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ORIGINAL ARTICLE

Electrical Muscle Stimulation (EMS) as an Innovative Training Tool to Enhance Speed and Performance Stability in Novice Swimmers

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ABSTRACT
Background. Electrical Muscle Stimulation (EMS) has gained recognition for enhancing neuromuscular performance in elite athletes, yet its application among novice swimmers remains underexplored. Novices often face unique challenges such as poor motor coordination, muscular imbalance, and inconsistent performance—gaps that conventional training alone may not effectively address. **Objectives.** This study aimed to evaluate the effectiveness of EMS, explicitly using the EMS Butterfly device, in improving swimming speed and performance consistency in novice swimmers. **Methods.** Twenty-one swimmers aged 15–18 were randomly allocated into an EMS group (n=14) and a control group (n=7). Over four weeks, the EMS group underwent biweekly EMS sessions targeting lower limb muscles, combined with regular swim training. Pre- and post-intervention assessments included 50-meter freestyle swim time and performance variability (Coefficient of Variation, CV). Data were analyzed using Repeated Measures ANOVA. **Results.** EMS significantly improved swim performance (mean time reduction of 16.5s vs. 2.4s in controls; $p<0.001$) and reduced intra-individual variability (lower CV). A strong time × group interaction effect was observed ($p<0.001$, $\eta^2_p = 0.704$). These outcomes suggest enhanced neuromuscular coordination, strength, and performance stability in the EMS group. **Conclusion.** EMS is a practical, low-impact intervention that supports physical and psychological readiness in novice swimmers. It offers a scalable solution to accelerate foundational development while minimizing injury risk. Future studies should explore its long-term efficacy, biomechanical integration, and application in individualized training protocols.

INTRODUCTION

Swimming training plays a fundamental role in developing athletic performance and achieving success in competitive swimming. An effective training regimen must integrate physical, technical, and psychological components to optimize athletic outcomes. Among these, physical conditioning through structured strength and endurance exercises has significantly enhanced swimming performance. Dry-land hypertrophy and maximal strength training improve muscular force production more than in-water training methods, especially for inexperienced athletes (1). Furthermore, sustained swim training improves cardiovascular capacity, pulmonary function, and respiratory muscle strength—key determinants of performance during prolonged efforts (2).

Technical refinement is equally crucial in swimming. Stroke mechanics, pacing strategies, and body positioning affect propulsion efficiency and drag reduction. Studies suggest incorporating visual pacing systems can improve swimmers' kinematic parameters, such as stroke length and rate, and enhance the overall swimming economy (3, 4). High-intensity interval training (HIIT) also contributes to anaerobic power and aerobic endurance, promoting faster sprint capabilities and better recovery (1). Complementing these physiological gains, team-based environments foster motivation, accountability, and psychological resilience.

However, these conventional approaches often prove suboptimal for novice swimmers. High-volume, high-intensity protocols designed for trained athletes may overwhelm beginners who typically lack foundational strength, neuromuscular control, and technical proficiency. As a result, novice swimmers are prone to inconsistent performance and a higher incidence of overuse injuries, including shoulder instability and muscle strain (1). Moreover, traditional training frameworks often overlook the specific neuromuscular deficits in beginners and rarely offer adaptive, low-impact solutions aligned with their developmental needs.

Electrical Muscle Stimulation (EMS) has emerged as a promising complementary modality. EMS involves the application of electrical impulses to elicit controlled muscular contractions, which mimic voluntary movement patterns. It effectively recruits fast-twitch motor units that are typically harder to activate via voluntary effort, enhancing muscle strength, endurance, and coordination (5, 6). Unlike conventional training, EMS can stimulate deep and hard-to-reach muscle fibers with minimal joint stress, making it particularly suitable for beginners with low muscular endurance or injury susceptibility.

One EMS modality gaining popularity is the EMS Butterfly, a compact, USB-rechargeable device known for its portability, affordability, and ease of use. Although widely perceived as a commercial electric massage tool, EMS Butterfly holds untapped therapeutic and performance-enhancing potential. The device allows for focused stimulation of key muscle groups, facilitating improvements in strength, speed, muscle recovery, and neuromuscular efficiency. However, the general public—and even some practitioners—remain unaware of its potential in structured athletic training or physiotherapy. This misperception and the scarcity of scientific evaluations involving EMS Butterfly in sports settings, particularly among novice swimmers, highlight a critical knowledge gap.

Moreover, EMS has been shown to improve muscle perfusion and facilitate metabolite clearance, accelerating recovery post-training (7). It also promotes neuromuscular adaptations such as improved proprioception and joint stability, contributing to performance consistency—a significant challenge for novice swimmers. Psychologically, EMS has the added benefit of enhancing confidence and intrinsic motivation. Enabling visible and measurable progress, even with minimal technical input, can increase adherence and satisfaction among beginners, who may otherwise experience frustration due to plateaued progress.

Despite these advantages, current EMS research focuses predominantly on elite populations, with little exploration of its application among novices. Most studies also fail to examine the psychological dimensions or assess long-term adaptations. Furthermore, inconsistencies in EMS protocol design—such as frequency, intensity, and application site—limit generalizability and hinder best-practice standardization.

This study aims to fill these gaps by evaluating the effects of EMS, particularly the EMS Butterfly, on swimming speed and performance consistency in novice swimmers. This research intends to assess physical and psychological impacts by targeting a beginner population, offering insights into how EMS can be systematically integrated into developmental swim training programs. The outcomes are expected to enrich the existing literature on EMS applications and provide practical recommendations for coaches and practitioners seeking innovative, accessible, and individualized training methods for new athletes.

MATERIALS AND METHODS

Study Design. This study employed a pretest-posttest experimental design with a control group to assess the impact of Electrical Muscle Stimulation (EMS) on swimming speed and performance consistency among novice swimmers. Participants were randomly assigned to either an experimental group receiving EMS intervention or a control group undergoing conventional swim training alone. Randomization ensured the elimination of allocation bias and maintained methodological rigor.

Participants. Twenty-one novice swimmers (14 in the EMS group and 7 in the control group), aged between 15–18 years, were recruited from local swimming clubs. Inclusion criteria comprised six months of basic swimming experience without prior competitive training. Exclusion criteria included any recent musculoskeletal injury, neurological condition, or cardiovascular disorder that could affect participation in physical exercise or EMS therapy. Before the intervention, all participants and their legal guardians provided written informed consent, and ethical clearance was obtained from the Institutional Ethics Committee (No. 11/UN40.K/PT.01.01/2024).

Device and Tools. The EMS intervention utilized a Butterfly EMS device, which is portable, USB-chargeable, and user-friendly, making it particularly suitable for youth athletes and field-based applications. The device allows for customizable stimulation parameters, including:

- Frequency: 30–50 Hz (to induce tetanic muscle contraction)
- Pulse width: Estimated at ~350 µs
- Stimulation mode: Biphasic symmetrical wave pattern (manufacturer default)
- Intensity scale: 1–8, adjusted individually based on comfort (subjective Borg scale 13–17)

Stimulation was applied via adhesive gel-pad electrodes directly to the quadriceps femoris and gastrocnemius muscles bilaterally, following standard EMS electrode placement protocols.

A manual digital stopwatch (Casio HS-80TW) was used for precise time measurement of swim tests. Performance data were recorded manually and double-entered into a digital spreadsheet to ensure accuracy.

Training Protocol. Participants in the EMS group completed a 4-week intervention comprising two EMS sessions per week (eight sessions total). Each session lasted approximately 20 minutes before swim training to facilitate neuromuscular priming. EMS stimulation began at intensity level 1 and increased by one level every minute until a maximum tolerable level (not exceeding level 8) was reached. Stimulation targeted the lower limbs (thigh and calf regions), mimicking voluntary contractions to prepare the musculature for functional training.

Vital signs—including blood pressure, heart rate, respiratory rate, and body temperature—were measured before each session to ensure participant readiness and safety. EMS intensity was individualized, and participants were instructed to report discomfort or signs of intolerance.

Immediately following EMS, swimmers engaged in a structured swim training session focused on lower limb strength and propulsion efficiency:

- 6 sets × 25-meter freestyle kicks (with kickboard)
- 8 sets × 25-meter full-stroke freestyle swims
- 30 seconds of rest between sets

Participants in the control group followed the same swim training protocol but did not receive EMS stimulation.

Performance Assessment. Swimming speed was assessed through a 50-meter freestyle swim test, performed at baseline (pretest) and after the 4-week intervention (posttest). Timing was conducted manually using a stopwatch, and swimmers were instructed to perform maximally.

Performance consistency was evaluated using the Coefficient of Variation (CV), calculated across three consecutive 50-meter swim trials for each testing session. The CV represents intra-individual variability and reflects performance stability.

Statistical Analysis. Data were analyzed using Repeated Measures ANOVA to assess within-group and between-group differences across two-time points (pretest and posttest). The analysis was conducted using IBM SPSS Statistics version 22.0. Significance was set at $p<0.05$. Partial eta-squared (η^2_p) was reported as the effect size indicator for ANOVA results. Normality and sphericity assumptions were tested using the Kolmogorov–Smirnov and Mauchly's tests, respectively. Where necessary, Greenhouse-Geisser corrections were applied.

RESULTS

Swimming Performance Improvement. The study revealed a substantial enhancement in 50-meter swimming performance among novice swimmers who received Electrical Muscle Stimulation (EMS). Participants in the EMS group demonstrated a mean time reduction of 16.5 seconds, from 69.2 ± 16.3 seconds at the pretest to 52.7 ± 13.8 seconds at the posttest. In contrast, the control group exhibited a modest mean reduction of 2.4 seconds, from 75.1 ± 15.2 seconds to 72.7 ± 13.6 seconds.

Statistical analysis using Repeated Measures ANOVA identified a significant main effect of time ($F(1, 19) = 89.32$, $p<0.001$, $\eta^2_p=0.824$) and a significant main effect of group ($F(1, 19) = 12.57$, $p=0.002$, $\eta^2_p=0.398$). Most notably, there was a significant time × group interaction effect ($F(1, 19) = 45.19$, $p<0.001$, $\eta^2_p=0.704$), indicating that the EMS intervention strongly influenced the improvement in swimming time.

These findings confirm that EMS is an effective modality for improving swimming speed in novice athletes. Figure 1 visually displays the comparative improvements between the EMS and control groups, while Figure 2 highlights individual-level changes in the EMS group, demonstrating consistent performance gains across all participants.

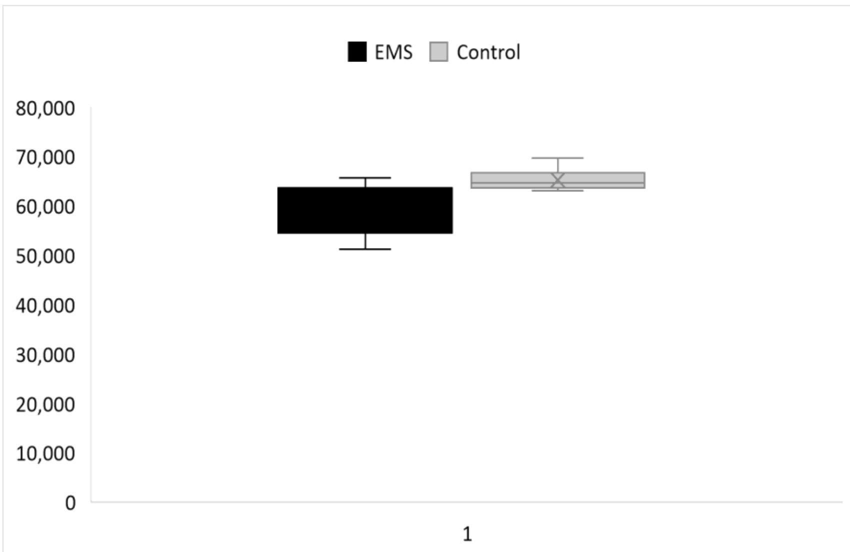

Figure 1. Mean changes in 50-meter swimming performance between the EMS and control groups (pretest vs. posttest).

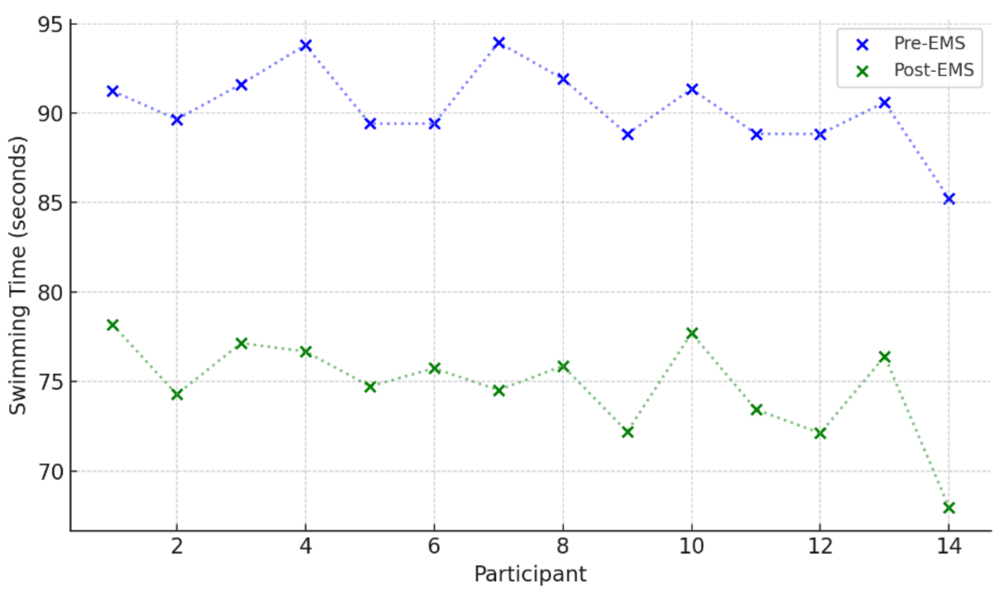

Figure 2. Individual improvements in swim performance for EMS group participants.

Performance Consistency. In addition to speed improvements, the EMS group also showed enhanced performance consistency, assessed via the Coefficient of Variation (CV) across repeated trials. Posttest CV values in the EMS group were significantly lower than those in the control group, indicating more stable and predictable performance outputs.

Figure 3 illustrates the reduction in variability within the EMS group, while Figure 4 presents the distribution of CV values. The EMS group displayed a narrower spread and fewer outliers, suggesting improved neuromuscular control and better pace regulation across swim sessions.

These results highlight that EMS boosts performance output and improves intra-individual reliability, an essential aspect of athlete development, especially in sprint-based aquatic events.

Performance consistency, as measured by the Coefficient of Variation (CV) across three consecutive trials, revealed a marked decrease in intra-individual variability within the EMS group. The EMS group significantly reduced CV values at the posttest, indicating enhanced performance stability. This result suggests a more repeatable and consistent performance profile, which is particularly important in competitive swimming contexts where timing precision is critical.

In contrast, the control group exhibited minimal changes in CV values, with no statistically significant differences between pretest and posttest. Figure 3 presents the trends in performance consistency, showing an apparent reduction in variability in the EMS group compared to the control group after the intervention period.

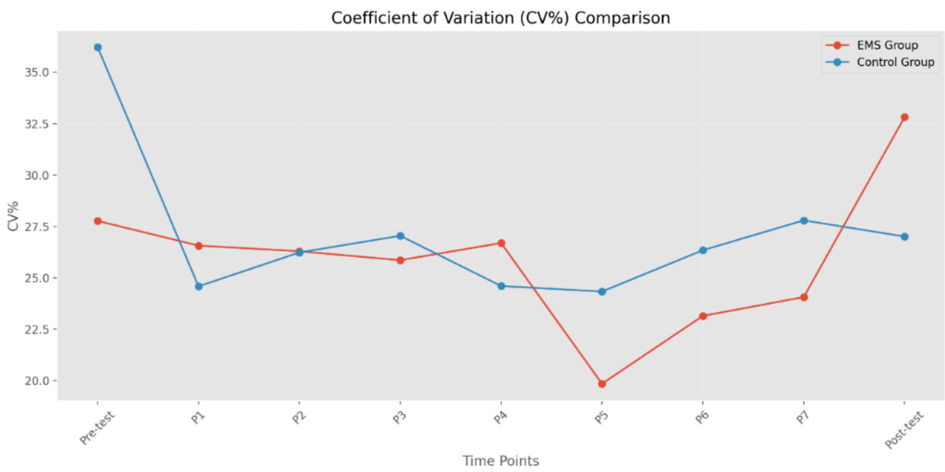

Figure 3. Comparison of performance consistency (Coefficient of Variation - CV) between EMS and control groups.

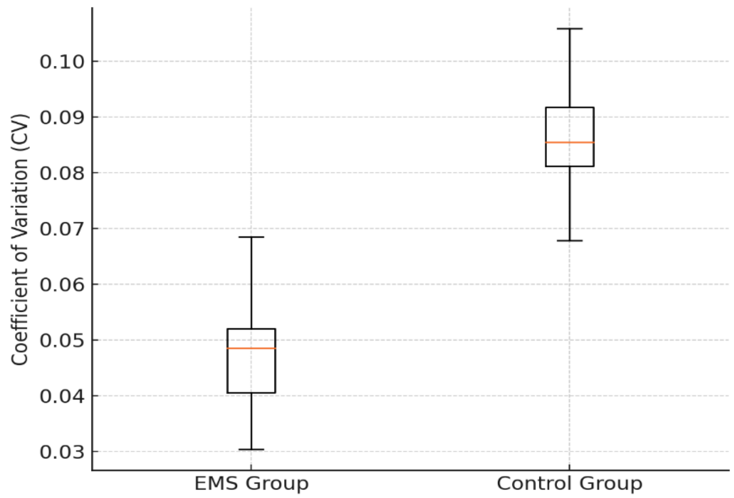

Figure 4. Distribution of performance stability (CV values) between EMS and control groups.

DISCUSSION

This study evaluated the effects of Electrical Muscle Stimulation (EMS) on swimming speed and performance consistency in novice swimmers. The findings indicate that EMS significantly enhances both components, affirming its utility as an effective and adaptable intervention in early-stage athlete development.

EMS's primary physiological benefit lies in its ability to improve muscular strength and neuromuscular coordination—two critical attributes for novice swimmers who typically exhibit biomechanical inefficiency and muscular imbalance. Prior studies have shown that strength gains, whether from resistance or electrostimulation protocols, contribute meaningfully to swimming propulsion and speed (8, 9). In this study, EMS was applied twice per week over four weeks, progressively increasing in intensity based on participant tolerance. Targeted stimulation to the thigh and calf regions facilitated safe, structured strength development without exposing participants to joint stress or overtraining, making it particularly suitable for beginners.

Beyond strength, EMS also enhanced performance stability, as reflected in the significant reductions in intra-individual variability (Coefficient of Variation). This aligns with prior findings that EMS promotes repeatable performance outcomes by improving neuromuscular control and body alignment (10, 11). A streamlined posture reduces hydrodynamic drag, and EMS contributes to maintaining this alignment, especially during starts and turns—critical phases in sprint swimming.

The individual improvement trends observed in the EMS group are further illustrated in Figures 2 and 4, underscoring the importance of accounting for inter-individual variability in training response. While all participants showed improvement, the magnitude varied, reflecting diverse neuromuscular adaptation profiles. Such variation highlights the potential for EMS to support personalized training models, which future studies should explore further.

In addition to biomechanical benefits, EMS contributed to psychological gains such as increased motivation, confidence, and training adherence. These are particularly important for novice populations vulnerable to dropout due to low self-efficacy. The ability to observe measurable improvements through EMS may reinforce persistence and commitment to training programs (12).

Notably, this study also highlights EMS's preventive and rehabilitative applications. By strengthening key muscle groups—particularly around the shoulders and lower limbs—EMS may help mitigate injury risks commonly faced by inexperienced swimmers (13). Moreover, EMS's low-impact nature makes it an attractive modality in return-to-sport (RTS) scenarios, especially for athletes recovering from musculoskeletal injuries that compromise joint function or muscular symmetry (12, 13).

These findings align with EMS applications across other sports. Research in cycling and running has demonstrated improved quadriceps activation, sprint performance, and fatigue resistance following EMS protocols, further confirming its cross-disciplinary physiological benefits (10, 12). Despite this, existing EMS literature has disproportionately focused on elite athletes, leaving a notable gap in novice populations. This study contributes original insights by targeting untrained youth athletes and proposing a scalable EMS protocol grounded in recent sports science literature.

However, several limitations must be acknowledged. First, the study included a relatively small and unequal sample size (EMS = 14; Control = 7), which may affect the statistical power and limit the generalizability of the findings. Although random assignment was used, future studies should employ larger, more balanced cohorts. Second, the short intervention period (four weeks) restricts conclusions regarding long-term adaptations and retention of gains. Third, the study focused primarily on two performance indicators—50-meter swim time and CV—without incorporating biomechanical (e.g., stroke length, drag) or physiological (e.g., EMG, lactate) metrics.

Future research should address these limitations by extending intervention duration, integrating biomechanical and physiological measurements (e.g., electromyography, motion capture), and applying more complex statistical models such as MANOVA or regression-based moderation analysis to capture nuanced relationships. Additionally, combining EMS with other training modalities—resistance, proprioceptive, or plyometric—could reveal synergistic effects not captured in isolated interventions.

Comparative studies suggest that resistance training improves strength and endurance, but it may pose injury risks if unsupervised, particularly for novices lacking baseline stability. Proprioceptive training enhances motor control but can be cognitively demanding. EMS is a complementary modality that enhances motor recruitment efficiency and fosters stable posture without cognitive overload or mechanical strain (8, 10).

The findings reinforce EMS as a multimodal intervention with the potential for performance enhancement, injury prevention, and rehabilitation. Its adaptability—through adjustable frequency, duration, and intensity—further supports these effects, making it suitable across different stages of athlete development. Moreover, EMS can be integrated with wearable technologies to offer real-time kinematic feedback, opening new avenues in performance diagnostics and personalized feedback systems (14, 15).

In summary, EMS emerges as a physical conditioning tool and a psychological and strategic intervention platform. It bridges the gap between motor inefficiency and high-performance readiness in novice athletes. While further studies are warranted, particularly those exploring long-term effects and broader performance metrics, the evidence presented here supports EMS as a transformative component in athlete development pipelines.

CONCLUSION

This study demonstrates that Electrical Muscle Stimulation (EMS) is a practical, adaptable, and low-impact modality for enhancing swimming speed and performance consistency in novice swimmers. The application of EMS over a short, four-week period resulted in significant reductions in swim time and intra-individual variability, indicating improvements in power output and performance stability. These outcomes are particularly relevant for beginners who typically struggle with muscular underdevelopment, poor coordination, and psychological insecurity in early training stages.

The study further confirms that EMS can address key biomechanical and neuromuscular challenges by stimulating underutilized muscle groups, enhancing postural control, and promoting efficient motor recruitment patterns. In addition, EMS supports injury prevention, psychological motivation, and possibly endurance capacity—making it a holistic training adjunct for talent development and return-to-sport (RTS) contexts.

Despite its promising results, the study acknowledges limitations, including the relatively small and unequal sample size, short intervention duration, and limited performance metrics. Future research should explore longitudinal effects, incorporate biomechanical and physiological indicators, and investigate combined EMS-conventional training models. Integrating EMS with motion tracking or wearable feedback systems also represents a promising direction for optimizing its application in recreational and professional sports.

In conclusion, EMS is a viable training supplement and a potentially transformative tool in modern sports science. Its ability to accelerate foundational athletic qualities in novice populations positions it as a strategic intervention for coaches, therapists, and sports development programs seeking to bridge the gap between early-stage ability and long-term performance potential.

APPLICABLE REMARKS

- Neuromuscular Priming for Swim Training: Incorporating short EMS sessions before swim workouts can enhance lower limb muscle activation, promoting improved propulsion and stroke efficiency without increasing injury risk.
- Injury Prevention Strategy: For beginners susceptible to overuse injuries, particularly in the shoulder and lower limb regions, EMS provides a low-impact method for strength development and muscular balance restoration.
- Performance Consistency Enhancement: Coaches may utilize EMS to reduce intra-individual performance variability, thereby improving athletes' pacing control and psychological confidence in competitive settings.
- Adherence and Motivation Tool: Measurable progress achieved through EMS can boost motivation and training adherence among youth athletes, particularly those struggling with early-stage performance stagnation.
- Scalability and Accessibility: Given its affordability and user-friendly interface, the EMS Butterfly device offers a feasible and scalable intervention for community swim

programs, especially in resource-limited settings.

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AUTHORS' CONTRIBUTIONS

Study concept and design: Boyke Mulyana. Acquisition of data: Afianti Sulastri. Analysis and interpretation of data: Afianti Sulastri. Drafting the manuscript: Boyke Mulyana. Critical revision of the manuscript for important intellectual content: Afianti Sulastri. Statistical analysis: Afianti Sulastri. Administrative, technical, and material support: Boyke Mulyana. Study supervision: Boyke Mulyana.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest regarding the publication of this manuscript. All procedures were conducted independently, and no financial, professional, or personal relationships influenced the design, implementation, analysis, or reporting of the study outcomes. The research was carried out without any commercial or proprietary influence that might be construed as a potential conflict.

FINANCIAL DISCLOSURE

The authors declare that there are no relevant financial interests or financial conflicts related to the material presented in this manuscript.

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ETHICAL CONSIDERATION

All research procedures complied with ethical standards outlined by the institutional ethics board. Participants and their guardians were thoroughly briefed about the study objectives, risks, and benefits. Participation was voluntary, and data confidentiality was ensured. No adverse effects were reported during the intervention.

ROLE OF THE SPONSOR

There were no external sponsors involved in this research. The funding provided was exclusively utilized for research purposes and had no influence on the study design, data collection, data analysis, interpretation of results, or manuscript preparation.

ARTIFICIAL INTELLIGENCE (AI) USE

AI tools were employed in this manuscript solely for language editing and improving readability. These tools did not contribute to scientific insights, data analysis, or the development of conclusions. The use of AI complies with the ethical standards outlined in https://aassjournal.com/content/94/, and all content was reviewed and approved by the authors. We have ensured transparency and compliance with all ethical guidelines the Annals of Applied Sport Science set forth.

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