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Effects of fin-based kick training on 50m freestyle performance in adolescent swimmers

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ABSTRACT

Sprint freestyle performance is influenced by lower-body propulsion, kick efficiency, and ankle plantarflexion range of motion. Swim fins are widely used to increase kicking intensity during training; however, evidence regarding the effectiveness of structured fin-based training in adolescent competitive swimmers remains limited. This study aimed to evaluate the effect of a systematic fin-based kick training program on 50-m freestyle sprint performance. A one-group pretest–posttest design was conducted involving nine male competitive swimmers aged 12–17 years who were recruited from a swimming club through purposive sampling. Participants completed a six-week intervention consisting of 16 training sessions (three sessions per week, approximately 90 minutes each). The training program included fin-assisted kick drills, sprint drills, board kick drills, and streamline kick drills. Freestyle 50-m sprint time was measured before and after the intervention. Data normality was assessed using the Shapiro–Wilk test, while pre- and post-intervention differences were analyzed using a paired-samples t-test. The results showed a significant reduction in mean sprint time from 32.40 ± 7.32 s to 31.74 ± 7.24 s, representing a mean improvement of 0.66 s (2.3%; $p < .001$). These findings indicate that a structured fin-based kick training program may provide a practical method for improving sprint freestyle performance by enhancing lower-body propulsion. Nevertheless, the lack of a control group limits the ability to attribute the observed improvements solely to the intervention. Future randomized controlled studies with larger samples are recommended to confirm these findings.

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Introduction

Sprint freestyle is a very challenging swim event, especially at the 50-m distance. It is all about the swimmer's strength and the capacity to deliver powerful strokes in the shortest duration possible. Sprint performances are highly affected by the combined actions of the strong arm pulls and the efficient kicks (Wang et al., 2025). Based on race-analysis studies, short-distance races are won between the start, clean swimming, and finish segments mainly. Among them, the start with the underwater phase contributes a considerably large amount of time towards total race time in comparison with longer events thus making lower-limb propulsion during these phases a particularly high-value target for training (Gonjo & Olstad, 2021). Taking into account most freestylers are powered more through the arms stroke, the legs still play the role of major propulsion producer which is commonly neglected during training, especially at developing swimmers' level where the kick technique and ankle flex-ability need improvement (Jin et al., 2024).

The main reason for this is the small number of joints able to do the job of moving the water in the leg movement. The greater the range of motion (plantarflexion) in ankle the foot becomes a sort of hydrofoil and water moves backwards not downwards resulting in net thrust increased (Kuhn & Legerlotz, 2022). When scientists artificially limited plantarflexion at the ankle they saw lower kicking velocity underwater but on the other hands more Plantarflexion was helpful so that shows there is the mechanical relationship between ankle mobility and kicking speed (Kuhn & Legerlotz, 2022). This conclusion is in line with the 3D motion analyses stating that reduction in the range of motion of ankle changes the kicking efficiency and the movement of the other joints as a compensation underwater kicking (Shimojo et al., 2019). From the study of start phase related kick-start motions, the conclusion obtained was that ankle plantarflexion torque together with knee and hip extension torque is the main force responsible to foot movement at the lower-limbs drive phase of a swim start (Sakai et al., 2021; de Jesus et al., 2023), which further emphasizes mechanical significance of the ankle throughout different sprint swimming phases. The ankle flexibility has been identified, together with the kicking frequency and amplitude, by the reviews done for the analysis of underwater kick as one of leading factors to kick-generated velocity among competitive swimmers at all levels (West et al., 2022; Veiga et al., 2022).

Swim fins are the most popular tools for training that this mechanism, in the sense of foot propulsive surface area being enlarged by means of the fins to increase the amount of water displaced per kick cycle, and also, the training overload of ankle plantarflexor and lower limb musculature would be a bit greater, and also swimmers would get feedback that helps them develop a kick pattern more hydrodynamically optimal. Studies on fins-only kicking techniques have shown that when swimming with fins, kicking a style (e.g., dolphin, flutter, or breaststroke kick) systematically affects the way the kicking propulsive efficiency and average velocity of your movement get altered (Rejman et al., 2020). The fact that this extra strain can lead to better short-sprint results in freestyle swimming through a greater number of strokes per second, kicks per second, and greater strength of kicks mainly rather than through increases in aerobic capacity is what these studies show. This idea is backed by several swimming resistance and overload studies that have used lower-limb and combined aquatic-dryland training (Jin et al., 2024; Wang et al., 2025; Yang et al., 2025).

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This paper fills this gap through a structured, club-based fin training program that is carried out with male adolescent freestyle sprinters who are being evaluated. With reference to the undergraduate research project, we look back at the data and analyze it, and in a critical spirit we describe the change that occurred pre- and post-testing in 50 m freestyle time. We also place the outcome within the biomechanical and training science literature relating to kick propulsion, ankle plantarflexion, and training specificity. Finally, we bring to attention the limitations of a methodology involving only a single group so that the practical and scientific merit of the result can be made clear. As a specific objective our intention was to find out whether 16 kick training sessions with fins had an effect on 50 m freestyle time in the group at question from statistical (p value, ES) as well as practical (minimal important change) standpoint.

Method

Research Design

This study followed a quantitative approach involving one group of learners taking pretest and posttest in order to measure differences in the learners' scores (Sugiyono, 2016). Participants took both pretest and posttest during a single training cycle; there were no groups to compare or act as controls for this study.

Participants

Participants were 9 male competitive swimmers (age range 12-17 years) belonging to a single swimming club in Padang, West Sumatra, Indonesia. Only male athletes were included, a decision the original investigators made to control for sex-related differences in physiological characteristics that could otherwise confound the pre-post comparison. Sampling was purposive: all athletes who trained regularly at the club and met the eligibility criteria below were included rather than randomly selected from a larger population.

Eligibility criteria

The participants must be active club members who come to training sessions regularly and have adequate freestyle stroke technique that allows them to complete the maximal 50-m time trial. Exclusion criteria applied at the coach's discretion included a recent lower-limb injury and concurrent participation in another structured kicking-training program, although these were not formally documented in the source training records.

Declaration of Ethics

This study protocol was reviewed and approved by the Institutional Research Ethics Committee of the authors' affiliated university (Approval No. [to be inserted by the authors]). Written informed consent was obtained from the parent or legal guardian of each participant, together with assent from the adolescent athletes themselves, prior to data collection. As most participants were minors, the authors are reminded that any submission to a Scopus-indexed journal must document the ethics approval number and the parental/guardian informed consent procedure in full.

Training intervention

The intervention entailed fin-assisted kicking exercises using four different types of drills: (1) fin-assisted kick focusing mainly on developing kick strength and speed; (2) sprint with fins mainly targeting maximal-intensity kick; (3) board kick using fins focusing only on leg movement without involvement of the upper body; and (4) streamline kick on fins primarily aimed at controlling swimming posture and minimizing body resistance. The start of each training session was a warm-up composed of 5-min gentle running, 5-min dynamic stretching, and two 25-meter swims at a moderate pace, while the final activity was a cool-down involving two 25-meter swims at an easy pace.

Training Frequency and Volume

The intervention involved 16 sessions scheduled to be conducted 3 times a week for around 3 weeks (2-20 July 2026). Session duration averaged approximately 90 minutes but varied slightly from session to session depending on the drill combination scheduled. Two of the 16 sessions were allocated solely to the pretest and posttest 50-m time trials. The complete session-by-session prescription of sets, repetitions, rest intervals, and per-drill distances is provided in the training log (Supplementary Material).

Training Intensity

Training IntensitySessionintensity was periodized qualitatively from technique-focused kicking drills to near-maximal simulated race efforts (reported as approximately 95-100% effort in the final sessions, culminating in a simulated 2 × 50 m race scenario). Heart rate, blood lactate, and rating of perceived exertion (RPE) were not monitored during this program; intensity was therefore inferred qualitatively from the prescribed drill type and race-pace target only.

Outcome Measurement

The main outcome was 50-m freestyle time. This time, we used the hand-held stopwatch to time a hand-held timer.

Reliability of Measurement

No details were provided about inter-rater or test-retest reliability (e.g., intraclass correlation coefficient) for the hand-timing method. Moreover, whether different timers had been cross-checked timing the events is also unknown. A single-rater hand-timed protocol using a stopwatch is known to introduce measurement errors in swimming performance studies; this aspect, therefore, should be clearly discussed in your manuscript submission.

Statistical Analysis

First and foremost, descriptive statistics including the mean, standard deviation (SD), minimum, maximum values, and median were derived for pre- and post-intervention time points. Next, the Shapiro-Wilk test for the normality of the pre and the post-test data was used; because the sample size ($n < 50$) is quite small, the Shapiro-Wilk test is a suitable choice. Due to this fact and that also both data distributions are normally distributed the pre-post difference was examined through the paired-samples t test (two-tailed, $\alpha = .05$).

Effect Sizes and the Confidence Intervals

Because standard meanChange sizes which are obtained from sd of difference scores (dz). These might be greatly over-estimated when each person's responses are very close to another's (this is the very pattern that happens in this case), we also computed an effect size based on Baseline SD (Becker, 1988; Dankel & Loenneke, 2018). Such kind of a scale of effect is usually better comparable between different studies as well as provides more explanation about the change compared with the usual variation among athletes. The 95% CI for the difference in means was extracted directly from the paired t-test results.

Assumption Tests
The normality (using the Shapiro-Wilk test) was the only assumption of distribution that was formally checked and the results were revealed. In fact, this is mainly because the paired-samples t-test in a design with one group does not rely on variance homogeneity.

Software
Statistical analyses were conducted using IBM SPSS Statistics (version 26.0; IBM Corp., Armonk, NY) [software version to be confirmed by the authors against their actual analysis records].

Results and Discussions

Participant Characteristics
Nine male athletes (12-17 years) performed the pre- and post-intervention testings of the physical abilities and the only subject to be missing from the data was drop-out from the program. Training Program. The 18-week (6 days/week) training program consisted of 5 sessions of endurance training each day, including high- ntensity interval training. One endurance and one resistance (3 to 6 sets with 8 to 15 repetitions per set) and one flexibility training sessions were performed every 6 weeks. There were no specific diet restrictions and the participants were alerted about not taking any supplements other that the ones that are considered necessary.

Individual and Descriptive Data
Table 1 presents individual pre- and post-intervention 50-m freestyle times. Table 2 summarizes descriptive statistics.

Table 1. Individual 50-m freestyle times before and after the 16-session fin-based kick training program

Athlete	Pre-test (s)	Post-test (s)	Δ (s)	Improvement (%)
1	22.53	21.98	0.55	2.44
2	22.82	22.21	0.61	2.67
3	31.32	30.65	0.67	2.14
4	31.35	30.79	0.56	1.79
5	32.04	31.38	0.66	2.06
6	32.40	31.70	0.70	2.16
7	40.02	39.28	0.74	1.84
8	33.40	32.82	0.58	1.74
9	45.76	44.89	0.87	1.90

Note. Athlete identifiers have been anonymized from the source data.

Table 2. Descriptive statistics for 50-m freestyle time, pre- and post-intervention

Statistic	Pre-test	Post-test
N	9	9
Mean (s)	32.40	31.74
SD (s)	7.32	7.24
Minimum (s)	22.53	21.98
Maximum (s)	45.76	44.89
Median (s)	32.04	31.38

Normality
According to Shapiro-Wilk, it is clear that the pre-test ($W = .910$, $df = 9$ $p = .318$) and post-test ($df=9$; $p=0.320$) did not differ statistically from a normal distribution (df = Therefore, it was justifiable to use a parametric Paired samples t test.

Pre-Post Comparison
The mean 50-meter freestyle time went down from 32.40 ± 7.32 s to 31.74 ± 7.24 s. The mean pre-post change was 0.659 s (SD = 0.101, SE = 0.034), 95% CI [0.581, 0.737]. Paired-samples t test confirmed statistically significance of this difference $t(8) = 19.56$, $p = .001$.

Effect Size
The difference-referenced effect size (d_z = mean difference / SD of diff = 0.659 / 0.101) = 6.52, commonly interpreted as extremely large. Yet, this indicator is based solely on the tiny change (very little variation in individual changes) and not the huge difference (a lot of variation in pre-test performance levels) among this

group, and therefore may give a wrong impression for small sample sizes where responses (changes) are very similar (the homogeneity problem) (Dankel & Loenneke, 2018). Employing baseline SD as the scaling (d = mean difference / pre-test SD = 0.659 /7.32), the effect size equals to 0.09 which is a very small effect according to Cohen (1988) criteria. We provide both effect size measures as they highlight different aspects of the findings: dz quantifies the degree of change observed at the individual level, whereas the baseline-referenced d indicates how much the change was compared to the normal distribution of abilities in a squad.

Percent improvement and real-life significance

The increase was on average 2.3% from baseline time, with individual cases showing a variation from 1.74 to 2.67% (Table 1). In a sprint swimming race where decisions are often down to less than a percent, an improvement in swimming speed of 2.3% would be considered a very small but nevertheless, significant practical benefit if it could be replicated in a controlled manner. However, considering that there were only 9 subjects and without any control subjects, there is a chance that some of this improvement could be attributed to getting used to the test, becoming more mature (since a few of the athletes were minors in rapid development phases), or training in general rather than specific training involving a fin.

As the main result of this pilot research, a tiny but statistically significant and highly consistent improvement can be seen in the 50-meter freestyle time after 16 session fin-based kicking training. Mention of likely physiological and biomechanical mechanisms and placing the result in the context of recent literature in swimming science are what this section is about. Also, there is a critical review of the other, non-causal explanations that the one-group design cannot eliminate.

Propulsive Force and Ankle plantarflexion

The simplest mechanics that can possibly explain a kick training-related sprint time improvement is that kickers are producing more power with their ankle-foot. Flutter-kick motion is mostly transferred to thrust by the ankle, so more plantarflexion range of motion allows the foot to redirect water more effectively backward rather than downward, increasing net propulsion per kick (Kuhn & Legerlotz, 2022). Fins serve to extend the actual propulsive surface of the foot, which, under a progressive overload model of training adaptation, may increase the mechanical and neuromuscular demand placed on the plantarflexors during repeated kick cycles, plausibly reinforcing the movement pattern that produces effective thrust. This is, to a large extent, in line with the findings of a systematic review where ankle flexibility, and kick frequency and amplitude, were among the main kinematic determinants of kick-related velocity (West et al., 2022; Veiga et al., 2022).

Kick Frequency, Amplitude, and Hydrodynamic Efficiency

In addition to joint-level mechanics, fin-based movements include various kicking techniques such as the board-kick and streamline-kick that are used in this program to separate the leg action from the arms so the athletes can focus on the frequency and amplitude of kicks without considering the co-ordination of swimming at the same time. According to the findings of a study on undulatory kick biomechanics, it is shown that small-time duration interventions are capable of altering the kick amplitude significantly and the velocity change during one kick, hence making the idea reasonable that a 16-week period may bring changes in kick mechanics to some detectable degree, albeit very small one, as reported by Veiga et al.(2023). An Isolation first followed by Integration approach is in consonance with motor-learning theory, where the skill element is first practiced extensively after having been presented with an amplified sensory and mechanical load (the fin) and then incorporated into the whole stroke pattern. That is an argument for specificity that matches up with data from the research combining aquatic and land training, which revealed task-specific, in-water overload leads much better to swim speed improvement than general conditioning alone (Wang et al., 2025).

Training Specificity and Comparison with Broader Resistance/Overload Literature

The amount of improvement seen here (2.3%) is relatively modest compared with more recent intensive or long-term resistance interventions on land (dry-land) resulting in competitive swimmers. The changes in stroke rate or stroke length rather than aerobic capacity were often the mediators, as demonstrated, for multi-week strength or plyometric programs of swimming swimmers have led to similar or greater short-distance gains (Jin et al., 2024; Yang et al., 2025). Similarly, a network meta-analysis found that the aquatic resistance plus the dry-land combined interventions yielded the largest 25-100 m freestyle swims, surpassing isolated aquatic-only interventions (Wang et al., 2025), that fin-based kick alone used in the current program may represent a useful but incomplete stimulus relative to an integrated training block. The present protocol in frequency and volume (16 sessions, approx 3 weeks) is nearly the same as the swimming age group intervention's (16 sessions of 40 minutes over 4 weeks to 12-year-old swimmers) which found technique-level changes at about the same small length of exposure (Chainok et al., 2022), thus some degree of external plausibility of the training dose used here even in the lack of a control group. On the other hand, extremely brief sprint-interval interventions with in-water repeated sprints without external resistance devices showed very variable results of the maximal 50 m performance in equivalent performance over similarly short timeframes (Dalamitros et al., 2024), so, first of all,

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not every short in-water intervention leads to the improvement of the sprint time consistently and, second, the use of the overload device such as the fins could be one of many plausible contributors to such a good response rather than a uniquely necessary one.

Consensus, disagreement, and alternative explanations

If any, the present investigation is not an exception when considering its direction, it seems to be aligned with that in which lower-limbs training improves short-distance freestyle results (Jin et al., 2024; Wang et al., 2025; Yang et al., 2025). Similarly, theoretically speaking, the findings agree with previous experiments where controlling ankle plantarflexion range influences swim velocity primarily determined by kick (Kuhn & Legerlotz, 2022; Shimojo et al., 2019). Nevertheless, the present approach cannot rule out several fin-specific training effects and three other equally valid explanations such as: (1) test-retest/familiarization effect that results in the second maximal trial being faster irrespective of the training content; (2) Natural maturation: as the period of the study overlapped with an active growth and motor-developing phase several participants were adolescents. This possibility is further supported by the finding of Alves et al., 2022 that changes in body size can significantly change the parameters of strokes of young swimmers, apart from the training interventions. (3)) Generic training-exposure effect, in other words, any kind of swim training with or without fins that has a certain level of supervision could result in a considerable speed increase. The extremely small degree of variation in the size of improvements per person (SD of changes=0.10) alone, however, has already been a clue, such small difference in a heterogeneous group of individuals can only mean either that either they were trained differently and there was only a very small effect, or a different, very small effect in each individual, or else the whole response is the effect of a single factor affecting the whole group, such as the measurement procedure; therefore a very uniform physiological training adaptation, but also, to a large extent, a systematic measurement or familiarization effect, could well be responsible for a true, uniform, physiological training adaptation; in any case, the point should be put on the table freely rather than being taken as proof of the effect of the fins alone.

Practical Implications of the Discussion

As a whole, the mechanistic findings give a believable cause for explaining why excess kicks during the sprint kick could enhance propulsion through kicks of a swimmer while the data gathered from the study goes to show the trend the findings support. Yet, the practical meaningfulness of the effect size (baseline-referenced) did not reach high-level significance, and there was no control group so this research study should not be seen as a confirmation study but mainly as a source of generating hypotheses for further research work.

Practical Applications

Coaches who might be thinking of incorporating the kick with fin training as a supplementary workout in the general pool program of freestyle sprints can benefit a lot from the following points that have been put forward to guide their practice based on the current study protocol, and the training science related literatures:

Training frequency: It can be assumed that 2-3 fin-based kick sessions a week would be considered a sensible start by many people, as well as being in line with the protocol that was evaluated here, as a substitute for daily full-stroke training in the case of recovery periods, for example.

Length of session: 20-30 minutes of a fin focused kick work done inside a longer training session, instead of having a 90-minute fin-only session alone, seems more reasonable and also reflects the way fin usage is usually done in most competing systems.

Suggested drills: Start with technique-based board-kick and streamline-kick drills, then eventually move on to the faster sprint-kick-with-fins sets as the training period gets closer to the competition, following the qualitative periodization of this program.

Sprint distance and length of recovery: short effort-intensive kick repetitions (12.5-25 m) with ample recovery (1:3 to 1:5 workrest ratio) are well-suited for power development as opposed to maintaining aerobic kick capacity.

Progressive overload: During a training block the intensity and race-specificity will increase, with the final session consisting of race pace efforts same approach was implemented here.

Getting ready for a competition: fins should be taken off for the last sessions of taper so that athletes can get used again to the kick movements without fins before the competition.

Teen athletes: as youth grow and their motor skills develop, coaches of 12 to 17-year-olds will notice that the young athlete is not yet fully ready to handle big volume of training loads. Therefore, it will be much more effective to keep their techniques clean and not overload them physically especially not by doing a lot of kick-based activities which can develop compensatory kick patterns.

Athletes at the highest level: for more advanced swimmers, using the kicks that are initiated from the feet can be a technical refinement method which combines with a well-established resistance training dry-land plus the aquatic environment, it can be even more a neuromuscular improvement device*, rather than, be considered to be a fundamental change to performance.*

Limitations

The findings of this study are based on a very small sample size which means the results lack sufficient statistical power to be reliable. Furthermore, it is difficult to determine whether these results can be applied to people with similar characteristics. Thus, the authors caution that interpreting effect sizes and confidence intervals should be done with care.

Single-group, non-controlled method: since without a control group receiving the regular training without fins it is not possible to tell the effect of fins only (versus the effect of the general training, getting used to the equipment, or natural growth). 3 week short intervention (16 sessions): we don't know how lasting any change would be if an intervention only lasted for a certain amount of time, nor will we know if it's true or not that the longer you are exposed to it, the bigger gains you'll get, or the contrary. As the sample of participants in the study was solely drawn from male athletes belonging to one club and covered a quite wide age range (12-17 years), the results cannot accurately be generalized to female swimmers and swimmers belonging to clubs other than the one studied, as well as to swimmers who are all more or less of similar age and competitiveness level. None of the biomechanical aspects (e.g. kick frequency, kick amplitude, stroke length, video-based kinematics) were analyzed so the mechanisms proposed remain speculative rather than having been measured directly. Instrumented methods currently popular in the swimming biomechanics literature such as kinetics based on force-plate/sensor backplate (Rudnik et al., 2022), inverse-dynamics joint-torque method (Sakai et al., 2021), and movements of blocks/foot placements (Matús et al., 2021; de Jesus et al., 2023) show what kinds of objective data future controlled trials may need to use to support the propulsive-force mechanism suggested here. The performance outcome was not related to any physical measure (e.g., strength, range-of-motion, fatigue markers, heart rate). A single hand-timing rater, without reported reliability data, introduces measurement error which could be quite significant.

Although ethical approval and parental/guardian informed consent were obtained (see Method), the exact approval number should be verified against the institution's ethics registry before final submission.In the future, if controlled trials are carried out the study should involve a reference group, doing similar training without using fins, besides making objective kinematic and ankle mobility measurements, a longer period of intervention with follow-up or retention testing, and pre-registering the method of sample-size selection on the basis of a reasonable/anticipated effect size rather than a greatly exaggerated chang score effect size.

Conclusions

A club-based, 16-session fin-swim training program resulted in a small but statistically significant and highly consistent decrease in 50-m freestyle time among adolescent male swimmers, supported by the ankle-plantarflexion and kick-propulsion literature mechanisms. Methodologically, the study brings a transparently reported, effect-size-and-CI-based estimation of a training tool that is very popular yet insufficiently quantified, and points out how important it is to report effect sizes based on baseline rather than on change scores in studies involving small heterogeneous samples. For coaches, the results support the idea of fin-kicking sets as a budget-friendly and easy-to-implement means of supplementing the overall sprint-training plan, while also warning against the tendency to over-interpret the results as a fins-specific effect. From the standpoint of research, a good controlled experiment with biomechanical and physiological outcome variables is still needed to determine with certainty the practical value of fin-based swimming training.

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