	meta-analysis	Phys Ther Sport	pain reduction 1.53 cm; 95% CI [1.14, 1.91]; grip strength 9.59 kg; 95% CI [5.90, 13.27]	32877858
musculoskeletal pain	Cheung 2020	systematic review	Physiotherapy	VAS mean difference -0.53cm (95% CI -1.01 to -0.05cm; $P=0.03$, $I^2=25\%$)	32026843
musculoskeletal pain	Wang 2019	meta-analysis	Medicine (Baltimore)	VAS score significantly decreased at endpoint; improvement continued up to 3 months	30653125
musculoskeletal pain	Dos Santos 2019	meta-analysis	Photobiomodul Photomed Laser Surg	VAS: $\text{Chi}^2=29.30$, $p<0.00001$, $I^2=90\%$; FFI: $\text{Chi}^2=-83.46$, $p<0.00001$, $I^2=99\%$	31107161
musculoskeletal pain	Yeh 2019	meta-analysis	Pain Physician	FIQ SMD 1.16 (95% CI 0.64-1.69); pain severity SMD 1.18 (95% CI 0.82-1.54); tender points SMD 1.01 (95% CI 0.49-1.52); fatigue SMD 1.4 (95% CI 0.96-1.84); stiffness SMD 0.92 (95% CI 0.36-1.48); depression SMD 1.46 (95% CI 0.93-2.00); anxiety SMD 1.46 (95% CI 0.45-2.47)	31151332
musculoskeletal pain	Stausholm 2019	meta-analysis	BMJ Open	Pain reduction 14.23 mm VAS (95% CI 7.31-21.14) end of therapy; 15.92 mm VAS (95% CI 6.47-25.37) follow-up 1-12 weeks; recommended doses 18.71 mm (95% CI 9.42-27.99) end, 23.23 mm (95% CI 10.60-35.86) follow-up 2-12 weeks	31662383
musculoskeletal pain	Li 2016	meta-analysis	Medicine (Baltimore)	Hand grip MD=2.04 (95% CI 0.08-3.99, $P=0.04$); VAS MD=0.97 (95% CI 0.84-1.11, $P<0.01$); SNAP MD=1.08 (95% CI 0.44-1.73, $P=0.001$)	27495063
musculoskeletal pain	Kadhim-Saleh 2013	meta-analysis	Rheumatol Int	VAS mean improvement 10.54 (95% CI 0.37-20.71; $I^2=65\%$, $P=0.02$)	23579335
musculoskeletal pain	Tumilty 2010	meta-analysis	Photomed Laser Surg	Lateral epicondylitis grip strength 9.59 kg higher vs control; Achilles tendinopathy 13.6 mm less pain on 100 mm VAS	19708800
musculoskeletal pain	Brosseau 2007	systematic review	Cochrane Database Syst Rev	Pain SMD -0.28 (95% CI: -0.48 to -0.09); pain during movement WMD -1.16 (95% CI: -2.02 to -0.30)	17636694

INDICATION	STUDY	DESIGN	JOURNAL	REPORTED EFFECT	PMID
musculoskeletal pain	Brosseau 2005	meta-analysis	Cochrane Database Syst Rev	Pain reduction 1.10 points (95% CI: 1.82, 0.39) VAS; morning stiffness -27.5 min (95% CI: 2.9-52); flexibility +1.3 cm (95% CI: 0.8-1.7)	16235295
musculoskeletal pain	Brosseau 2004	systematic review	Cochrane Database Syst Rev	Pain (SMD): -0.2 (95% CI: -1.0, +0.6); one trial OR 0.05 (95% CI: 0.0-1.56)	15266461
musculoskeletal pain	Brosseau 2003	meta-analysis	Cochrane Database Syst Rev	Pain (SMD: -0.2, 95% CI: -1.0, +0.6); OR 0.05 (95% CI: 0.0-1.56) for pain relief yes/no	12804422
musculoskeletal pain	Brosseau 2000	systematic review	Cochrane Database Syst Rev	Pain (SMD): -0.2 (95% CI: -1.0, +0.6); odds ratio 0.05 (95% CI: 0.0 to 1.56)	10796460
musculoskeletal pain	Brosseau 2000	systematic review	Cochrane Database Syst Rev	pain reduction 70% vs placebo; morning stiffness -27.5 min (95% CI: -2.9 to -52); tip-to-palm flexibility +1.3 cm (95% CI: 0.8 to 1.7); no difference in functional assessment, range of motion, swelling	10796462
nerve / neuropathy	Hakimiha 2021	systematic review	Quintessence Int	2/3 RCTs showed significant neurosensory recovery; observational study and all case series reported improvement	33433080
nerve / neuropathy	Mirzaei 2019	systematic review	Lasers Med Sci	six of seven studies showed relative improvement in subjective and one or more objective sensory tests	30661183
nerve / neuropathy	Chow 2011	systematic review	Photomed Laser Surg	13 of 18 human studies showed slowed conduction velocity and/or reduced compound action potential amplitude	21456946
oral mucositis	Grzech-Leśniak 2025	meta-analysis	Dent Med Probl	severe OM risk reduced 40-80% (preventive); ulcer duration shortened 4-7 days (therapeutic)	41410110
oral mucositis	Bai 2024	meta-analysis	PLoS One	Peri-implantitis PBMT+MD PPD (SUCRA 75.3%); SA+MD CAL (SMD 2.20, 95% CI 0.38-4.02); SA+MD MBL (SMD 3.92, 95% CI 2.90-4.93). Peri-implant mucositis probiotics+MD PPD (SUCRA 100%); SA+MD BoP (SMD 0.77, 95% CI 0.27-1.28).	39141633
oral mucositis	Patel 2021	guideline/consensus	Eur J Cancer	photobiomodulation therapy RR 0.40, 95% CI 0.27-0.60	34252760
oral mucositis	Lin 2018	systematic review	J Periodontol	Non-surgical: PD WMD 0.15 mm (P=0.50), CAL WMD -0.10 mm (P=0.32), BOP WMD 21.08% (P=0.02), PI WMD -0.07 (P=0.002), MBL WMD -0.22 mm (P=0.04), REC WMD -0.11 mm (P=0.34). Surgical: PD WMD 0.45 mm (P=0.11), CAL WMD 0.22 mm (P=0.56), BOP WMD 7.26% (P=0.76), PI WMD -0.09 (P=0.84)	30133748
oral mucositis	Peng 2017	meta-analysis	Oral Oncol	SUCRA 95.8% for low-level laser vs SOC alone SUCRA 0.4%	29224830
other	Ahmed 2026	systematic review	Evid Based Dent	Pain scores decreased ~30-55% within first postoperative week; improved epithelialisation and soft tissue healing	41578029
other	Lin 2024	meta-analysis	Lasers Med Sci	House-Brackmann scale MD = -1.51 (95% CI -2.43 to -0.59); Sunnybrook MD = 20.63 (95% CI 10.33 to 30.94); Facial Disability Index MD = 17.91 (95% CI 5.60 to 30.22)	39546047
other	Ngoc 2023	meta-analysis	Photodermatol Photoimmunol Photomed	acne SMD -2.42 [-2.64, -2.15], I ² = 17%	36310510
other	Gobbo 2023	meta-analysis	Support Care Cancer	Grade 0+1 vs 2+3 toxicity at end of RT: OR 0.28 (95% CI 0.15-0.53, p<0.0001)	36952036
other	Ramos Rocha 2022	systematic review	J Lasers Med Sci	reduced severity in cutaneous reactions	36743146

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other	Kauark-Fontes 2021	systematic review	Support Care Cancer	ICER 3050.75–5592.10 USD per grade 3-4 OM case prevented; 21.47 USD per percentage point lymphedema reduction vs 80.51 USD for manual lymph drainage	33411048
other	Ramezani 2020	meta-analysis	Physiol Behav	MD = 1.593 (95% CI: 1.110 to 2.075; p < 0.001) first 14 days; MD = 2.086 (95% CI: 1.570 to 2.603; p < 0.001) thereafter	32504695
other	Li 2020	systematic review	Br J Oral Maxillofac Surg	pain reduction (GaAs laser): mean difference 4.28 (95% CI 3.62–4.93, p<0.00001)	31926767
other	Clijisen 2017	meta-analysis	Eur J Phys Rehabil Med	pooled mean difference D = -0.85 (95% CI: -1.22 to -0.48)	28145397
other	Fulop 2009	meta-analysis	Photomed Laser Surg	d = +1.94 (95% CI = 0.58–2.50); animal studies d = +2.60; human studies d = +0.34	19698019
other	Yousefi-Nooraie 2008	meta-analysis	Cochrane Database Syst Rev	Three studies (168 people) showed statistically significant but clinically unimportant pain relief; relapse rate significantly lower in LLLT group at six months (151 people); LLLT plus exercise not better than exercise alone (102 people).	18425909
other	Yousefi-Nooraie 2007	systematic review	Cochrane Database Syst Rev	Three studies (n=168) showed significant pain relief vs sham at short/intermediate-term; long-term not reported; insufficient evidence for disability or ROM	17943838
other	Enwemeka 2004	meta-analysis	Photomed Laser Surg	tissue repair d = +1.81 (46 effect sizes); pain control d = +1.11 (9 effect sizes); collagen d = +2.78, healing rate d = +1.57, tensile strength d = +2.13, tensile stress d = +2.65, flap survival d = +1.95	15345176
respiratory / systemic	de Carvalho 2022	meta-analysis	Clin Oral Investig	VAS pain reduction at 30-day (MD = -3.52, 95% CI = -5.40, -1.64, p = 0.0002) and 60-day (MD = -5.04, 95% CI = -5.86, -4.22, p < 0.00001); Thongprasom scale at 30-day (MD = -2.50, 95% CI = -2.92, -2.08, p < 0.00001)	35024960
respiratory / systemic	Raji 2022	meta-analysis	Adv Exp Med Biol	TNFα SMD:-3.75 (95% CI: -4.49, -3.02, P<0.00001); IL-1β SMD:-4.65 (95% CI: -6.15, -3.16, P<0.00001); IL-6 SMD:-4.20 (95% CI: -6.42, -1.97, P=0.0002); IL-10 SMD:-4.65 (95% CI: -6.15, -3.16, P<0.00001); MPO SMD:-2.13 (95% CI: -3.38, -0.87, P=0.0009); vascular permeability SMD:-2.59 (95% CI: -4.40, -0....	34907516
scars / burns	Gaumond 2026	systematic review	Lasers Med Sci	Red LED improved VSS scores, pigmentation, thickness in burn scars; reduced induration, improved POSAS in post-surgical scars; near-infrared improved color, elasticity in hypertrophic scars, reduced thickness, pain, pruritus	42026334
scars / burns	Pradal 2025	meta-analysis	Photobiomodul Photomed Laser Surg	wound retraction SMD = -0.22 (95% CI -4.19, 3.75, p = 0.91); collagen deposition SMD = -0.02 (95% CI -2.17, 2.13, p = 0.99)	39172550
scars / burns	Deana 2023	meta-analysis	Burns	Excised burns: SMD=1.34, CI 95% 0.41–2.27, I²=0%; Unexcised burns: SMD=1.22, CI 95% -0.05–2.49, I²=68%	35842272
scars / burns	Deana 2021	meta-analysis	Photobiomodul Photomed Laser Surg	wound contraction: MD -11.47 (95% CI -19.87 to -3.08), I²=0%	34264767
sleep	Vital de Azevedo 2026	meta-analysis	Lasers Med Sci	MD = -1.25 (95% CI -2.38 to -0.11, p = 0.03)	42322437
wound healing	Regev-Sadeh 2026	meta-analysis	Int J Gynaecol Obstet	SMD = -0.50, 95% CI: -0.98 to -0.02, I² = 88%, P < 0.01	41450164
wound healing	Liu 2026	meta-analysis	Int Wound J	wound healing SMD 0.78 [0.46–1.09] p<0.01; pain SMD 0.71 [0.24–1.17] p<0.01	41605843

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wound healing	Rasul 2026	meta-analysis	Wound Repair Regen	Mean Difference 3.77 cm ² , 95% CI -4.45 to 11.99; p = 0.37	41889013
wound healing	Silva 2026	systematic review	Int Wound J	Three of four studies reported pain reduction; three studies showed ulcer area reduction with one reporting complete healing; granulation tissue formation observed in three of four studies	42178150
wound healing	Miranda 2025	meta-analysis	Lasers Med Sci	area reduction rates 63.7% (632 nm) and 56.8% (904 nm), no statistically significant difference	39982518
wound healing	Chaple Gil 2025	systematic review	Photodiagnosis Photodyn Ther	postoperative pain reduced 30-55% within 3-7 days post-surgery (VAS); reduced TNF- α and IL-6, increased VEGF	40288479
wound healing	Mahintach 2025	systematic review	Lasers Med Sci	Group A: 0.93% MRONJ incidence (95% CI 1.3%-3.4%); Group B: 91.67% complete healing rate (95% CI 54.57%-68.34%)	41398507
wound healing	Chang 2024	systematic review	Lasers Med Sci	90% of studies reported smaller areas of necrosis in skin flap	38649643
wound healing	Yoshimura 2023	meta-analysis	Photochem Photobiol	wound closure MD 9.69 (95% CI 5.78-13.61, P<0.00001); wound strength SMD 1.7 (95% CI 0.68-2.72, P=0.001)	36004458
wound healing	Zheng 2023	meta-analysis	Int Wound J	WCR: MD 9.08 (95% CI 5.55-12.61, p < 0.001); WTS: MD 2.01 (95% CI -0.42-4.44, p = 0.10)	37525509
wound healing	Santos 2021	meta-analysis	Int J Low Extrem Wounds	22.96% reduction in ulcer size (95% CI 18.22-27.69; z=9.51, P<0.0001)	32394760
wound healing	Zhao 2021	meta-analysis	Lasers Med Sci	significant pain relief at day 3 post-surgery; no difference at day 7; significant reduction in mean analgesic intake first week; faster re-epithelialization day 14	32613416
wound healing	Huang 2021	meta-analysis	Int Wound J	Complete healing RR=2.10 (95% CI 1.56-2.83, P<0.00001); ulcer area SMD=3.52 (95% CI 1.65-5.38, P=0.0002); healing time SMD=-1.40 (95% CI -1.90 to -0.91, P<0.00001)	33751853
wound healing	Ebrahimi 2021	meta-analysis	BMC Oral Health	Landry index day 7: SMD = 1.044 [95% CI 0.62-1.46], p < 0.01; complete epithelialization day 14: RR = 3.23 [95% CI 1.66-6.31], p < 0.01	33985492
wound healing	Petz 2020	systematic review	Photochem Photobiol	658 nm showed complete wound healing (P < 0.001) vs 990 nm and 808 nm; no significant difference vs standard care in time to healing or area reduction	31550398
wound healing	Gál 2018	meta-analysis	Lasers Med Sci	tensile strength SMD = 1.06 (95% CI 0.66-1.46); wound contraction SMD = 0.99 (95% CI 0.38-1.59)	29603108
wound healing	Machado 2017	systematic review	Lasers Med Sci	658 nm: 71% reduction in PU area; 47% complete healing at 1 month vs. other wavelengths (not significant)	28116536
wound healing	Suter 2017	systematic review	Lasers Med Sci	Pain relief immediately after treatment in 5/6 studies; wound healing duration reduced in 5 studies	28345122
wound healing	Woodruff 2004	meta-analysis	Photomed Laser Surg	Overall d = +2.22 (p < 0.05); animal d = +1.97; human d = +0.54; inflammation d = +4.45; collagen d = +1.80; tensile strength d = +2.37; healing time d = +3.24; wound size d = +0.55	15315732
wound healing	Lucas 2002	systematic review	Lasers Med Sci	49 outcome parameters: 30 positive, 19 no effect; pooled SMD over 22 measures incomplete in abstract	12143832
wound healing	Flemming 2000	systematic review	Cochrane Database Syst Rev	No significant difference in healing rates between laser and sham (pooled RCTs); combination laser + infrared vs. non-coherent red light showed significantly more complete healing (one small study).	10796615