DOI 10.26773/smj.251004

SportMont

ORIGINAL SCIENTIFIC PAPER

Impact of an AI-Based Functional Resistance Program on Some Physical and Physiological Variables in Students Attending a Swimming Course

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Abstract

This study aimed to examine the impact of an AI-designed functional resistance training program on selected physical and physiological variables among students enrolled in a swimming course in Jordan. A quasi-experimental pre-test–post-test design was used with two groups: experimental and control. The sample included 19 male students from Amman Al-Ahliyya University and Jadara University, with a mean age of 22.1 years. The experimental group (10 students from Al-Ahliyya Amman University) participated in a six-week AI-designed functional resistance training program, conducted three times per week. Each session consisted of 40 minutes of functional training followed by 30 minutes of swimming drills. In contrast, the control group (9 students from Jadara University) only engaged in swimming drills for 60 minutes per session. Physical variables measured included hand grip strength, upper and lower limb power and endurance, and trunk flexibility. Physiological variables included body mass, body mass index, body fat percentage, muscle mass, total body water, protein percentage, basal metabolic rate, bone mass, resting heart rate, systolic and diastolic blood pressure, visceral fat, and fasting blood glucose. Measurements were taken before and after the intervention. Statistical analysis revealed no significant differences between the experimental and control groups in the post-test measurements across all variables. Despite this, the experimental group showed significant improvements in several physical and physiological variables, including upper and lower limb power, trunk flexibility, body mass, along with a reduction in resting heart rate. In contrast, the control group showed significant improvements in bone mass and upper limb endurance.

Keywords: *functional training, program design, swimmers, artificial intelligence (AI), Chat GPT*

Introduction

Technology has brought about fundamental changes in the field of sports, leading to enhanced athletic performance, improved training quality, and the development of competitive standards. Artificial Intelligence (AI) has become one of the most prominent technologies driving this evolution, as it facilitates access to data and enables accurate analysis across various domains, including sports (Pardeshi, 2024). Despite these advancements, traditional training approaches face lack of personalized, adaptive, and scalable training solutions. This issue is particularly evident in swimming, where swimmers have diverse physical and physiological needs that are often not addressed through conventional methods. However, AI holds potential to overcome these limitations. These limitations may be attributed to several factors, including restricted usage by individuals and coach-

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es, challenges in training AI systems, and concerns regarding usability, accuracy, and ethical principles (Chaurasiya et al., 2024).

Swimming is a unique sport due to the horizontal position swimmers maintain during training and competition. Swimmers must adhere to specific training programs that align with the types of races in which they specialize, as the physical and physiological demands vary (González-Ravé et al., 2021). While González-Ravé et al. (2021) emphasized the importance of race-specific training demands, their study did not integrate AI to design a program. The current study builds upon this by employing AI to design a functional training program tailored to swimmers' needs. As technical performance alone is no longer sufficient to achieve competitiveness, it is now essential to place particular emphasis on physical aspects (Shlool et al., 2018).

Functional resistance training has emerged as a modern approach focused on enhancing movement efficiency and simulating actual sports performance. It has been shown to positively impact physical and physiological variables (Brisebois et al., 2018). As a result, it can be tailored to any sport, enhancing muscle function, reducing injury risk, and improving coordination, balance, flexibility, and motor speed (Cao et al., 2024). In swimming, functional training strengthens the core muscles to improve body positioning and minimize water resistance. It also enhances upper limb strength for pulling and pushing motions, as well as lower limb strength to support starts and turns (Zhang & Siriphan, 2024). However, while Zhang and Siriphan (2024) effectively outlined the general benefits of functional training in swimming, they did not explore how such training can be designed and customized through AI. The present study addresses this gap by integrating AI into the design of functional resistance training tailored to swimming.

Based on these analyses, AI can play a significant role in designing physical training programs that support swimmers' performance. However, studies integrating these technologies with sports training remain limited globally, and particularly in the Arab region. This highlights the importance of the present study as one of the first in Jordan and the Middle East to employ AI in designing a functional resistance training program for swimmers. Moreover, it emphasizes how functional training can be delivered in low-cost tools compared to traditional training equipment, while focusing on simulating actual swimmers' performance.

Traditional training programs are often developed based on general coaching experience and conventional periodization models. In contrast, AI-designed programs can leverage existing data to create more structured and potentially optimized training content. While functional training has become widespread, its effects on certain variables in swimmers remain not fully clear, particularly when designed using AI technology.

Accordingly, this study aims to investigate the impact of an AI-designed functional resistance training program on selected physical and physiological variables among students enrolled in a swimming course in Jordan. By addressing a clear gap in the integration of AI into functional resistance training design, particularly in swimming and within the Arab region, this study hypothesizes that the AI-designed functional resistance training program will lead to statistically significant improvements in some physical and physiological variables compared to a control group following swimming drills only.

Methods

Design

A quasi-experimental pretest-posttest design with two groups—experimental and control—was used due to its suitability for the nature and objectives of the study in measuring the effect of the training program. The study population consisted of male students enrolled in swimming course within the Faculties of Physical Education at Jordanian universities.

Participants

The total study sample initially consisted of 31 male students enrolled in swimming courses at Al-Ahliyya Amman University and Jadara University. The experimental group included 14 students from Al-Ahliyya Amman University; however, one student withdrew, and three were excluded due to lack of attendance, resulting in 10 participants. The control group initially comprised 17 students from Jadara University; four students withdrew, two were excluded for not attending, and three were excluded for not completing the post-tests, leaving 9 participants. Thus, the final sample consisted of 19 students with an average age of 22 years and average height of 175 cm. Participants were purposively assigned into two groups: an experimental group (10 students from Al-Ahliyya Amman University) and a control group (9 students from Jadara University). Inclusion criteria required that participants have no current or previous injuries affecting performance, no chronic illnesses, and no adherence to regulated training or dietary programs during the study period. Detailed description of research sample is presented in Table 1.

Table 1. Descriptive statistics of research sample

Variable	Experimental (n=10)	Control (n=9)
Age (year)	22.90±1.44	21.22±1.92
Body height (cm)	178.90±6.42	171.22±6.11
Body mass (kg)	77.73±11.74	66.04±11.26

Instruments

A set of tests was employed to measure the physical and physiological variables, including: hand grip strength, seated medicine ball throw, standing broad jump, endurance squat test, endurance push-up test, sit-and-reach test, body composition analysis, resting heart rate, resting systolic and diastolic blood pressure, and fasting blood glucose level. Content validity of these tests was confirmed by referencing previous reliable studies relevant to the nature of each variable. Test reliability was verified using the test-retest method. Pearson correlation analysis was conducted, and the results indicated that all tests were highly reliable, with statistically significant correlations ($p<0.05$).

The equipment used in the training program was limited to: kettlebell, resistance bands, stability ball, exercise mat, and plyo-soft boxes.

Procedures

The training program in this study was designed using artificial intelligence. A written prompt was developed and directed to an AI system (OpenAI GPT-4). The researcher conducted several iterative trials to formulate a prompt that would consistently yield coherent and relevant responses each time it was submitted to the model. The prompt specified the duration of the training period, the duration of each training session, the type and components of training, the equipment used, and the target population. Once the final version of the prompt was completed, it was submitted to the AI system. The final version of the prompt was as follows:

"Design a six-week functional resistance training program consisting of one circuit with three rounds, three days per week each day 40 minutes include eight exercises depending on time not reps and maintaining one structure throughout the six weeks. Utilizing resistance band, a kettlebell, stability ball, and Plyometric box. This program is designed for swimmers"

The AI-designed training program was implemented over a period of six weeks, with three training sessions conducted per week, each lasting 40 minutes. The exercises were organized in a circuit format, with one full round repeated three times. The circuit included eight exercises designed based on time intervals rather than repetitions. The complete AI-generated training program, which was implemented without modification throughout the six-week intervention, is provided in Figure 1. All sessions were supervised by the researchers and assistance coach to ensure proper technique and full adherence to the program.

Design a six-week functional strength training program consisting of one circuit with three rounds, three days per week each day 40 minutes include eight exercises depending on time not reps and maintaining one structure throughout the six weeks. Utilizing resistance band, a kettlebell, stability ball, and Plyometric box. this program is designed for swimmers

ChatGPT said:

ChatGPT

Sure! Here's a six-week functional strength training program for swimmers, using the specified equipment. Each session lasts 40 minutes, structured in a circuit format with three rounds.

Weekly Schedule:

- **Days:** Sunday, Tuesday, Thursday

Circuit Structure:

- **Warm-up (5 minutes)**: Dynamic stretches (arm circles, leg swings, torso twists)
- **Circuit (30 minutes)**: 3 rounds of the following exercises (40 seconds work, 20 seconds rest between exercises)

Exercises:

1. **Resistance Band Pull Apart** (Shoulder stability)
2. **Kettlebell Swings** (Hip power)
3. **Stability Ball Plank** (Core stability)
4. **Box Jumps** (Explosive power)
5. **Seated Resistance Band Rows** (Upper back strength)
6. **Kettlebell Goblet Squats** (Leg strength)
7. **Stability Ball Pass** (Core engagement)
8. **Box Step-Ups** (Leg endurance)

Cool Down (5 minutes):

Stretching focusing on shoulders, hips, and legs.

FIGURE 1. The complete AI-generated functional resistance training program used in the experimental group. The program was implemented without modification over the six-week intervention period

The program was applied exclusively to the experimental group, who performed 40 minutes of AI-designed functional resistance training followed by 30 minutes of swimming drills. In contrast, the control group engaged only in swimming drills for 60 minutes per session, with no additional strength or resistance training included.

Ethics

Ethical approval for this study was obtained from the Institutional Review Board (IRB) at Al-Ahliyya Amman University (Decision Number: FES-18G-118). All participants voluntarily provided written informed consent prior to participation.

Statistical analysis

Data were analyzed using SPSS software (version 22). Means and standard deviations were calculated. To verify the assumptions for statistical analysis, Levene's test was used to assess homogeneity of variance, and the Shapiro-Wilk test was applied to assess normality of distribution. Group equivalence at pretest was verified using independent samples t-tests or Mann-Whitney U tests, depending on data distribution. Within group changes were assessed using paired samples t-tests or Wilcoxon signed-rank tests.

Finally, a multivariate analysis of covariance (MANCOVA) was employed to compare post-test outcomes between groups while controlling for the effects of non-equivalent variables. As

only two groups were compared and no multiple-level comparisons were required, no additional correction for multiple comparisons was applied. The significance level was set at $p<0.05$.

Results

Descriptive statistics and within-group comparison of pre- and post-measurements of physical and physiological variables in experimental group are presented in Table 2. Significant improvements were observed in upper and lower limb power, as well as trunk flexibility. However, no significant changes were found in hand grip strength, upper limb endurance, or lower limb endurance. Among the physiological variables, significant differences were observed in body mass, basal metabolic rate, bone mass, and resting heart rate. Conversely, no significant changes were noted in body mass index, body fat percentage, muscle mass, body water percentage, body protein percentage, or resting systolic and diastolic blood pressure. Additionally, non-normally distributed variables, including visceral fat level and fasting blood glucose level, showed no significant changes following the intervention.

In the control group, significant differences were observed in bone mass (2.76±0.28 to 2.85±0.22, t=2.475, p=0.038) and upper limb endurance (47.67±18.6 to 51.11±18.03, t=7.75, p<0.001). No significant differences were found in the remaining normally distributed physical and physiological variables, with p-values ranging from 0.061 to 0.987. Additionally, non-normally distributed variables, including BMI, resting systolic blood pressure, fasting blood glucose, muscle mass, and trunk flexibility, showed no significant changes (p=0.066 to 0.945).

Table 2. Within-group comparison of pre- and post-test measurements of physical and physiological variables in the experimental group (n = 10) using paired t-test and Wilcoxon signed-rank test

Variable	Mean±SD		Test statistic	p
	Pre	Post		
Hand grip strength (kg)	44.47±7.63	45.41±9.17	0.59	0.567
Upper limb power (cm)	326.00±71.93	395.00±52.30	5.42	<0.001*
Lower limb power (cm)	197.90±21.26	214.00±12.34	3.05	0.014*
Upper limb endurance (reps)	30.40±14.66	30.00±13.39	-0.16	0.870
Lower limb endurance (reps)	71.40±27.88	94.20±45.45	2.24	0.051
Trunk flexibility (cm)	29.90±7.12	32.80±5.20	2.95	0.016*
Body mass (kg)	77.73±11.74	79.02±11.75	2.68	0.025*
BMI (kg/m2)	24.29±2.67	24.65±2.61	2.08	0.067
Body fat%	21.78±5.05	22.35±4.95	1.87	0.094
Muscle mass (kg)	57.29±5.44	57.76±5.27	3.05	0.140
Body water%	53.65±3.45	53.45±3.15	-1.00	0.341
Body protein%	20.57±1.34	20.51±1.21	-0.73	0.483
BMR (Kcal)	1701.90±171.44	1723.40±171.89	2.72	0.023*
Bone mass (kg)	3.07±0.29	3.09±0.28	3.05	0.014*
RHR (beats/min)	75.00±6.61	70.50±5.72	-2.34	0.043*
SBP at rest (mmHg)	121.90±5.21	122.20±6.42	0.15	0.883
DBP at rest (mmHg)	73±5.31	73.30±4.54	0.14	0.889
Visceral fat (level) §	9.00 (8.00-10.00)	9.00 (8.00-10.00)	-1.00	0.317
FBG (mg/dL) §	98.50 (88.75-103.50)	99.00 (92.75-100.00)	-0.17	0.859

Note. Values are presented as mean ± standard deviation (SD) for normally distributed variables and as median (interquartile range) for variables indicated by §, which were analyzed using the Wilcoxon signed-rank test. All other variables were analyzed using the paired t-test. *p<0.05 indicates statistical significance. BMI: body mass index; BMR: basal metabolic rate; RHR: resting heart rate; SBP: systolic blood pressure; DBP: diastolic blood pressure; FBG: fasting blood glucose.

A multivariate analysis of covariance (MANCOVA) was conducted to compare post-test measurements between the experimental and control groups, while controlling for the effects of baseline differences in non-equivalent variables (Table 3). The analysis revealed no statistically significant differences between groups across any of the physical or physiological variables ($p>0.05$). However, several trends were noted. Upper limb power was higher in the experimental group compared to the control group, approaching statistical significance ($p=0.081$, partial $\eta^2=0.273$), indicating a potentially substantial effect. Additionally, the experimental group exhibited greater post-test means in lower limb power, trunk flexibility, and lower limb endurance, although these differences did not reach statistical significance.

No significant between-group differences were observed in hand grip strength or upper limb endurance. Regarding physiological variables, no significant differences emerged between groups in body fat, muscle mass, body water, and protein, basal metabolic rate, visceral fat, or resting heart rate and blood pressure. Most effect sizes were small to moderate, although some variables, such as resting heart rate (partial $\eta^2=0.097$) and diastolic blood pressure (partial $\eta^2=0.098$), showed moderate effects, suggesting potential practical relevance. Detailed estimated marginal means, standard errors, and effect sizes are provided in Table 3.

Table 3. Between-group comparison of post-intervention measurements in physical and physiological variables using MANCOVA

Variable	Group	EMM±SE	f-value	p	Partial η^2
Hand grip strength (kg)	EXP	41.47±3.83	1.78	0.211	0.152
	CON	51.39±4.19			
Upper limb power (cm)	EXP	395.07±20.40	3.76	0.081	0.273
	CON	318.46±22.32			
Lower limb power (cm)	EXP	216.31±11.64	0.24	0.633	0.024
	CON	205.21±12.74			
Upper limb endurance (reps)	EXP	38.77±3.07	0.18	0.673	0.019
	CON	41.36±3.36			
Lower limb endurance (reps)	EXP	98.06±24.10	0.44	0.521	0.042
	CON	67.04±26.37			
Trunk flexibility (cm)	EXP	36.86±2.60	2.53	0.142	0.202
	CON	28.81±2.85			
Body mass (kg)	EXP	72.80±0.94	0.29	0.597	0.029
	CON	73.81±1.03			
BMI (kg/m^2)	EXP	23.69±0.24	0.01	0.934	0.001
	CON	23.73±0.27			
Body fat (%)	EXP	19.03±0.94	0.06	0.799	0.007
	CON	18.55±1.03			
Muscle mass (kg)	EXP	49.65±6.33	0.37	0.556	0.036
	CON	57.11±6.93			
Body water (%)	EXP	55.61±0.65	0.02	0.885	0.002
	CON	55.42±0.71			
Body protein (%)	EXP	21.32±0.25	0.01	0.959	0.001
	CON	21.30±0.28			
BMR (Kcal)	EXP	1637.48±14.93	0.46	0.512	0.044
	CON	1657.12±16.34			
Bone mass (kg)	EXP	2.97±0.02	0.18	0.675	0.018
	CON	2.99±0.03			
Visceral fat (level)	EXP	7.01±0.43	0.31	0.588	0.030
	CON	6.54±0.47			
RHR (beats/Min)	EXP	70.49±3.46	1.07	0.324	0.097
	CON	77.44±3.78			
SBP at rest (mmHg)	EXP	120.26±2.67	0.50	0.495	0.048
	CON	123.92±2.92			
DBP at rest (mmHg)	EXP	76.08±4.16	1.08	0.322	0.098
	CON	67.68±4.55			
FBG (mg/dL)	EXP	96.24±5.87	0.09	0.765	0.009
	CON	99.73±6.43			

Note. EMM: estimated marginal mean, indicates the adjusted post-test means after controlling for pre-test covariates; SE: standard error; Partial η^2: partial eta squared (effect size); EXP: experimental group; CON: control group; BMI: body mass index; BMR: basal metabolic rate; RHR: resting heart rate; SBP: systolic blood pressure; DBP: diastolic blood pressure; FBG: fasting blood glucose. $p<0.05$ was considered statistically significant.

Discussion

In this study, the impact of an AI-designed functional resistance training program on selected physical and physiological variables was analyzed. The results showed statistically significant improvements in upper and lower limb power as well as trunk flexibility, suggesting a potential positive response to the functional resistance training program developed using artificial intelligence. These improvements can be attributed to neuromuscular adaptations resulting from multi-joint resistance exercises, which enhance motor unit recruitment and muscular coordination (Kraemer & Ratames, 2004; Yang, 2023). Furthermore, the program's design, which incorporat-

ed progressive dynamic movements and appropriate training principles, likely contributed to the improvements in trunk flexibility by promoting soft tissue adaptations and increasing the range of motion. This type of training mimics daily motor activities and is particularly relevant to movements involved in swimming performance. However, the lack of statistically significant differences between the two groups limits the strength of the conclusions that can be drawn regarding these variables (Cao et al., 2024; Knudson, 2024; Xiao et al., 2025).

No statistically significant changes were observed in handgrip strength in either group, which may be attributed to the absence of exercises specifically targeting the grip muscles. This finding aligns with the principle of training specificity (Kraemer & Ratames, 2004). Notably, the effect size for this variable was high (partial η^2=0.152), suggesting a potential trend toward improvement that did not reach statistical significance. The limited program duration of six weeks may also have been insufficient to elicit meaningful changes in grip strength, as suggested by Teixeira et al. (2020). Regarding muscular endurance, the lower limbs demonstrated a trend toward improvement (p=0.051), although this did not reach statistical significance. This outcome underscores the potential need for a longer training duration to achieve measurable gains, as supported by Zuo et al. (2022). Improvements in upper limb endurance were also limited, possibly due to insufficient training intensity or repetitions, and this is consistent with the findings of Purnamasari et al. (2022). Additionally, individual variability may have influenced these outcomes, considering the role of genetic factors in exercise response (Bouchard & Rankinen, 2001).

The mechanical effects induced by functional resistance training have been shown to enhance bone remodeling and increase bone density (Hoffstetter et al., 2016). Improvements in basal metabolic rate (BMR) observed in the experimental group may contribute to better absorption of nutrients, such as vitamin D, which supports these adaptations by promoting calcium uptake and regulating phosphate balance, thereby promoting bone remodeling and structural enhancement in response to mechanical loading (Zhou et al., 2013).

Since muscle tissue is metabolically active and requires more energy to maintain its functions, the observed slight, non-significant increase in muscle mass may reflect the onset of muscle hypertrophy or temporary fluid retention (Amankwaah et al., 2016). Conversely, the unexpected increase in body fat percentage within the experimental group may be attributed to uncontrolled lifestyle factors such as hydration status and unbalanced nutrition, both of which are associated with increased visceral fat accumulation, overall fat deposition, and disruptions in fluid balance (Amini et al., 2020). Additionally, poor sleep quality has been linked to higher visceral fat levels (Sweatt et al., 2018), while stress-induced cortisol secretion is also associated with visceral fat accumulation (Drapeau et al., 2003).

The slight decrease in protein percentage within the experimental group may reflect increased protein utilization due to exercise without adequate dietary intake. In contrast, the minor increase in protein percentage observed in the control group could be attributed to natural individual variability, including genetic differences and variations in dietary habits (Amini et al., 2020; Drapeau et al., 2003; Sweatt et al., 2018). These findings underscore the importance of aligning physical effort with nutritional support to ensure effective and sustainable muscular and structural adaptations.

The general improvements observed in the variables discussed above may also be attributed to enhanced physical fitness, potentially resulting from cardiorespiratory adaptations induced by the training program (de Rezende Barbosa et al., 2016). The experimental group demonstrated a reduction in resting heart rate with an effect size approaching moderate, suggesting improved cardiovascular efficiency as a result of adaptations to the functional resistance training program. This suggests that the heart became more efficient at pumping blood, resulting in a lower resting heart rate, which is considered an indicator of enhanced physical fitness, improved cardiac health, and better overall physiological function. However, no statistically significant differences were observed between the two groups, indicating the need for further investigation.

No statistically significant differences were observed between the groups in blood pressure, basal metabolic rate, or fasting glucose levels. Some physiological adaptations may require a longer intervention period to become detectable (Engel et al., 2019; Feito et al., 2019). The stability in fasting blood glucose may indicate improved insulin sensitivity, even in the absence of observable changes in glucose concentration (Segal et al., 1991). Furthermore, individual variability may account for these findings, given the established influence of genetic factors on training responsiveness (Bouchard & Rankinen, 2001).

Despite positive trends in the experimental group, the lack of statistically significant differences between groups suggests the program's effectiveness remains uncertain. While effect sizes for some variables are promising, they are insufficient for definitive conclusions. The hypothesis was only partially supported, emphasizing the need for longer interventions, larger samples, and tighter control of external factors, including diet, hydration, sleep, and stress, to accurately assess the program's impact.

Conclusion

This study found that the AI-designed functional resistance training program led to improvements in limb strength, trunk flexibility, and certain physiological markers within the experimental group. However, the absence of statistically significant differences between groups suggests these benefits may not be solely due to the intervention. While the AI-based approach appears promising as an alternative to traditional training, its effectiveness remains inconclusive. Future studies are recommended to involve larger, more diverse samples, include female participants, and extend intervention periods. Investigating its impact on sport-specific skills, particularly in swimming, may also clarify its practical value.

Acknowledgments
There are no acknowledgments.

Conflict of interest
No conflicts of interest, financial or otherwise, are declared by the authors.

Received: 03 June 2025 | **Accepted:** 08 July 2025 | **Published:** 01 October 2025

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