Muscle Light Therapy

One of the lesser known parts of the body that light therapy studies have examined is the muscles. Human muscle tissue has highly specialised systems for energy production, needing to be able to provide energy for both long periods of low consumption and short periods of intense consumption. Research in this area has accelerated dramatically in the last couple of years, with dozens of new high quality studies every month. Red and infrared light have been studied intensively for a variety of ailments and conditions, from joint pain to wound healing, possibly because the cellular effects are theorised to work on a foundational energetic level. So if light penetrates down into muscle tissue, can it exert beneficial effects there? In this article we will examine how light interacts with these systems and what benefits it may bring, if any.

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Light might interact with muscle function, but how?

To understand how light might affect muscle tissue, we need to first understand how muscle tissue actually functions. Energy is necessary for life in every cell of every species we currently know of. This fact of life is more obviously apparent in muscle tissue, from a mechanical perspective, than any other type of tissue. Since muscles are involved in movement, they must be generating and using energy, or they wouldn't move. Anything that helps with this fundamental energy production will be valuable.

- The light therapy mechanism

Light therapy has a well-known mechanism in any nearly any cell of the body with a mitochondrion (mitochondria being the organelles responsible for energy production). You can look into Cytochrome C Oxidase and Nitric Oxide to learn more of the specifics here, but basically the hypothesis is that both red and near-infrared light help our mitochondria to complete the process of respiration, giving more CO_2 and ATP (energy). This would in theory apply in pretty much any cell of body, besides those lacking mitochondria such as red blood cells.

- The muscle-energy connection

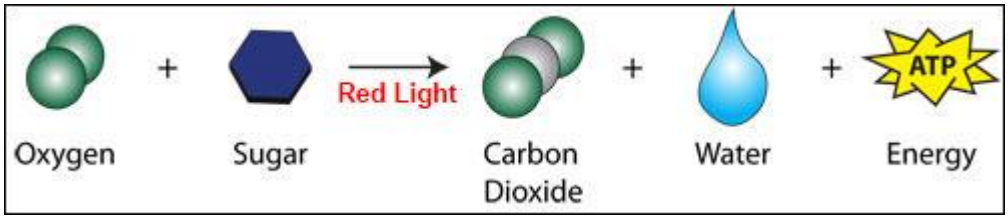
One of the key characteristics of muscle cells is that they are exceptionally abundant in mitochondria, needing them to fulfil the high energy demands. This applies to skeletal muscle, cardiac muscle, and smooth muscle tissue like you would find in internal organs. The density of mitochondria in muscle tissue varies between species and parts of the body, but they all need a high degree of energy to function. The rich presence overall suggests why light therapy researchers are interested in the application of targeting muscles, even more so than other tissues.

- Muscle stem cells – growth & repair enhanced by light?

Myosatellite cells, a type of muscle stem cell involved in growth and repair, are also a key potential target of light therapy[1,5], perhaps even the main target that gives long term effects. These satellite cells become active in response to strain (such as from mechanical movement like exercise or from injury) – a process that could be enhanced by light therapy[9]. Like stem cells in any location of the body, these satellite cells are essentially the precursors to normal muscle cells. They usually exist in a relaxed, inactive state, but will turn into other stem cells or turn into fully functional muscle cells as part of the healing process, in response to injury or exercise trauma. Recent research points to mitochondrial energy production within stem cells as the primary regulator of their fate[6], essentially determining their 'programming' as well as their speed and efficiency. Since the hypothesis behind light therapy is that it might be a potent promoter of mitochondrial function, a clear mechanism exists to explain how light could maybe improve our muscle growth and repair via stem cells.

- Inflammation

Inflammation is a typical feature associated with muscle damage or stress. Some researchers think that light might help (if used appropriately) to reduce the severity of the inflammation[3] (by increasing levels of CO_2 – which then goes on to inhibit inflammatory cytokines/prostaglandins), thus allowing more efficient repair without scarring/fibrosis[5].



Light therapy may or may not also help muscles indirectly by:

- *Thyroid regulation*

Considered by some as the master regulatory hormone of the body, thyroid hormones are involved in cellular energy production in a big way. As mentioned above energy production is essential for both muscular performance and recovery. Studies have been done with (near)infrared light on the thyroid gland with the aim of seeing whether it can help normalise thyroid hormone levels, thus potentially helping muscle performance downstream. You can read more about thyroid light therapy here.

- *Sleep improvement*

Better sleep is one of the most often reported effects of red light therapy, with several studies now showing evidence to support the common claim. As bodybuilders and athletes will testify to, good deep sleep is one of the most important parts of recovery, so any improvement here will help muscle function and healing.

- *Testosterone boost*

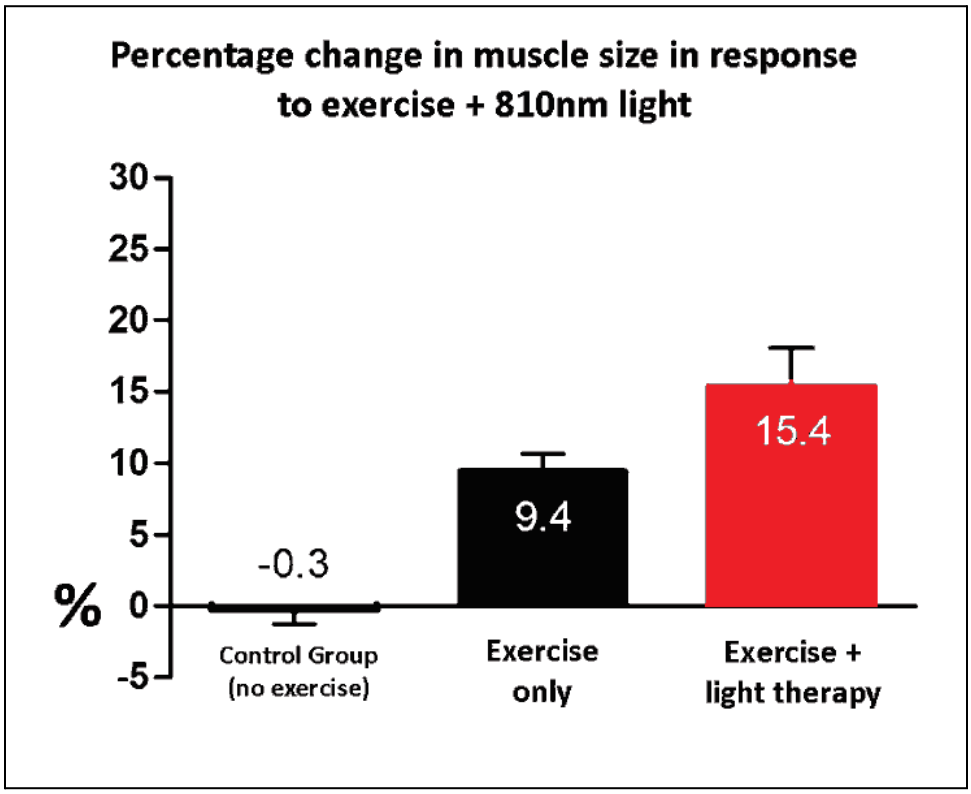
Some researchers think, and some animal studies have shown, that for men, red light can be used directly in the vicinity of the testes to potentially improve levels of the hormone testosterone. This hormone is well established in endocrinology as directly useful in boosting muscle strength, size and performance. We have a whole blog post on this topic here.

The potential benefits to muscle function from light therapy

Essentially anyone that uses their muscles, or has a problem using their muscles, has been studied in terms of light therapy – athletes[10,11,12,16,18], people with injuries and muscular disorders, bodybuilders[20], and even just regular people exercising to stay in shape[2,17]. The same applies to pretty much any animal too, such as horses and dogs, whether involved in competitive racing or otherwise. Below are some of the effects studied in relation to light therapy on muscles:

- ## Hypertrophy

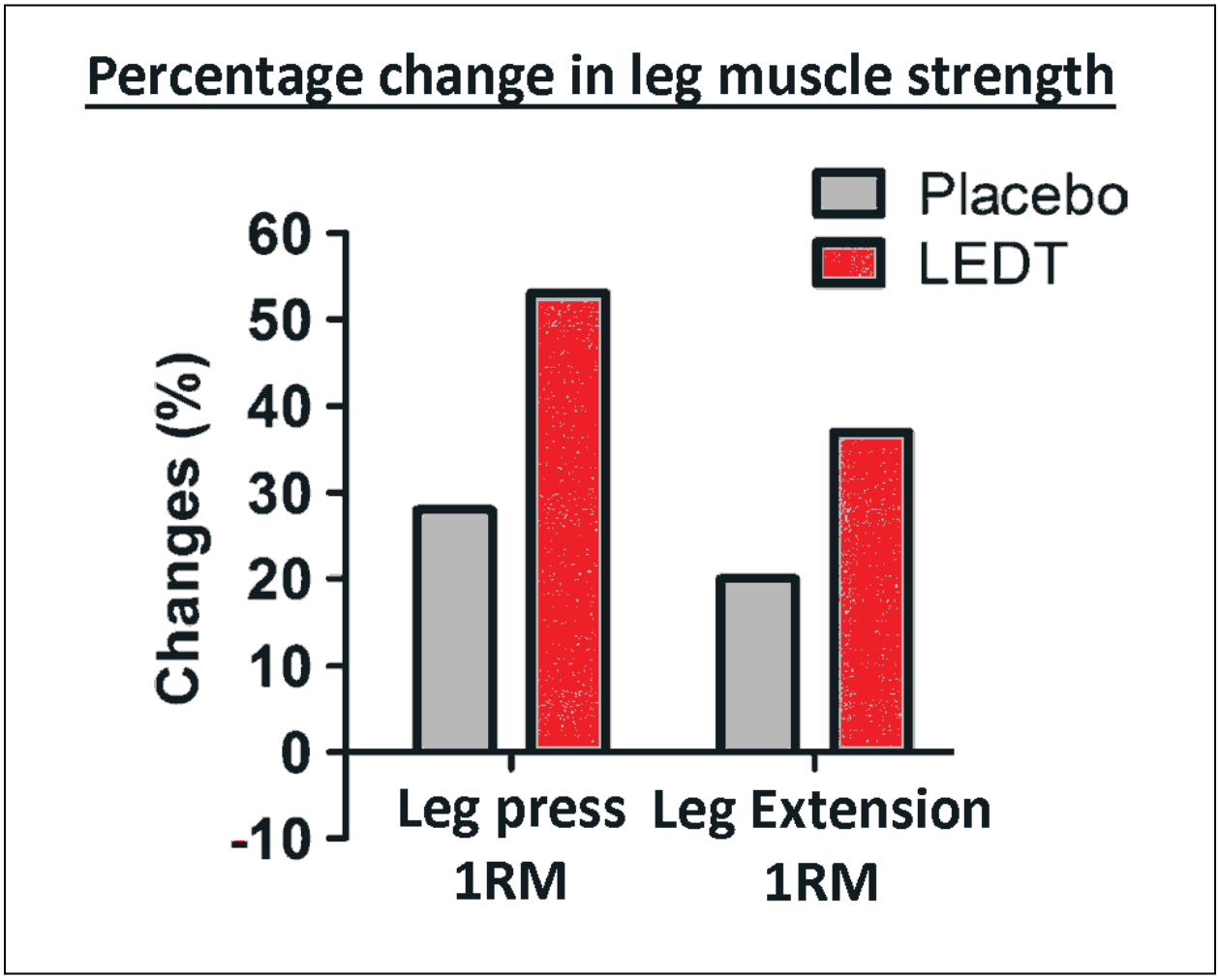
The increase in size of muscles as a result of exercise (known as hypertrophy) has been studied in conjunction with light therapy, with interesting results[2,14]. In the context of muscle tissue, hypertrophy is part of an adaptive response that helps the tissue to generate more force with less fatigue. The physical appearance of long term gains in muscle size is highly sought after by bodybuilders and anyone trying to improve their shape/physique.



Changes in muscle size over an 8 week period of resistance training of leg muscles. Control (no exercise, no light) vs Exercise only vs Exercise+Light.[2]

Strength – get stronger with light therapy?

Briefly mentioned above, light could interact with Myosatellite cells and regular muscle cells by potentially improving energy production. This would in theory give an immediate increase in strength and endurance through the regular muscle cells[12,13,14,20], but also a long term increase through the myosatellite cells (relative to exercising without any complimentary light therapy)[4].

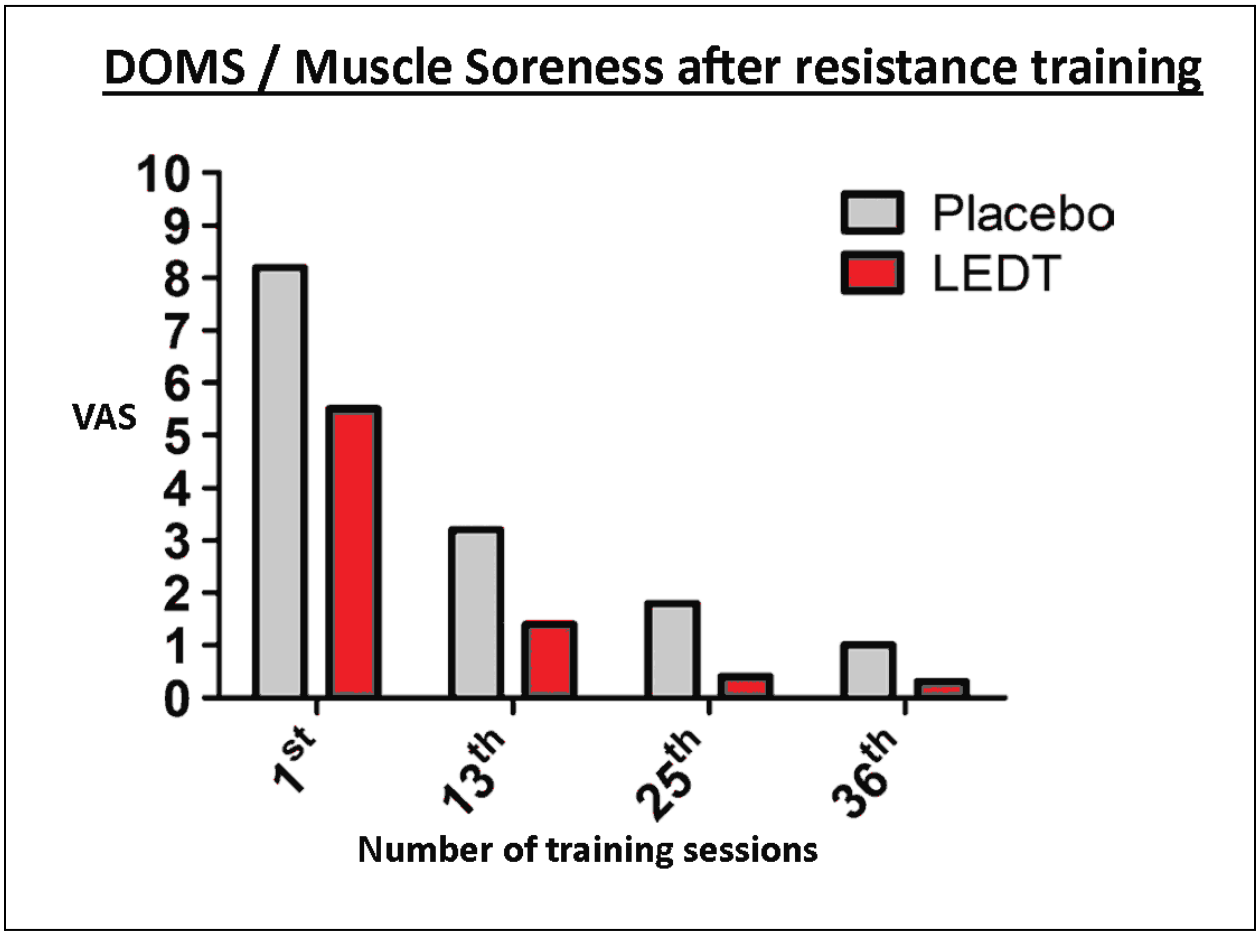


One-rep max after dozens of training sessions, followed by either placebo treatment or 850nm LED treatment, in identical twins[14].

The studies looking at this tend to examine peak torque – the maximum force generated by a specific movement – and how this changes over time. Just like with hypertrophy, or to some extent because of hypertrophy, light therapy in conjunction with exercise, in these studies, clearly improved the gains in strength compared to exercise alone[2]. The gains have been significant across a wide range of studies, so much so that international regulatory authorities for sports are considering whether light therapy should even be permitted[10].

Reduce DOMS/soreness with light therapy?

Several studies on muscle light therapy now point to the potential reduction, and quicker resolution, of delayed onset muscle soreness[4,14] – the uncomfortable, yet sometimes satisfying, feeling you get in muscles the day after a tough workout. DOMS is thought to be caused by microtrauma to muscle fibers and is characterised on a cellular level by a rapid influx of calcium into the cell (amongst other things), which inhibits respiration. The displaced calcium entering the muscle cells can lead to damage and inflammation, hence the painful/sore feeling.



Severity of muscle soreness after exercise (DOMS) measured by the visual analogue scale (VAS) with placebo or with 850nm LED light therapy after exercise[14]

The calcium needs to be transported out of the cell again for recovery to proceed, and the cell needs ATP (energy) to do this. Fortunately the hypothesis explaining light therapy is that it potentially speeds up production of ATP (not to mention helping us to produce CO_2 which reduces inflammation), and would thereby perhaps speed up the whole muscle recovery process[7,8,9], which would in theory reduce both the severity of DOMS and the length of time until full recovery.

- ## Improve injury/strain recovery with light?

Various studies point to the potentially positive effects of appropriately used light on post-injury recovery[3,4,7,9]. One risk of muscle injuries in general is the formation of fibrosis or scar tissue. Just as we get scars on the skin as a result of damage, we can also get them inside the muscles as the inflammatory response causes a spike in collagen formation. Light therapy may help to prevent that scarring[5]. When scar tissue forms in muscles, this

permanently alters the function and mechanical properties of the muscle, leading to reduction in mobility/strength, long term pain, perhaps ending an athlete's career or even disability in extreme cases. Resolving the injury as quickly as possible with as little inflammation as possible is crucial. Light therapy could be effective here for several reasons – as mentioned above it seems to be useful in reducing the acute inflammatory response, but also in kick starting and supporting the key processes of the muscle recovery process on a cellular level. Indeed this healing effect found in some studies on light therapy is apparent on not just muscle injuries, but also studied on wounds anywhere on the body, such as the skin but even brain trauma and broken bones.

Ideal light for muscle light therapy

There are several factors to consider to ensure that a light device is suitable for muscle light therapy.

- Infrared penetrates more than red

Perhaps the most obvious barrier to successful light therapy on muscles is actually getting the light down into the muscles. The majority of light applied to the body is absorbed in the skin, making treatment of deeper tissue problematic. Fortunately, we know that the infrared light therapy wavelengths between about 700-900nm penetrate much better than other wavelengths, including the red wavelengths at 600-700nm. This makes near-infrared light by far the most chosen wavelength range in studies muscle treatment. This doesn't include any other form of infrared light, such as the mid-infrared or the far-infrared heat, neither of which are at all suitable. Even the near-infrared over 900nm is not really suitable, since it is progressively blocked by water in skin cells. Red light is still studied for this purpose, but will need a much higher application dose compared with an equal dose of infrared. Red light around 660-670nm is actually used in a large amount of studies on the topic, referenced below, especially in smaller animals like rodents, where penetration is less of an issue due to their tiny size. It still gives interesting results. 760-780nm is used in quite a few studies too, showing equally good effects. Most of the studies seem to indicate light around 810-830nm as the most chosen range[17,18,19], especially in larger animals like humans/horses.

- Higher power density / high dose required

Even using the most penetrative types of near-infrared light at about 740-830nm, most of the energy is still absorbed by the skin and first layers of tissue (albeit a lower percentage than other wavelengths). So once you have ensured your light device has the suitable wavelengths, you need to ensure the right power. A low light intensity of even the most ideal wavelength of light isn't going to do much good. In terms of light strength, below 50mW/cm² is definitely too weak for muscle depth penetration in humans. 200mW/cm² or more is popular in studies since it would provide sufficient energy penetration in reasonable time frames[2,15]. Doses of 100J/cm² or more, even up to 700J/cm², are studied for penetrating into deeper muscles with sufficient energy over time. If you want to know more about light therapy dosing, see this post here.

- Before or after exercise?

Once you have a light device with the correct wavelengths and enough power output, you need to figure out the best time to apply the dose. Studies at the moment indicate superior results when light is used before exercise[4,11,15]. This is also the conclusion is several literature reviews and meta-analyses on the subject. Using light therapy this way may potentially improve not only exercise performance (strength, speed, endurance) but also muscle recovery post-exercise. It makes sense that using it this way may also reduce the chance of injury.

Using light after exercise is still potentially effective for recovery however, and much better than no light at all. Even using light several hours after exercise could be helpful. It could be that using light on the target muscles both before and after exercise is the best method, although this protocol has not been thoroughly compared to other protocols.

- Which light specifically?

All of the studies on the topic of muscle light therapy, and indeed the light therapy field in general, use either LEDs or lasers, both of which seem to be equally useful, with minor variations in parameters. This type of energy efficient, heat free, and specific wavelength lighting technology is required for muscle light therapy for various reasons. As the muscles are deep within the body, high doses of light must be applied to the skin in order for a reasonable dose to reach the actual muscle tissue. If a less specific lighting technology such as heat lamps, 'infrared bulbs', incandescents and other broad spectrum lights are used for the same purpose, a truly ridiculous amount of energy would have to be applied to skin to ensure the muscles receive a good dose, resulting in severe overexposure. Using these types of lights at a range that gives a good power density of the penetrative 700-850nm wavelengths would also burn the skin almost immediately.

Summary

- Light therapy is studied for muscles in a variety of ways
    - Exercise recovery, injury recovery, muscle strength/endurance, hypertrophy, pain reduction and more.
- Red and near-infrared light (600 – 900nm wavelengths) are studied for and may help muscle cells and muscle stem cells by potentially improving energy production, reducing inflammation and speeding healing.
- Near-infrared (at 740-830nm wavelengths) is the most penetrative range into biological tissue.
    - In theory requires a high power density of light (200mW/cm² or more) to achieve the penetration in bigger muscles.
- LEDs and lasers are the only currently viable, studied devices. Heat lamp light does not penetrate to muscles in sufficient density.
- Light therapy seems best used BEFORE exercise to maximise results, rather than after, according to current information.