

Designing a palm pressure measurement device to improve motor coordination in freestyle swimming among female students

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Abstract:

Problem Statement: Despite the critical role of arm movement in freestyle swimming, many learners—specially female students at Baghdad University's College of Physical Education and Sport Sciences— face difficulties executing the pushing phase of the stroke correctly. This phase essential for generating propulsion and maintaining body coordination in water. Traditional teaching methods lack immediate feedback on the quality and force of arm movements, impeding effective motor learning and coordination. **Approach:** the researchers developed a custom-made device designed to measure the pressure force exerted by the palms during freestyle swimming. The device features pressure sensors attached both hands, a processor that analyzes the collected data, and a display unit that presents information on force symmetry. A three-month educational program incorporating the device was implemented with an experimental group, while a control group followed traditional training without the device. **Purpose:** The primary objective was to evaluate the effect of the device on improving motor coordination and balance of pushing force between the arms during freestyle swimming. The study also aimed to assess the effectiveness of the device in skill development and technical refinement among female students. **Results:** Statistical analysis revealed significant improvements in the experimental group compared to the control group. The mean distance achieved in freestyle swimming increased substantially in the experimental group post-intervention (from 14.125m to 20.687m), while the control group showed minimal change. The T-test results confirmed the statistical significance of these differences at $p < 0.05$.

Conclusions: The use of a biomechanically informed device provided accurate, real-time feedback that enhanced learners' awareness and corrected arm movement imbalances. These findings emphasize the potential of technological interventions in physical education and support the integration of innovative tools to enhance motor learning efficiency, particularly in swimming instruction.

Key word: Biomechanical Feedback, Motor Coordination, Performance, Sensor-Based Training, Hand Propulsion Dynamics

Introduction

The role of modern technologies in enhancing learning processes has become increasingly significant in various educational fields, particularly in physical education and sports sciences. The integration of devices such as computers, smartphones, and educational software into training regimens has proven to accelerate skill acquisition and create more flexible, adaptable learning environments (Sripavithra et al., 2022). These tools enable the delivery of educational content in engaging, interactive formats, thus motivating learners and enhancing their comprehension and application of new concepts (Ahnaf Istiqlal Berutu et al., 2024). In the context of swimming, advanced devices offer visual and simulated lessons that allow learners to acquire and practice practical skills more efficiently (Prasad & Paras, 2024a). Furthermore, technology enables the customization of learning experiences to meet the individual needs of learners, potentially accelerating their mastery of complex skills (Putra et al., 2024).

The importance of assistive devices in improving performance during physical activities, particularly in sports, cannot be overstated. These tools are designed to address specific learning needs by enhancing physical, motor, and skill development. They aid in the refinement of sensory abilities and motor coordination, offering immediate feedback that helps learners improve their performance. This personalized feedback is often vital for correcting technique and boosting motivation (BULZ et al., 2024).

Similarly, recent research has highlighted the effectiveness of mental training interventions in improving athletic performance. This underscores the role of mental exercises, particularly techniques that focus on thought control, in amplifying athletic abilities and enhancing the overall performance of athletes (Abdulkareem & Ali Hassan, 2025).

Swimming, one of the oldest and most widely practiced physical activities, is not only beneficial for physical fitness but also promotes both mental and physical endurance (Lin, 2024). Swimming enhances overall

health, strengthening the muscles of the body and increasing flexibility, thus contributing to better stamina and well-being (Moffatt, 2017). Among the critical aspects of swimming, arm movement plays an indispensable role in forward propulsion and speed. Effective arm movement is essential for maintaining balance in the water and improving overall swimming efficiency. The ability to generate optimal push and pull forces through the arms directly impacts the swimmer's speed and body coordination (McLeod, 2009). Recent studies on training methods, including controlled hypoxic training, have highlighted their beneficial effects on athletic performance, particularly in swimming. For example, a study investigating the effects of six-week high-intensity hypoxic training on adolescent competitive swimmers showed significant improvements in various performance parameters, including apnea duration, breath-hold distance, and swimming time (Effect Size, $ES = 0.26 - 1.57$) (GRZNÁR et al., 2025). Furthermore, recent research has shown the potential of using advanced technological devices to improve swimmers' performance. A study on the Iraqi national swimming team demonstrated that the use of a proposed laser device during the rotational phase of the 100-meter freestyle event led to positive improvements in biomechanical variables, enhancing swimmers' rotational accuracy and increasing horizontal distance (Zaher Yahya et al., 2024).

The modernization of pedagogical education for coaches and supplementary education teachers in sports is crucial for improving their professional knowledge and skills. A study found that developing professional competencies among teachers of swimming for infants led to significant improvements in their knowledge and teaching effectiveness. By applying modern pedagogical technologies, teachers of children's swimming education significantly enhanced their competencies, which resulted in better alignment with professional standards (Mischenko et al., 2024).

Recent analyses of competitive swimming performance at the 21st World Aquatics Championships (Doha, 2024) have highlighted significant gender and age-related differences in swimming skills. Notably, men demonstrated superior speeds across most distances, particularly in short-distance events and relays, whereas smaller performance gaps were noted in long-distance and mixed relay events. These findings suggest an evolving performance gap between genders, particularly in endurance disciplines, and underscore the continuous improvements in competitive swimming techniques across various ages and genders (Ganchar et al., 2025). Despite the crucial role of arm movement, many learners—particularly female students—struggle with executing the proper technique for the "push" phase in freestyle swimming. The "push" phase, which involves applying force through the palms of the hands, is vital for propulsion. Without it, the swimmer cannot maintain sufficient forward movement, thus diminishing overall performance. Many learners exhibit errors such as pushing only with the palms without utilizing the forearms effectively. This inefficiency is often due to improper elbow positioning, leading to suboptimal water displacement (Barnamehei et al., 2022; Gomes et al., 2014). As arm movement is integral to swimming propulsion, correcting these errors is essential to improving swimmers' performance, especially among female students, who often face difficulties in mastering this critical skill.

The motivation for this research stems from the need to improve the motor coordination of arm movements during freestyle swimming, specifically targeting the force balance between the two arms. While the importance of arm movement in swimming is well-established, there has been a lack of tools that provide real-time feedback to help learners correct their errors. Most traditional methods of teaching swimming do not offer immediate or accurate feedback on the forces exerted by the arms, which results in ineffective motor learning. This research is designed to address this gap by developing a device that measures the pressure force exerted on the palms during swimming, providing immediate feedback on the force balance between the arms.

This device aims to facilitate the correction of errors in arm movement and enhance motor coordination. By incorporating this device into training, learners receive precise information about their arm movements and can make real-time adjustments to their technique. The research focuses specifically on female students at the Faculty of Physical Education and Sports Sciences at Baghdad University, where there is a noticeable challenge in mastering the pushing phase of freestyle swimming.

The approach of this study involved designing and constructing a custom device equipped with pressure sensors placed on both palms of the swimmer. This device captures the force exerted during the push phase and provides immediate feedback to the swimmer through a display unit. The data collected by the device is processed and analyzed to assess the symmetry of the pushing forces and to highlight discrepancies that may be impeding the swimmer's performance. The experimental group used the device as part of a three-month training program, while the control group followed traditional training methods without the device. This comparative approach allowed for a thorough evaluation of the device's effectiveness in enhancing motor coordination and balance between the arms.

The primary objective of the research is to assess the impact of the pressure-measuring device on improving motor coordination and balance between the arms during freestyle swimming. The study also aims to evaluate the device's effectiveness in skill development and technical refinement, focusing on the potential for real-time feedback to enhance learning efficiency.

The research hypotheses include:

- There are no statistically significant differences between the pre-test and post-test results of the experimental and control groups concerning the balance of arm forces during freestyle swimming.

- There are no statistically significant differences between the post-test results of the experimental and control groups regarding motor coordination of the arms during freestyle swimming. By providing accurate feedback on the forces exerted by each arm, this device aims to assist learners in achieving more balanced and coordinated arm movements, ultimately improving their overall swimming technique and performance.

Materials and Methods

The study adopted an experimental design for the experimental and control groups, where the training program using the designed device was applied to the experimental group, while the control group did not receive the intervention. This design allows comparing the performance levels between the two groups and extracting the effect of the experimental intervention on improving the motor balance of the arms during freestyle swimming for female students.

Research Participants

The research population represents the female students of Baghdad University, Faculty of Physical Education and Sport Sciences, Jadiriya, second stage for the academic year 2024-2025.

Research sample

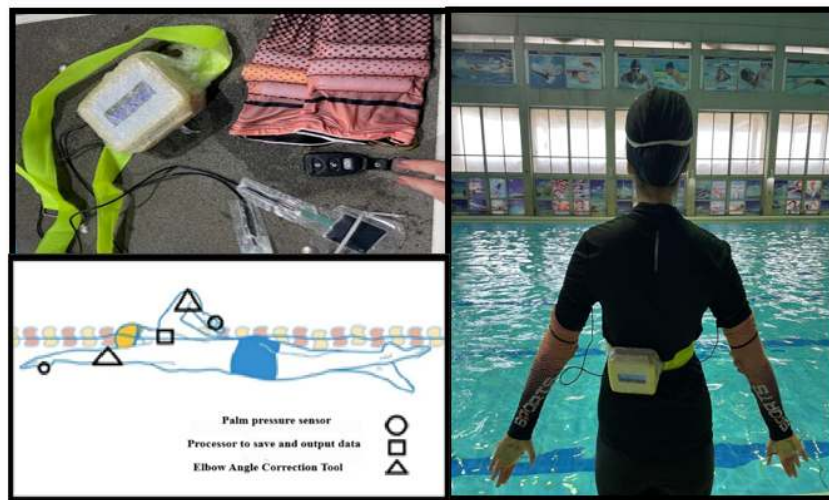
The study sample of (32) female students was randomly selected according to the availability of information to ensure that all target groups in terms of age and skill level are available.

The sample was divided into: Experimental group: (n=16) Students who receive the intervention using the palm pressure force measurement and the control group: (n=16) those who follow the traditional method of learning arm movement without using the device.

Components of the device

1. Two sensors are installed on the palms of the arms that read the force of the pressure applied to the learner's palm.
2. A processor to calculate the sensor reading simultaneously with each arm stroke and compare the force between the two arms.
3. A tool to determine and correct the angle of the elbows while pushing the arms.

A screen to show the results of the sensor reading that will give the average pressure force applied to each arm, the highest reading of the pressure rate and the difference between the right and left arm (force symmetry = weak arm/strong arm)



Procedure

The researcher conducted the first exploratory experiment on Thursday, 10/17/2024, inside a small basin to test the efficiency of the sensor for the pressure force inside the water and find out how successful the process of isolating the water from the sensor was and the extent of its effect on this isolation, and the researcher concluded that the method he adopted in isolation was successful and effective. Also, correct and clear readings were obtained for the pushing process, as well as checking the readings and matching them with the company's recommendations and dispensing with the medical palm that was likely to place the sensor inside the palm on the palm of the hand and adopting the plastic installed on the sides of the water isolator as shown in Figure 2.



Figure 2. The performance of the first exploratory experiment

The researcher conducted the second exploratory experiment on (Wednesday), 6/11/2024 in the swimming pool of the Faculty of Physical Education and Sports Sciences at the University of Baghdad on a group of female students (3) outside the research sample find simple swimming to know the average number of strokes per arm during a distance (25 meters) and after obtaining the results that ranged within the range (8 - 14) strokes during (25 meters). and the design of the device was adopted (10) strokes to read the pressure force applied to each arm (the sensor on the palm) for one student in learning and comparing the results between the right and left arms and knowing the difference between them “as described in Table 1”.

Table 1. Show Stroke count in freestyle with the distance of the second exploratory experiment

No.	Stroke count in freestyle	Distance
1	10	20M
2	5	7M
3	14	25M

The test was performed for the experimental and control samples and the test was to swim freestyle for the farthest distance (Yang et al., 2025).

Purpose of the test: To measure the distance traveled by the tester when performing freestyle **swimming**.

Instruments: Swimming pool, tape measure, stopwatch. **Test description:** The tester stands inside the pool with their back facing the edge of the pool, one leg straight with the foot on the ground while the other leg is bent backwards from the knee joint with the foot resting on the edge of the pool and performs freestyle swimming for as far as possible. **Scoring the test:** The test is recorded by calculating the distance traveled from the edge of the pelvis to the tester's feet.

The researcher developed an educational curriculum for 3 months with 24 educational units and an average of 8 units per month and 2 educational units per week (Sunday, Wednesday). The researcher's educational curriculum is only the main part of the educational unit for students whose time ranges between 25 and 30 minutes, and the transition of exercises from easy to difficult emphasizes performance with consistency and calm in order to adjust the correct paths of movements and ensure the repetition and use of feedback by the researcher with the help of readings extracted from the designed device that shows the difference in pressure force for both arms.

The pre-tests were conducted for the research sample, which numbered 32 learners, divided into two groups, experimental (16 female students) and control (16 female students), on (Wednesday) 11/12/2024, at the Faculty of Physical Education and Sport Sciences.

The researcher conducted the post-tests and performance evaluation on Wednesday, 12/3/2025, after completing the application of the educational curriculum under the same conditions as the pre-tests on the female learners of the sample and on the swimming pool of the Faculty of Physical Education and Sports Sciences at Baghdad University/Jadiriya.

Statistical analysis

The researcher used the statistical package (SPSS ver. 26) in extracting the results of the study, where the statistical operations were used for the normal distribution of the sample, namely arithmetic mean, standard deviation, and skewness, and T-test the equivalence between the control and experimental groups was used for the pre-test and post-tests for the experimental and control groups, and T-test for the post-test for the experimental and control groups was used after the educational curriculum and under the significance level of 0.05.

Result

The normal distribution of the sample was performed to ensure the homogeneity of the sample in terms of the variables of height, weight and age, and the results showed that the sample is normally distributed when looking at the skewness from within (± 1) “as described in Table 2”.

Table 2. shows the normal distribution of the sample (Means, Standard deviation and Skewness)

Variable	Means	Std. Deviation	Skewness
Age	20.468	1.343668	0.241096
Weight	57.68	7.257643	0.187054
Length	160.562	6.174545	0.291735

Equivalence and homogeneity tests were conducted for the experimental and control research samples in the variables to start with a similar starting position and the results showed non-significant and greater than (0.05) indicating the sample is equivalent “as described in Table 3”

Table 3. shows the equivalence between the experimental and control groups in the research variables

Variable	Experimental group		Control group		T value	Sig. value	Mean Difference	Std. Error Difference
freestyle for the farthest distance	Means	Std. Deviation	Means	Std. Deviation	0.103	0.918	0.062	0.606
	14.125	1.707	14.187	1.721				

* at a significance level of 0.05 with a degree of freedom of 30

The results of the pre-test and post-test for the experimental group showed significant differences in the test “as described in Table 4”

Table 4. shows the results of the pre and post tests for the experimental group

Variable	Means	Std. Deviation	Std. Error Mean	t	df	Sig. value
freestyle for the farthest distance	6.562	3.119	0.779	8.415	15	0.000

* at a significance level of 0.05

The results of the pre- and post-test for the control group, which showed no statistically significant differences “as described in Table 5”

Table 5. show the results of the pre- and post-tests for the control group

Variable	Means	Std. Deviation	Std. Error Mean	t	df	Sig. value
freestyle for the farthest distance	0.375	0.957	0.239	1.566	15	0.138

* at a significance level of 0.05

The results of the posttest between the experimental and control groups, which showed statistically significant differences for the experimental group “as described in Table 6”

Table 6. shows the results of the post-tests for the experimental and control groups

Variable	Experimental group		Control group		T value	Sig. value	Mean Difference	Std. Error Difference
freestyle for the farthest distance	Means	Std. Deviation	Means	Std. Deviation	7.764	0.000	6.125	0.788
	20.687	2.821	14.562	1.412				

* at a significance level of 0.05 with a degree of freedom of 30

Discussion

The results of the study showed the effectiveness of using the device designed to measure the palm pressure force during freestyle swimming in improving the motor performance of the arms of female students, as the statistical tables showed statistically significant differences in favor of the experimental group in the test of swimming the farthest distance.

These results were reflected in a significant improvement in the average distance traveled, indicating that the use of the device helped to achieve better motor coordination and balanced distribution of force between the arms, which helped the students to achieve more efficient and accurate movement in the water. which examined how the coach navigated cultural and environmental challenges while enhancing team performance. The study underscored the importance of adapting to a culturally distinct coaching environment, negotiating role expectations, and having access to sufficient resources to balance job demands and resources. These challenges, along with the coach’s ability to craft tasks beyond immediate expectations, reflect the importance of cultural

adaptation and resource accessibility in optimizing performance, similar to how technological feedback systems enhance athlete performance (MIZUSHIMA & TOMURA, 2025).

Moreover, research on strength training in distance running has shown that while it has a positive impact on running economy and performance in short-distance events (3 to 10 km), it does not significantly improve other aerobic factors such as VO₂ max or lactate threshold. The study also points out that while muscle weakness has been identified as a factor contributing to running injuries, the role of strength training in preventing such injuries remains unclear, particularly for novice and recreational runners. This highlights the importance of strengthening key muscle groups, such as the hip, which may be crucial in preventing injuries in both running and swimming (KARP, 2024).

This improvement is attributed to the intelligent design of the device, which provided quantitative and immediate information about the level of pressure applied by each arm, enabling students to recognize and correct the differences in strength between the left and right arms during training. Some studies have indicated that immediate feedback directed towards correcting performance contributes significantly to accelerating the learning process and improving learners' skill performance, especially in the early stages of skill acquisition, and that this type of immediate feedback contributes significantly to accelerating the learning process and improving learners' skill performance (Schmidt & Lee, 2019) (Magill & Anderson, 2012).

Moreover, the practical application of the device in a realistic training environment enabled students to relate the biomechanical analysis of performance to the learning process itself, enhancing their kinesthetic awareness and increasing their ability to internalize the fine details of arm movement. The importance of combining modern technology with kinetic analysis to improve performance in games and sports that require high precision in muscle coordination (Prasad & Paras, 2024b).

The findings from the present study align with research on other mind-body practices, such as Tai Chi, where similar improvements in motor abilities and cognitive functions were observed. In a study by (Lopez et al., 2025), practitioners of Tai Chi exhibited better motor control and improved executive functions, attributed to the attentional focus inherent in the practice.

This suggests that enhancing motor-cognitive integration through deliberate movement may contribute significantly to improving coordination and performance in various physical activities, including swimming. These results support the idea that real-time feedback mechanisms, such as those used in this study, could similarly promote neuromuscular coordination and refine athletic performance.

The results of the study are in line with the kinetic concept of force and propulsion theory in swimming, as the improved palm pressure helped to achieve more effective water propulsion, which was reflected in improved speed and kinetic efficiency (Koga et al., 2022). This finding is important in light of the fact that arm movement is the main factor in navigating through the water during freestyle swimming, and improving the mechanics of this movement leads to tangible results in overall performance (ITO, 2007) (Cohen et al., 2015).

In light of the above, it can be emphasized that the use of smart technologies, especially devices based on sensing and motor analysis, is an effective step in improving fine motor skills and enhancing the professional learning process in the sports field. These results indicate the possibility of extending the use of the device to other groups of learners or similar water sports, as well as the possibility of developing it to include additional kinematic indicators such as the angle of propulsion and the time of each movement.

Conclusion

The results of this study underscore the practical importance of employing assistive technology in sports education, particularly in teaching and enhancing fine motor skills such as hand grip strength during freestyle swimming. The designed device demonstrated high precision in recording the exerted force during performance, which enabled the participants to identify weaknesses in their movement and work on correcting them through immediate feedback provided by the device.

The use of this device contributed significantly to the improvement of motor coordination between the arms among the participants, reflecting the effectiveness of technological intervention in enhancing the quality of motor learning. The progress achieved by the experimental group compared to the control group indicates that custom-designed devices for evaluating and monitoring detailed motor performance can play a vital role in both teaching and training settings.

These findings reinforce the credibility of integrating biomechanical knowledge with applied educational design, supporting a shift toward incorporating innovative technological tools within the field of physical education. This is especially valuable in early stages of skill acquisition, where clarity of feedback and accuracy in assessment are critical.

Thus, this study not only contributes to the development of students' motor performance but also opens the door to broader applications of similar technologies in teaching various sports skills. Furthermore, it highlights the potential of locally manufactured educational devices as cost-effective and efficient alternatives to expensive imported tools, promoting greater self-sufficiency and innovation within educational institutions.

Recommendations

1. Adopting the device in educational curricula for swimming to help learners gain a better understanding of proper arm mechanics and improve pushing force symmetry.
2. Expanding the use of biomechanical measurement tools in other swimming styles and across different age groups to evaluate their effectiveness in diverse learning contexts.
3. Encouraging collaboration between sports technologists and educators to further develop assistive devices that support motor learning and technique correction.
4. Conducting follow-up studies with larger and more varied samples to validate the current findings and explore long-term performance improvements.

Conflicts of interest: The authors declare that there are no conflicts of interest regarding the publication of this paper.

Author contributions: Lina was responsible for the conceptualization and methodology of the study. She played a significant role in designing the research framework, developing the study's theoretical background, and overseeing the data analysis process. Additionally, she was heavily involved in writing the original draft of the manuscript, presenting the study's findings, and reviewing the final draft for academic quality. **Muhanad** contributed to data collection and formal analysis of the results. He assisted in organizing and gathering the data required for the study and conducted the preliminary analysis, he also participated in the review and editing process, ensuring the manuscript adhered to academic standards and that the findings were presented clearly. **Omar** provided valuable input during the supervision and validation stages of the project. He ensured the research adhered to ethical standards and rigorously checked the findings for accuracy, he was also instrumental in overseeing the overall project administration and providing guidance on the final manuscript's structure and presentation. He also contributed to revising and improving the manuscript before submission.

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