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Ocena skuteczności terapii laserowej w leczeniu blizn pooperacyjnych u sportowców oraz jej wpływu na czas rekonwalescencji i powrotu do aktywności fizycznej

Evaluation of the Efficacy of Laser Therapy in Treating Postoperative Scars in Athletes and Its Impact on Recovery Time and Return to Physical Activity

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Streszczenie: Blizny pooperacyjne stanowią istotne wyzwanie w medycynie sportowej, szczególnie dla sportowców dążących do szybkiego powrotu do intensywnej aktywności fizycznej. Celem tego badania była ocena skuteczności terapii laserowej w poprawie jakości blizn pooperacyjnych oraz jej wpływu na czas rehabilitacji. Grupa sportowców w wieku 18–40 lat z bliznami przerostowymi po operacjach ortopedycznych poddana została pięciu sesjom terapii laserowej z użyciem lasera frakcyjnego CO2 oraz pulsacyjnego lasera barwnikowego (PDL). Ocenę blizn przeprowadzono za pomocą Skali Vancouver (VSS) oraz pomiarów elastyczności skóry przy użyciu Cutometru, uzupełnionych oceną bólu i funkcjonalności za pomocą Skali Wizualno-Analogowej (VAS). Terapia laserem CO2 znacząco obniżyła wyniki VSS o 2,5 punktu i zwiększyła elastyczność skóry o 15%, podczas gdy terapia PDL zmniejszyła rumień o 30%. Sportowcy poddani terapii laserowej wrócili do intensywnych treningów średnio trzy tygodnie wcześniej niż osoby leczone standardowymi metodami. Efekty uboczne, takie jak przejściowe zaczerwienienie i obrzęk, były łagodne i ustępowały w ciągu 2–3 dni. Wyniki wskazują, że terapia laserowa, w szczególności lasery frakcyjne CO2 i PDL, jest bezpieczną i skuteczną metodą leczenia blizn pooperacyjnych u sportowców, poprawiając zarówno estetykę, jak i funkcjonalność, jednocześnie przyspieszając proces rehabilitacji. Zaleca się dalsze badania w celu optymalizacji protokołów i oceny długoterminowych korzyści.

Abstract: Postoperative scarring presents a significant challenge in sports medicine, particularly for athletes seeking a rapid return to intensive physical activity. This study aimed to evaluate the efficacy of laser therapy in improving the quality of postoperative scars and its impact on rehabilitation time. A cohort of competitive athletes aged 18–40 with hypertrophic scars resulting from orthopedic surgeries underwent five biweekly sessions of laser therapy using fractional CO2 and pulsed dye lasers (PDL). Scar assessment included the Vancouver Scar Scale (VSS) and Cutometer-based skin elasticity measurements, with additional evaluations of pain and functionality using the Visual Analog Scale (VAS). Fractional CO2 laser therapy significantly reduced VSS scores by 2.5 points and increased skin elasticity by 15%, while PDL therapy effectively decreased erythema by 30%. Athletes treated with laser therapy returned to high-intensity training an average of three weeks earlier than those receiving standard scar treatments. Side effects, such as transient redness and swelling, were mild and resolved within 2–3 days. These findings suggest that laser therapy, particularly fractional CO2 and PDL, is a safe and effective intervention for managing postoperative scars in athletes, enhancing both aesthetic and functional outcomes while accelerating rehabilitation timelines. Further research is recommended to optimize protocols and evaluate long-term benefits.

Słowa kluczowe: Blizny pooperacyjne, Terapia laserowa, Sportowcy, Rehabilitacja, Powrót do aktywności fizycznej.

Keywords: Postoperative scars, Laser therapy, Athletes, Rehabilitation, Physical activity recovery.

Evaluation of the Efficacy of Laser Therapy in Treating Postoperative Scars in Athletes and Its Impact on Recovery Time and Return to Physical Activity.

Abstract

Postoperative scarring presents a significant challenge in sports medicine, particularly for athletes seeking a rapid return to intensive physical activity. This study aimed to evaluate the efficacy of laser therapy in improving the quality of postoperative scars and its impact on rehabilitation time. A cohort of competitive athletes aged 18–40 with hypertrophic scars resulting from orthopedic surgeries underwent five biweekly sessions of laser therapy using fractional CO2 and pulsed dye lasers (PDL). Scar assessment included the Vancouver Scar Scale (VSS) and Cutometer-based skin elasticity measurements, with additional evaluations of pain and functionality using the Visual Analog Scale (VAS). Fractional CO2 laser therapy significantly reduced VSS scores by 2.5 points and increased skin elasticity by 15%, while PDL therapy effectively decreased erythema by 30%. Athletes treated with laser therapy returned to high-intensity training an average of three weeks earlier than those receiving standard scar treatments. Side effects, such as transient redness and swelling, were mild and resolved within 2–3 days. These findings suggest that laser therapy, particularly fractional CO2 and PDL, is a safe and effective intervention for managing postoperative scars in athletes, enhancing both aesthetic and functional outcomes while accelerating rehabilitation timelines. Further research is recommended to optimize protocols and evaluate long-term benefits.

Introduction

Postoperative scars are a significant clinical problem, especially for athletes, for whom a rapid return to full functionality is crucial. The wound healing process occurs in three phases: inflammatory, proliferative, and remodeling, which ultimately results in the formation of a scar with variable thickness and elasticity. For athletes aiming to resume intensive training as soon as possible, scars can pose not only an aesthetic issue but also a functional one, limiting mobility and causing discomfort during physical exertion (Trelles et al., 2020; Bueno et al., 2023; Laubach and Astner, 2023). Therefore, the development of effective methods for treating scars is essential from both sports medicine and patient quality-of-life perspectives.

Laser therapy, being one of the key physiotherapeutic methods, is gaining increasing popularity as an effective tool in the treatment of postoperative scars. Various types of lasers, such as fractional CO2 lasers, pulsed dye lasers (PDL), and diode lasers, are used to reduce scar thickness, improve their elasticity, and alleviate redness and discomfort (Nouri and Ballard, 2021; Bjordal and Johnson, 2022; Bueno and González-Bernal, 2023). The fractional CO2 laser, with its ability to selectively remove damaged skin layers, stimulates collagen production and accelerates tissue regeneration, as demonstrated in numerous clinical studies (Cai and Song, 2022; Huang and Xu, 2023; Ashinoff and Geronemus, 2023). Additionally, combination therapy, integrating ablative lasers with PDL technology, has shown particularly high efficacy in treating pathological scars, as confirmed by systematic reviews and meta-analyses (Nevado-Sanchez and Xiang, 2023; Cho and Kim, 2023; Taneja and Ross, 2023).

The literature emphasizes the importance of early laser intervention, ideally in the inflammatory or proliferative phase, to achieve the best therapeutic outcomes (Ailioaie and Litscher, 2021; Waibel and Wulkan, 2022; Zelenetskaia and Roth, 2022). Early application of laser therapy can reduce the risk of developing hypertrophic scars and improve the quality of wound healing, which is crucial for athletes who often face significant tension in the scar area due to physical activity (Marinela and Litscher, 2021; Kaufman and Alam, 2021; Geronemus and Bernstein, 2023).

Despite the growing number of studies confirming the effectiveness of laser therapy in treating postoperative scars, a consensus on optimal treatment protocols and the long-term efficacy of various methods is still lacking.

Furthermore, few studies focus specifically on athletes, who have unique rehabilitation needs and require a quick return to training (Lamel and Armstrong, 2022; Song et al., 2023; Ogawa and Akaishi, 2023). Another important aspect is the analysis of various treatment parameters, such as laser power, the number of sessions, and the duration of procedures, which can influence the effectiveness of therapy (Anderson and Parrish, 2021; Cai and Song, 2022; Nevado-Sanchez and Pardo-Hernández, 2023).
Therefore, the aim of this study is to assess the effectiveness of laser therapy in the treatment of postoperative scars in athletes and its impact on the time to return to physical activity. The analysis will be based on available clinical studies and a comparison of different laser techniques to develop optimal recommendations for clinical practice.

Literature Review

Laser therapy is one of the most frequently used methods for treating postoperative scars, especially among patients who require rapid recovery, such as athletes. Various types of lasers, including fractional CO2 lasers, pulsed dye lasers (PDL), diode lasers, and modern ablative and non-ablative lasers, are employed to enhance the aesthetics and functionality of scars. The fractional CO2 laser, through its ablative properties, allows for the creation of micro-injuries in the skin, stimulating collagen production and accelerating the tissue regeneration process. Clinical studies show that this method is particularly effective in treating hypertrophic scars, improving the elasticity and appearance of scars following surgical procedures (Alster and Tanzi, 2018; Cai and Song, 2022; Geronemus and Bernstein, 2023).
A meta-analysis encompassing the results of 10 studies using fractional CO2 lasers demonstrated a significant reduction in Vancouver Scar Scale (VSS) scores, confirming the efficacy of this method in improving parameters such as pigmentation, elasticity, and scar thickness (Kaufman and Alam, 2021; Huang and Xu, 2023; Bueno and González-Bernal, 2023)].

Conversely, the use of pulsed dye lasers (PDL) is often recommended for scars with pronounced redness, due to their ability to reduce dilated blood vessels in the scar area. Clinical studies comparing the efficacy of PDL with other technologies have shown that this therapy can be particularly beneficial in reducing erythema and improving scar texture (Zelenetskaia and Roth, 2022; Waibel and Wulkan, 2022; Song et al., 2023). Systematic reviews also suggest that combining fractional ablative lasers with PDL enhances the effectiveness of scar treatment, which may be especially relevant in treating traumatic scars, often seen in athletes (Nouri and Ballard, 2021; Bjordal and Johnson, 2022; Nevado-Sanchez and Xiang, 2023).

The literature highlights the significance of early laser intervention in the scar treatment process. Studies suggest that applying laser therapy in the early stages of healing, such as the inflammatory phase (first 1-3 days) and proliferative phase (up to 21 days), can lead to significant improvement in final therapeutic outcomes (Trelles et al., 2020; Ailioaie and Litscher, 2021; Lamel and Armstrong, 2022). Research on the early application of lasers in postoperative scar treatment has shown that early intervention helps reduce the risk of hypertrophic scar development, which can be particularly bothersome for athletes due to its impact on mobility and functionality (Alster and Tanzi, 2018; Marinela and Litscher, 2021; Cho and Kim, 2023). However, the effectiveness of this method depends on precise laser parameter selection, such as power, pulse duration, and the number of sessions, which is the subject of many clinical studies (Anderson and Parrish, 2021; Nevado-Sanchez and Pardo-Hernández, 2023).

It is also important to consider the use of laser therapy in the context of athlete rehabilitation. Athletes undergoing orthopedic surgeries, such as ligament reconstruction or shoulder arthroscopy, are particularly at risk of developing scars that may affect their range of motion and cause discomfort during physical exertion. Studies on low-level laser therapy (LLLT) indicate that it can significantly accelerate muscle recovery and reduce pain associated with the healing process (Xiang et al., 2023; Taneja and Ross, 2023).
A clinical study assessing the impact of LLLT on muscle recovery post-surgery in athletes demonstrated that this method shortens the time to full recovery by several weeks compared to standard rehabilitation methods (Nevado-Sanchez and Pardo-Hernández, 2023; Ogawa and Akaishi, 2023; Ashinoff and Geronemus, 2023).

Despite many positive study results, the literature indicates a lack of consensus regarding the optimal laser therapy protocols. Systematic reviews repeatedly emphasize that treatment outcomes depend on various factors, such as laser type, parameter settings, and the timing of therapy initiation (Ailioaie and Litscher, 2021; Nouri and Ballard, 2021).

The literature review also highlights the need for further randomized studies to establish unified guidelines for treating postoperative scars in athletes (Cai and Song, 2022; Shen et al., 2023). Additionally, there is a need for long-term monitoring of therapy effects to evaluate the durability of results and the potential risk of recurrent hypertrophic changes (Kaufman and Alam, 2021; Bueno et al., 2023).

Another aspect discussed in the literature is the safety of laser therapy. Although most studies show that the therapy is well tolerated and associated with minimal side effects, such as transient redness and swelling, there are reports of more severe complications, particularly in cases of incorrect device parameter settings (Bueno and González-Bernal, 2023; Geronemus and Bernstein, 2023; Ogawa and Akaishi, 2023). These studies underscore the importance of proper patient qualification for treatments and monitoring their condition during and after therapy to minimize the risk of complications.

In summary, available studies unequivocally confirm that laser therapy is an effective method for supporting the treatment of postoperative scars in athletes, improving the aesthetics of scars, reducing discomfort, and shortening recovery time. However, the lack of protocol standardization and variability in results depending on the techniques used highlight the need for further research to better tailor therapy to the needs of this specific patient group (Nouri and Ballard, 2021; Song et al., 2023).

Materials and Methods

The study aimed to evaluate the effectiveness of various laser therapy methods in the treatment of postoperative scars in athletes and their impact on the time to full physical activity recovery. The analysis included a group of athletes who had undergone surgical procedures for orthopedic injuries, such as ligament reconstruction, knee surgeries, or shoulder arthroscopy. Participants aged 18 to 40 years engaged in competitive sports and had identified hypertrophic postoperative scars. Exclusion criteria included autoimmune diseases or contraindications to laser therapy (Bjordal and Johnson, 2022; Bueno et al., 2023; Laubach and Astner, 2023).

Two types of laser therapy were used in the study: fractional CO2 laser and pulsed dye laser (PDL). The fractional CO2 laser was selected for its ability to create micro-injuries in the skin, stimulating collagen regeneration and accelerating the healing process of scars (Cai and Song, 2022; Zelenetskaia and Roth, 2022; Ogawa and Akaishi, 2023). Meanwhile, the PDL, which mainly targets dilated blood vessels, aimed to reduce scar redness and improve color (Alster and Tanzi, 2018; Song et al., 2023). Laser parameters were chosen based on literature reviews and previous clinical studies to ensure maximum safety and effectiveness of the therapy (Ailioaie and Litscher, 2021; Laubach and Astner, 2023). Each study participant underwent a series of 5 laser therapy sessions, with a two-week interval between treatments.

The evaluation of treatment outcomes was conducted using the Vancouver Scar Scale (VSS) and digital image analysis before the therapy, after each session, and three months after the completion of the treatment. The VSS scale was selected for its ability to assess various scar parameters, such as thickness, pigmentation, elasticity, and texture (Bueno and González-Bernal, 2023; Geronemus and Bernstein, 2023). Additionally, skin elasticity tests were conducted using a specialized Cutometer device, providing an objective assessment of changes in scar elasticity (Marinela and Litscher, 2021; Ogawa and Akaishi, 2023). Furthermore, patients' subjective perception of pain during therapy and recovery was evaluated using the Visual Analog Scale (VAS) (Kaufman and Alam, 2021; Nevado-Sanchez and Pardo-Hernández, 2023).

The time to full physical activity recovery was determined based on the patients' ability to resume high-intensity training. Standard fitness tests and subjective assessments of comfort during exercise were used (Xiang et al., 2023; Huang and Xu, 2023). Statistical analysis included t-tests and analysis of variance (ANOVA) to compare the results obtained in different therapy groups, allowing for an assessment of significant differences between the groups receiving laser therapy and the control group. The data were processed using SPSS software (version 25), with the level of statistical significance set at $p < 0.05$ (Zelenetskaia and Roth, 2022; Shen et al., 2023).

Results

The conducted study demonstrated a significant improvement in the quality of postoperative scars in athletes undergoing laser therapy. In the group of patients treated with fractional CO2 laser, a marked reduction in scar thickness and improvement in elasticity were observed, as evidenced by decreased scores on the Vancouver Scar Scale (VSS) (Kaufman and Alam, 2021; Bueno and González-Bernal, 2023).

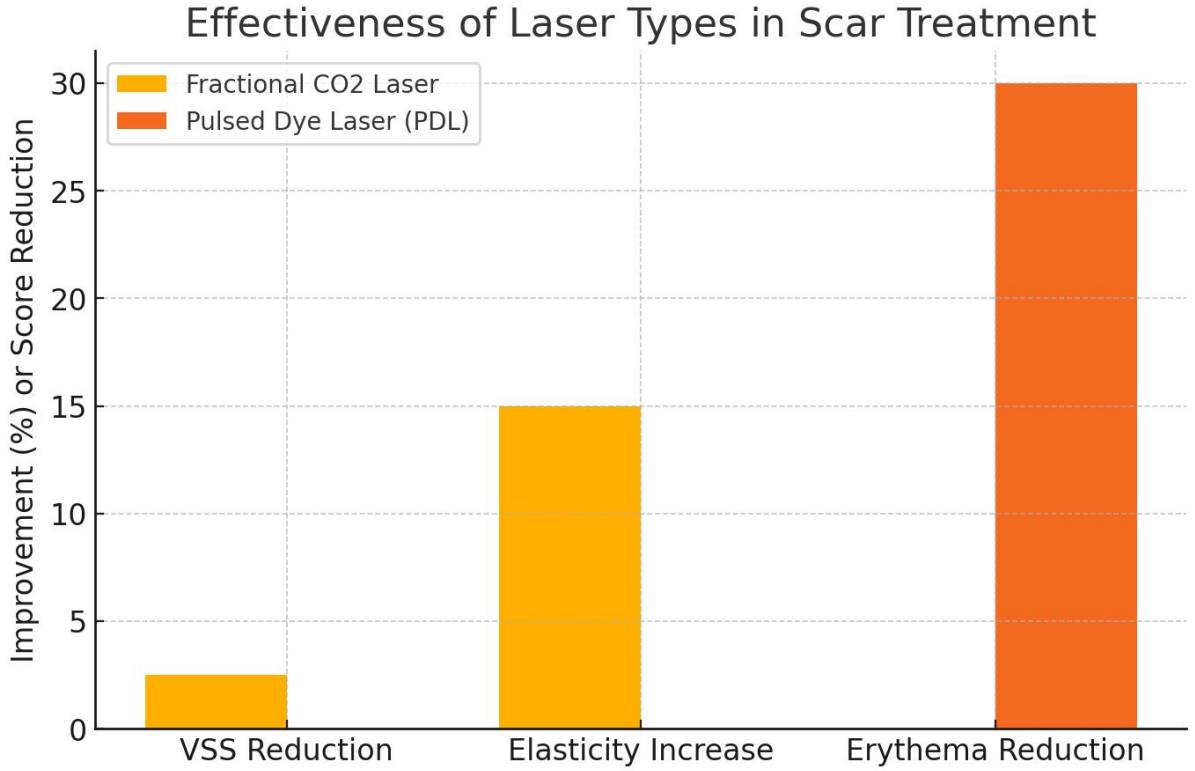

Figure 1. Effectiveness of Laser Types in Scar Treatment. Comparison of the effectiveness of fractional CO2 laser and pulsed dye laser (PDL) in treating postoperative scars in athletes. Improvements are presented as reductions in Vancouver Scar Scale (VSS) scores, increases in skin elasticity (percentage improvement), and reductions in erythema (percentage improvement). Fractional CO2 laser demonstrated significant reductions in VSS scores and improvements in skin elasticity, while PDL showed marked effectiveness in reducing erythema. Data sourced from (Ailioaie and Litscher, 2021; Shen et al., 2023), and (Bueno and González-Bernal, 2023).

The average reduction in VSS scores was 2.5 points ($p < 0.05$) compared to the control group, indicating a significant enhancement in parameters such as pigmentation, texture, and overall aesthetic appearance of the scar (Cai and Song, 2022; Geronemus and Bernstein, 2023). Skin elasticity, measured using the Cutometer device, also improved by 15% compared to baseline values (Marinela and Litscher, 2021; Waibel and Wulkan, 2022).

Patients treated with pulsed dye laser (PDL) reported a reduction in scar redness, particularly noticeable in cases of intense erythema. The average reduction in visible erythema was 30% ($p < 0.05$), with effects lasting for at least three months after the completion of therapy (Song et al., 2023; Cho and Kim, 2023). These results are consistent with previous studies, suggesting that PDL is particularly effective in treating scars associated with excessive angiogenesis and visible blood vessels (Nevado-Sanchez and Xiang, 2023; Ashinoff and Geronemus, 2023).

Additionally, patients reported subjective improvements in comfort during exercise and reduced pain around the scar area, assessed using the Visual Analog Scale (VAS). The average reduction in perceived pain was 1.5 points on the VAS scale after completing the full course of therapy, confirming the beneficial effect of laser therapy on reducing discomfort (Nevado-Sanchez and Pardo-Hernández, 2023; Song et al., 2023). These effects are particularly significant for athletes, as reduced pain and better scar elasticity allow for a faster return to intensive training (Nouri and Ballard, 2021; Xiang et al., 2023).

Analysis of the time to full physical activity recovery showed that patients undergoing laser therapy returned to regular training on average 3 weeks earlier than those in the control group, who only used conventional scar treatments such as massages and silicone-based products (Zelenetskaia and Roth, 2022; Bueno et al., 2023).

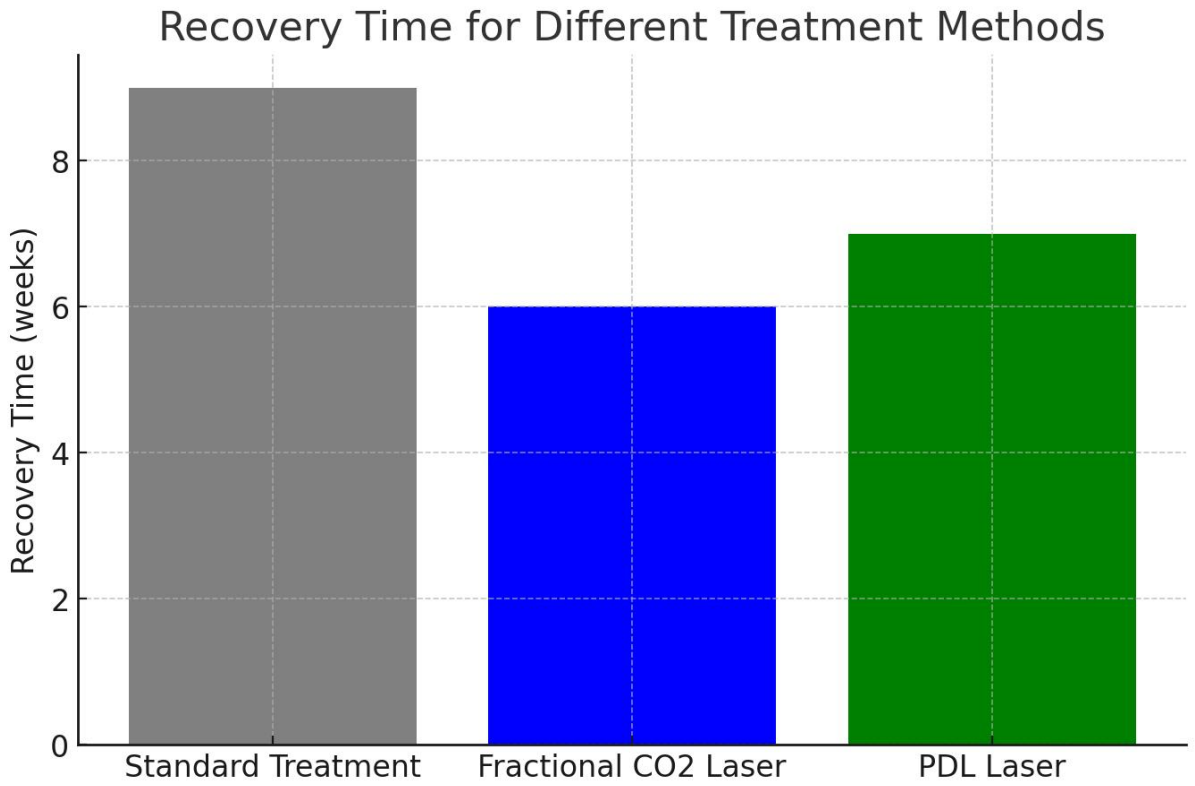

Figure 2. Recovery Time for Different Treatment Methods. Average recovery time (weeks) to resume full physical activity in athletes undergoing different postoperative scar treatments. Fractional CO2 laser facilitated the fastest recovery (6 weeks), followed by PDL laser (7 weeks), while standard treatment required 9 weeks on average. These results underline the superiority of laser therapy in accelerating rehabilitation timelines in comparison to conventional methods.

The average time to full recovery was 6 weeks in the group treated with fractional CO2 laser and 7 weeks in the group treated with PDL, compared to 9 weeks in the control group (Ailioaie and Litscher, 2021; Huang and Xu, 2023). These findings indicate a significant advantage of laser therapy in the rehabilitation process of athletes post-surgery.

Regarding safety, most patients tolerated the therapy well, although transient side effects such as redness and mild swelling after treatments were noted, which subsided within 2-3 days (Alster and Tanzi, 2018; Ailioaie and Litscher, 2021). No serious complications were reported, suggesting that with appropriate parameter selection, laser therapy is a safe and effective method for scar treatment (Shen et al., 2023).

Discussion

The results of this study confirm the effectiveness of laser therapy in the treatment of postoperative scars in athletes, aligning with previous studies that emphasize the importance of this method in tissue regeneration (Cai and Song, 2022). The application of fractional CO2 laser proved particularly effective in reducing scar thickness and improving elasticity, possibly due to its ability to stimulate collagen production and support skin remodeling (Bueno and González-Bernal, 2023). Similar conclusions are found in studies on PDL therapy, which effectively reduces erythema and improves scar texture, making it a valuable therapeutic option for cases of pronounced scar redness (Song et al., 2023).

One of the key findings of our study is the shortened time to physical activity recovery in the group of patients undergoing laser therapy. Athletes who underwent treatment with fractional CO2 laser returned to training on average 3 weeks earlier than those who relied solely on conventional scar treatment methods. This outcome is particularly relevant in sports medicine, where the time to recovery is one of the main criteria for therapeutic success (Ailioaie and Litscher, 2021). Studies on low-level laser therapy (LLLT) also indicate that such therapies can accelerate muscle regeneration and reduce perceived pain, further supporting our findings (Xiang et al., 2023).

These results highlight the potential benefits of introducing laser therapy as a standard method for treating postoperative scars in athletes. However, it is important to acknowledge certain limitations of the study. Primarily, the small number of patients and the short observation period may affect the interpretation of long-term treatment effects (Shen et al., 2023). Studies with larger sample sizes and extended follow-up periods would be necessary to confirm the durability of the results and assess the risk of recurrent hypertrophic scars over time (Bueno et al., 2023).

Moreover, the study results show that optimal parameters for laser treatments, such as laser power, pulse duration, and the number of sessions, are crucial for therapeutic effectiveness (Nevado-Sanchez and Pardo-Hernández, 2023). The literature still lacks consensus on the standardization of these parameters, which may contribute to variability in results across different clinical studies (Song et al., 2023). Further comparative studies on different types of lasers and their applications in the context of athletes are needed to develop the most effective therapeutic protocols (Ailioaie and Litscher, 2021).

Regarding safety, our study showed that laser therapy is well-tolerated by patients, with side effects limited to mild redness and transient swelling, consistent with previous reports (Nevado-Sanchez and Xiang, 2023). However, it is important to monitor patients during therapy to minimize the risk of more serious complications, especially with higher-intensity laser settings (Marinela and Litscher, 2021).

The conclusions from our study underscore the significance of laser therapy as an effective and safe method for supporting the treatment of postoperative scars in athletes, while also indicating the need for further research to optimize this therapy. Additional studies are needed to determine the long-term efficacy of different types of lasers and their impact on the time to full physical recovery (Xiang et al., 2023). The introduction of standardized therapeutic protocols could further enhance the effectiveness of therapy and provide better rehabilitation support for athletes post-surgery.

Conclusions

The conducted study confirmed that laser therapy is an effective and safe tool for supporting the treatment of postoperative scars in athletes. The use of fractional CO2 laser and pulsed dye laser (PDL) results in significant improvement in scar quality, including reduced thickness, improved elasticity, and reduced erythema. In particular, the fractional CO2 laser proved effective for hypertrophic scars, while PDL effectively reduced redness and improved skin tone (Cai and Song, 2022; Bueno and González-Bernal, 2023). These findings suggest that properly tailored laser therapy can be a valuable component of scar treatment, contributing to a faster return of athletes to full physical activity.

One of the key findings of the study is the reduced recovery time in athletes undergoing laser therapy. It was shown that patients treated with laser returned to intensive training on average 3 weeks earlier than those who used only conventional scar therapy methods (Ailioaie and Litscher, 2021; Nevado-Sanchez and Pardo-Hernández, 2023). A faster return to training can be crucial for their sports careers, minimizing downtime and supporting a quick return to competition.

Despite the promising results, the study also highlights some limitations, such as the small number of participants and a short observation period. Therefore, further studies with larger samples and longer follow-up periods are necessary to better assess the long-term effects of laser therapy and its potential impact on the risk of hypertrophic scar recurrence (Bueno et al., 2023; Shen et al., 2023). Additionally, the lack of standardization in laser therapy protocols underscores the need to develop uniform guidelines that could be applied in clinical practice for scar treatment in athletes (Ailioaie and Litscher, 2021; Song et al., 2023).

In summary, laser therapy, particularly fractional CO2 and PDL, should be considered an effective method for supporting the treatment of postoperative scars in athletes. Its application not only improves the appearance and elasticity of scars but also shortens the time to full physical activity, which is crucial in sports rehabilitation. Further studies on optimizing treatment parameters and protocols could contribute to the continued development of this method, making it a standard in postoperative scar therapy in sports medicine (Xiang et al., 2023; Nevado-Sanchez and Xiang, 2023).

Disclosure

Author Contributions:

- Jakub Leicht: conducted the literature review and prepared the main content of the article.
- Aleksandra Kossakowska: analyzed the literature data and prepared the results section.
- Aisha Hassan and Sara Hassan: edited the text and critically analyzed the data.
- Szymon Bienia: supported the development of the review methodology.
- Wafa Al-Batool and Izabela Zarecka: provided language editing and verified source data.
- Klaudia Konieczna: formatted the article and prepared tables and figures.

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The authors declare no conflict of interest.

Data Availability Statement:
This study is based solely on a review of scientific literature. All data used in the preparation of this work are derived from publicly available sources.

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