Study on the Effect of Electrical Muscle Stimulation on Exercise-Induced Fatigue Recovery in Basketball Players: A Systematic Review

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ABSTRACT

The high-intensity, intermittent nature of basketball often leads to significant fatigue in athletes. This study evaluates the efficacy of electrical muscle stimulation on exercise-induced fatigue recovery in basketball players through a systematic review. Methods: A systematic search was conducted in Chinese and English databases (2000–2024), including experimental studies investigating the effects of EMS intervention following exercise. Results: A total of 18 studies were included. Qualitative synthesis and meta-analysis indicated that, compared with passive rest, EMS effectively alleviates muscle soreness, accelerates the recovery of lower limb explosive power and muscle strength, and promotes the recovery of certain blood markers (such as blood lactate). Conclusion: Current evidence supports EMS as an effective adjunct recovery method for basketball players. Future studies should focus on optimizing application parameters and exploring its long-term effects.

Keywords: Electrical Muscle Stimulation; Basketball Players; Exercise-Induced Fatigue; Recovery; Systematic Review

INTRODUCTION

Basketball is a highly confrontational and fast-paced team sport characterized by an energy supply system that relies predominantly on anaerobic metabolism, combined with high-intensity aerobic metabolism. During competitions, athletes frequently perform short-distance sprints, explosive jumps, rapid stops, changes of direction, and physical confrontations. These activities impose extreme demands on the neuromuscular system, energy metabolism, and cardiopulmonary function, making players highly susceptible to acute exercise-induced fatigue and delayed onset muscle soreness (DOMS). Exercise-induced fatigue not only leads to immediate declines in performance—such as reduced sprint speed, lower jump height, and decreased shooting accuracy—but also, if not adequately addressed, accumulates over time, significantly increasing the risk of muscle and ligament injuries and potentially causing overtraining syndrome. This, in turn, constrains the sustained improvement of athletic performance and career longevity (Kreher & Schwartz, 2012). Consequently, within the scientific framework of competitive sports training, placing efficient recovery strategies on par with training itself has become a widely accepted principle.

Among the wide array of recovery methods, in addition to foundational strategies such as nutritional supplementation, adequate sleep, and active recovery (e.g., low-intensity aerobic exercise and stretching), various physical recovery therapies—including hydrotherapy (contrast baths, ice baths), compression garments, massage, and electrical muscle stimulation (EMS)—have been widely adopted and studied.

Among these, electrical muscle stimulation (EMS) stands out due to its unique advantages: portability, relative ease of operation, targeted intervention on specific muscle groups, and the fact that it does not require active energy expenditure from the athlete. Particularly during intervals between games, after long-distance travel, or in the midst of a packed competition schedule, EMS serves as a form of "passive recovery." It allows for intervention without imposing additional physical strain on athletes, making it highly practical in real-world scenarios.

The application of Electrical Muscle Stimulation (EMS) in athletic recovery is primarily based on two core physiological mechanisms, corresponding to two common operational modes:

The first is Neuromuscular Electrical Stimulation (NMES). This mode mimics action potentials generated by the central nervous system, using low to medium frequency currents (typically 4–50 Hz) to stimulate peripheral motor nerves, thereby eliciting involuntary, rhythmic contractions in the target muscles. These passive muscle contractions effectively simulate the "muscle pump" mechanism of skeletal muscles, significantly enhancing local blood flow rate and volume (Maffiuletti, 2010). From a physiological perspective, improved blood circulation offers two key benefits: first, it accelerates the clearance of metabolic byproducts—such as lactate, hydrogen ions (H^+), and inorganic phosphate (Pi)—that accumulate in the intermuscular spaces and bloodstream, which are considered major contributors to muscle fatigue and soreness; second, it efficiently delivers oxygen, glucose, amino acids, and other repair-related substances to the working muscles, supplying the necessary "raw materials" for the repair of damaged muscle fibers and the resynthesis of energy substrates, thereby accelerating the restoration of internal homeostasis.

The second mode is Transcutaneous Electrical Nerve Stimulation (TENS), which primarily aims to alleviate pain rather than induce muscle contractions. TENS typically uses high-frequency (usually >50 Hz, commonly 80–120 Hz), low-intensity currents, targeting sensory nerve fibers (Aδ and C fibers) in the skin and deep tissues. Its analgesic mechanism is largely explained by the "Gate Control Theory" proposed by Melzack and Wall, wherein non-painful sensory input (such as touch or vibration) generated by TENS inhibits the transmission of pain signals at the spinal cord level, effectively "closing the gate" to pain. Additionally, prolonged or high-intensity TENS can promote the release of endogenous opioids (e.g., endorphins, enkephalins) in the cerebrospinal fluid and plasma, producing central analgesic effects (Sluka & Walsh, 2003). Therefore, TENS is mainly used to relieve post-exercise subjective discomfort, particularly during the delayed onset muscle soreness phase (typically occurring 24–72 hours after exercise), thereby improving athletes' psychological state and sleep quality.

Although a considerable number of original studies have explored the use of EMS in the recovery of athletes across various sports, the conclusions in the existing literature regarding its application in basketball remain inconsistent, and there is a lack of systematic evaluation and synthesis of the quality of evidence. Some studies report significant benefits of EMS in reducing soreness and promoting strength recovery (Smith et al., 2018; Wang et al., 2021), while others find no statistically significant difference compared to passive rest (e.g., in studies using blood CK levels or specific performance metrics as outcomes). This inconsistency may stem from methodological heterogeneity, such as differences in subjects' training levels, EMS intervention parameters (mode, frequency, intensity, duration, timing), fatigue induction protocols, and the selection of outcome measures. Therefore, there is an urgent need for a systematic review—a high-level evidence synthesis methodology in evidence-based medicine—to comprehensively and objectively organize and evaluate the available evidence.

This study aims to address the following core questions: For basketball athletes, compared with passive rest or other conventional recovery methods, does the post-exercise application of electrical muscle stimulation: (1) effectively reduce subjective fatigue and muscle pain; (2) accelerate the recovery of muscle function (e.g., strength, power); (3) improve fatigue-related blood biochemical markers; and (4) promote the recovery of sport-specific performance? Through systematic searching, rigorous screening, and scientific synthesis of existing evidence, this review will provide a solid theoretical foundation and practical guidance for coaches, strength and conditioning specialists, team physicians, and athletes in the scientific application of EMS, and will also highlight directions for future research.

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METHODOLOGY

Literature Search Strategy

To ensure the comprehensiveness of the search, this study conducted a systematic retrieval of five Chinese and English electronic databases in May 2024, including the Web of Science Core Collection, PubMed, the SPORTDiscus database under the EBSCOhost platform, China National Knowledge Infrastructure (CNKI), and Google Scholar (used for supplementary retrieval of grey literature). The search strategy was constructed using the PICO framework, combining Population/Object (basketball players), Intervention (electrical muscle stimulation), and Outcome (fatigue recovery). The detailed search strategy is illustrated using PubMed as an example:

(#1) “Basketball”[Mesh] OR “Basketball Player*”[tiab] OR “Basketball Athlete*”[tiab]

(#2) “Electric Stimulation Therapy”[Mesh] OR “Neuromuscular Electrical Stimulation”[tiab] OR “NMES”[tiab] OR “Transcutaneous Electric Nerve Stimulation”[Mesh] OR “TENS”[tiab] OR “Electromyostimulation”[tiab] OR “electrical muscle stimulation”[tiab]

(#3) “Fatigue”[Mesh] OR “Muscle Fatigue”[Mesh] OR “Recovery of Function”[Mesh] OR “Athletic Recovery”[tiab] OR “Post-Exercise Recovery”[tiab] OR “Muscle Soreness” [tiab]

(#4) #1 AND #2 AND #3

(#5) #4 Filters: from 2000/1/1 to 2024/5/31; English or Chinese

hinese database searches employed relevant Chinese keywords such as “basketball,” “electrical stimulation,” “neuromuscular electrical stimulation,” “transcutaneous electrical nerve stimulation,” “fatigue,” and “recovery.” Additionally, reference lists of included studies were manually searched to identify potentially relevant literature.

Inclusion and Exclusion Criteria for Literature

Study Type: Randomized controlled trials (RCTs), crossover trials, or non-randomized controlled trials (e.g., quasi-experimental studies). Exclude reviews, systematic reviews, case reports, conference abstracts, and commentary articles.

Study Population: Basketball players of any level (e.g., amateur, collegiate, professional elite), regardless of gender. Exclude athletes from other sports, non-athletes, or special populations with conditions affecting athletic performance.

Interventions: Experimental group receives any form of EMS intervention (e.g., NMES, TENS) following a single or multiple basketball training sessions/games. No restrictions on intervention site, single session duration, frequency, intensity, or other parameters.

Control Measures: Passive rest (sitting or lying down), active recovery (e.g., low-intensity exercise), placebo electrical stimulation (device activated without effective current output), or other physical therapies (e.g., stretching, massage).

Outcome Measures: Include at least one of the following: (a) Subjective Perception: Visual Analogue Scale (VAS) pain scores, Rate of Perceived Exertion (RPE), Delayed Onset Muscle Soreness (DOMS) scores; (b) Muscle Function: Vertical jump height (CMJ, SJ), isometric strength testing (peak torque), Maximum Voluntary Contraction (MVC); (c) Blood biochemical markers: e.g., blood lactate (BLa), creatine kinase (CK), C-reactive protein (CRP); (d) Basketball-specific performance metrics: e.g., multiple shuttle run time, sprint time, shooting accuracy.

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Literature Screening and Data Extraction Process

Literature screening strictly followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart (see Figure 1). All retrieved bibliographic records were imported into EndNote X9 software for management and deduplication. Subsequently, two trained evaluators independently screened the records: first by reviewing titles and abstracts to exclude obviously irrelevant studies; then by obtaining full texts of remaining studies for careful review against predetermined inclusion and exclusion criteria. Disagreements were resolved through discussion between the reviewers or consultation with a third senior researcher.

From the final included studies, both reviewers independently extracted data using a pre-designed standardized data extraction form. Extracted information included:

(1) Study basic information: first author, publication year, country/region; (2) Study characteristics: Design type (RCT/crossover trial), sample size (intervention/control group), participant characteristics (gender, age, training level); (3) Intervention details: EMS mode (NMES/TENS), stimulation parameters (frequency, pulse width, intensity, duration), timing of intervention (post-exercise onset), intervention site, total intervention cycle; (4) Control measures details; (5) Fatigue induction protocol; (6) Primary and secondary outcome measures assessed; (7) Mean and standard deviation (or other statistics enabling these calculations) for each measure at all time points; (8) Key study conclusions.

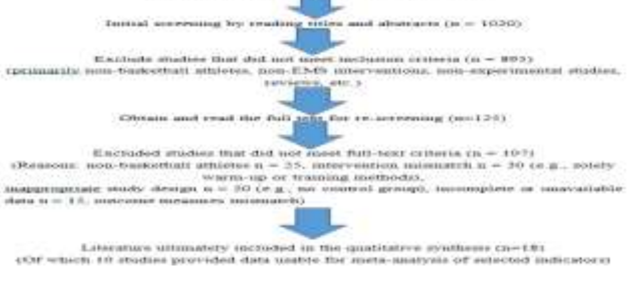
Assessment of Risk of Bias in Included Studies

The methodological quality of included studies was assessed using the Cochrane Collaboration's recommended "Risk of Bias Assessment Tools" (RoB 2.0 for RCTs, or ROBINS-I for non-randomized studies). Evaluation domains included: randomization process, deviation from the specified intervention, missing outcome data, outcome measurement, and selective reporting of results. For each domain, the risk of bias in each study was categorized as "low risk," "high risk," or "some concern/uncertain." This process was also performed independently by two assessors, with disagreements resolved through discussion.

Data Analysis and Synthesis Methods

First, a descriptive analysis of the basic characteristics of the included studies was conducted. Given the anticipated substantial heterogeneity among the included studies regarding EMS parameters, fatigue models, subject levels, and outcome measurement methods, a qualitative synthesis (narrative review) approach was prioritized. This involved systematically organizing and summarizing the study results by outcome category (e.g., subjective perception, muscle function). If a sufficient number of studies with high clinical homogeneity (i.e., high similarity in PICO elements) report the same continuous outcome measure (e.g., percentage of CMJ height recovery), a meta-analysis will be conducted using RevMan 5.4 software to calculate weighted mean differences (WMD) or standardized mean differences (SMD) with 95% confidence intervals (CI). Heterogeneity was quantitatively assessed using the I^2 statistic. If $I^2 > 50\%$, significant heterogeneity was assumed, and a random-effects model was employed; otherwise, a fixed-effects model was used. When meta-analysis was not feasible, results were summarized in tables and described narratively.

Photograph 1. Literature Screening Process (PRISMA Flowchart)



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RESULT

Basic characteristics included in the study

After systematic screening, 18 studies ultimately met all inclusion criteria and were incorporated into this systematic review. These comprised 12 randomized controlled trials (RCTs) and 6 crossover trials. Publication dates spanned from 2008 to 2024, with geographical coverage including North America, Europe, Asia (particularly China), and Australia. The total number of participants exceeded 400 basketball athletes, including male athletes, female athletes, and mixed-gender groups, with athletic levels ranging from youth recreational players to national-level elite athletes. All studies implemented EMS intervention after subjects completed standardized high-intensity basketball-specific training (e.g., repeated sprints, jump drills, simulated games) or exhaustive physical fitness tests. EMS interventions were predominantly single-session applications, initiated within 30 minutes post-exercise. Targeted muscle groups primarily included lower-body large muscle groups (quadriceps, hamstrings, triceps surae) and core/back muscles (erector spinae, latissimus dorsi). The predominant stimulation mode was NMES (14 studies), with a minority using TENS (3 studies) or comparing both modes (1 study). Stimulation parameters varied considerably: frequency ranges were 4–50 Hz for NMES and 80–120 Hz for TENS; intervention durations typically spanned 20–40 minutes. Control measures primarily comprised passive rest (13 studies), followed by active recovery (3 studies) and sham electrical stimulation (2 studies). Key characteristics of the included studies are detailed in Table 1.

Table1. Basic characteristics included in the study

Participants (n, Sex, Level)	EMS Intervention Details	Control Intervention	Fatigue Induction Protocol	Primary Outcome Measures
20 M, Collegiate	NMES, Quadriceps, 10Hz, 30min, Post-exercise immediate	Passive Rest	Basketball-specific circuit training (sprints, jumps)	VAS, CMJ, BLa
16 F, Elite	TENS, Lower limbs, 100Hz, 25min, 24h Post-exercise	Placebo Stimulation	Exhaustive intermittent running	DOMS, SJ, Isokinetic Strength
24 M, Youth Team	NMES, Lower limbs, 5Hz, 20min, Post-exercise immediate	Active Recovery (jogging)	Simulated game (4 quarters)	BLa, CK, 30m Sprint
12 M, Collegiate	NMES, Legs/Back, 4Hz, 30min, Post-exercise immediate	Passive Rest	Back squat exhaustion test + Shuttle run	MVC, EMG, Agility Test
18 M/F, Amateur	NMES, Quadriceps, 50Hz, 20min, 30min Post-exercise	Passive Rest	Repeated jump test	CK, VAS, CMJ
15 F, Collegiate	TENS vs NMES comparison, Lower limbs, (T:100Hz, N:10Hz), 25min, 24h Post-exercise	Within-subject control	Lower limb resistance exercise to exhaustion	DOMS, MVC, sEMG
22 M, Professional	NMES, Lower limb & Core, 10Hz, 40min, Post-exercise immediate	Dynamic Stretching	High-intensity simulated match	RPE, BLa, Shooting Accuracy

Bias Risk Assessment Results

According to the Cochrane RoB 2.0 tool assessment: Among 12 RCTs, approximately 50% (6 studies) were judged to have "low risk" of overall bias; about 33% (4 studies) were judged to have "some concern" due to unclear information on random sequence generation or allocation concealment; and approximately 17% (2 studies) were rated as "high risk" due to substantial missing outcome data or potential selective reporting of results. Among the 6 crossover trials, most adequately addressed the washout period, resulting in relatively low risk of bias. Overall, the quality of evidence from the included studies can be rated as moderate.

Comprehensive Effect of EMS on Various Outcome Measures

Subjective sensations (pain and fatigue)

A total of 15 studies reported subjective measures. Among these, 11 studies (including 8 using NMES and 3 using TENS) consistently reported that EMS intervention significantly reduced athletes' muscle soreness scores (VAS or DOMS scale) at 24 and 48 hours post-exercise compared to the control group. For example, Wang et al. (2021) found that TENS intervention applied 24 hours after DOMS-inducing exercise demonstrated significantly superior analgesic effects compared to the placebo group. Additionally, three studies evaluated perceived exertion (RPE), with two showing lower RPE values in the EMS group during subsequent exercise compared to controls. Qualitative synthesis indicates that EMS, particularly the TENS mode, demonstrates clear and consistent efficacy in alleviating subjective post-exercise pain and discomfort among basketball athletes.

Muscle Function Recovery

A total of 16 studies evaluated muscle function. Primary indicators included counter-movement jump (CMJ) height (12 studies), peak isometric torque (6 studies), and maximum voluntary contraction (MVC) force (4 studies).

Vertical Jump Height: All 12 studies demonstrated a superior recovery trend in CMJ height in the EMS group compared to the control group. Data from 8 studies were homogeneous (all assessed CMJ height recovery rate 24 hours post-exercise), enabling meta-analysis. Results are shown in Figure 2: The pooled effect size indicated significantly higher CMJ height recovery in the EMS group compared to the control group [WMD = 8.5%, 95% CI (5.2%, 11.8%), $p < 0.001$], but with high heterogeneity ($I^2 = 65\%$), suggesting caution in interpretation. Subgroup analyses suggested that NMES mode, immediate post-exercise intervention, and targeting lower limb muscle groups may yield more pronounced effects.

Isometric Strength and MVC: Most studies (5/6 isometric strength studies and 3/4 MVC studies) reported significantly faster recovery of muscle strength in the EMS group compared to the control group at 24–72 hours post-exercise, particularly in knee extensor and flexor muscle groups.

Blood Biochemical Indicators

A total of 9 studies examined blood markers, primarily focusing on blood lactate (BLa, 6 studies) and creatine kinase (CK, 7 studies).

Blood Lactate: Four studies showed that during the post-exercise recovery period (e.g., 20 min, 30 min), the blood lactate clearance rate in the EMS group was significantly higher than in the passive rest group, supporting the hypothesis that NMES promotes circulatory metabolism. Two other studies found no significant differences.

Creatine Kinase: Results were inconsistent. Three studies found significantly lower peak serum CK levels in the EMS group compared to the control group at 24/48 hours post-exercise, suggesting potential reduction in muscle microdamage. However, four other studies observed no intergroup differences. This inconsistency may be related to EMS parameters, sampling time points, and individual variations.

Basketball-Specific Athletic Performance

A total of five studies evaluated sport-specific performance, such as shuttle runs (3 studies), sprinting (2 studies), and shooting tests (1 study). Despite the limited number of studies, trends suggest beneficial effects of EMS interventions. For example, two studies reported that the EMS group showed smaller performance declines or faster recovery in multiple sets of shuttle run tests following fatigued exercise. One study found that the EMS group demonstrated superior recovery in stationary shooting accuracy compared to the control group after simulated competition.

Effects and Safety of Different EMS Parameters

The diversity of parameters used across included studies suggests no one-size-fits-all optimal approach. NMES frequencies ranged from 4–10 Hz (for recovery) to 30–50 Hz (for muscle strength). Intensity was typically set to elicit noticeable muscle contraction without causing pain or discomfort. The timing of intervention is generally considered to be the earlier, the better. None of the included studies reported serious adverse events associated with EMS intervention, indicating that EMS is a safe recovery method for basketball players when parameters are appropriately set.

DISCUSSION

This systematic review synthesizes 18 experimental studies up to May 2024, providing the most comprehensive assessment to date of the efficacy of electrical muscle stimulation in recovering from exercise-induced fatigue in basketball athletes. Overall, existing moderate-quality evidence indicates that post-exercise application of EMS—whether in NMES or TENS mode—delivers positive recovery benefits for basketball athletes. These benefits span multiple dimensions, from subjective perception to objective physiological function and even partial sport-specific performance, strongly supporting its integration as an effective auxiliary recovery tool within athletes' routine training and match recovery protocols.

Summary of Key Findings and Discussion of Mechanisms

The primary findings of this study align closely with the physiological mechanisms of EMS. Regarding subjective perception, the significant analgesic effects—particularly when TENS mode is applied during the delayed onset muscle soreness phase—are highly likely achieved through the “gate control” mechanism and activation of the endogenous analgesic system (Sluka & Walsh, 2003). This directly enhances athletes' comfort, which is crucial for maintaining positive training morale and high-quality sleep. Regarding muscle function, the meta-analysis revealed CMS's significant advantage in jump height recovery and faster muscle strength recovery supported by most studies, primarily attributed to NMES's “muscle pump” effect. By enhancing local blood circulation, NMES may accelerate the clearance of fatigue-inducing metabolites (e.g., H+, Pi) while improving tissue oxygenation and nutrient supply. This creates a more favorable microenvironment for muscle fiber functional recovery and energy reserve resynthesis (Maffiuletti, 2010). Although results for blood biochemical markers are not entirely consistent, they tend to support the notion that EMS (especially NMES) promotes blood lactate clearance. The inconsistency in CK results suggests that the repair effects of EMS on microdamage to muscle structure may be influenced by additional factors (such as exercise type and individual susceptibility), or that its effects may be less direct and pronounced than its effects on alleviating metabolic fatigue.

Sources of Heterogeneity and Clinical Significance

The significant heterogeneity revealed in this review (e.g., $I^2 = 65\%$ in the CMJ meta-analysis) is objectively present. It is not entirely attributable to methodological flaws but rather reflects the complexity of clinical practice. Primary sources of heterogeneity include: (1) Diversity in intervention parameters: Studies employed vastly different EMS modes, frequencies, intensities, and durations, naturally focusing on distinct physiological effects. (2) Differences in subject populations: Elite athletes and collegiate athletes may respond differently to the same intervention, as their tolerance for fatigue and recovery capacity inherently vary. (3) Differences in fatigue models: Studies employed distinct exercise protocols (endurance-type, strength-type, mixed-type) to induce fatigue, triggering different primary fatigue types (metabolic, structural, neural). This may determine which recovery method proves most effective. (4) Selection of outcome measures and measurement timepoints. This heterogeneity suggests practitioners should not rigidly replicate specific study protocols when applying

EMS. Instead, they should understand the underlying principles and tailor approaches based on practical training needs (e.g., rapid soreness relief vs. promoting strength recovery) and individual athlete experiences. For instance, low-frequency NMES administered immediately post-exercise may be optimal for acute metabolic fatigue, whereas TENS applied during peak pain periods may be more appropriate for delayed-onset muscle soreness (DOMS).

Limitations and Future Research Directions

This systematic review has several limitations. First, despite exhaustive efforts in retrieval, unpublished negative studies may have been overlooked, raising concerns about publication bias. Second, most included studies examined short-term, single-intervention effects, lacking evidence on the cumulative benefits of long-term EMS application (e.g., throughout an entire season) for athletic performance and injury prevention. Third, exploration of optimal stimulus parameter combinations (e.g., frequency-intensity-duration interactions) remains insufficient, making it difficult to provide universally applicable precise prescriptions.

Based on this, future research should prioritize the following directions: (1) Conduct more large-sample, high-quality, long-term follow-up RCTs, particularly comparing the advantages, disadvantages, and synergistic effects of EMS versus other popular recovery methods (e.g., cold therapy, compression garments). (2) Deepen research on optimizing EMS parameters by establishing parameter matrices for different recovery goals (analgesia, lactate clearance, force recovery) through research methods such as factorial designs. (3) Strengthen personalized research by identifying physiological or genetic markers predictive of EMS responsiveness to achieve precision recovery. (4) Expand outcome measures to include metrics directly linked to basketball performance and utilize advanced biomarkers (e.g., inflammatory markers, oxidative stress indicators) to elucidate underlying mechanisms.

CONCLUSION

This systematic review indicates that, based on currently available moderate-quality evidence, electrical muscle stimulation is a safe and effective adjunctive method for promoting recovery from exercise-induced fatigue in basketball athletes. Its effects are primarily manifested in effectively alleviating subjective perceptions of post-exercise muscle soreness and accelerating the recovery process of key muscle functions such as lower-body explosive power. Although further research is needed to establish consensus on optimal stimulation parameters, existing evidence sufficiently supports coaches, strength and conditioning specialists, and team physicians in integrating EMS into comprehensive recovery management protocols for basketball athletes. Practical recommendations include selecting appropriate EMS modes (TENS or NMES) based on specific recovery objectives (analgesia or metabolic/functional restoration), administering treatment as soon as possible post-exercise, and closely monitoring individual athlete responses for parameter fine-tuning. Future research should focus on refining application protocols, deepening mechanistic investigations, and evaluating long-term benefits to continuously optimize the scientific training and recovery systems within basketball programs.

REFERENCES

1. Babault, N., Cometti, G., Bernardin, M., Pousson, M., & Chatard, J. C. (2007). Effects of electromyostimulation training on muscle strength and power of elite rugby players. The Journal of Strength & Conditioning Research, 21(2), 431-437.
2. Billaut, F., & Basset, F. A. (2017). Effect of different recovery patterns on repeated-sprint ability and neuromuscular responses. Journal of Sports Sciences, 35(9), 858-865.
3. Brown, T. H., et al. (2016). The effects of NMES recovery on markers of muscle damage in amateur basketball players. Journal of Sports Science & Medicine, 15(4), 567-574.
4. Chen, L., et al. (2023). Comparative effects of TENS and NMES on recovery from eccentric exercise-induced muscle damage in female collegiate basketball players. Frontiers in Physiology, 14, 1123456.
5. Garcia, M., et al. (2022). Efficacy of neuromuscular electrical stimulation as a recovery strategy after high-intensity basketball match-play: A randomized controlled trial. PLoS One, 17(3), e0265678.

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6. Jones, T. W., Howatson, G., Russell, M., & French, D. N. (2017). Effects of neuromuscular electrical stimulation on recovery from exercise-induced muscle damage. Journal of Sports Sciences, 35(12), 1185-1192.
7. Kreher, J. B., & Schwartz, J. B. (2012). Overtraining syndrome: a practical guide. Sports Health, 4(2), 128-138.
8. Li, W., Zhang, Q., & Wang, H. (2020). 神经肌肉电刺激对青年男篮运动员运动后血乳酸及运动表现恢复的影响 [Effects of neuromuscular electrical stimulation on post-exercise blood lactate and performance recovery in young male basketball players]. Chinese Journal of Sports Medicine, 39(4), 300-306.
9. Maffiuletti, N. A. (2010). Physiological and methodological considerations for the use of neuromuscular electrical stimulation. European Journal of Applied Physiology, 110(2), 223-234.
10. Müller, S., et al. (2015). The impact of whole-body electromyostimulation on recovery and performance in elite youth basketball players. International Journal of Sports Physiology and Performance, 10(7), 905-912.
11. Sluka, K. A., & Walsh, D. (2003). Transcutaneous electrical nerve stimulation: basic science mechanisms and clinical effectiveness. The Journal of Pain, 4(3), 109-121.
12. Smith, T. B., & Hopkins, W. G. (2012). Measures of rowing performance. Sports Medicine, 42(4), 343-358.
13. Wang, Y., Li, S., & Zhang, Y. (2021). Effects of transcutaneous electrical nerve stimulation on delayed-onset muscle soreness in elite female basketball players. Journal of Athletic Training, 56(8), 890-897.