DOI 10.xxxx/xxxxx

ORIGINAL SCIENTIFIC PAPER

The Effects of Swim-Specific Dry-Land Training on 50-m Freestyle Performance in 12–13 Year Old Swimmers

Jannatul Khairoh[1], Syahrastani[2], Umar[3], Asep Sujana Wahyuri[2], Masrun[3], Sri Gusti Handayani[2], Arsil[2], Padli[3], Sari Mariati[3]

[1]Doctoral in Sports Science, Universitas Negeri Padang, Padang, Indonesia

[2]Department of Sport Education, Faculty of Sport Science, Universitas Negeri Padang, Padang, Indonesia

[3]Department of Sport Coaching Education, Universitas Negeri Padang, Indonesia

Corresponding Author: Syahrastani, e-mail: syahrastani@fik.unp.ac.id

Abstract

This study aimed to examine the effects of swim-specific dry-land training on 50-m freestyle performance in 12–13 year old swimmers. This research employed a quantitative approach using a one-group pretest–posttest experimental design. The participants consisted of 15 male swimmers aged 12–13 years from FITT Swimming Club Padang, selected through purposive sampling. The intervention consisted of 16 sessions of swim-specific dry-land training, including plank, close-grip push-up, V-up, chin-up, flutter kicks, physioball upper-trunk rotation, and physioball bridge. Swimming performance was measured using a 50-m freestyle performance before and after the intervention, with time recorded in seconds using digital stopwatches operated by three independent timekeepers. Data were analyzed using descriptive statistics, Kolmogorov–Smirnov normality test, and paired-samples t-test through IBM SPSS Statistics version 26. The results showed that the mean pre-test time was 45.239 seconds, while the mean post-test time decreased to 44.495 seconds, indicating an improvement of 0.744 seconds. Normality testing confirmed that the data were normally distributed ($p > 0.05$). The paired-samples t-test revealed a statistically significant difference between pre-test and post-test results ($t = 9.117$; $p = 0.001 < 0.05$). It can be concluded that swim-specific dry-land training had a significant positive effect on improving 50-m freestyle performance in 12–13-year-old swimmers. These findings suggest that this training method can be effectively integrated into swimming conditioning programs to enhance sprint performance.

Keywords: swim-specific dry-land training, freestyle swimming, sprint swimming.

1. Introduction

Swimming is a highly competitive performance sport in which athletes' success is objectively measured through time efficiency. In modern training systems, swimming performance is determined by the integration of physical capacity, technical proficiency, and biomechanical efficiency in the water (Ruiz-Navarro et al. 2025). Among the various competitive events, the 50-m freestyle performance is considered one of the most physiologically demanding disciplines, requiring athletes to generate maximal speed within a very short duration while maintaining movement efficiency.

From a hydrodynamic perspective, swimming velocity results from the complex interaction between propulsion and water resistance (drag). Therefore, the ability to maximize propulsion while minimizing drag becomes a primary determinant of sprint performance (Takagi et al. 2021).

In swimming mechanics, the coordination between arm muscle strength and lower-limb explosive power forms the foundation of swimming speed. While the contribution of each physical component may vary across different swimming strokes, upper-body dominance in freestyle swimming remains a major consideration, as the arms contribute approximately 56–63% of total propulsion (Keller, Olstad, and Wahl 2024). This finding highlights the importance of systematically developing muscular strength and explosive power to improve the swimmer's power-to-drag ratio (Schreven, Smeets, and Beek 2022).

In addition to propulsion, core stability plays an important role in maintaining body posture and facilitating force transfer between the upper and lower extremities (Liu et al. 2025). However, practical conditions in the field indicate that many athlete development programs have not yet implemented scientifically based approaches to physical training. The absence of organized training programs (daily, weekly, and annual plans) and the limited application of coaching science represent serious barriers to achieving sustainable athletic performance.

In response to these limitations, swim-specific dry-land training has emerged as a strategy to bridge the gap between general strength training and the biomechanical demands of swimming. Previous studies have shown that the integration of dry-land training can significantly improve propulsive force and stroke efficiency (Amara et al. 2021; Wirth et al. 2022).

Furthermore, a recent meta-analysis by Wang et al. (2025) confirmed that combining swimming practice with dry-land strength training produces superior outcomes compared with those of conventional swimming training alone.

The urgency of this study is further reinforced by national competition standards. According to the Qualification Entry Times (QET) document for the Indonesia Open Swimming Championships 2025, male swimmers aged 12–13 years are expected to achieve a time of 29.82 seconds in the 50-meter freestyle event (Championships 2025). This demanding qualification standard highlights the need for optimal physical preparation from an early age. Observations conducted at FITT

Swimming Club Padang revealed that young swimmers often experience difficulty maintaining speed during the final phase of the race, indicating the need for more specific and measurable physical training interventions outside the pool.

Based on this background, the present study aims to analyze the effects of swim-specific dry-land training on 50-m freestyle performance in 12–13-year-old swimmers. This study is expected to provide scientific evidence for coaches regarding the importance of transitioning from experience-based training toward to data-driven and biomechanically oriented training approaches to improve young swimmers' performance.

2. Materials and Methods

This study was conducted in October 2025 at Wirabraja Swimming Pool, Padang City, Indonesia. The study employed a quantitative approach using a one-group pretest–posttest experimental design to examine the effects of swim-specific dry-land training on 50-m freestyle performance.

The participants consisted of 15 male swimmers aged 12–13 years from FITT Swimming Club Padang. Participants were selected using purposive sampling because this technique allowed the selection of participants with specific characteristics relevant to the objectives of the study, particularly young swimmers who met predetermined training and performance criteria. The selection criteria included actively participating in regular club training sessions, possessing basic freestyle swimming ability, being in healthy physical condition, and being willing to participate in the entire research procedure. All participants and their parents/guardians provided informed consent prior to the study. The research was conducted voluntarily while adhering to ethical principles involving human subjects in accordance with the Declaration of Helsinki. Ethical approval for this study was obtained from the Faculty of Sport Science under approval number 6865/UN35.3/AK/2025.

The research design consisted of a pretest, an intervention program, and a posttest. The pretest was conducted to determine the participants' baseline 50-m freestyle performance. Subsequently, all participants completed a swim-specific dry-land training program consisting of 16 training sessions integrated into the club's regular training schedule. Participants also continued their regular in-water swimming training throughout the intervention period. The training program was implemented using a circuit training method, in which participants performed a sequence of exercise stations consecutively with predetermined work and rest intervals. Each training session applied a circuit training method consisting of several exercise stations performed consecutively. Each exercise was performed for 30 seconds with a 30-second rest interval between stations and a 3-minute rest interval between sets. The training program applied the principle of progressive overload across the 16 sessions. During sessions 1–8, participants trained at 50% intensity with 4 sets; during sessions 9–12, the intensity was increased to 60% with 5 sets; and during sessions 13–16, the intensity was further increased to 70% with 6 sets. Training load progression was implemented gradually through increases in exercise intensity and the number of sets performed.

DOI 10.xxxx/xxxxx

This method was applied to improve muscular strength, endurance, core stability, and movement efficiency related to 50-m freestyle performance.

The training program included plank, close-grip push-up, V-up, chin-up, flutter kicks, physioball upper-trunk rotation, and physioball bridge exercises. These exercises were selected to enhance upper-body muscular strength, core stability, postural control, and movement efficiency that support freestyle swimming biomechanics. All training sessions were supervised directly by the coach and the researcher to ensure that each exercise was performed with proper technique.

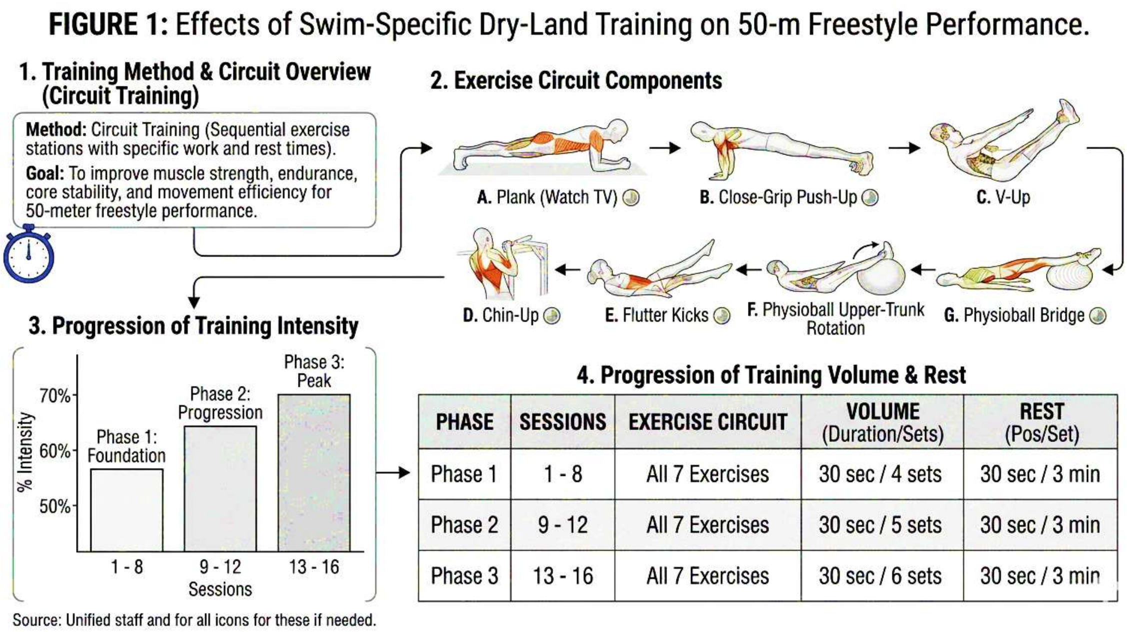

Figure 1. Swim-Specific Dry-Land Training Program for 50-m Freestyle Performance

Performance measurements were conducted twice, namely during the pre-test and post-test sessions. Both tests consisted of a 50-m freestyle performance performed under the same conditions. Prior to testing, all participants completed a standardized 15-minute warm-up session. Swimming time was measured using a digital stopwatch with an accuracy level of 0.01 seconds. To improve measurement reliability, performance times were recorded by three independent timekeepers, and the value used for analysis was the average of the three recorded times.

Data were analyzed using IBM SPSS Statistics version 26. Descriptive statistical analysis was used to obtain the mean, standard deviation, minimum value, and maximum value. Because the sample size was relatively small (n = 15), normality was assessed primarily using the Shapiro–Wilk test, which is considered more appropriate for small samples. The Kolmogorov–Smirnov test was used as an additional reference for distribution assessment. Differences between pre-test and post-test results were then analyzed using a paired-samples t-test with a significance level of $p < 0.05$.

3. Results

The results of the study are presented through descriptive statistical analysis, normality testing, and hypothesis testing to determine the effects of swim-specific dry-land training on 50-m freestyle performance in 12–13-year-old swimmers.

3.1. Descriptive statistics

Table 1. Descriptive Statistics of Pre-Test and Post-Test Results in the 50-m freestyle performance

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Pre-test	15	34.56	55.34	45.239	6.38	40.74
Post-test	15	33.85	54.93	44.495	6.45	41.61
Valid N (listwise)	15					

Based on Table 1, the mean pre-test result was 45.239 seconds, while the mean post-test result was 44.495 seconds. This indicates a decrease in swimming time of 0.744 seconds after the implementation of the swim-specific dry-land training intervention. The reduction in swimming time reflects an improvement in 50-m freestyle performance among the study participants.

Table 2. Normality Test of the Data

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Preliminary test results for the 50-m freestyle performance (seconds)	0.122	15	0.200*	0.946	15	0.470
Final test results for the 50-m freestyle performance (seconds)	0.132	15	0.200*	0.941	15	0.394

Based on Table 2, all significance values in the Kolmogorov–Smirnov and Shapiro–Wilk tests were greater than 0.05. Therefore, the data were normally distributed and met the assumptions required for parametric analysis using the paired-samples t-test.

Table 3. Results of the Paired-Samples t-Test

Variable	Mean Difference	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pre-Test – Post-Test	0.7440	0.3160	0.0816	9.117	14	0.001

Based on Table 3, the results of the paired-samples t-test showed a mean difference of 0.7440 seconds, with a t-value of 9.117 and a significance value of 0.001. The 95% confidence interval (CI) for the mean difference ranged from 0.569 to 0.919 seconds, indicating a consistent reduction in swimming time following the intervention. Furthermore, the effect size analysis showed a Cohen's d value of 2.35, representing a very large practical effect of the intervention.

Since the significance value was lower than 0.05 ($p < 0.05$), there was a significant difference between the pre-test and post-test results. Therefore, the research hypothesis was accepted.

The findings of this study indicate that swim-specific dry-land training had a significant effect on improving 50-m freestyle performance in 12–13-year-old swimmers at FITT Swimming Club Padang. The training program proved effective in reducing swimming time, thereby increasing the participants' swimming speed after the intervention.

4. Discussion

This study demonstrated that swim-specific dry-land training had a positive effect on 50-m freestyle performance in 12–13-year-old swimmers. These findings indicate that dry-land exercises designed according to the biomechanical characteristics of swimming are capable of improving physical capacities that support sprint swimming performance.

The improvement in swimming performance observed in this study was likely associated with enhanced propulsion generated by the upper extremities. In freestyle swimming, the arms are the primary source of propulsive force and contribute substantially to swimming speed. Keller et al., (2024) reported that the upper extremities contribute approximately 56–63% of propulsion and freestyle swimming velocity. This finding is supported by Ruiz-Navarro et al. (2025) who stated that sprint swimming performance largely depends on the ability to generate propulsion through arm stroke actions. Therefore, exercises such as close-grip push-ups, chin-ups, and physioball upper-trunk rotations may have contributed to improvements in the participants' propulsive capacity.

The present findings are also consistent with the study by Amara et al. (2021) which showed that the combination of dry-land strength training and in-water resistance training improved upper-body strength and sprint swimming performance. In addition, Pratama et al. (2025) explained that arm muscle strength has a strong relationship with 50-m freestyle swimming performance. Compared with previous studies involving adolescent swimmers, the magnitude of improvement observed in the present study was comparable to findings showing that dry-land interventions can positively influence sprint swimming performance through enhancements in muscular strength and movement efficiency.

In addition to propulsion, the performance improvements found in this study may also be related to increased core stability. Exercises such as plank, V-up, flutter kicks, and physioball bridge likely enhanced trunk stability, allowing swimmers to maintain a more effective streamline position during swimming. Liu et al. (2025) stated that core stability plays an important role in maintaining body balance, movement efficiency, and drag reduction while swimming. Good core stability also facilitates more effective force transfer between the upper and lower extremities (Rodríguez et al. 2024).

The findings of this study further support the Specificity of Training theory proposed by Bompa and Haff, which states that training adaptations occur specifically according to the movement patterns and muscle groups being trained. The swim-specific dry-land training program in this study was designed to target the dominant muscles involved in freestyle sprint swimming. Wang et al. (2025) through a meta-analysis, reported that the combination of dry-land and swimming training produced greater improvements in sprint performance compared with swimming training alone. Similarly, Fone & Van Den Tillaar, (2022) stated that strength training with biomechanical relevance to swimming can positively transfer to swimming speed performance.

Beyond improvements in strength and body stability, the results of this study may also be explained through neuromuscular adaptation mechanisms. Khiyami et al. (2022) found that core training improved neuromuscular coordination, stroke efficiency, and freestyle swimming performance. These neuromuscular adaptations may allow swimmers to maintain propulsion effectiveness and movement efficiency throughout sprint performance. Improved neuromuscular coordination enables swimmers to sustain stroke frequency and movement control more consistently.

From a practical perspective, the mean improvement of 0.744 seconds observed in this study may be considered meaningful in youth competitive swimming. In sprint events such as the 50-m freestyle, performance differences between athletes are often determined by fractions of a second. Therefore, a reduction of approximately 0.744 seconds may substantially increase competitiveness and potentially contribute to achieving qualification standards in youth swimming competitions.

Nevertheless, this study has several limitations, particularly the relatively small number of participants, the absence of randomization, the lack of a control group, and the inclusion of only male participants. These limitations may reduce the generalizability of the findings. Therefore, future studies are recommended to employ more complex experimental designs with larger and more diverse sample sizes to allow a more comprehensive evaluation of the effectiveness of swim-specific dry-land training programs.

5. Conclusions

Based on the findings of this study, swim-specific dry-land training significantly improved 50-m freestyle performance in 12–13-year-old swimmers. Therefore, this type of training may be considered an effective complementary approach within structured training programs for enhancing youth swimming performance.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this study.

References

1. Amara, Sofiene, Tiago M. Barbosa, Yassine Negra, Raouf Hammami, Riadh Khalifa, and Sabri Gaied Chortane. 2021. "The Effect of Concurrent Resistance Training on Upper Body Strength, Sprint Swimming Performance and Kinematics in Competitive Adolescent Swimmers. A Randomized Controlled Trial." International Journal of Environmental Research and Public Health 18(19):10261. doi: 10.3390/ijerph181910261.
2. Championships, Indonesia Open Swimming. 2025. Qualification Entry Times (QET) Indonesia Open Swimming Championships 2025. Akuatik Indonesia.
3. Fone, L., and R. Van Den Tillaar. 2022. "Effect of Different Types of Strength Training on Swimming Performance in Competitive Swimmers: A Systematic Review." Sports Medicine - Open 8. doi: 10.1186/s40798-022-00410-5.
4. Keller, S., B. Olstad, and P. Wahl. 2024. "Lower and Upper Extremity Contributions to Propulsion and Resistance During Semi-Tethered Load-Velocity Profiling in Front Crawl Swimming." Journal of Sports Sciences 42:215–21. doi: 10.1080/02640414.2024.2326347.
5. Khiyami, A., S. Nuhmani, R. Joseph, T. Abualait, and Q. Muaidi. 2022. "Efficacy of Core Training in Swimming Performance and Neuromuscular Parameters of Young Swimmers: A Randomised Control Trial." Journal of Clinical Medicine 11. doi: 10.3390/jcm11113198.
6. Liu, S., J. Dai, P. Gou, and M. Lin. 2025. "The Effects of Core Stability Training on Swimming Performance in Youth Swimmers: A Systematic Review and Meta-Analysis." BMC Sports Science, Medicine and Rehabilitation 17. doi: 10.1186/s13102-025-01366-1.
7. Pratama, A., M. Personi, and F. Perdima. 2025. "Contribution of Arm Muscle Strength to Freestyle Swimming Speed in SPC Swimming Club Athletes." Journal of Physical Education and Sports. doi: 10.37676/jpes.v1i2.690.

8. Rodríguez, S., C. León-Prieto, M. Jaime, and A. Peña. 2024. "Meta-Analysis of the Effects of Core Stability Training on 50-Meter Freestyle Performance in Men and Women." Revista de Investigación e Innovación En Ciencias de La Salud. doi: 10.46634/riics.359.
9. Ruiz-Navarro, Jesús J., Catarina C. Santos, Dennis-Peter Born, Óscar López-Belmonte, Francisco Cuenca-Fernández, Ross H. Sanders, and Raúl Arellano. 2025. "Factors Relating to Sprint Swimming Performance: A Systematic Review." Sports Medicine 55(4):899–922. doi: 10.1007/s40279-024-02172-4.
10. Schreven, S., J. Smeets, and P. Beek. 2022. "Sprint Performance in Arms-Only Front Crawl Swimming Is Strongly Associated With the Power-To-Drag Ratio." Frontiers in Sports and Active Living 4. doi: 10.3389/fspor.2022.758095.
11. Takagi, H., M. Nakashima, Y. Sengoku, T. Tsunokawa, D. Koga, K. Narita, S. Kudo, R. Sanders, and T. Gonjo. 2021. "How Do Swimmers Control Their Front Crawl Swimming Velocity? Current Knowledge and Gaps from Hydrodynamic Perspectives." Sports Biomechanics 22:1552–71. doi: 10.1080/14763141.2021.1959946.
12. Wang, Z., K. Liu, X. Zhao, and J. Gao. 2025. "Comparative Effectiveness of Physical Training Modalities on Swimming Performance: A Two-Tier Network Meta-Analysis." Frontiers in Physiology 16. doi: 10.3389/fphys.2025.1636595.
13. Wirth, K., M. Keiner, S. Fuhrmann, A. Nimmerichter, and G. Haff. 2022. "Strength Training in Swimming." International Journal of Environmental Research and Public Health 19. doi: 10.3390/ijerph19095369.