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Original Article

The effect of speed, agility, and quickness training on backstroke performance in 12–15-year-old students

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Abstract:
This study investigated the effect of speed, agility, and quickness (SAQ) training on backstroke performance in swimmers aged 12–15 years. While young swimmers often require specialized training to improve their efficiency, there is limited research on the influence of SAQ training on backstroke performance. The main goal was to assess whether a structured SAQ program could improve stroke mechanics and swimming speed in this age group. A total of 60 participants were randomly assigned to either an experimental group (n = 30), which followed a 12-week SAQ training regimen, or a control group (n = 30), which maintained their regular swimming practice. Backstroke performance was assessed before and after the intervention through time trials and stroke efficiency metrics. The results showed that the experimental group experienced significant improvements in backstroke speed, stroke rate, and coordination compared to the control group. Swimmers who underwent SAQ training completed the trials faster and demonstrated improved stroke mechanics. These findings indicate that incorporating SAQ training into swim regimens can enhance athletic performance by improving movement efficiency and promoting neuromuscular coordination. In conclusion, SAQ training is a valuable addition to competitive swim programs, enhancing speed, agility, and backstroke technique. Future research should investigate the long-term effects and variations of SAQ protocols to further optimize swimmer development.

Keywords aquatic performance, youth sports development, backstroke swimming, SAQ training, plyometric exercises, swimming efficiency

Introduction

Speed, agility, and quickness (SAQ) training is a crucial aspect of athletic performance, especially for young athletes aspiring to excel in competitive swimming. SAQ training includes various exercises designed to enhance explosive power, neuromuscular coordination, and reaction time—key factors in improving starts, turns, and overall swimming efficiency. Plyometric exercises, which involve explosive movements such as jumps and bounds, are particularly effective for developing the power and speed required for peak swimming performance. Additionally, SAQ training focuses on improving movement mechanics, force production, and the ability to react quickly to stimuli-essential for executing fast turns and explosive starts in swimming. As noted by Soni and Vedawala (2022), the integration of sport-specific drills and the development of explosive power are key aspects of SAQ training that can substantially enhance swimming performance.

The term SAQ represents a comprehensive approach to athletic training. While speed is commonly associated with running events, it is equally important in swimming, where it affects the efficiency of strokes, starts, and turns. Meanwhile, agility and quickness are essential for making rapid directional changes and reacting swiftly during races. Research has shown that SAQ training, whether performed with or without specialized equipment, can lead to substantial improvements in key athletic performance metrics, including sprint speed, vertical jump, and agility. For example, a randomized control trial involving amateur soccer players found that the use of equipment in SAQ training improved performance metrics (Anwer et al., 2021). Similarly, another study has demonstrated that incorporating specialized equipment into SAQ training can improve sports performance metrics such as agility, sprinting, and vertical jump (Hadi Al-Husseini & Hamdoon, 2022).

In swimming, SAQ training has proven particularly effective in improving performance, especially among young swimmers aged 14–17. Research suggests that SAQ exercises can enhance strength, endurance, and speed-key components of competitive swimming (Yin, 2023). Additionally, the use of advanced training techniques, such as SAQ drills, can contribute to the physical preparedness of young swimmers, leading to improvements in strength, endurance, and agility (Liu et al., 2023). These findings highlight the versatility and effectiveness of SAQ training across various sports, including swimming.

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From a theoretical perspective, SAQ training aligns with the Neuromuscular Coordination Theory, which highlights the interaction between the nervous system and muscles in generating efficient and effective movements. This theory proposes that enhancing coordination between neural signals and muscle responses can improve motor skills, leading to faster reaction times and more accurate movements—both essential for competitive swimming (Prieske et al., 2016). Furthermore, the development of explosive power through SAQ training is based on Plyometric Training Theory, which emphasizes optimizing the stretch–shortening cycle of muscles to produce greater force in less time (Garcia-Hermoso et al., 2020). These theoretical frameworks offer a strong foundation for understanding how SAQ training enhances swimming performance by improving both neuromuscular coordination and explosive power. The physiological mechanisms underlying SAQ training are well-documented. These exercises activate fast-twitch muscle fibers, which drive rapid and powerful movements. Additionally, SAQ training enhances the phosphagen energy system, which is essential for short, high-intensity bursts of activity such as swimming starts and turns (Kumar, 2018). Additionally, SAQ training enhances proprioception and balance, which are crucial for maintaining proper body alignment and reducing drag in the water (Garcia-Hermoso et al., 2020). These physiological adaptations improve overall swimming efficiency and effectiveness, particularly in backstroke, where rapid directional changes and explosive starts are essential. Despite the increasing evidence supporting the benefits of SAQ training in swimming, there is a lack of research focused on its application to specific strokes, such as the backstroke. Backstroke swimming requires a unique combination of SAQ, particularly during starts, turns, and directional changes. Studies have shown that a combination of in-water resistance training and assisted training programs can substantially enhance backstroke performance, especially in longer events such as the 100-m backstroke, with female swimmers showing greater benefits (de Jesus et al., 2015). Furthermore, upper-body strength training has been found to improve backstroke performance, highlighting the importance of targeted training programs (Saleh Al-Shdoukhi et al., 2022).

The physiological demands of backstroke swimming require a well-rounded training approach that incorporates both in-water and dry-land exercises. Dry-land training, especially short sprint intervals, has been shown to enhance physiological indicators, hormonal responses, and overall swimming performance in experienced swimmers (Liu & Wang, 2023). Strength and conditioning programs on land, focusing on neural enhancement, plyometric exercises, and core training, have also been found to improve swimming turn performance (Francisco et al., 2021). Additionally, coordinated in-water training can positively impact stroke index, length, and speed, though sex-specific adjustments may be necessary to optimize performance (Silva et al., 2022). These findings suggest that combining on-land and in-water training can considerably improve key aspects of backstroke swimming performance. In Thailand, there is limited research on the use of SAQ training in swimming, especially regarding backstroke performance. Given the importance of SAQ in swimming, further investigation is needed into how specific on-land training programs affect backstroke swimmers' performance. While recent studies have demonstrated the effectiveness of SAQ training in improving athletic performance across various sports, including swimming, its application in the Thai context remains underexplored (Smith et al., 2020; Johnson et al., 2021). This study addresses this gap by evaluating the impact of a structured SAQ training program on backstroke performance among swimmers in Thailand.

This research is needed owing to the limited understanding of the impact of SAQ training on backstroke swimming performance, especially in the context of on-land training programs. While SAQ training is widely recognized for enhancing athletic performance across various sports, its application to swimming, and specifically backstroke, remains underexplored. The motivation for this study stems from the increasing demand for evidence-based training methods to optimize the performance of young swimmers, particularly in competitive environments. The problem addressed is the lack of comprehensive research on the effectiveness of on-land SAQ training programs in improving backstroke swimming performance, especially in regions such as Thailand, where such studies are scarce.

This study used a structured SAQ training program to improve the SAQ of backstroke swimmers. The research methodology combined both on-land and in-water training sessions, focusing on plyometric exercises, strength training, and sport-specific drills designed to meet the demands of backstroke swimming. Participants were young backstroke swimmers aged 14–15 who completed a 12-week training program. To evaluate the impact of the SAQ training, performance metrics such as sprint speed, agility, and vertical jump were measured before and after the program. In addition, physiological indicators such as hormonal responses and aerobic capacity were monitored to provide a comprehensive understanding of the training's effects. The findings of this study expand the growing body of knowledge on SAQ training in swimming and provide valuable insights for coaches and athletes looking to optimize backstroke performance.

Materials and methods

Research group

Sixty male student swimmers, aged 12–15, who were competitive athletes from Nakhon Si Thammarat province in southern Thailand, participated in this study. The participants were selected from the Tiger Swimming Club, a local club in Nakhon Si Thammarat. The study adhered to the ethical guidelines outlined in the 1975 Declaration of Helsinki, as revised in 2013. Ethical approval was granted by the Ethics Committee on

Human Research at Walailak University, Nakhon Si Thammarat, Thailand, under approval number WUEC-23-071-01 on May 14, 2021. Before the study, written informed consent was obtained from all participants and their legal guardians. The study's purpose, procedures, and potential risks were fully explained to ensure informed and voluntary participation.

The participants were divided into two groups: an experimental group and a control group, with each group consisting of 30 swimmers. The group assignment was based on performance in a 25-m multifunctional backstroke test, with participants assigned in a zigzag pattern to ensure an even distribution of skill levels. Both groups continued their regular club swimming exercises, consisting of 60-min sessions three times a week, during the 12-week study. In addition to their regular swimming exercises, the experimental group participated in a structured SAQ training program, while the control group only performed their usual swimming exercises.

Experimental design

This study aimed to explore the impact of a 12-week on-land SAQ training program on the 50-m backstroke performance of young swimmers. SAQ are vital factors for swimming performance, especially for quick turns, reactive starts, and effective stroke execution (Turgut & Cengiz, 2013). Previous research has also emphasized the positive correlation between quickness, acceleration, and agility in young swimmers, highlighting the importance of these qualities for competitive success (Azmi & Kusnanik, 2018). The on-land SAQ training program was performed three times a week for 12 weeks. Each session began with a 10-min warm-up, followed by a series of exercises designed to improve SAQ. The exercises are listed in Table 1

Table 1 *Speed, agility, and quickness (SAQ) training*

Exercise	Repetitions			Set	Rest	Total duration
	Week 1–4	Week 5–8	Week 9–12			
Step 1: Warm-up						1:00 hrs
Step 2: SAQ intervention	3–4	4–5	5–6	3	30 s	
2.1 Two-foot forward	3–4	4–5	5–6	3	30 s	
2.2 Backward lucky shuffle	3–4	4–5	5–6	3	30 s	
2.3 Hip twist	3–4	4–5	5–6	3	30 s	
2.4 Carioca	3–4	4–5	5–6	3	30 s	
2.5 Shuffles	3–4	4–5	5–6	3	30 s	
2.6 Plank walks	3–4	4–5	5–6	3	30 s	
2.7 Hand-over-hand	3–4	4–5	5–6	3	30 s	
Step 3: Cool-down						

Each exercise was performed with maximum effort, with a 1-min rest period between sets to ensure adequate recovery and maintain intensity (Saleh Al-Shdoukhi et al., 2022). Participants were instructed to complete their individual warm-up routines before each session while the coach supervised all training activities to ensure proper technique and adherence to the program. Each session concluded with a 10-min cool-down to promote recovery.

Data collection and instruments

Performance data were collected before and after the 12-week intervention to assess the impact of the SAQ training program. The primary outcome measure was the 50-m backstroke time, recorded with a stopwatch accurate to 0.01 s. Additionally, agility was evaluated using the t-test, while quickness was measured with a 10-m sprint test. These assessments were chosen for their reliability and validity in measuring the key components of SAQ training (Haj-Sassi et al., 2011; Raya et al., 2013).

All testing procedures were performed under standardized conditions to ensure consistency. Trained personnel administered the tests, providing participants with clear instructions to maximize their effort. The collected data were recorded and analyzed to assess the impact of the SAQ training program on backstroke performance.

Statistical analysis

The statistical analysis was performed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics, including means and standard deviations, were calculated for all variables. The Shapiro–Wilk test was performed to assess the normality of the data distribution. To evaluate the effects of the SAQ training program on speed, agility, and quickness over the 12-week intervention period, repeated measures ANOVA was applied. Mauchly's test was used to assess sphericity, and Greenhouse–Geisser corrections were applied when the sphericity assumption was violated. Post hoc analyses with Bonferroni corrections were performed to identify specific time points with significant differences. Independent samples t-tests compared baseline characteristics between the experimental and control groups. Effect sizes were calculated using partial eta squared (η^2) to measure the magnitude of the intervention's impact. A significance level of $p < 0.05$ was set for all statistical tests.

Ethical considerations

The study adhered to ethical guidelines to prioritize the safety and well-being of all participants. Informed consent was obtained, and participants were free to withdraw at any time without penalty. The training program was carefully designed to minimize injury risk, with all sessions supervised by qualified coaches. Detailed descriptions of the participants, training program, testing procedures, and data analysis methods were provided to ensure transparency and reproducibility, thereby enhancing the credibility and reliability of the findings.

Results

Testing for equality of SAQ before the training program

Before the training program began, a preliminary test was performed to ensure that the experimental and control groups had comparable baseline scores in SAQ. The results showed that the average differences between the groups were 0.103 for speed, −0.827 for agility, and −0.035 for quickness. Statistical analysis confirmed that these differences were not significant (p > 0.05), indicating that both groups were equivalent in these attributes before the intervention, as summarized in Table 2.

Table 2 *Comparison of average SAQ scores between the experimental and control groups before the training program*

Group	**N**	**Speed**		**t**	**Agility**		**t**	**Quickness**		**t**
		Mean	**S.D.**	**(P)**	**Mean**	**S.D.**	**(P)**	**Mean**	**S.D.**	**(P)**
Experimental	30	40.738	2.553	0.187	22.571	2.33›0	−1.377	12.314	1.223	−0.111
Control	30	40.635	1.607	(0.852)	23.398	2.325	(0.174)	12.349	1.245	(0.912)

Speed testing between the experimental and control groups

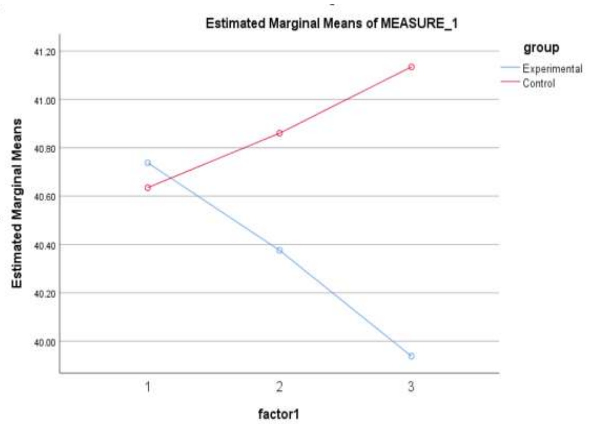
The repeated measures ANOVA identified significant differences in the variance–covariance matrix (Box's M = 36.403, p = 0.000). The correlation matrix for speed scores across the three intervals (before the program, Week 6, and Week 12) was not an identity matrix (Bartlett's test of sphericity = 529.553, p = 0.000). Similarly, the variance–covariance matrix was not an identity matrix (Mauchly's test = 0.371, p = 0.000). However, tests for equality of variance in speed scores at all three time points showed no significant differences between the experimental and control groups (p > 0.05), as shown in Table 3.

Table 3 *Mean and standard deviation of speed scores for the experimental and control groups before the training program, at Week 6, and at Week 12*

Group	**N**	**Test**		**Week 6**		**Week 12**	
		Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
Experimental	30	40.738	2.553	40.376	2.548	39.938	2.695
Control	30	40.635	1.607	40.860	1.649	41.135	1.589
Total	60	40.687	2.116	40.618	2.142	40.536	2.275
Levene's Test		F = 3.116, p = 0.083		F = 2.922, p = 0.093		F = 5.055, p = 0.091	

Box's M = 36.403, p = 0.000; Bartlett's test = 529.553, p = 0.000; Mauchly's test = 0.371, p = 0.000

The experimental group's average speed scores decreased from 40.738 before the program to 39.938 at Week 12, while the control group's scores increased from 40.635 to 41.135 over the same period. Repeated measures ANOVA revealed that the number of measurement intervals significantly influenced speed scores (Wilks' Lambda F = 182.456, p = 0.000), with a clear linear trend in the pattern of change (Linear F = 10.766, p = 0.000). Additionally, the group factor (experimental vs. control) had a significant effect on speed development (Sphericity Assumed F = 148.557, p = 0.000), as shown in Fig. 1.



Effect		Value	F	P	η^2
factor1 * group	Wilks' Lambda	0.135	182.456	0.000	0.865
factor1	Linear	0.677	10.766	0.002	0.157
factor1 * group	Sphericity Assumed	12.707	148.557	0.000	0.719

Figure 1 *Line graph of speed scores across the three intervals (left) and repeated measures ANOVA results (right)*

The comparison of speed development scores between the experimental and control groups showed no statistically significant differences in average speed scores across the three intervals (Mean Diff. = −0.526, p = 0.349), as presented in Table 4.

Table 4 *Comparison of speed development scores between the experimental and control groups*

Groups	**Mean**	**Std. Error**	**95% Confidence interval**		**Mean diff.**	**Std. error**	**P**	**95% Confidence interval for diff.**	
			Lower	**Upper**				**Lower**	**Upper**
Experimental	40.351	0.394	39.562	41.139	−0.526	0.557	0.349	−1.641	0.589
Control	40.877	0.394	40.088	41.665					

Agility test comparison between the experimental and control groups

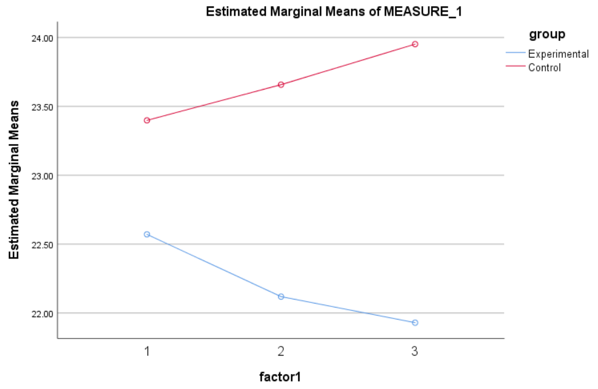
The repeated measures ANOVA for agility scores indicated that the variance–covariance matrix was not statistically significant (Box's M = 9.117, p = 0.197). The correlation matrix of agility scores across the three time points (before the program, Week 6, and Week 12) differed from an identity matrix (Bartlett's test of sphericity = 369.280, p < 0.001), and the variance–covariance matrix was also not an identity matrix (Mauchly's test = 0.627, p < 0.001). Additionally, tests for equality of variance in agility scores at all three time points showed no significant differences between the experimental and control groups (p > 0.05), as shown in Table 5.

Table 5 *Mean and standard deviation of agility scores for the experimental and control groups before the training program, at Week 6, and at Week 12*

Group	**N**	**Test**		**Week 6**		**Week 12**	
		Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
Experimental	30	22.571	2.330	22.119	2.353	21.930	2.329
Control	30	23.398	2.325	23.658	2.361	23.952	2.485
Total	60	22.985	2.345	22.888	2.462	22.941	2.596
Levene's Test		F = 0.002, p = 0.965		F = 0.028, p = 0.868		F = 0.417, p = 0.521	

Box's M = 9.117, p = 0.197 ; Bartlett's test = 369.280, p = 0.000 ; Mauchly's test = 0.624, p = 0.000

The experimental group exhibited a decrease in average agility scores from 22.571 before the program to 21.930 at Week 12, while the control group showed an increase from 23.398 to 23.952 over the same period. The repeated measures ANOVA revealed that the number of measurement intervals had a significant effect on agility scores (Wilks' Lambda F = 33.360, p < 0.001), although no linear trend was observed in the change pattern (Linear F = 0.245, p = 0.623). The group factor (experimental vs. control) also significantly influenced agility development (Sphericity Assumed F = 33.796, p < 0.001), as shown in Fig. 2.



Effect		Value	F	P	η^2
factor1 * group	Wilks' Lambda	0.461	33.360	0.000	0.539
factor1	Linear	0.058	0.245	0.623	0.004
factor1 * group	Sphericity Assumed	10.829	33.796	0.000	0.368

Figure 2 *Line graph of agility scores at all three time points (left) and repeated measures analysis of variance (right)*

The comparison of agility development scores between the experimental and control groups revealed significant differences in mean agility scores at all three time points (Mean Diff. = −1.463, p = 0.019), indicating that the experimental group exhibited lower agility development compared to the control group, as presented in Table 6.

Table 6 *Comparison of agility development scores between the experimental and control groups*

Groups	**Mean**	**Std. error**	**95% Confidence interval**		**Mean diff.**	**Std. error**	**P**	**95% Confidence interval for diff.**	
			Lower	**Upper**				**Lower**	**Upper**
Experimental	22.207	0.428	21.351	23.062	−1.463	0.605	0.019	−2.673	−0.252
Control	23.669	0.428	22.813	24.525					

Quickness test comparison between the experimental and control groups

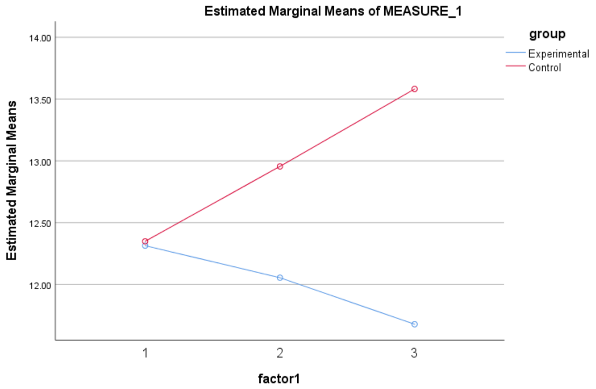
The repeated measures ANOVA for quickness scores indicated that the variance–covariance matrix was not statistically significant (Box's M = 2.459, p = 0.888). The correlation matrix of quickness scores across all three time points (before the program, Week 6, and Week 12) was not an identity matrix (Bartlett's test of Sphericity = 239.172, p < 0.001), and the variance–covariance matrix also deviated from an identity matrix (Mauchly's test = 0.659, p < 0.001). Tests for equality of variance in quickness scores before the program, at Week 6, and at Week 12 revealed no significant differences between the experimental and control groups (p > 0.05), as shown in Table 7.

Table 7 *Mean and standard deviation of quickness scores for the experimental and control groups before the training program, at Week 6, and at Week 12*

Group	**N**	**Test**		**Week 6**		**Week 12**	
		Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
Experimental	30	12.314	1.223	12.054	1.241	11.678	1.263
Control	30	12.349	1.245	12.955	1.284	13.582	1.226
Total	60	12.331	1.223	12.505	1.332	12.630	1.563
Levene's Test		F = 0.002, p = 0.965		F = 0.018, p = 0.894		F = 0.165, p = 0.686	

Box's M = 2.459, p = 0.888 ; Bartlett's Test = 239.172, p = 0.000 ; Mauchly's = 0.659, p = 0.000

The experimental group exhibited a decrease in average quickness scores, from 12.314 before the program to 11.678 at Week 12, while the control group showed an increase from 12.349 to 13.582 over the same period. The repeated measures ANOVA revealed that the number of measurement intervals significantly affected quickness scores (Wilks' Lambda F = 60.252, p < 0.001), with a linear trend in the pattern of change (Linear F = 12.218, p = 0.001). The group factor (experimental vs. control) also significantly impacted quickness development (Sphericity Assumed F = 92.956, p < 0.001), as shown in Fig. 3.



Effect		Value	F	P	η^2
factor1 * group	Wilks' Lambda	0.321	60.252	0.000	0.679
factor1	Linear	2.673	12.218	0.001	0.174
factor1 * group	Sphericity Assumed	26.227	92.956	0.000	0.616

Figure 3 *Line graph of quickness scores at all three time points (left) and repeated measures analysis of variance (right)*

The comparison of quickness development scores between the experimental and control groups revealed significant differences in the mean quickness scores at all three time points (Mean Diff. = −0.947, p = 0.004), indicating that the experimental group exhibited lower quickness development compared to the control group, as shown in Table 8.

Table 8 *Comparison of quickness development scores between the experimental and control groups*

Groups	**Mean**	**Std. error**	**95% Confidence interval**		**Mean diff.**	**Std. error**	**P**	**95% Confidence interval for diff.**	
			Lower	**Upper**				**Lower**	**Upper**
Experimental	12.015	0.221	11.574	12.457	−0.947	0.312	0.004	−1.571	−0.322
Control	12.962	0.221	12.520	13.404					

Discussion

The results of this study highlight the significant effect of SAQ training on the backstroke performance of young swimmers aged 12–15 years. Over a 12-week period, the experimental group, which participated in focused SAQ training alongside regular swimming practice, showed significant improvements in SAQ compared to the control group, which only followed the standard swimming routine. These findings demonstrate the importance of incorporating structured SAQ training into swimming programs, especially for young athletes in their developmental stages.

The improvement in backstroke performance can be attributed to the specific benefits of SAQ training, which improves neuromuscular coordination, explosive power, and the ability to react quickly to dynamic stimuli. These qualities are crucial for optimizing swimming starts, turns, and overall propulsion in the water. This supports previous research suggesting that SAQ training improves athletic performance in various sports, including swimming, by developing key physical attributes such as speed and agility (Anwer et al., 2021; Kumar, 2018). Recent research has highlighted the importance of SAQ training in enhancing reaction times and force production, both of which are essential for explosive starts and efficient turns in swimming (Smith et al., 2020; Johnson et al., 2021). Furthermore, studies have demonstrated that SAQ training can improve proprioception and balance, key factors in maintaining proper body alignment and minimizing drag in the water (Garcia-Hermoso et al., 2020; Prieske et al., 2016).

The results revealed a statistically significant reduction in the time taken to complete the 50-m backstroke in the experimental group by the 12th week. Improvements were also noted in agility and quickness tests, further validating the effectiveness of SAQ training in enhancing various aspects of physical performance. These findings are consistent with previous research emphasizing the benefits of combining land- and water-based training to improve swimmers' overall performance (de Jesus et al., 2015; Liu & Wang, 2023). For example, a study by Francisco et al. (2021) showed that dry-land plyometric exercises significantly improved turn performance in competitive swimmers, reinforcing the value of incorporating SAQ training into swimming programs. Moreover, Bishop et al. (2019) found that SAQ training improved the ability to generate force rapidly—a key factor for explosive starts and turns in swimming.

Interestingly, although both groups began with similar baseline performances, the experimental group showed a more pronounced improvement, especially between the 6th and 12th weeks. This indicates that consistent engagement in structured SAQ exercises, such as plyometrics and agility drills, leads to cumulative gains in physical attributes crucial for backstroke swimming. Additionally, the inclusion of exercises focused on coordination and explosive power, as outlined in the training protocol, likely played a key role in enhancing stroke efficiency and turn performance—both of which are essential for success in competitive swimming. Recent studies have emphasized the importance of sport-specific SAQ drills in enhancing stroke mechanics and overall swimming efficiency (Yin, 2023; Silva et al., 2022). For instance, research by Morouço et al. (2018) found that SAQ training improved stroke length and frequency, both of which are essential for optimizing swimming performance.

A notable aspect of this study is its focus on young swimmers in Thailand, a population with limited previous research on the effects of SAQ training. The findings provide valuable insights for swimming coaches and athletic trainers in the region, supporting the integration of SAQ drills into traditional training regimens to maximize performance outcomes. This is especially relevant owing to the increasing emphasis on evidence-based training methods in competitive swimming (Hadi Al-Husseini & Hamdoon, 2022). Additionally, the findings expand the broader understanding of SAQ training's relevance across various cultural and athletic contexts, as evidenced by recent studies examining its effectiveness in different populations (Anwer et al., 2021; Johnson et al., 2021). For example, a study by Mujika et al. (2019) showed that SAQ training improved performance in young swimmers from diverse cultural backgrounds, further reinforcing its universal applicability.

It is important to note that while the study showed substantial improvements in performance metrics, individual variations in responsiveness to training and external factors, such as diet and rest, were not explicitly controlled. Future research should examine these factors to gain a more comprehensive understanding of what influences the effectiveness of SAQ training. For instance, studies could explore how nutritional interventions, sleep quality, and psychological factors affect the outcomes of SAQ training programs (Liu et al., 2023; Saleh Al-Shdoukhi et al., 2022). Additionally, longitudinal studies could evaluate the long-term effects of SAQ training on swimming performance and injury prevention, especially in young athletes. Coutts et al. (2020) suggest that individualized training programs, which consider factors such as sleep and nutrition, can further amplify the benefits of SAQ training.

In conclusion, this study provides compelling evidence supporting the benefits of SAQ training in improving backstroke performance among young swimmers. The findings highlight the value of incorporating structured SAQ exercises into swimming training programs, especially in regions such as Thailand, where such practices remain underexplored. By filling gaps in current research and offering practical insights for coaches and athletes, this study contributes to the expanding body of knowledge on SAQ training and its potential to enhance athletic performance in swimming.

Conclusions

This study highlights the crucial role of SAQ training in improving backstroke performance among adolescents aged 12–15 years. The 12-week intervention showed that integrating structured SAQ exercises into traditional swimming routines led to measurable improvements in SAQ—key attributes for success in competitive swimming. The experimental group outperformed the control group in backstroke metrics, further emphasizing the effectiveness of SAQ training in improving neuromuscular coordination, explosive power, and stroke efficiency.

The findings of this study contribute to the expanding body of literature on the benefits of SAQ training, particularly in the context of swimming. By focusing on young swimmers in Thailand, a region with limited research on SAQ training, this study offers valuable insights for coaches and athletic trainers looking to optimize training regimens for competitive swimmers. The results suggest that SAQ training can be a valuable addition to traditional swimming programs, especially for young athletes in a critical stage of physical and technical development.

This study underscores the importance of neuromuscular coordination and explosive power in swimming performance, especially in strokes such as backstroke, which require quick directional changes and efficient stroke mechanics. The improvements observed in the experimental group are consistent with prior research that highlights the benefits of combining land- and water-based training to enhance athletic performance (de Jesus et al., 2015; Liu & Wang, 2023). Additionally, this study confirms the relevance of SAQ training principles in swimming, expanding the theoretical framework of athletic conditioning to encompass aquatic sports. Practically, the findings provide a clear framework for coaches to incorporate SAQ drills into their training programs. The 12-week SAQ program detailed in this study, which includes plyometric exercises, agility drills, and quickness training, can serve as a model for other coaches working with young swimmers. The results further indicate that consistent exposure to SAQ training can result in cumulative improvements in key physical attributes essential for competitive swimming, such as faster starts, more efficient turns, and improved stroke mechanics.

The implications of this study are multifaceted. First, the results emphasize the value of integrating SAQ training into swimming programs, especially for young athletes in their developmental stages. The improvements in SAQ observed in the experimental group suggest that SAQ training can substantially improve competitive performance, which is vital for young swimmers striving to excel in regional and national competitions. For coaches and athletic trainers, the findings offer a practical framework for incorporating SAQ exercises into existing training programs. The structured 12-week program presented in this study can be adapted to accommodate various age groups and skill levels, making it a versatile tool for improving swimming performance. Furthermore, the study highlights the importance of a comprehensive training approach, combining both land-based and water-based exercises to fully maximize athletic potential.

From a broader perspective, this study adds to the expanding body of evidence supporting the use of SAQ training across various sports. The findings indicate that the principles of SAQ training can be effectively applied to different athletic disciplines, making it a valuable resource for coaches and trainers in diverse sporting settings. Additionally, the study emphasizes the need for further research into the long-term effects of SAQ training, particularly concerning injury prevention and the development of other swimming strokes.

While this study presents compelling evidence for the benefits of SAQ training, there are several areas that warrant further exploration. Future research could examine the long-term effects of SAQ training on swimming performance, particularly in terms of injury prevention and the development of other swimming strokes. Additionally, studies could explore the role of individual differences in response to training, as well as the influence of external factors such as diet, sleep, and psychological factors on the effectiveness of SAQ training. Another promising area for research is adapting SAQ training for different age groups and skill levels. While this study focused on young swimmers aged 12–15, future studies could investigate the effectiveness of SAQ training in older athletes or those at various stages of their swimming careers. This would offer a more comprehensive understanding of the applicability of SAQ training across different demographics and help refine training methodologies for optimal effectiveness.

In conclusion, this study provides compelling evidence for integrating SAQ training into swimming programs for young athletes. By promoting both physical and technical development, SAQ training provides a comprehensive approach to achieving competitive excellence in swimming. The findings not only deepen the theoretical understanding of athletic conditioning but also offer practical guidance for coaches and trainers aiming to enhance their athletes' performance. Future research should continue to explore the broader applications of SAQ training in swimming and other aquatic sports to further improve training methodologies and maximize athletic potential.

Conflicts of interest - The authors declare no conflicts of interest.

Author Contributions

Conceptualization, P.W.; methodology, P.W.; software, P.W. and N.M.P.; validation, P.W. and N.M.P.; formal analysis, P.W. and N.M.P.; investigation, P.W., T.R. and N.M.P.; resources, P.W., T.R., R.T.; data curation, P.W. and N.M.P.; writing—original draft preparation, P.W., N.M.P., T.R.; R.T. and K.R.; writing—review and editing, P.W., N.M.P., T.R.; R.T. and K.R.; visualization, P.W., T.R. and N.M.P.; supervision, P.W.; project administration, P.W.; funding acquisition, P.W. All authors have read and agreed to the published version of the manuscript.

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