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Developing a Functional Training Program Based on the Fundamental Movement Screen (FMS) to Improve Stroke Length in University Crawl Stroke Swimmers

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Abstract

Background and Aims: Swimming plays a critical role in collegiate sports in China, with short-distance Crawl events demanding explosive power, precise technique, neuromuscular coordination, and efficient stroke mechanics. Conventional strength and speed training often fails to address underlying movement deficiencies that limit stroke length, turn transitions, and underwater propulsion. The main objective of this study was to develop a functional training program based on the fundamental movement screen (FMS) to improve stroke length on crawl stroke swimmers in a university, with subsidiary objectives including: 1. To study the problem and current situation of swimming training methods on university swimmers. 2. To draft the functional training program based on the fundamental movement screen (FMS) to improve stroke length on crawl stroke swimmers at the university. 3. To experiment on the application of a functional training program based on the fundamental movement screen (FMS) to improve stroke length on crawl stroke swimmers at the university.

Methodology: This study employed a mixed-method research approach, combining quantitative and qualitative methods. A total of 200 questionnaires were distributed, with 197 valid responses collected to examine the current application of FMS in swimming training. Semi-structured interviews were conducted with nine swimming coaches to identify training issues and propose improvement suggestions, while five experts were interviewed to refine the training content. Subsequently, a focus group of nine experts was organized to optimize the draft training program, and the final eight-week training program was validated by seven experts using the Connoisseurship method.

Results: 1. The current situation of FMS application in swimming training was at a high level overall (M = 3.65 ± 0.93). 2. After the intervention, the experimental group performed significantly better than the control group in single-arm left stroke (p = 0.01), single-arm right stroke (p = 0.01), bilateral arm stroke (p = 0.01), and swimming count (p = 0.01). Repeated measures ANOVA also showed significant changes across testing periods in left arm stroke length (p = 0.01), right arm stroke length (p = 0.000), bilateral arm stroke length (p = 0.000), and stroke count over 50 meters (p = 0.01).

Conclusion: The study developed an FMS-based functional training program for university crawl stroke swimmers, involving 200 male swimmers and nine coaches, with 24 swimmers selected for an experimental intervention, integrating individualized corrective exercises,

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stroke-length monitoring, strength development, technical drills, and recovery management; post-intervention results demonstrated that the experimental group showed significant improvements in left-arm, right-arm, and bilateral stroke length as well as 50-meter swimming count compared to the control group, with repeated-measures analysis and Bonferroni tests confirming progressive, continuous gains across pre-test, mid-test, and post-test, highlighting the effectiveness of structured, FMS-informed training in enhancing stroke efficiency, technical performance, and overall swimming outcomes.

Keywords: Functional Training Program; Fundamental Movement Screen (FMS); Stroke Length; Crawl Stroke Swimmers

Introduction

Swimming has increasingly been recognized as a pivotal component of collegiate sports development in China, contributing not only to students' physical fitness and health literacy but also to their technical competence and competitive performance in short-distance crawl stroke events, such as the 50m and 100m, which demand explosive power, precise movement efficiency, and neuromuscular coordination. Conventional strength and speed training programs have demonstrated limited effectiveness in addressing underlying deficiencies in fundamental movement patterns, including hip control, shoulder mobility, and core-to-limb force transfer, which directly affect stroke mechanics, turn execution, and underwater propulsion. Functional Movement Screen (FMS) assessments provide a framework for evaluating seven essential movement patterns: deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability, with particular tasks influencing stroke length, body roll, and force transfer. Sawczyn (2020) reported that a periodized functional strength program significantly improved FMS scores and overall coordination among physical education students, suggesting benefits for aquatic sports, while Ervuz et al. (2022) confirmed a strong predictive relationship between FMS performance and short-lane crawl times, and Bond et al. (2014) demonstrated that youth swimmers with optimal FMS and anthropometric profiles exhibited more efficient stroke mechanics and faster sprint times, emphasizing the importance of targeted functional interventions to enhance propulsive stroke length without compromising rate.

Despite this evidence, university swimming programs in China largely rely on linear resistance training, aerobic intervals, and technical drills, neglecting systematic assessment and correction of movement dysfunctions that constrain performance. Athletes often exhibit deficiencies in hip flexion, scapular stability, and trunk control, which impair starts, flip turns, and streamline efficiency, yet receive minimal individualized intervention based on movement screening protocols. The lack of routine FMS evaluation allows deficits in shoulder mobility, trunk stability, push-up, rotary stability, and active straight leg raise to

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persist, limiting torso rotation, catch reach, and lower limb contribution. Functional training programs informed by movement quality have demonstrated utility in diverse contexts, with Xu and Xue (2024) highlighting their impact on maritime students' fitness and coordination. Research involving elite athletes has demonstrated significant associations between functional movement quality and sport-specific performance outcomes (Li et al., 2024). Similar findings in swimming indicate that movement quality assessed through the Functional Movement Screen is related to swimming performance and technical efficiency (Bond et al., 2015; Lucas et al., 2021). Therefore, corrective exercises targeting FMS patterns associated with stroke length and movement efficiency may provide an individualized training approach that enhances stroke mechanics, reduces injury risk, and improves competitive performance.

Objectives

Main Objective

To develop a functional training program based on the fundamental movement screen (FMS) to improve stroke length in crawl-stroke swimmers at the university.

Subsidiary Objectives

1. To study the problem and current situation of the swimming training method for university swimmers.

2. To draft the functional training program based on the fundamental movement screen (FMS) to improve stroke length on crawl stroke swimmers at the university.

3. To experiment on the application of a functional training program based on the fundamental movement screen (FMS) to improve stroke length on crawl stroke swimmers at a university.

Literature Review

Functional training program

A sport-specific functional training program in university swimming prioritized movement quality before training volume, integrating screening, corrective exercises, strength and mobility work, and aquatic technique to improve stroke length, with the Functional Movement Screen (FMS) serving as the diagnostic backbone rather than an optional tool, as higher-quality foundational movement patterns correlate with superior performance indicators in youth and adult athletes (Fitton Davies, 2022). Comparative analyses indicated that swimmers with higher composite FMS scores exhibited better postural control, joint range, and segment timing, which enabled longer effective pull paths and enhanced propulsion (Lucas et al., 2021). Implementing periodized functional strength and core-focused interventions demonstrated concurrent gains in trunk stability, shoulder mobility,

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rotary stability, and hip-line dissociation, resulting in measurable improvements in distance per stroke without increasing energetic cost or compromising technique.

Crawl Stroke skills

Structured swim training programs demonstrated that integrating functional movement development with conventional strength and technical work substantially enhanced short-distance Crawl performance in student swimmers, with higher FMS scores correlating with superior sprint outcomes and efficient body alignment during starts, underwater gliding, and stroke execution (Chen, 2014). Programs that combined dynamic balance, single-leg support drills, rotational stability exercises, and resistance-based mobility training produced significant improvements in both FMS scores and sprint times, indicating that refined neuromuscular control and reduced asymmetrical energy loss underpin stroke-length efficiency rather than strength gains alone (Baydemir and Kaçay, 2025).

Fundamental Movement Screen (FMS)

Functional Movement Screen (FMS) assessments provided a practical framework for evaluating movement efficiency, coordination, and neuromuscular control in athletes, revealing that higher FMS scores correlated with superior execution in sport-specific tasks and consistency in stroke mechanics among university swimmers (O'Brien et al., 2023). Early identification of deficits in shoulder mobility, rotary stability, deep squat, and trunk control enabled structured corrective training programs that improved posture, force transfer, and energy efficiency, ultimately enhancing stroke performance and reducing fatigue-induced breakdowns (Wu et al., 2021). Evidence from elite youth functional training programs demonstrated that low-load, individualized interventions informed by FMS effectively enhanced dynamic balance, multi-joint coordination, and movement symmetry, underscoring the tool's value not only for diagnosis but also for ongoing performance monitoring and adaptive program design in swimming (Bieniec and Grabara, 2024).

Principles of Sport Training

Functional sport training programs emphasized restoring movement quality prior to increasing load or skill complexity, integrating FMS diagnostics to identify deficits in joint mobility, postural control, and neuromuscular coordination, which guided corrective exercises that improved stroke mechanics, efficiency, and injury resilience in athletes (Chen, 2014). Empirical studies demonstrated that interventions aligned with sport-specific biomechanics, progressive load modulation, and proprioceptive training enhanced dynamic balance, core engagement, and movement symmetry, leading to measurable performance gains while minimizing compensatory patterns and overuse injuries (Feng, 2025). Longitudinal approaches combining variability, specificity, and repeated FMS-based assessments ensured training content adapted to each athlete's functional state, reinforcing skill transfer to technical tasks and competitive outcomes, highlighting that elite performance depends on

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integrated movement efficiency rather than isolated strength or volume metrics (Ge and Zhang, 2023).

Sport Training Program Development

FMS-based sport training programs demonstrated that integrating movement diagnostics with traditional conditioning improved neuromuscular control, posture, and stroke mechanics in university swimmers, ensuring that functional deficits such as poor core-limb activation, asymmetry, or limited thoracic extension were corrected before volume or intensity escalation, which enhanced stroke efficiency and injury resilience (Yang and Zhang, 2022). Empirical interventions showed that cycling through assessment, targeted corrective exercises, and reintegration into dryland and aquatic sets led to measurable gains in glide distance, stroke symmetry, and breathing rhythm, demonstrating that functional mastery underpins performance improvements more than raw volume or strength alone (Zhan, Xiaoyu, 2023). Studies on swimmer-specific functional movement assessment indicate that corrective training programs guided by FMS results can improve movement quality and biomechanical efficiency, which may positively influence swimming performance and technical consistency during competition (Fitton Davies et al., 2022; Lucas et al., 2021).

Summary

University swimming programs that prioritized functional movement quality before training volume integrated screening, corrective exercises, strength and mobility work, and aquatic technique to enhance stroke mechanics, propulsion, and efficiency, ensuring that deficits in core-limb activation, asymmetry, shoulder mobility, rotary stability, and trunk control were addressed before increasing load or intensity, which led to measurable improvements in stroke length, glide distance, symmetry, and breathing rhythm, while reducing fatigue-induced breakdowns and injury risk, demonstrating that structured functional diagnostics combined with targeted interventions consistently translated into more efficient and resilient swimming performance under varied competitive conditions.

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Conceptual Framework

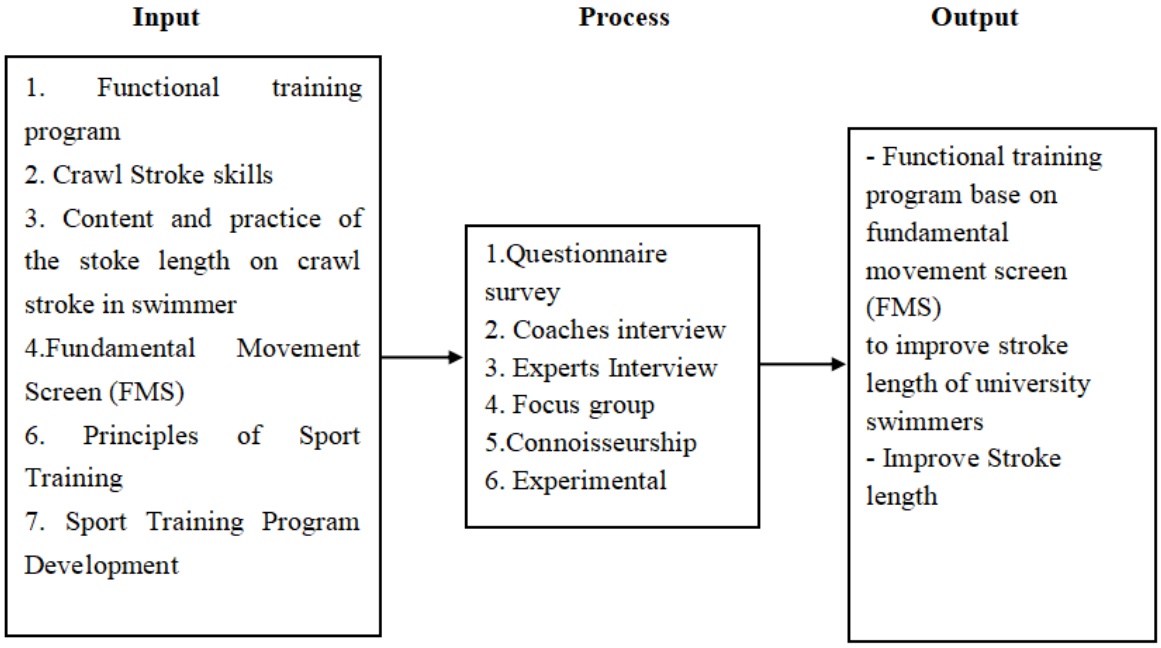


Figure 1 Conceptual Framework

Methodology

Research Tools

1. Questionnaire for students
2. Coaches interview questionnaire
3. Expert interview questionnaire
4. Focus group outline
5. Connoisseurship outline
6. Functional Training Program
7. Fundamental Movement Screen (FMS) Test
8. Stroke length test

Population and Sample

1. Population

This study involved male university swimmers and swimming coaches from Henan Province, China. A total of 200 questionnaires were distributed to swimmers from four universities, and 197 valid responses were collected, giving a response rate of 98.5%. The swimmers, aged 17–22 years, all possessed basic crawl stroke skills and had received systematic swimming training. In addition, 9 swimming coaches from Henan Normal University were interviewed to investigate the current situation and problems related to university swimming training methods.

2. Sample

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Twenty-four male university swimmers were selected from the collegiate swim teams of Henan Normal University, whose recent performances in short-distance crawl events indicated a need for physical conditioning and technical improvement.

Data Collection

Data were collected using structured electronic questionnaires for male university swimmers to assess training habits, physical limitations, and FMS awareness; semi-structured expert interviews and focus groups to evaluate key physical attributes and the feasibility of the training program; connoisseurship reviews for scientific validity and effectiveness; a preliminary small group trial to test clarity and practicality; and an eight-week randomized controlled experiment assigning 24 swimmers to functional or traditional training groups with pre-, mid-, and post-tests measuring FMS scores, stroke counts, and 50-meter crawl performance to assess improvements in stroke length and overall performance.

Data Analysis

1. Questionnaire survey method analysis using descriptive statistics ($\bar{x}$, S.D.).

The criteria for the 5-level evaluation scale are as follows:

- An average score of 4.51 to 5.00 indicates the highest
- An average score of 3.51 to 4.50 indicates a High
- An average score of 2.51 to 3.50 indicates a Medium
- An average score of 1.51 to 2.50 indicates a Low
- An average score of 1.00 to 1.50 indicates a Low

2. Coaches' interviews, expert interviews, focus groups, and connoisseurship method data analysis using content analysis.

3. Experimental data analysis: An independent-samples t-test was used for data comparison between groups. The comparison within groups used a dependent-samples t-test. Repeated measures ANOVA was used for within-group comparisons and post hoc (Bonferroni).

Results

The research findings are organized into three main sections as follows:

Part 1: To study the problem and current situation of the swimming training method for university swimmers

The study investigated the current issues in university swimming training through questionnaires with 197 male swimmers and interviews with nine coaches, revealing that swimmers recognized the importance of Functional Movement Screen (FMS) in evaluating movement quality, identifying physical limitations, and guiding personalized training plans to enhance stroke technique, core stability, shoulder and hip flexibility, neuromuscular control, and endurance, while coaches emphasized that current programs often lack individualized

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planning, balanced strength and conditioning, flexibility work, and proper recovery, which limits performance and increases fatigue, highlighting stroke length and efficiency as key concerns; expert interviews further supported using FMS data to design functional training programs targeting core stability, shoulder mobility, and movement symmetry, balancing flexibility and strength through exercises such as planks, stability ball work, resistance bands, and dynamic movements, ensuring that swimmers develop functional strength, improve mobility, optimize stroke mechanics, and prevent injuries, with program adjustments guided by ongoing FMS assessments and performance monitoring.

Part 2: To draft the functional training program based on the fundamental movement screen (FMS) to improve stroke length in university crawl stroke swimmers at the university

Interviews with eight experts indicated that university crawl stroke swimmers benefit from an FMS-based 8-week functional training program designed to enhance stroke length, incorporating progressive speed endurance, aerobic and anaerobic capacity, core stability, shoulder flexibility, and lower-body strength, while emphasizing gradual load progression to prevent fatigue and optimize fundamentals. Experts highlighted the importance of personalized corrective exercises, technique refinement, biomechanical feedback, and mental preparation to improve stroke mechanics, efficiency, and performance consistency.

Focus Group Results: Discussions with nine specialists reinforced the need for structured, phased training integrating FMS assessments, dynamic reassessment, corrective exercises, stroke-length monitoring, strength and power training, technical drills, and recovery protocols, ensuring individualized plans, continuous evaluation, and alignment with academic schedules, competitive preparation, and energy system demands to maximize stroke length improvement, reduce injury risk, and enhance overall swimming performance.

Table 1 Training Plan Draft for Weeks 1-8

Phase	Component	Training Activities
Foundation Phase (Week 1)	Flexibility & Stability	Squat (3×10 reps): Focus on lower body flexibility and stability. Straight Leg Raise (3×12 reps per leg): Improve hamstring flexibility for better flutter kick. Shoulder Mobility Drills (3×15 reps): Dynamic stretches targeting shoulder flexibility for better stroke.
Foundation Phase	Core & Balance	Core Stability Exercises (Planks, Russian

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Phase	Component	Training Activities
(Week 2)		Twists, 3×1 min): Improve core strength and stability for stroke efficiency. Single Leg Stance (3×30 sec per leg): Focus on lower body coordination and balance for stroke fluidity.
Foundation Phase (Week 3)	Flexibility & Strength	Deep Squats (3×10 reps): Focus on strengthening the legs and improving movement coordination. Straight Leg Raise (3×12 reps): Maintain hamstring flexibility and improve kick efficiency. Shoulder Mobility (3×15 reps): Increase shoulder flexibility for a more efficient pull phase.
Foundation Phase (Week 4)	Core Strength & Stability	Planks (3×1 min): Strengthen core to enhance overall stroke mechanics. Russian Twists (3×15 reps): Focus on rotational core strength for a stronger pull and improved posture.
Foundation Phase (Weeks 5-6)	Stroke Technique	Technique Drills: 50m focus on improving stroke form, posture, and breathing techniques. Core Engagement (3×30 sec): Maintain core stability while swimming to reduce drag and improve efficiency.
Performance Phase (Weeks 5-6)	Strength & Stability	Single Leg Squats (3×12 reps per leg): Improve leg strength for better push-off and stability during strokes. Core Stability (3×1 min): Engage core muscles to maintain swimming posture and streamline stroke length.
Performance Phase (Week 7)	Power & Stroke Efficiency	Deadlifts (3×8 reps at 75-80% 1RM): Build overall strength for powerful strokes and better propulsion. Shoulder Mobility Drills (3×15 reps): Maintain shoulder flexibility to enhance

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Phase	Component	Training Activities
		stroke efficiency.
Performance Phase (Week 8)	Final Technique & Review	Full Stroke Sets (50m×5 sets): Perform with optimal technique, focusing on fluidity and coordination. Video Analysis (5-minute review): Review stroke form with biomechanical feedback for final adjustments.

Part 3: To experiment on the application of a functional training program based on the fundamental movement screen (FMS) to improve stroke length in crawl stroke swimmers at a university

Table 2 Basic Information of Subjects in Experimental and Control Groups

Variables	Experimental group	Control group
	$\bar{x}$±SD	$\bar{x}$±SD
Age (year)	20.23±1.13	19.92±1.23
Height (cm)	177.72±3.14	177.30±3.45
Weight (kg)	70.95±4.73	69.24±5.37
BMI	22.47±2.17	22.03±2.66

*p<0.05 indicates a significant difference

The data in Table 2 show the basic information of the experimental and control groups, including age, height, weight, and BMI. The experimental group has an average age of 20.23 years, while the control group has a slightly younger average age of 19.92 years. The heights of the two groups are similar, with the experimental group averaging 177.72 cm and the control group at 177.30 cm. Similarly, the weight of the experimental group is slightly higher (70.95 kg) compared to the control group (69.24 kg). Both groups have similar BMI values, with the experimental group at 22.47 and the control group at 22.03.

Table 3 Comparison results of stroke length (m/stroke) between Experimental and Control Groups at pre-test using an independent-samples t-test.

Variables	Experimental group	Control group	t	p
	$\bar{x}$±SD	$\bar{x}$±SD		
Single arm (left)	1.53 ± 0.22	1.55 ± 0.21	0.24	0.782
Single arm (right)	1.55 ± 0.19	1.56 ± 0.20	0.21	0.889
Bilateral arm stroke	2.88 ± 0.31	2.86 ± 0.33	0.19	0.897

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Variables	Experimental group $\bar{x}$±SD	Control group $\bar{x}$±SD	t	p
Swimming count	23.18 ± 1.20	23.19± 1.21	0.18	0.905

*p>0.05 represents no significant difference

Table 3 found that there were no significant differences between the experimental and control groups at the pre-test for stroke length in any of the variables. The t-values for single arm (left), single arm (right), bilateral arm stroke, and swimming count were all low, with p-values exceeding 0.05 (p = 0.782, p = 0.889, p = 0.897, and p = 0.905, respectively). The $\bar{x}$ scores of the experimental and control groups were very similar in single arm (left) (1.53 ± 0.22 vs 1.55 ± 0.21), single arm (right) (1.55 ± 0.19 vs 1.56 ± 0.20), bilateral arm stroke (2.88 ± 0.31 vs 2.86 ± 0.33), and swimming count (23.18 ± 1.20 vs 23.19 ± 1.21), indicating that both groups had comparable baseline performance before the intervention.

Table 4 Comparison results of stroke length (m/stroke) between the Experimental and Control Groups at post-test using an independent-samples t-test.

Variables	Experimental group $\bar{x}$±SD	Control group $\bar{x}$±SD	t	p
Single arm (left)	2.01 ± 0.13	1.56 ± 0.23	3.46	0.01*
Single arm (right)	2.03 ± 0.14	1.58 ± 0.22	3.61	0.01*
Bilateral arm stroke	3.92 ± 0.25	2.88 ± 0.34	3.84	0.01*
Swimming count	17.26 ± 1.35	23.14± 1.19	3.54	0.01*

*p<0.05 represents a significant difference

Table 4 presents the comparison results of stroke length between the Experimental and Control groups at post-test, using independent-samples t-tests. The results show significant improvements in stroke length for the Experimental group in all measured variables, including single arm (left), single arm (right), bilateral arm stroke, and swimming count. For example, the Experimental group achieved a higher stroke length in the single arm (left) (2.01 ± 0.13) compared to the Control group (1.56 ± 0.23), with a t-value of 3.46 and a p-value of 0.01, indicating a statistically significant difference. Similarly, the Experimental group outperformed the Control group in single arm (right) (2.03 ± 0.14 vs 1.58 ± 0.22), bilateral arm stroke (3.92 ± 0.25 vs 2.88 ± 0.34), and swimming count (17.26 ± 1.35 vs 23.14 ± 1.19), with all p-values less than 0.05, confirming the effectiveness of the intervention.

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Table 5 Comparison results of stroke length (Left arm) within Experimental Groups at Pre-Test, Mid-Test, and Post-Test using Repeated Measures ANOVA

variable	Source of variance	Sum of squares	df	MS	F	p
Stroke length (Left arm)	Between group	196.31	2	198.14	18.72	0.01*
	Within group	245.26	43	6.87		
	Total	441.57	45			

*p< 0.05 represents a significant difference

Table 5 found that there was a significant difference in the stroke length (left arm) within the experimental group across the pre-test, mid-test, and post-test, as indicated by the repeated measures ANOVA. The F-value was 18.72 with a p-value of 0.01, which is less than 0.05, demonstrating a statistically significant change in stroke length over time. The sum of squares between groups was 196.31, suggesting a substantial difference in performance between the different testing phases.

Table 6 Comparison of stroke length (Left arm) within Experimental Groups at Pre-Test, Mid-Test, and Post-Test using the Bonferroni Test

Variables	Test	Pre-test	Mid-test	Post-test
Stroke length (Left arm)	Pre-test	-	4.20*	9.30*
	Mid-test	-	-	5.10*
	Post-test	-	-	-

*p< 0.05 represents a significant difference

Table 6 found that there were significant differences in stroke length (left arm) within the experimental group across the pre-test, mid-test, and post-test, as indicated by the Bonferroni test. The results showed that the stroke length improved significantly from the pre-test to both the mid-test (p = 4.20) and post-test (p = 9.30), as well as from the mid-test to the post-test (p = 5.10). These findings suggest that the functional training program had a substantial positive effect on the stroke length for the left arm over the course of the study.

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Table 7 Comparison results of stroke length (Right arm) within Experimental Groups at Pre-Test, Mid-Test, and Post-Test using Repeated Measures ANOVA

variable	Source of variance	Sum of squares	df	MS	F	p
Stroke length (Right arm)	Between group	212.45	2	106.225	21.79	0.000*
	Within group	321.78	66	4.875		
	Total	534.23	68			

*p< 0.05 represents a significant difference

Table 7 found that there was a significant difference in stroke length (right arm) between the experimental and control groups at the pre-test, mid-test, and post-test, as indicated by the repeated measures ANOVA. The F-value was 21.79 with a p-value of 0.000, which is less than 0.05, indicating a significant difference in stroke length over time. The sum of squares between groups was 212.45, showing a notable difference in performance between the phases.

Table 8 Comparison of stroke length (Right arm) within Experimental Groups at Pre-Test, Mid-Test, and Post-Test using the Bonferroni Test

Variables	Test	Pre-test	Mid-test	Post-test
Stroke length (Right arm)	Pre-test	-	0.023*	0.041*
	Mid-test	-	-	0.018*
	Post-test	-	-	-

*p< 0.05 represents a significant difference

Table 8 found that the Bonferroni test showed significant improvements in stroke length (right arm) within the experimental group from the pre-test to the mid-test (p = 0.023) and from the pre-test to the post-test (p = 0.041). Further, there was a significant difference between the mid-test and post-test (p = 0.018). These results suggest that the functional training program led to significant improvements in the stroke length of the right arm, with the most pronounced changes observed between the pre-test and post-test.

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Table 9 Comparison results of stroke length (Bilateral arm) within Experimental Groups at Pre-Test, Mid-Test, and Post-Test using Repeated Measures ANOVA

variable	Source of variance	Sum of squares	df	MS	F	p
Stroke length (Bilateral arm)	Between group	56.38	2	28.190	21.28	0.000*
	Within group	87.45	66	1.325		
	Total	143.83	68			

*p< 0.05 represents a significant difference

Table 9 found that there were significant differences in stroke length (bilateral arm) within the experimental group across the pre-test, mid-test, and post-test, as indicated by the repeated measures ANOVA. The F-value was 21.28 with a p-value of 0.000, which is less than 0.05, showing significant improvements over time. The sum of squares between groups was 56.38, indicating a meaningful difference in stroke length across the test phases.

Table 10 Comparison of stroke length (Bilateral arm) within Experimental Groups at Pre-Test, Mid-Test, and Post-Test using the Bonferroni Test

Variables	Test	Pre-test	Mid-test	Post-test
Stroke length (Bilateral arm)	Pre-test	-	0.031*	0.055*
	Mid-test	-	-	0.024*
	Post-test	-	-	-

*p< 0.05 represents a significant difference

Table 10 found that there were significant differences in stroke length (bilateral arm) within the experimental group across the pre-test, mid-test, and post-test, as indicated by the Bonferroni test. The results showed that stroke length improved significantly from the pre-test to the mid-test (p = 0.031) and from the pre-test to the post-test (p = 0.055). There was also a significant difference between the mid-test and post-test (p = 0.024).

Table 11 Comparison results of Stroke Count (50-meter Stroke Rate) within Experimental Groups at Pre-Test, Mid-Test, and Post-Test using Repeated Measures ANOVA

variable	Source of variance	Sum of squares	df	MS	F	p
Stroke Count (50-meter Stroke Rate)	Between group	103.80	2	51.40	12.345	0.01*

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variable	Source of variance	Sum of squares	df	MS	F	p
	Within group	116.60	28	4.164		
	Total	221.40	30			

*p< 0.05 represents a significant difference

Table 11 found that there was a significant difference in stroke count (50-meter Stroke Rate) between the experimental and control groups across the pre-test, mid-test, and post-test, as indicated by the repeated measures ANOVA. The F-value was 12.345, with a p-value of 0.01, which is less than 0.05, indicating significant changes in stroke count over time. The sum of squares between groups was 103.80, showing a considerable difference in performance between the groups.

Table 12 Comparison of stroke length and stroke count (50-meter Stroke Rate) within Experimental Groups at Pre-Test, Mid-Test, and Post-Test using the Bonferroni Test

Variables	Test	Pre-test	Mid-test	Post-test
Stroke Count (50-meter Stroke Rate)	Pre-test	-	2.80*	5.30*
	Mid-test	-	-	2.50*
	Post-test	-	-	-

*p< 0.05 represents a significant difference

Table 12 found that the Bonferroni test showed significant improvements in stroke count (50-meter Stroke Rate) within the experimental group from the pre-test to the mid-test (p = 2.80) and from the pre-test to the post-test (p = 5.30). There was also a significant difference between the mid-test and post-test (p = 2.50). These results suggest that the functional training program led to significant improvements in stroke count, with the most substantial changes observed between the pre-test and post-test.

Discussion

The pre-test results indicated no significant differences between the experimental and control groups regarding age, height, weight, BMI, 50-meter freestyle performance, and stroke count, confirming comparable baseline characteristics and ensuring the validity of subsequent comparisons. After eight weeks of FMS-based functional training, the experimental group demonstrated significant improvements in 50-meter freestyle performance and reduced stroke count, with repeated measures analysis confirming progressive gains over time. These findings align with Fitton Davies (2022), who emphasized

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prioritizing movement quality over training volume and using FMS as the diagnostic core of program design, and Lucas et al. (2021), who reported that swimmers with higher FMS scores and better movement patterns exhibit stronger competitive outcomes, supporting the targeted correction of movement limitations to enhance stroke length and efficiency.

The program's effectiveness is derived from integrating FMS assessments, expert-validated corrective exercises, and targeted training of shoulder mobility, core stability, and rotary stability. Chen (2014) highlighted customizing training based on FMS screening to address asymmetries in strength, balance, and joint range, while Gunay et al. (2017) reported that certain components of functional movement, including trunk stability and movement quality, were associated with swimming performance, highlighting the potential role of functional movement assessment in swimmer development. The eight-week intervention confirmed Sawczyn (2020), showing that foundational movement qualities are trainable within academic schedules, improving stroke efficiency without additional energetic cost, indicating that movement-quality-focused training is both physiologically effective and pedagogically sustainable for university swim programs.

Recommendations

Application of the research

1. Implement FMS-based functional training programs in university swim teams to enhance stroke length, efficiency, and athlete performance consistency.

2. Incorporate dynamic assessments, personalized corrective exercises, and technical drills to optimize shoulder mobility, core stability, and movement symmetry.

3. Monitor training loads and recovery protocols regularly, integrating video feedback and biomechanical evaluation to prevent injuries and maximize skill transfer.

For further research

1. Investigate long-term effects of FMS-based interventions on competitive performance and endurance in collegiate crawl stroke swimmers across multiple universities.

2. Explore adaptive programming integrating aerobic and anaerobic conditioning with functional movement assessments to further enhance stroke mechanics and propulsion efficiency.

3. Examine the influence of individualized corrective strategies on fatigue resistance, neuromuscular control, and technique retention under variable training volumes and competition stress.

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