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Effect of Upper Body Strength Training on Artistic Swimming Performance and Basic Kinematic Characteristics

Fatma Hussien Ali Omar
Lecturer - Applications and Theories of Aquatic Sports Department, Faculty of Sports Science for Girls - Helwan University, Egypt.
fatma.hussien@pef.helwan.edu.eg

Abstract

Artistic swimming is unique among aquatic sports, requiring a variety of athletic abilities such as strength, endurance, flexibility, agility, and acrobatics, along with a sense of rhythm and team spirit. Upper body Strength training, for artistic swimmers enhances the ability to sustain sculling over extended periods, a critical factor in maintaining vertical positions and executing complex figures. Without adequate strength, swimmers may struggle to maintain consistent hand velocities and angles, resulting in reduced propulsion and potential misalignments. Furthermore, stronger shoulders and arms minimize fatigue during repetitive sculling motions, ensuring the swimmer can perform with precision throughout a routine. **The aim of study**: to examine the Effect of upper Body Strength Training on Artistic Swimming Performance and Basic Kinematic Characteristics. **Methodology**: 10 female athletes subject's aged 13 years, height 142.08cm, Weight 37.38Kg were randomly and equally assigned into two groups: the control group (CG) and the experimental group (EG). All participants were competitive swimmers familiar with artistic swimming practice. The CG followed a traditional training program volume and the program for the EG include a combination of resistance training by using Swiss ball, Medicine ball and Bumb bells. The program focusses on key muscle groups to developing upper body strength, with particular emphasis on the shoulders, back, arms, and core for 6 weeks 4 days per week. **The results** of this study indicate significant improvements for the experimental group (EG) showed substantial improvements in physical performance, artistic swimming performance, and kinematic characteristics compared to the control group (CG), highlighting the effectiveness of targeted dry-land strength exercises.

Keywords: Strength training, Artistic Swimming, Kinematic Characteristics.

ملخص البحث باللغة العربية

تُعدّ السباحة الفنية رياضة مائية فريدة من نوعها، حيث تتطلب مستوي عال من القدرات الرياضية مثل القوة، التحمل، المرونة، الرشاقة، التوافق والتوازن، بالإضافة إلى الإحساس بالإيقاع والعمل الجماعي. يعزيز تدريب قوة عضلات الجزء العلوي من الجسم الي قدرة اللاعبات للحفاظ على حركات السجم لفترات طويلة، وهو عامل أساسي في الحفاظ على اوضاع الجسم المختلفة اثناء الاداء الفني للحركات في السباحة الفنية. وبدون القوة الكافية، قد يواجه اللاعبات صعوبة في الحفاظ على حركة الذراعين وزواياها بشكل ثابت، مما يؤدي إلى تقليل الدفع المائي واحتمال حدوث اختلالات للجسم اثناء الاداء. علاوة على ذلك، فإن تقوية عضلات الكتفين والذراعين تقلل من الإجهاد أثناء الحركات المتكررة للذراعين، مما يضمن قدرة السباح على الأداء بدقة طوال الروتين الفني وذلك لطبيعة الأداء الفني بتلك الرياضة الذي يتطلب تحقيق الكمال التقنى للمهارات الفنية في إطار منسق وجميل. **يهدف البحث**، التعرف علي تدريب قوة عضلات الجزء العلوي من الجسم علي اداء السباحة الفنية والخصائص الحركية الاساسية. **استخدمت الباحثة المنهج التجريبي** نظراً لملائمة لطبيعة البحث وذلك لمجموعتين: مجموعة تجريبية (EG) واخري ضابط (CG). أشتملت **عينة البحث** على لاعبات السباحه الفنية والبالغ قوامهم (١٠) لاعبات، واللاتي يتراوح أعمارهن ١٣ سنة، تراوحت مدة البرنامج الي ستة أسابيع . اتبعت المجموعة الضابطة البرنامج التقليدي بالتدريب، بينما اشتمل برنامج المجموعة التجريبية على مزيج من تدريبات المقاومة باستخدام الكرة السويسرية، الكرة الطبية، وأثقال الدمبل. ركز البرنامج على تطوير القوة العضلية في مجموعات العضلات الرئيسية، مع التركيز بشكل خاص على الكتفين والظهر والذراعين والجزء العلوي من الجسم. **وكانت اهم النتائج** وجود فروق دالة إحصائياً بين القياس البعدى للمجموعتين التجريبية والضابطة فى الاختبارات البدنية، مستوي الاداء الفني والخصائص الحركية لمهارات قيد البحث لصالح المجموعة التجريبية حيث جاءت قيمة "ت" المحسوبة أعلى من قيمة "ت" الجدولية.

مصطلحات البحث : تدريب القوة ، السباحة الفنية، الخصائص الحركية.

Effect of Upper Body Strength Training on Artistic Swimming Performance and Basic Kinematic Characteristics

Introduction

Artistic swimming (AS) is unique among aquatic sports, requiring a variety of athletic abilities such as strength, endurance, flexibility, agility, and acrobatics, along with a sense of rhythm and team spirit. (Dzimbova & Markov, 2023).

Strength training (ST) is a milestone of athletic performance, its improving muscular strength and endurance to optimizing biomechanical efficiency and injury prevention. (Bellver et al., 2021). Moreover, it improves force of sculling techniques, lifts, throws, and transitions, enabling more precise and powerful routines. These elements demand strength to maintain alignment, stability, and fluid transitions both above and below water. (Mujika et al., 2019).

Upper body ST, for artistic swimmers enhances the ability to sustain sculling over extended periods, a critical factor in maintaining vertical positions and executing complex figures. Without adequate strength, swimmers may struggle to maintain consistent hand velocities and angles, resulting in reduced propulsion and potential misalignments. Furthermore, stronger shoulders and arms minimize fatigue during repetitive sculling motions, ensuring the swimmer can perform with precision throughout a routine.(Homma et al., 2023).

Strength directly influences these attributes by enabling swimmers to maintain vertical alignment, execute rapid transitions, and control their movements against water resistance. For instance, core and upper body strength are essential for supporting sculling motions.(Ponciano et al., 2023).

Measuring kinematic characteristics in artistic swimming is crucial for optimizing performance, improving technique, and evaluating athletes' efficiency in executing routines. Kinematic analysis provides detailed insights into body alignment, angular velocity, and the coordination of movements, which are key for achieving high scores in artistic swimming competitions. By assessing parameters such as leg angle, sculling efficiency, and body alignment, coaches can identify technical flaws and develop targeted training interventions to enhance performance(Edriss et al., 2024).

Additionally, it helps in assessing the effectiveness of strength programs by correlating improvements in movement patterns with physical training

outcomes. This allows for a data-driven approach to enhancing propulsion, stability, and overall artistic execution, ultimately ensuring athletes meet the rigorous demands of the sport. (Fantozzi et al., 2016).

Through research observations and follow-up as a national judge in the Egyptian Swimming Federation, swimmers face several challenges related to the strength during competitions, primarily due to the sport's complex technical and physical demands. These challenges include maintaining core stability and upper body endurance for prolonged routines, executing precise sculling movements, and achieving explosive power for lifts and acrobatic elements. (Yue et al., 2023). Strength and core stability is crucial for maintaining alignment during vertical positions and complex hybrid figures, while weak strength and core muscles can lead to deviations and deductions in scoring. Additionally, upper body and shoulder strength are essential for sculling, which generates propulsion and stability. Fatigue in these muscles can cause inefficiency and reduced control during routines. (Homma et al., 2023). Insufficient strength, especially in the upper body can lead to performance inconsistencies, alignment deviations, and scoring penalties in "Execution" and "Difficulty" judging panels.

Aim of the study

This study aimed to examine the Effect of upper Body Strength Training on Artistic Swimming Performance and Basic Kinematic Characteristics.

Materials and Methods Participants

The study included ten female athletes of AS, participated in the current study. They were randomly and equally assigned into two groups: the control group (CG) and the experimental group (EG). All participants were competitive swimmers familiar with artistic swimming practice and the experimental assessments used.

The selection criteria were as follows: participants were required to be within an average age of approximately 13 years at the time of the study. They were in the national level, indicating a good level of proficiency and competitive experience in the sport. The initial approval for the participation of the athletes was given by the head coach, the team manager of each club, and the athletes' parents.

Table 1. Descriptive statistics for subject's characteristics in Age, Height and Weight

(N= 10)

Variables	Mean	Minimum	Maximum	Std. Deviation
Age (years)	13.24	13.00	13.60	.667
Height (cm)	142.08	132.00	165.00	1.186
Weight (kg)	37.38	30.10	50.00	1.048

Table 1. shows the descriptive statistics for subject's characteristics in Age, Height and Weight.

Table 2. Descriptive statistics for Dry-Land Performance, Artistic Swimming Elements, and Kinematic Characteristics

(N= 10)

Variables	Measuring Unit	Minimum	Maximum	Mean	Std. Deviation	Skewness
push-ups	Reps	6	10	8.1	1.37	0.104
Hanging Leg raise to 90°	Reps	4	8	5.7	1.252	0.28
Barracuda	Degree	3.5	5.5	4.97	0.343	0.544
Kip	Degree	4.25	4.75	4.52	0.219	-0.223
Barracuda Height	Degree	4.5	5.5	5.0	0.53	0.00
Kip Height	Degree	4.5	5.5	4.9	0.52	0.41
Barracuda Deviation	Angle	6.5	15.1	12.3	3.25	-1.013
Kip Deviation	Angle	9.6	23,1	14.47	4.181	0.980

Table 2. shows the descriptive statistics for dry-land performance, artistic swimming elements, and kinematic characteristics.

Table 3. The Significance of the Differences Between the EG and CG in Dry-Land Measurements, Artistic Swimming Elements and Kinematic Characteristics

(N1=N2=10)

Variables	Measuring Unit	Pre-measurements EG		Pre—measurements CG		Mean Differences	T
		$\underline{X}$	SD	$\underline{X}$	SD		
push-ups	**Reps.**	8.2	1.30	8.0	1.58	0.2	0.22
Hanging Leg raise to 90°	**Reps.**	5.8	1.48	5.6	1.14	0.2	0.24
Barracuda	**Degree**	4.5	0.25	4.55	0.21	-0.05	-0.34
Kip	**Degree**	5.05	0.33	4.90	9.38	0.15	0.67
Barracuda Deviation	**Angle**	10.96	3.76	13.30	2.47	-2.34	-1.16
Kip Deviation	**Angle**	12.82	3.79	16.12	4.26	-3.3	-1.29

Table 3. shows there are no statistically significant differences at the P<0.05 significance level between the experimental and control groups.

Design and Procedures

Before the tests were administered, both groups were informed about the procedures. To achieve optimal results, participants were evaluated on tasks both in-water (technical elements) and out-of-water (strength). The evaluations were performed in two periods: before the experimental period (M1) and after 6 weeks of combined strength training program (M2). Both groups underwent testing at the same time (Annex 8).

Dry-Land Measurements

Strength Tests

The push-ups test and Hanging Leg raise to 90°, were used to measure upper body (UB) Strength**.** For the push-ups test, Swimmers begins in a high plank position with hands slightly wider than shoulder-width apart and straight line was formed from toes to hips and shoulders. The upper body was brought down and the elbows were bent about 90 degrees and again

the body was lifted up. The swimmers performed the test as much as possible and the examiner counted the number of repetitions.
For the Hanging Leg raise to 90°, Swimmers begins grip the bar with an overhand grip (palms facing away from you) about shoulder-width apart. Arms fully extended and legs straight. Swimmers slowly raise their legs upward 90-degree and keeping them as straight as possible and parallel to the ground. Slowly lower your legs back to the starting position in a controlled manner. Avoid letting them drop or swinging. The swimmers performed the test as much as possible and the examiner counted the number of repetitions.

Examination of Artistic Swimming Elements

This study analyzes two AS elements, Kip and Barracuda by using two cameras for 2D video analysis. The cameras were positioned precisely vertically and placed at the pool's edge, 2 meters distance from the swimmers. One camera was placed 30 cm below the water surface, and the other 25 cm above it, capturing the AS performance laterally. The cameras were positioned on the judge's side to replicate the judges' perspective to achieve the best score. Each participant performed the skills three times, with the best trial selected for analysis. The total score for each trial was calculated based on the score scale outlined(ARTISTIC SWIMMING et al., n.d.). The Kinovea motion analysis program was used to measure the vertical height and body alignment by using the line tool to track the deviation angle at the performance execution peak in both techniques. The deviation is defined as a leg angle that is either more or less than 90°, indicating whether the leg is oriented vertically relative to the horizontal plane (Annex 6 & 7). Additionally, the athletes' performances were evaluated by three official judges, all of whom are qualified to assess Artistic Swimming at both National and International levels.

Barracuda

The starting position, begins in a back layout position, body extended with face, chest, thighs and feet at the surface of the water. Head (ears specifically), hips and ankles in horizontal alignment. Back Pike Position, body bent at hips to form an acute angle of 45° or less. Legs extended together and trunk extended with the back straight and head in line. The toes under the surface, arms are used for sculling to provide stability and propulsion. Thrust Phase, from a Submerged back pike position with the legs perpendicular to the surface of the water a vertical upward movement of the legs and hips is rapidly executed as the body unrolls to assume

a vertical position. The power generated from core strength and leg extension is critical for achieving height. vertical position, the swimmer must align their body in a perfectly straight, vertical position above the water. The head, hips, arms, and ankles should be in one line at the end of the movement. Maximum height is desirable while performing this movement. Maintaining a vertical position the body descends along its longitudinal axis until the toes are submerged.(ARTISTIC SWIMMING et al., n.d.)

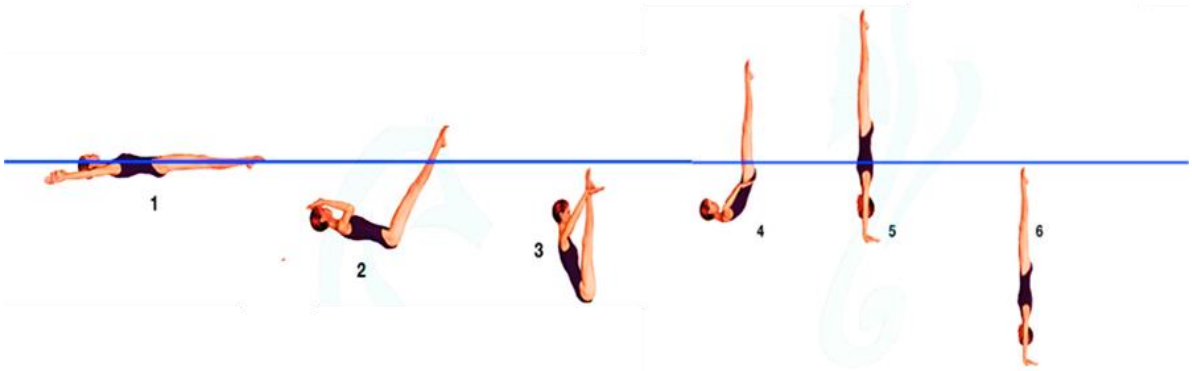

Figure 1. Barracuda Technique

Kip

The preparing position begins in a back layout position, with the body extended and aligned. The arms scull at the hips to provide stability and propulsion. Tuck Position, the body as compact as possible, with the back rounded and the legs together. Heels close to buttocks and head close to knees. Vertical Position, body extended perpendicular to the surface of the water. Head (ears specifically), hips and ankles in line together. Maintaining a Vertical Position the body descends along its longitudinal axis until the toes are submerged. The swimmer descends smoothly, maintaining body alignment.(ARTISTIC SWIMMING et al., n.d.)

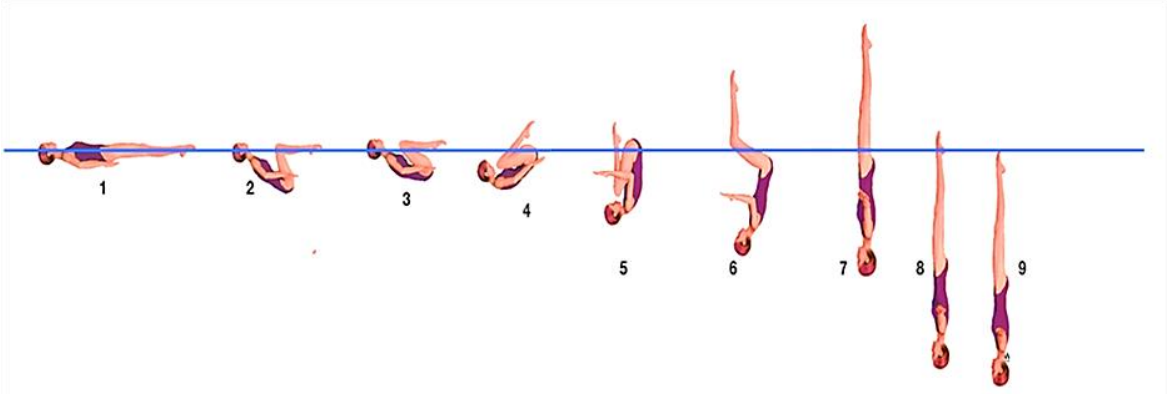

Figure 2. Kip Technique

Strength Training Protocol

The training program was conducted 4 days per week for both groups over a 6 weeks period (24 sessions). The CG followed a traditional training program volume. Prior to the start of the EG training period, the researcher demonstrated and thoroughly explained the proper techniques for all exercises to the artistic swimmers and detailing the volume and intensity of the training (including the number of sets and repetitions, rest intervals, and daily load). The program for the EG include a combination of resistance training by using Swiss ball, Medicine ball and Bumb bells. The program focusses on key muscle groups to developing upper body strength, with particular emphasis on the shoulders, back, arms, and core (Annex 9).

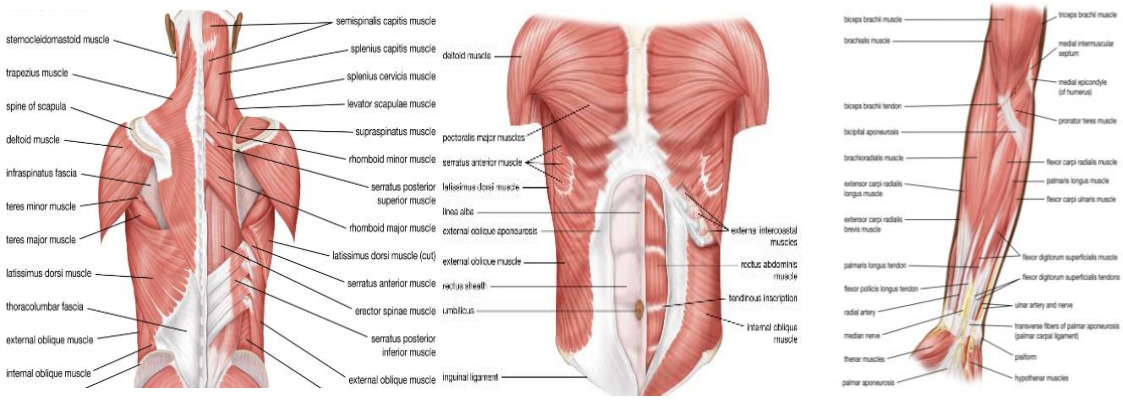

Figure 3. Upper Body Muscle Groups

Strength Training program

The training program was meticulously designed based on an extensive review of related research, references, and insights gathered from experts through a structured questionnaire. This approach ensured the program was tailored to enhance participants' physical abilities and technical performance effectively. The Program, followed a standardized routine. This included 10 minutes warm-up designed to prepare them physically, consisted of submaximal running to gradually increase heart rate and blood circulation, followed by a series of stretching exercises to enhance flexibility. Additionally, a full-body warm-up was performed to engage all major muscle groups.

Main Workout approximately 30 - 40 minutes for the essential part of the training, and 10 minutes cooling down. The exercises were performed with each set lasting 2-3 sets of 10-12 reps with 15-s rest periods between sets. The exercises were gradually increased every week during the weeks of the program (Annex8).

Statistical Analysis

Statistical analyses were performed using the SPSS version 20 in addition the improvement ratios were analyzed. Paired samples T test was used for evaluating and comparing the variables between pre and post-tests, level of significant P<0.05.

Results

Table 4. Mean (±SD), T-Value, P-Value, and Progress Percentage of Dry-Land Performance, Artistic Swimming Elements, and Kinematic Characteristics for the EG

(N=5)

Variables	Measuring Unit	Pre-measurements		Post-measurements		T	P value	Progress %
		$\underline{X}$	SD	$\underline{X}$	SD			
push-ups	Reps.	8.2	1.30	13.8	1.64	22.86	0.00	68.29
Hanging Leg raise to 90°	Reps.	5.8	1.48	11.0	1.58	26.00	0.00	89.66
Barracuda	Degree	4.5	0.25	5.5	0.18	12.65	0.00	22.22
Kip	Degree	5.05	0.33	6.0	0.25	19.00	0.00	18.81
Barracuda Height	Degree	5.1	0.55	6.5	0.71	5.72	.004	27.45
Kip Height	Degree	4.9	0.55	6.1	0.55	6.00	.003	24.49
Barracuda Deviation	Angle	10.96	3.76	4.78	2.47	3.870	0.018	56
Kip Deviation	Angle	12.82	3.79	5.02	2.05	3.72	0.020	61

Table 4. shows that there is a significant difference between the Pre and Post for the experimental group in Dry-Land Performance, Artistic Swimming Elements, and Kinematic Characteristics with a progress percentage from (18.81-89.66%).

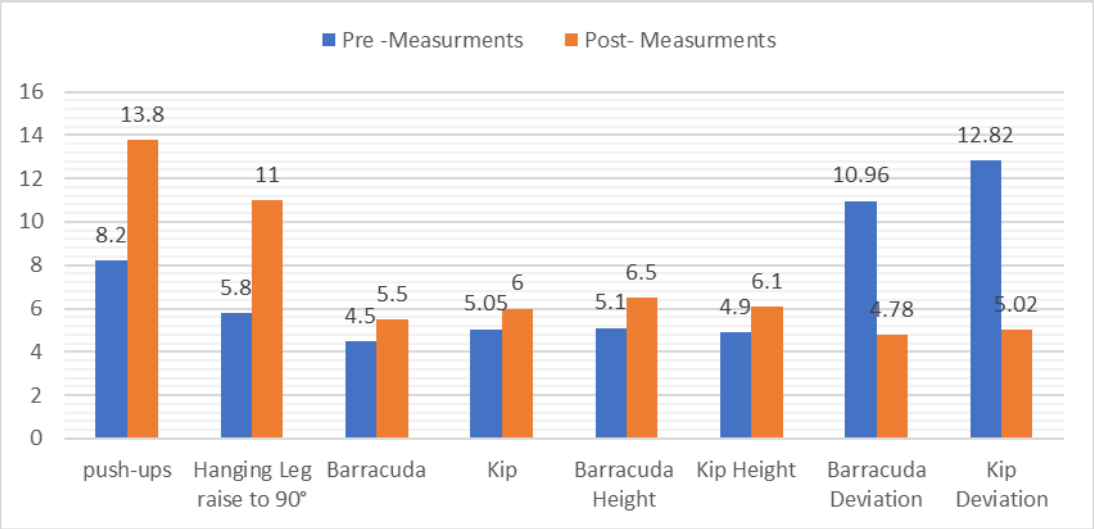

Figure 4. Average Pre- and Post- Measurements for the EG in Dry-Land Measurements, Artistic Swimming Elements and Kinematic Characteristics

Table 5. Mean (±SD), T-Value, P-Value, and Progress Percentage of Dry-Land Performance, Artistic Swimming Elements, and Kinematic Characteristics for the CG

(N=5)

Variables	Measuring Unit	Pre-measurements		Post-measurements		T	P value	Progress %
		$\underline{X}$	SD	$\underline{X}$	SD			
push-ups	**Reps.**	8.0	1.58	9.8	1.79	9.00	.000	22.50
Hanging Leg raise to 90°	**Reps.**	5.6	1.14	7.4	1.14	9.00	.000	32.14
Barracuda	**Degree**	4.55	0.21	4.85	0.14	6.00	.003	6.59
Kip	**Degree**	4.90	0.38	5.10	0.29	4.00	.016	4.08
Barracuda Height	**Degree**	4.9	0.44	5.3	0.44	3.00	.030	8.16
Kip Height	**Degree**	4.9	0.44	5.1	0.44	2.22	.045	4.08
Barracuda Deviation	**Angle**	13.3	2.47	9.7	2.18	8.259	.001	27
Kip Deviation	**Angle**	16.12	4.26	8.7	2.13	2.764	.050	32

Table 5. shows that there is a significant difference between the Pre and Post for the control group in Dry-Land Performance, Artistic Swimming Elements, and Kinematic Characteristics with a progress percentage from (4.08-32.14%).

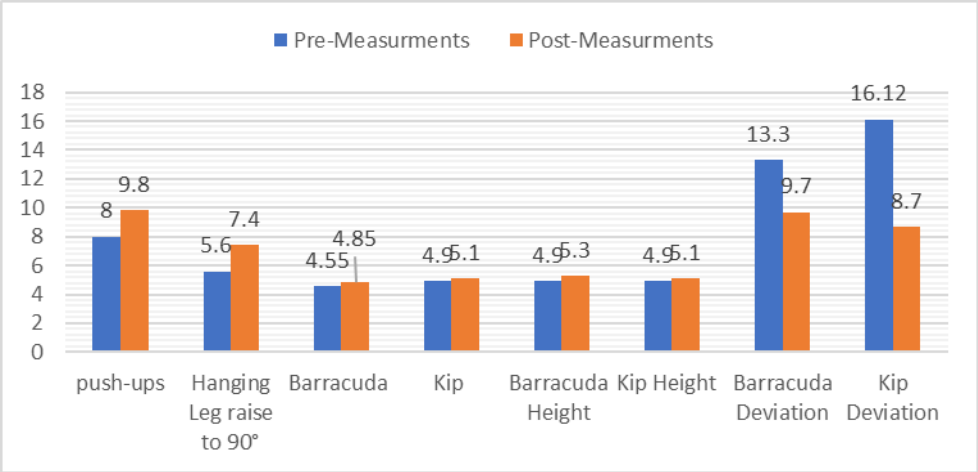

Figure 5. Average Pre- and Post- Measurements for the CG in in Dry-Land Measurements, Artistic Swimming Elements and Kinematic Characteristics

Table 6. Mean (±SD), T-Value, and P-Value for the EG and CG in Post-Measurements of Dry-Land Performance, Artistic Swimming Elements, and Kinematic Characteristics

(N1=N2=5)

Variables	Measuring Unit	Post-measurements (EG)		post-measurements (CG)		T	P value
		$\bar{X}$	SD	$\bar{X}$	SD		
push-ups	Reps.	13.8	1.64	9.8	1.79	7.30	.001
Hanging Leg raise to 90°	Reps.	11.0	1.58	7.4	1.14	4.81	008
Barracuda	Degree	6.0	0.25	5.10	0.29	14.70	.000
Kip	Degree	5.5	0.18	4.85	0.14	6.50	.002
Barracuda Height	Degree	6.3	0.44	5.3	0.44	3.16	.021
Kip Height	Degree	5.1	0.44	6.1	0.44	2.236	.048
Barracuda Deviation	Angle	4.78	2.91	9.7	2.18	8.259	.001
Kip Deviation	Angle	5.02	2.05	8.7	2.25	-2.704	.027

Table 6. shows that there is a significant difference between the Post-Measurements for the EG and CG in Dry-Land Performance, Artistic Swimming Elements, and Kinematic Characteristics.

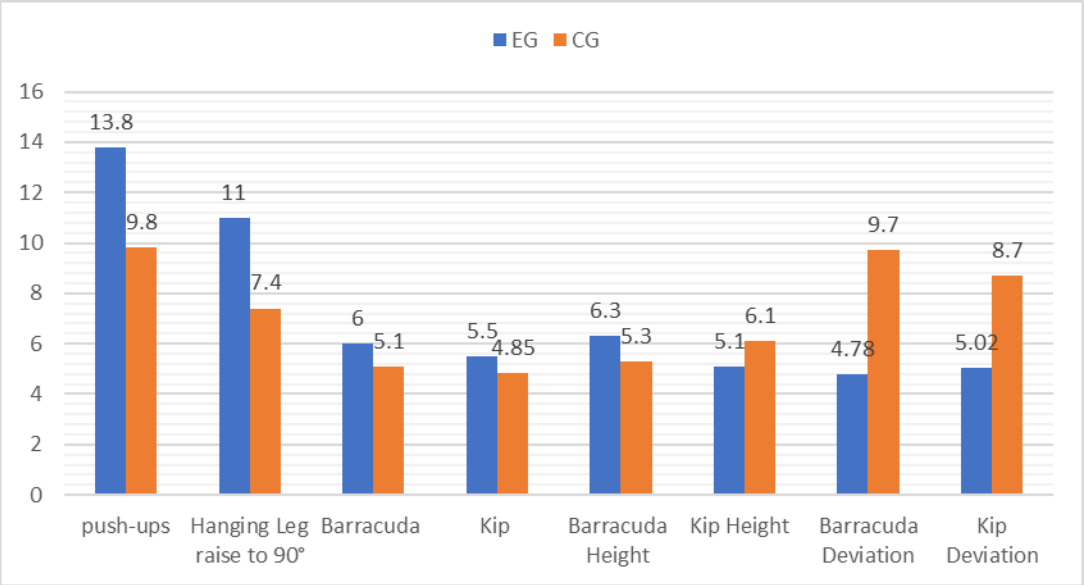

Figure 6. Average Post- Measurements for the EG and CG in Post-Measurements of Dry-Land Performance, Artistic Swimming Elements, and Kinematic Characteristics

Discussion:

The results of this study indicate significant improvements in upper body strength and basic kinematic characteristics across various measures following the targeted program. These findings highlight the effectiveness of focused strength training in enhancing both physical strength and movement mechanics.

As presented in table 4, all variables for the Pre and Post measurements for the experimental group show significant progress with P-values of 0.00, indicating that the improvements are statistically significant. Push-ups improved from 8.2 to 13.8 reps, a 68.29% increase, with a highly significant, Hanging Leg Raises to 90° showed the most improvement, increasing from 5.8 to 11.0 reps (89.66% progress), Barracuda increased from 4.5 to 5.5 (22.22% improvement) and Kip improved from 5.05 to 6.0, a 18.81% increase. Barracuda height, the pre-measurement average is 5.1 and the post-measurement average is 6.5. Similarly, Kip's height shows a smaller increase from 4.9 to 6.1. In terms of deviation, Barracuda's pre-measurement average is 10.96°, while post-measurements show a decrease to 4.78°. Both Barracuda and Kip show positive changes in height and

deviation, but Barracuda demonstrates a more significant improvement in both areas.

As presented in table 5, there is a significant difference between the pre- and post-measurements for the control group. The number of push-ups increased from 8.0 ± 1.58 to 9.8 ± 1.79, reflecting a 22.50% improvement. A significant 32.14% improvement was observed in hanging leg raises to 90°, with repetitions increasing from 5.6 ± 1.14 to 7.4 ± 1.14. The barracuda movement improved from 4.55 ± 0.21 to 4.85 ± 0.14, marking a 6.59% increase. The kip movement showed an increase from 4.90 ± 0.38 to 5.10 ± 0.29, reflecting a 4.08% improvement. For Barracuda height, the pre-measurement average is 4.9, and the post-measurement average increases to 5.3, with an 8.16% progress in height. Kip height shows a smaller increase from 4.9 to 5.1, but with a lower progress percentage of 4.08%. Barracuda's deviation shows a decrease from 13.3 to 9.7°, indicating a substantial improvement of 27%. Kip deviation also shows a decrease from 16.12 to 8.7°, with significant improvement of 32%.

As presented in Table 6, shows that the Experimental Group (EG), which underwent the strength training intervention, made significantly greater improvements in all measurements compared to the Control Group (CG). These results confirm the positive impact of targeted strength training on improving performance in artistic swimming.

For push-ups, the CG improved from an average of 9.8 ± 1.79 reps to 13.8 ± 1.64 reps in the EG, with a T-value of 7.30 and a P-value of 0.001, indicating a significant difference between the groups. The hanging leg raise saw an improvement from 7.4 ± 1.14 reps (CG) to 11.0 ± 1.58 reps (EG), with a T-value of 4.81 and a P-value of 0.008, also showing significant progress in the EG. For artistic swimming elements, the barracuda, the CG achieved 5.10 ± 0.29°, while the EG improved to 6.0 ± 0.25°, with a T-value of 14.70 and a P-value of 0.000, reflecting a highly significant improvement in the EG. For the kip, the CG reached 4.85 ± 0.14°, and the EG improved to 5.5 ± 0.18°, with a T-value of 6.50 and a P-value of 0.002, indicating a significant improvement in the EG. For Barracuda height, the EG shows a post-measurement average of 6.3, while the CG shows average 5.3. Kip height in the EG shows a post-measurement average of 5.1, while the CG has average of 6.1. Barracuda deviation, the EG has a post-measurement average of 4.78°, whereas the CG has an average of 9.7°, indicate a statistically significant improvement in the experimental group, with a substantial difference in deviation between the

groups. Kip deviation in the EG shows average of 5.02° compared to 8.7° in the CG.

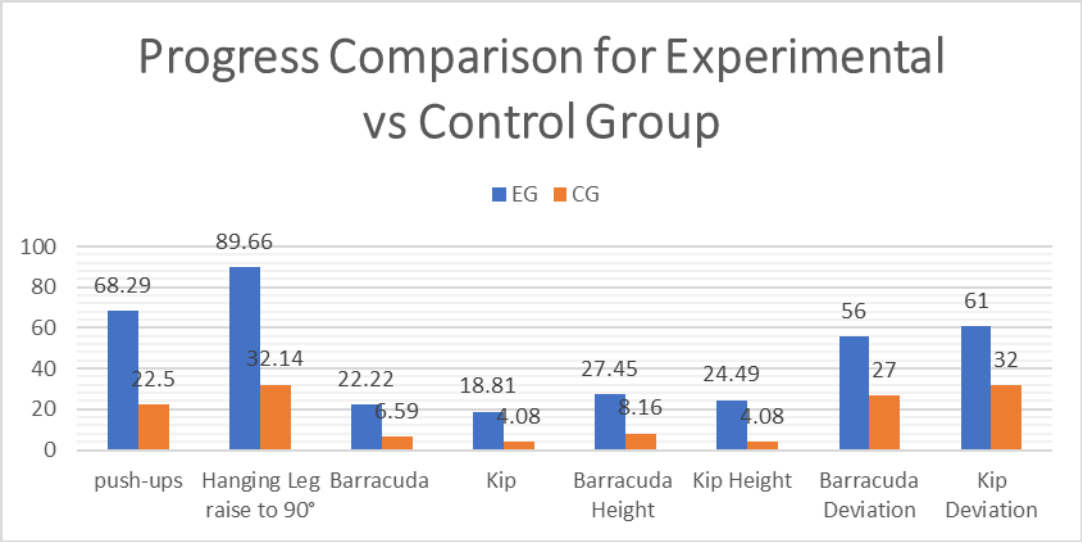

Figure 7. The Progress Comparison for EG and CG in in Post-Measurements of Dry-Land Performance, Artistic Swimming Elements, and Kinematic Characteristics

The (EG) showed significantly greater improvements across all exercises, especially in push-ups (68.29% vs. 22.50%) and hanging leg raises (89.66% vs. 32.14%), highlighting the effectiveness of the strength training intervention.

The (EG) improvement is due to, that the program focused specifically on strengthening the upper body muscles involved in artistic swimming, such as the shoulders, chest, arms, core stability, and back. These muscles play a key role in stabilization, propulsion, and maintaining body control in water. Dry-land training is essential for developing strength, stability, and control in artistic swimming. The program effectively translated strength gains into water performance and overall artistic swimming elements.

The findings of this study align with prior research that has demonstrated the effectiveness of targeted strength training in improving upper body strength and performance in aquatic sports. by (Amara et al., 2021) found that a 9-week concurrent resistance training program led to a 12% increase in upper body strength, resulting in enhanced sprint velocity and stroke rate. Similarly, (Saini et al., 2022) reported significant performance improvements in backstroke swimmers who underwent upper body strength training. These studies support the notion that dry-land strength training is essential for enhancing swimming performance, particularly in artistic swimming, where upper body strength plays a crucial role in stability and

propulsion. (Rodríguez González et al., 2023) further emphasized that incorporating strength training in swim programs enhances force transmission and stroke biomechanics, which is particularly important in synchronized routines requiring precise and controlled movements. These prior findings corroborate our study's results, which highlight significant improvements in push-ups, hanging leg raises, and artistic swimming elements following the strength training program.

At the same time, similarities exist between this study and previous research regarding the impact of strength training on swimming performance. Studies like (Amara et al., 2021) and (Rodríguez González et al., 2023) have consistently highlighted the importance of strength training in improving stroke efficiency and force transmission. The significant improvements in Barracuda and Kip movements observed in our study further promote these findings, demonstrating how targeted upper body strength training contributes to better control, propulsion, and stability in water.

The program improved barracuda movement, which requires a quick and forceful upward thrust out of the water to achieve maximum height while maintaining alignment during vertical descent. A significant portion of this thrust is generated by the arms and shoulders, emphasizing the importance of strong latissimus dorsi, triceps, and deltoids. These muscles play a crucial role in pushing water downward forcefully and enhancing sculling efficiency, both of which are essential for optimal performance in artistic swimming.

Furthermore, the program improved the kip movement. The body should remain straight and aligned without bending at the hips, knees, or ankles, and the legs must remain together, fully extended, with pointed toes throughout the movement. The vertical position should be controlled without losing height during the vertical movement. Additionally, the sculling should generate maximum propulsion while maintaining body alignment.

The improvement in height and deviation observed in the study following the strength training program for the upper body highlights the benefits of such training in enhancing both physical performance and stability. The results show statistically significant increases in height and reductions in deviation for the experimental groups (EG) compared to the control groups (CG). This suggests that upper body strength training can positively influence both the height achieved during movements and the consistency

or stability of those movements. These improvements could lead to better movements and impressive performances.

As for deviation, both Barracuda and Kip demonstrate significant reductions in deviation after the strength training intervention. The decrease in deviation suggests that strength training not only improves the physical capacity for greater height but also helps in stabilizing the movements, leading to more controlled and precise execution. A reduction in deviation is particularly important for artistic swimmers, as it ensures that their movements are graceful and accurate, which is critical for synchronized routines.

The control group (CG) showed improvement, but at a much lower rate. The researcher observed this in relation to the traditional training approach used for the CG, which primarily focused on technique and endurance rather than strength development. Additionally, the CG relied more on in-water training than on dry-land training, which does not provide sufficient resistance to stimulate significant muscle adaptation compared to dry-land strength exercises. Furthermore, the CG trained with their usual workload, which was not challenging enough to induce rapid strength improvements.

This study builds on existing knowledge by providing specific quantitative improvements in artistic swimming movements such as Barracuda and Kip. While previous research has broadly discussed the benefits of strength training in swimming, limited studies have examined its direct impact on artistic swimming elements. By showing significant reductions in deviation and improvements in movement height, this research offers new insights into how targeted upper body strength training translates to enhanced control and stability in the water. Moreover, it highlights the importance of dry-land strength training in artistic swimming, an area that has been less explored in previous studies. These findings suggest that future research could further investigate optimal strength training protocols specific to artistic swimming and explore how different resistance training methodologies impact Artistic swimming performance.

Conclusion:

The study demonstrates that upper body strength training significantly enhances physical performance, artistic swimming performance, and kinematic characteristics. The experimental group (EG) showed substantial improvements in all tests compared to the control group (CG), highlighting the effectiveness of targeted dry-land strength exercises. The EG increased strength in key muscle groups, such as the shoulders, chest, and core, which

directly transferred to better performance in artistic swimming elements like the barracuda and kip, leading to improved height and reduced deviation. These findings emphasize the importance of incorporating strength training into artistic swimming programs to enhance performance, stability, and precision.

Recommendation:

1- Targeted strength training enhances key muscle groups (shoulders, chest, and core), leading to improved height and reduced deviation in movements like the barracuda and kip.
2- Use Progressive Overload with gradually increase resistance and intensity for continuous improvement.
3- Monitor Performance by regular kinematic analysis and video feedback.

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