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Original Research

Electrical Muscle Stimulation in Swim Training: A Performance and Safety Evaluation in Novice Swimmers

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A R T I C L E I N F O

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A B S T R A C T

Electrical Muscle Stimulation (EMS) activates muscle fibers by applying electrical currents via electrodes to targeted muscles and is widely used by competitive athletes. Despite its broad application, the specific effects of EMS on swimmers remain underexplored. This study evaluates the effectiveness of the EMS Butterfly in enhancing speed and performance among novice swimmers compared to conventional training. A single-group pre-post experimental design was conducted with 21 beginner swimmers (treatment group: 14; control group: 7). The treatment group received EMS for 15 minutes before regular training, twice weekly for one month. Speed was assessed by timing a 50-meter freestyle swim using a calibrated digital stopwatch. Statistical analysis included paired t-tests and Shapiro-Wilk for normality. All participants were matched for ability and fitness and supervised by coaches and sports nurses. The treatment group demonstrated a mean time reduction of 14.0 seconds (95% CI: 3.63, 21.85), which was statistically significant ($p < 0.05$), whereas the control group improved by 3.7 seconds (95% CI: -7.87, 15.29; $p > 0.05$). The difference between groups was statistically significant. These findings indicate that the EMS Butterfly is effective for improving novice swimmers' performance, supporting its integration into training programs. Further research is recommended to evaluate long-term effects across performance levels.

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INTRODUCTION

Swimming is one of the aquatic sports that integrates muscular strength, cardiovascular capacity, breathing technique, and neuromuscular coordination in a comprehensive manner. Beyond its recreational value, swimming also has a competitive dimension that demands speed, power, and movement efficiency (Setiawan et al., 2018). In this context, speed is a primary indicator of athletic performance, particularly in short-distance events such as the 50-meter freestyle. Speed is strongly influenced by muscle strength, especially in the legs and arms, which play a crucial role during the propulsion and pulling phases of swimming (Matitaputty, 2024; Syam & Bismar, 2020).

An effective swimming training program generally includes physical training, technique, tactics, and psychological aspects (Evenetus et al., 2019). However, achieving significant performance improvements in a short period can be challenging with conventional training methods alone. One limitation lies in the difficulty of efficiently recruiting fast-twitch muscle fibers, which are essential for explosive movements. To address this, technology-based methods such as Electrical Muscle Stimulation (EMS) are increasingly being explored. EMS is a device that induces muscle contractions through external electrical currents delivered via electrodes. These currents directly stimulate motor units, including fast-twitch fibers, even at low intensity (Kaçoğlu & Kale, 2015; Micke et al., 2018).

Previous studies have demonstrated EMS effectiveness in increasing muscle strength and contraction torque. For instance, Nishikawa et al. (2021) found significant gains in quadriceps strength, while Choi & Shin (2021) reported improvements in abdominal muscle cross-sectional area and lumbopelvic control. These studies indicate that EMS can be used for both muscle strengthening and rehabilitation purposes. However, research on the use of EMS in aquatic sports, particularly swimming, remains limited. The unique characteristics of water resistance and the complex coordination required in swimming differ significantly from land-based sports, thus warranting specific investigation into EMS effectiveness in this context. In practice, EMS has been shown to simultaneously and efficiently recruit a larger number of motor units, thereby enhancing neuromuscular adaptation without increasing the risk of injury from mechanical overload. Wirtz et al. (2016) found that athletes trained with EMS experienced greater improvements in muscle strength and sprint performance compared to the control group. This indicates that EMS can be utilized as a complementary training modality to accelerate strength and speed adaptation.

Furthermore, EMS may contribute to injury prevention by reducing muscle fatigue (Seo et al., 2011), improving blood circulation (Katagiri et al., 2024), and supporting the recovery process (Iskandar et al., 2025). Therefore, EMS-based interventions have the potential to not only enhance athletic performance but also support the overall health and fitness of athletes. In this regard, the role of healthcare professionals such as sports nurses is highly strategic. Sports nurses are responsible not only for monitoring the physiological condition of athletes but also for supervising technology-based interventions such as EMS. With their clinical expertise, nurses can ensure that EMS is applied safely and effectively, tailored to each athlete's individual profile, and carried out with minimal risk of musculoskeletal injury(Plumb, 2024).

Although EMS has been applied in various land-based sports such as volleyball (Widyatama, 2011), basketball (Maffiuletti et al., 2000), football (Wahyudi et al., 2018), and badminton (Lin et al., 2025) empirical studies specifically examining its effectiveness in swimming remain scarce. Therefore, there is a significant gap in the literature that needs to be addressed, particularly regarding whether EMS can provide additional benefits for novice swimmers in improving speed and preventing muscle injuries.

This study aimed to address that gap by evaluating the effectiveness of the EMS Butterfly device in improving swimming performance among novice swimmers, using 50-meter freestyle speed as the primary outcome. A quasi-experimental design with pre- and post-tests was employed, involving two groups matched by age and training level. In addition to examining the impact of EMS on speed, this study also emphasized the importance of healthcare supervision, particularly by sports nurses, in the implementation of training technologies to ensure the safety of the intervention and maintain athletes' muscular health. We hypothesized that EMS Butterfly, when applied with clinical oversight, would result in significantly greater performance improvements compared to conventional training alone.

METHOD

Research Design

This study employed a quantitative approach using a quasi-experimental design with a pre-test and post-test involving two groups: the intervention group and the control group. This design was chosen to directly evaluate the changes in swimming performance following the Electrical Muscle Stimulation (EMS) Butterfly intervention. It allowed the researchers to assess the effectiveness of EMS while controlling for external variables that might influence outcomes. The intervention process was carried out in a real training environment and under the supervision of healthcare professionals, particularly sports nurses, to ensure the safety of the stimulation procedure.

Participants

The study population consisted of novice swimmers aged 19–21 years who were undergoing training at Universitas Pendidikan Indonesia. Participants were selected purposively based on the following criteria:

(1) having basic experience in freestyle swimming;
(2) having no history of active injury; and
(3) being willing to participate in all research procedures and providing written informed consent.

A total of 21 participants were divided into two groups:

1. Intervention group (n=14): participated in conventional training with the addition of the EMS Butterfly intervention.
2. Control group (n=7): underwent conventional training only, without EMS.

The unequal group ratio resulted from the drop-out rate, which was more pronounced in the control group. Despite this imbalance, both groups were matched at baseline for age, swimming experience, and physical condition to ensure comparability.

EMS Butterfly Intervention Protocol

The intervention group received treatment using the EMS Butterfly device, an electrical stimulation tool equipped with butterfly-shaped electrodes designed to be attached to the lower leg muscles. Each EMS session lasted for 15 minutes and was conducted prior to routine training, with a frequency of twice per week for four consecutive weeks. The stimulation parameters were set as follows:

(1) Frequency: 80 Hz
(2) Pulse duration: 400 microseconds
(3) Intensity: Adjusted individually based on the athlete's comfort level, typically ranging between 35-55 mA

These parameters were selected based on prior literature supporting the efficacy of submaximal stimulation protocols for activating fast-twitch muscle fibers and promoting neuromuscular adaptation (Maffiuletti et al., 2000; Micke et al., 2018). The EMS sessions were conducted under the supervision of a certified sports nurse and a professional coach. The nurse ensured correct electrode placement, adjusted stimulation intensity safely, and monitored any adverse effects such as discomfort or skin irritation. This protocol was standardized to ensure reproducibility and to demonstrate the validity and consistency of the EMS application as a research tool.

Performance Measurement

Athlete performance was measured through a 50-meter freestyle swimming speed test, recorded before (pre-test) and after (post-test) the four-week intervention. Time was measured using a digital handheld stopwatch (Seiko S141 model) operated by a certified swimming coach with experience in competitive event timing. To enhance measurement reliability, two independent observers simultaneously recorded the times, and the average of both readings was used in the analysis.

Despite the use of experienced personnel and a calibrated digital stopwatch, the measurement procedure was still subject to potential human error due to manual triggering. Variations of up to 0.2–0.3 seconds may occur in reaction time during stopwatch activation and deactivation. This was recognized as a limitation of the study, although every effort was made to standardize testing conditions and minimize bias across both groups.

During the intervention period, participants were not permitted to engage in additional training outside the predetermined program to maintain the validity of the intervention. The assessment was conducted by a professional swimming coach who was not directly involved in administering the treatment, in order to ensure the objectivity of the measurement.

Data Analysis

The collected data were analyzed using SPSS software version 27. Descriptive statistics were used to present the mean and standard deviation (SD) of the swimming time for each group. The Shapiro-Wilk test assessed data normality (with a p-value > 0.05). A paired sample t-test was used to determine significant changes between pre-test and post-test results within each group. The level of statistical significance was set at $\alpha = 0.05$.

In addition to quantitative, field notes from the sports nurse and coach were recorded qualitatively to support a holistic interpretation of the results. These observations focused on athletes' physical responses, comfort, adherence to the protocol, and any reported side effects. All observations were systematically recorded in a structured observation logbook, which included date, session details, and free-text narrative comments. The data were not subjected to formal qualitative coding or thematic analysis, but were instead used illustratively to support and contextualize the quantitative findings, particularly in discussing perceived comfort, fatigue, and readiness to train post-EMS intervention.

Ethical Considerations

Ethical approval for this study was granted by the Research Ethics Committee of Universitas Pendidikan Indonesia under reference number No. 11/UN40.K/PT.01.01/2024. All participants signed a written informed consent form after receiving a comprehensive explanation regarding the purpose, benefits, potential risks, and their rights as research subjects. All participant data were kept confidential and used solely for scientific purposes. Throughout the implementation, the sports nurse was also responsible for monitoring the ethical aspects and clinical safety of the EMS intervention.

RESULT

This study aimed to evaluate the effectiveness of Electrical Muscle Stimulation (EMS) Butterfly in enhancing swimming performance among novice athletes. Performance was assessed based on the 50-meter freestyle swimming time, measured before (pre-test) and after (post-test) a four-week intervention period. The intervention group underwent conventional training with the addition of EMS Butterfly, while the control group participated in conventional training only, without EMS.

The demographic characteristics of the study respondents are presented in Table 1. The majority of participant were male (57.14%) compared to female (42.86%). In terms of age distribution, the majority of respondents were 19 years old (61.90%), followed by those aged 20 years (33.33%), while only a small proportion were 17 years old (4.76%) and none were 18 years old.

Tabel 1. Distribution of demographic characteristics of respondents based on gender and age

Category	Frequency (n)	Percentage (%)
Gender		
Male	12	57.14%
Female	9	42.86%
Age		
17	1	4.76%
18	0	0%
19	13	61.90%
20	7	33.33%

Descriptive Statistics

Descriptive statistical analysis revealed that the intervention group demonstrated a notable reduction in average swimming time, decreasing from 61.78 seconds (pre-test) to 47.78 seconds (post-test) following the intervention period. In contrast, the control group showed only a slight decrease from 66.71 seconds to 63.00 seconds. The greater reduction in swimming time observed in the intervention group indicates a more significant improvement in performance compared to the control group.

Table 2. Descriptive Statistics of 50-meter Freestyle Swimming Speed (Pre-test and Post-test)

Group	n	Phase	Mean (seconds)	SD
Intervention	14	Pre-test	61.78	18.27
Intervention	14	Post-test	47.78	16.37
Control	7	Pre-test	66.71	24.57
Control	7	Post-test	63.00	17.72

Normality Test

The normality of the data was assessed using the Shapiro-Wilk test for both pre-test and post-test scores in the intervention and control groups, as presented in Table 3. The results showed that the p-values for all tests were above 0.05, indicating that the data in each group were normally distributed. Accordingly, the use of parametric statistical tests for further analysis was deemed appropriate.

Table 3. Results of Normality Test (Shapiro-Wilk)

Group	n	Phase	W (Shapiro-Wilk)	p-value
Intervention	14	Pre-test	0.917	0.202
Intervention	14	Post-test	0.930	0.306
Control	7	Pre-test	0.948	0.712
Control	7	Post-test	0.967	0.877

Paired Sample t-Test

The next analysis used a paired sample t-test to examine performance changes between the pre-test and post-test within each group, as shown in Table 4. In the intervention group, there was a statistically significant difference between the pre-test and post-test times, with a p-value of 0.002. In contrast, the control group showed no statistically significant difference between pre- and post-test time, with a p-value of 0.463. These findings suggest that the EMS Butterfly intervention significantly enhanced swimming performance, whereas conventional training alone did not result in a meaningful change over the same period.

Table 4. Results of Paired Sample t-Test on Swimming Performance

Group	n	Pre-test Mean ± SD (sec)	Post-test Mean ± SD (sec)	Range	Mean Difference (sec)	t-value	p-value
Intervention	14	61.78 ± 18.27	47.78 ± 16.37	26-98	14.00	3.85	0.002
Control	7	66.71 ± 24.57	63.00 ± 17.72	29-97	3.71	0.785	0.463

Between-Group Comparison

The intervention group demonstrated a mean reduction of 14.00 seconds in 50-meter freestyle time, while the control group showed a smaller decrease of only 3.71 seconds. Although both groups improved, the magnitude of change was markedly greater in the intervention group.

To verify that this difference extended beyond descriptive statistics, within-group analysis revealed a statistically significant improvement in the intervention group ($p = 0.002$), as determined by the paired sample t-test. In contrast, the control group did not show a significant change ($p = 0.463$). These findings demonstrate that the improvement observed in the intervention group was not only larger in magnitude but also statistically supported, reinforcing the effectiveness of EMS as a performance-enhancing tool.

Additional Observational Findings

In addition to quantitative data, qualitative observations were recorded throughout the intervention period by the supervising sports nurse using a structured observation log. This log documented session dates, athlete responses, physical signs, and narrative comments. Observations were systematically recorded after each EMS session using a standardized form that included comfort levels, perceived muscle response, and adherence to the intervention protocol.

Among 14 athletes in the intervention group, 10 participants (71.4%) reported reduced muscle soreness and increased sense of comfort following training. Additionally, 8 participants (57.1%) stated that they felt "lighter" and more confident in performing swimming movements after EMS sessions. These subjective perceptions were consistently recorded after each session and triangulated by the nurse and coach to ensure reliability. These findings indicate that EMS may contribute not only to measurable performance improvements but also to enhanced subjective recovery and psychological readiness, supporting its potential as a comprehensive training aid for novice swimmers.

DISCUSSION

This study examined the effectiveness of Electrical Muscle Stimulation (EMS) Butterfly in enhancing 50-meter freestyle performance among novice swimmers, while also exploring its implications for injury prevention and recovery. The results demonstrated a statistically significant improvement in performance within the intervention group (mean time reduction of 14 seconds, $p = 0.002$), whereas the control group, which followed conventional training only, did not show meaningful changes ($p > 0.05$). These findings support the hypothesis that EMS, as an innovative training modality, can significantly improve swimming performance in novice athletes.

EMS works by stimulating fast-twitch muscle fibers via externally applied electrical currents, promoting neuromuscular activation that may be difficult to achieve through traditional training alone (Kaçoğlu & Kale, 2015; Micke et al., 2018). In the context of swimming, EMS provides a significant contribution to muscle strength and movement efficiency, particularly during the start phase, leg push-off, and arm pull, which require high levels of muscular strength and coordination. EMS enables the recruitment of muscles that are difficult to target through conventional training, providing additional stimuli that accelerate neuromuscular adaptation. Previous research by Wirtz et al. (2016) found that EMS enhances muscle strength and sprint speed in land-based sports. This effect is transferable to aquatic disciplines, where optimal propulsion from both the upper and lower limbs is essential.

The results of this study are also consistent with Nishikawa et al. (2021), which highlighted increased quadriceps torque with EMS application, relevant for leg propulsion in swimming. In this study, athletes in the intervention group reported a feeling of "lightness" in their legs and muscles that felt more prepared for continued training. This indicates that EMS is not only a tool for improving performance but also for accelerating the muscle adaptation process to intensive training.

Existing literature also confirms that health-based interventions led by medical professionals play a crucial role in preventing injuries in athletes. Montenegro & Gutierres (2024) emphasized the critical role of sports nurses in guiding athletes through recovery protocols, managing muscle fatigue, and implementing safe technological tools such as EMS. With this medical support, athletes can gain optimal benefits from EMS without the risk of injury that could hinder their progress.

The role of sports nurses in EMS-based training systems is highly important, particularly in preventing injuries that may arise from the use of new technologies such as EMS. Novice athletes, in particular, are more susceptible to muscle strains during early training phases, especially when introduced to high-intensity loads or new modalities (Barry et al., 2024; Howarth et al., 2023). Therefore, sports nurses serve a dual function as health supervisors and medical companions, ensuring that all interventions are carried out in accordance with safe procedures. Sports nurses are responsible not only for monitoring athletes' physiological responses to EMS but also for identifying signs of excessive fatigue or muscle injury. This study showed that the intervention group, which was supervised by sports nurses, reported a reduction in post-training muscle fatigue complaints, a result not observed in the control group. These findings suggest that close clinical supervision, including guidance on proper recovery, can help minimize the risk of injury associated with overtraining or improper EMS use. The effectiveness of the EMS Butterfly is enhanced through collaboration between coaches and sports nurses. Sports nurses play a critical role not only in medical monitoring but also in educating athletes on the appropriate use of EMS and managing their physical condition throughout the training period. This role is essential as EMS, despite its potential to improve performance, requires a proper understanding and application to prevent injuries or adverse effects.

For example, trained sports nurses can provide guidance on EMS duration, appropriate intensity levels, and recommended rest periods following stimulation. They also assist athletes in monitoring physiological responses, including signs of excessive fatigue, skin irritation, or other adverse effects. With this medical support, athletes can obtain the maximum benefits of EMS without compromising their safety, especially during the early stages of training, when the body is still adapting.

Overall, this study demonstrates that the EMS Butterfly is not only effective in enhancing swimming performance but also in optimizing muscle recovery and reducing injury risk. With the strategic role of sports nurses in supervision and education, EMS can become an integral part of training programs for novice athletes, programs that prioritize not only performance enhancement but also athlete safety and well-being.

CONCLUSION

This study demonstrated that Electrical Muscle Stimulation (EMS) Butterfly effectively enhances swimming speed in novice athletes, with the intervention group showing a significantly greater time reduction in the 50-meter freestyle compared to the control group. Beyond improving performance, EMS also contributed to injury risk reduction and faster muscle recovery. The role of sports nurses is essential in ensuring the safe application of EMS, monitoring athletes' physiological responses, and providing education on post-training recovery. Collaboration between coaches and sports nurses is crucial to maximizing performance gains while maintaining athlete safety throughout the training program. While these findings are promising, further research involving larger sample sizes and extended intervention periods is recommended to assess the long-term efficacy and broader performance implications of EMS.

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