RESEARCH
www.commprac.com
ISSN 1462 2815

ARM MUSCLE STRENGTH AND LEG MUSCLE CONTRIBUTE TO FREESTYLE SWIMMING SPEED

Aulia Rahmad [1], Syahrastani [2], Andri Gemaini [3]*, Usama Ashmawi [4], Özgür EKEN [5], Ratko Pavlovic [6] and Novadri Ayubi [7]

[1,2,3] Universitas Negeri Padang, Padang, Indonesia.
[4] Port Said University, Port Fouad, Egypt.
[5] Inonu University, Malatya, Turkey.
[6] University of East Sarajevo, East Sarajevo, Bosnia and Herzegovina.
[7] Universitas Negeri Surabaya, Surabaya, Indonesia.
*Corresponding Author Email: andrigemaini@fik.unp.ac.id

DOI: 10.5281/zenodo.11229853

Abstract

This study set out to investigate the relationship between arm and leg muscular strength and freestyle swimming speed. A total of 30 male swimmers participated in this research and the subjects were selected using the purposive sampling method. Before the research begins, research subjects received instructions on research procedures and signed an informed consent form. Tests of arm and leg muscle strength (the Push Up and Standing Broad Jump tests), as well as 50-meter freestyle swimming speed, are used to gather research data. Contribution tests and multiple correlation tests were employed in the data analysis. The results of this study report that arm muscle strength and 50-meter freestyle swimming speed are significantly correlated, leg muscle strength and 50-meter freestyle swimming speed have a large relationship, 50-meter freestyle swimming speed is significantly influenced by arm and leg muscle strength. It has been proven that strengthening the muscles in the arms and legs helps swimmers perform better.

Keywords: Physical Condition, Muscle Strength, Freestyle Swimming.

INTRODUCTION

Unquestionably, one of the most important aspects of optimizing swimming performance is strength [1]. Strength plays a crucial part in moving the body through the water with force and efficiency, whether in freestyle or other strokes [2]. Strong muscles are necessary to produce the force needed to pull, push, and kick efficiently, which increases swimming speed and endurance. This is especially true of the arms and legs [3].One of the most widely used and competitive swimming strokes in the world is freestyle swimming, sometimes referred to as front crawl [4]. Freestyle swimming, which is well-known for its speed and effectiveness, calls for the harmonious coordination of several muscle groups in order to move the swimmer through the water as quickly and efficiently as possible [5]. Arm strength is essential for performing the pull part of the freestyle stroke, which provides the majority of the propulsion [6]. Strong arm muscles, such as those in the shoulders, chest, and back, enable swimmers to propel themselves forward more quickly and by pulling in more water with each stroke [7]. Similar to this, sustaining a powerful and effective kick that aids in body stabilization and extra propulsion requires strong legs [8].

Speed is crucial for a swimmer to perform well over short distances like 50 meters. It uses quick; powerful hand movements as well as leg kicks to give a powerful push. The strength of the arm and leg muscles is the primary determinant of the action's success. The strength of the arm and leg muscles is the primary aspect that helps swimmers achieve their maximal speed [9]. Arm and leg muscle strength are two of the most important variables that affect freestyle swimming performance [10]. These

two essential components play a major role in improving speed and stroke proficiency [11]. Strong-arm muscles provide the necessary force to move the body forward into the water with each stroke. These muscles include the shoulders, upper back, and chest [12]. During a good flutter kick, leg muscles such as the quadriceps, hamstrings, and calf are crucial for maintaining stability and generating propulsion [13]. Therefore, building muscle strength in the arms and legs is essential for maximizing speed and performance in freestyle swimming [14]. It has been frequently noted in literature searches for systematic reviews and meta-analyses that the strongest muscles in the arms and legs are those that help swimmers' speed performance particularly well [15, 16]. Numerous earlier research have demonstrated that speed might be achieved through the use of hand and leg muscle strength. However, it will be challenging for swimmers to reach their greatest potential if they lack hand and leg muscle strength.

It is impossible to exaggerate the value of arm muscle strength in freestyle swimming [17]. For each stroke, the majority of propulsion is produced during the arm pull phase, which is defined by the arms' strong extension and pull-through motion [18]. Swimmers with strong arm muscles may perform this phase with more force, which increases acceleration and forward motion [19]. Strong leg muscles let swimmers to maximize propulsion and reduce drag in the water with a forceful and reliable flutter kick [20]. Stronger arm and leg muscles also help the swimmer's body remain balanced and stable overall, which promotes more fluid and effective stroke mechanics.

This study aims to investigate the association between freestyle swimming speed, leg muscular strength, and arm muscle strength. Through examining the ways in which these variables interact and impact swimming performance, this research attempts to shed light on the fundamental mechanisms that propel speed enhancement in freestyle swimming [21]. The study aims to ascertain how much arm and leg muscular strength affects a swimmer's capacity to produce propulsion and sustain momentum in the water through a mix of physiological measurements and performance testing [22]. The study also intends to investigate the possible mediating function of other variables in the association between swimming speed and muscular strength, such as technique expertise and body composition [23]. The study intends to provide insight into these linkages in order to guide the development of coaching tactics and focused training interventions that maximize freestyle swimming performance [24]. The arms and legs include the majority of the muscles that contribute significantly to increased freestyle swimming speed. The muscles in the arms, including the pectoralis major, the latissimus dorsi, and the shoulder and chest muscles, are crucial for producing the thrust needed for the pulling and pushing motions [25,26,27,28] . In the meanwhile, the legs' quadriceps, hamstrings, and calf muscles contribute to the force of kicks and the stability of the body during motions [1,29,30]. Through appropriate training, swimmers can enhance their capacity to create speed and maximize performance in freestyle swimming by strengthening and growing these two muscular groups.

Other than that, the study specifically attempts to evaluate how differences in muscle strength levels affect a swimmer's capacity to propel themselves and sustain speed in the water [31]. The study looks at how swimming performance and muscular strength are related in an effort to pinpoint the main elements that improve freestyle swimming speed [32]. The study also intends to investigate possible relationships between technique skill, muscle strength, and other pertinent factors in order to offer a thorough grasp of the factors that influence swimming speed [33]. The ultimate objective is to offer insightful information that can guide training plans, coaching techniques, and

performance-enhancing tactics designed to maximize efficiency and speed in freestyle swimming [34].

Using this data, the study aimed to offer evidence-based suggestions and instructions for improving freestyle swimming coaching methods and training regimens. The study sought to shed light on the relationship between swimming speed, leg and arm muscular strength, and to provide useful strategies for enhancing competitive swimming performance. In order to improve propulsion and stability during the freestyle stroke, the research also sought to emphasize the significance of adding strength-training activities that target both upper and lower body muscle groups. Additionally, by investigating possible relationships between muscular strength, technique competency, and other pertinent variables, the study sought to provide a comprehensive picture of the variables affecting swimming speed. The ultimate objective was to provide evidence-based knowledge to coaches, athletes, and sports professionals so they may improve training regimens and performance results in freestyle swimming competitions.

MATERIAL AND METHODS

Study Design

The aim of this correlational study design is to determine how the independent and dependent variables are related to one another. The 50-meter freestyle swimming speed (Y) is the dependent variable in this study, whereas the independent factors are arm muscle strength (X1) and limb muscle strength (X2).

Subject

A total of 30 male swimmers participated in this research and the subjects were selected using the purposive sampling method. Research subjects received instructions on research procedures and signed an informed consent form.

Procedure

The research sample has completed and filed the research consent form, and before to the start of the study, the researcher gives a description of the goal of the investigation. Push-up, standing board jump, and 50-meter freestyle swimming tests will be used to assess the strength of both arms and legs in 30 swimmers. The test results will be analyzed to discover the relationship between each variable.In the data analysis, numerous correlation tests and contribution tests were used.

Statistical Analysis

To investigate the connection between arm and leg muscular strength and freestyle swimming speed, statistical analysis will be done. The age, height, weight, and BMI of the subjects will all be summed together using descriptive statistics. The strength and direction of the correlations between arm muscular strength, leg muscle strength, and swimming speed will be investigated using Pearson correlation analysis. The degree to which leg and arm muscle strength predict swimming speed can also be ascertained using multiple regression analysis, which accounts for any confounding factors including body composition and technique skill. Training plans and coaching tactics targeted at improving performance in competitive swimming will be informed by these statistical studies, which will offer insightful information on the relationship between arm and leg muscle strength and freestyle swimming speed. For the statistical analysis

in this study, IBM SPSS version 26 was used. To find the mean, standard deviation, and standard error, descriptive tests were performed. Furthermore, the Shapiro-Wilk technique is employed to verify normalcy. If the data is normally distributed then it will continue with the contribution test.

The data analysis technique used multiple correlations.

$$\text{Ry. 12} = \sqrt{\frac{r^2 y_1 + r^2 y_2 - 2ry_1 ry_2 r_{12}}{1 - r^2_{12}}}$$

Information:

Ry12 = Double correlation coefficient

ry1 = Correlation coefficient between x1 and y

ry2 = Sum of correlation coefficients x2and y

r12 = Sum of correlation coefficients x1 and x2. To find out whether what has been calculated through the coefficients is significant or not, a multiple correlation significance test will be carried out using the F-test formula.

$$F = \frac{R^2 / k}{(1 - R^2)/(n - k - 1)}$$

Information:

F = Significant correlation test

R = Multiple Correlation

k = Number of independent variables

n = Number of data

RESULTS

Arm Muscle Strenght (X1)

The Push up Test was used to test arm muscle strength. The results showed that the maximum score was 64 and the lowest score was 20. In addition, the mean (average score) was 36.50 and the standard deviation was 11.755. Several sample results were acquired using the Arm Muscle Strength Test. The frequency distribution table below has more information.

Table 1: Frequency Distribution of Arm Muscle Strength

Interval Class	Frequency	Percentage (%)	Category
20 - 24	5	16,7	Very Low
25 - 29	4	13,3	Low
30 - 34	6	20	Medium
35 - 39	3	10	More than Medium
40 - 44	2	6,7	Good
≥45	10	33,3	Very Good
	30	100%	

5 people (16.7%) have Arm Muscle Strength ranging from 20–24, 4 people (13.3%) ranging from 25–29, 6 people (20%) ranging from 30-34, 3 people (10%) ranging from 35–39, 2 people (6.7%) ranging from 40–44, and 10 people who have a range of more

than 45 times, according to the calculations listed in the table above of 30 samples. based on the arm muscle strength measurement results' average value of 36.50. Ten persons (33.3%) represent the interval class > 45, which has the highest number of samples.

Leg Muscle Strenght (X2)

The Standing Broad Jump Test was used to test leg muscle strength. The results showed that the maximum score was 2.80 and the lowest score was 1.77. Furthermore, it was found that the Standard Deviation was 0.217 and the Mean (average score) was 2.19. The conducted test of limb muscle strength yielded a variety of sample findings. The frequency distribution table below has more information.

Table 2: Frequency Distribution of Leg Muscle Strength

Interval Class	Frequency	Percentage (%)	Category
1,77 – 1,99	5	16,7	Very Low
2,00 – 2,20	10	33,3	Low
2,21 – 2,41	12	40	Medium
2,42 – 2,62	2	6,7	Good
≥ 2,63	1	3,3	Very Good
	30	100%	

5 people (16.7%) have a range of 1.77 - 1.99, 10 people (33.3%) have a range of 2.00 - 2.20, 12 people (40%) have a range of 2.21 - 2.41, 2 people (6.7%) have a range of 2.42 - 2.62, and 1 person (3.3%) has a range of more than 2.63, according to the calculations listed in the table above of the 30 samples. As a result, according to the average value of the leg muscle strength measurement results, which is 2.19, the majority of samples—12 individuals, or 40%—fall into the interval class 2.21–2.41.

50 Meter Freestyle Swimming Speed (Y)

The fastest time recorded during a 50-meter freestyle swimming test was 39 seconds, while the slowest time was 1.08 seconds. In addition, the results showed a mean (average score) of 55.3 and a standard deviation of 7.458. A variety of example results were obtained from the 50-meter freestyle swimming speed test. The frequency distribution table below has more information.

Table 3: Frequency Distribution of 50 Meter Freestyle Swimming Speed

Interval Class	Frequency	Percentage (%)	Category
64 – 68	4	13,3	Very Low
59 – 63	7	23,3	Low
54 - 58	6	20	Medium
49 – 53	8	26,7	More than Medium
44 - 48	2	6,7	Good
39 - 43	3	10	Very Good
	30	100%	

Three individuals (10%) are in the interval class (39–43), two individuals (6.7%) are in the interval class (44–48), eight individuals (26.7%) are in the interval class (49–53), six individuals (20%) are in the interval class (54-58), seven individuals (23.3%) are in the interval class (59–63), and four individuals (13.3%) are in the interval class (64-68), according to the results of the calculation of the 50-meter freestyle swimming speed in swimmers.

DISCUSSION

The results of this study indicate that leg and arm muscle strength are important factors that affect freestyle swimming speed. The findings suggest that there is a positive relationship between swimming speed and arm muscular strength, with individuals who had stronger arms swimming faster. This emphasizes how crucial it is to grow and maintain strong arm muscles in order to improve propulsion and produce power during the freestyle stroke's arm pull phase [35]. A similar positive association between swimming speed and leg muscle strength was also discovered in the study, suggesting that stronger leg muscles are associated with a more potent and effective flutter kick, which aids in maintaining momentum and improving the swimmer's ability to move through the water [32].

Additionally, the results imply that swimming speed is positively impacted by the synergistic interaction between arm and leg muscular strength [36,37]. The quickest swimming times were achieved by those with higher levels of muscle strength in both the arms and legs, highlighting the significance of a well-rounded strength training program that works both upper and lower body muscle groups [38,39]. These findings show that in order to improve their swimming performance, swimmers should concentrate on strengthening all of their muscles rather than just one particular muscle group.

Overall, this study offers insightful information about the connection between muscular strength and freestyle swimming speed, highlighting the significance of including strength-training activities that work the arms and legs in competitive swimmers' training regimens. Swimmers can achieve quicker swimming times by strengthening their arm and leg muscles, which will improve their propulsion and momentum generation abilities [13,40]. These results have applications for athletes and coaches in the form of tailored strength training regimens designed to maximize performance in freestyle swimming competitions.

CONCLUSIONS

It can be concluded that strength is important for optimizing swimming performance. Strong muscles, especially in the arms and legs, help swimmers increase speed. This contributes to improved performance in competitive swimming. A swimmer can achieve his goals in the pool and swim to his maximum ability by including strength training in his training plan. To achieve optimal swimming performance, the study also highlights the need for a balanced approach to strength training, ensuring that the arms and legs receive similar training. Swimmers and coaches should use a series of exercises that focus on the muscles used in the arm pull phase of freestyle and the flutter kick movement. A balanced training program can help swimmers develop their muscles to the maximum, thereby increasing their speed and efficiency in the water.

Furthermore, this research provides in-depth information to athletes, coaches and sports professionals who want to improve their freestyle swimming abilities. Through awareness of the correlation between swimming speed, leg strength, and arm strength, coaches can create customized training programs that target and improve specific muscle groups to maximize performance results. Ultimately, these findings may lead to better training plans and methods for increasing the performance levels of competitive swimmers in freestyle swimming competitions.

Conflicts of Interest

This study does not contain any conflicts of interest.

References

1) Wirth K, Keiner M, Fuhrmann S, Nimmerichter A, Haff GG. Strength training in swimming. *Int J Environ Res Public Health*. 2022;19(9):5369.

2) Khiyami A, Nuhmani S, Joseph R, Abualait TS, Muaidi Q. Efficacy of Core Training in Swimming Performance and Neuromuscular Parameters of Young Swimmers: A Randomised Control Trial. *J Clin Med*. 2022;11(11). doi:10.3390/jcm11113198

3) Jakubczyk N, Zwierzchowska A, Maszczyk A. Core stability training and young para-swimmers' results on 50 meters and 100 meters freestyle. *Balt J Heal Phys Act*. 2019;11(4):28-36. doi:10.29359/BJHPA.11.4.04

4) Lanos MEC, Ihsan N, Okilanda A, Handayani W, Manullang JG, Lestari H. Effectiveness of Interactive Multimedia Supported Physical Education Using Jurus Tunggal Tangan Kosong in the New Normal Era. *Int J Hum Mov Sport Sci*. 2023;11(2):261-267. doi:10.13189/saj.2023.110201

5) Born DP, Stöggl T, Petrov A, Burkhardt D, Lüthy F, Romann M. Analysis of freestyle swimming sprint start performance after maximal strength or vertical jump training in competitive female and male junior swimmers. *J Strength Cond Res*. 2020;34(2):323-331.

6) Diversi T, Franks-Kardum V, Climstein M. The effect of cold water endurance swimming on core temperature in aspiring English Channel swimmers. *Extrem Physiol Med*. 2016;5(1):1-12. doi:10.1186/s13728-016-0044-2

7) Özçadirci A, Öztürk F, Cinemre ŞA, Kınıklı Gİ. Muscle strength evaluation of limb dominance in prepubescent swimmers boys and girls. *Balt J Heal Phys Act*. 2021;13(3):23-30. doi:10.29359/BJHPA.13.3.03

8) Marani IN, Subarkah A, Octrialin V. The effectiveness of core stability exercises on increasing core muscle strength for junior swimming athletes. *Int J Hum Mov Sport Sci*. 2020;8(6):22-28. doi:10.13189/saj.2020.080704

9) Ozeker KY, Bilge M, Yildirim Kose DS. The effect of dry-land training on functional strength and swimming performance of 10-12 years old swimmers. *Prog Nutr*. 2020;22(September). doi:10.23751/pn.v22i2-S.10615

10) Marques MC, Yáñez-García JM, Marinho DA, González-Badillo JJ, Rodríguez-Rosell D. In-season strength training in elite junior swimmers: the role of the low-volume, high-velocity training on swimming performance. *J Hum Kinet*. 2020;74(1):71-84.

11) Ihsan N, Hanafi R, Sepriadi, Okilanda A, Suwirman, Mario DT. the Effect of Limb Muscle Explosive Power, Flexibility, and Achievement Motivation on Sickle Kick Performance in Pencak Silat Learning. *Phys Educ Theory Methodol*. 2022;22(3):393-400. doi:10.17309/tmfv.2022.3.14

12) Neldi DH. Hand-Eye Coordination and Arm Muscles Explosive Power to Basketball Player's Shooting. *Int J Psychosoc Rehabil*. 2020;24(5):728-733. doi:10.37200/ijpr/v24i5/pr201740

13) Jones J V, Pyne DB, Haff GG, Newton RU. Comparison Between Elite and Subelite Swimmers on Dry Land and Tumble Turn Leg Extensor Force-Time Characteristics. *J strength Cond Res*. 2018;32(6):1762-1769. doi:10.1519/JSC.0000000000002041

14) Evans S, Gahreman D. The Influence of a Supervised and Unsupervised Strength and Conditioning Program for Elite Adolescent Freestyle Swimmers. *Res Directs Strength Perform*. 2023;3(1):1-10. doi:10.53520/rdsp2023.10594

15) Muniz-Pardos B, Gomez-Bruton A, Matute-Llorente A, et al. Nonspecific resistance training and swimming performance: strength or power? A systematic review. *J Strength Cond Res*. 2022;36(4):1162-1170.

16) Gemaini A, Kiram Y, Syahrastani, Ashmawi U, Zakaria J, Purnomo E. Plyometric training method potentially increasing explosive power of swimmer's leg muscles compared to untrained swimmer's. *J Phys Educ Sport*. 2023;23(12):3183-3188. doi:10.7752/jpes.2023.12363

17) Tsunokawa T, Mankyu H, Takagi H, Ogita F. The effect of using paddles on hand propulsive forces and Froude efficiency in arm-stroke-only front-crawl swimming at various velocities. *Hum Mov Sci*. 2019;64(June 2018):378-388. doi:10.1016/j.humov.2019.03.007

18) Amaro NM, Marinho DA, Marques MC, Batalha NP, Morouço PG. Effects of Dry-Land Strength and Conditioning Programs in Age Group Swimmers. *J strength Cond Res*. 2017;31(9):2447-2454. doi:10.1519/JSC.0000000000001709

19) Mardesia P, Dlis F, Sukur A, Rusdi, Abdillah. Effectiveness of teaching style: An alternative breaststroke swimming learning model in higher education. *Int J Hum Mov Sport Sci*. 2021;9(6):1236-1243. doi:10.13189/saj.2021.090618

20) Matitaputty J. The Relationship Between Leg Muscle Strength, Arm Muscles and Confidence With 50 Meter Freestyle Swimming Speed. *Int J Educ Inf Technol Others*. 2023;6(2):149-164.

21) Jocellyn J, Lesmana SI, Amir TL, Wahyuddin W. The Relationship between Leg Muscle Explosive Power and Swimming Speed of 50-Meter Breaststroke Sprint Athlete. In: *Academic Physiotherapy Conference Proceeding*. ; 2022:102-110.

22) Schumann M, Notbohm H, Bäcker S, Klocke J, Fuhrmann S, Clephas C. Strength-training periodization: No effect on swimming performance in well-trained adolescent swimmers. *Int J Sports Physiol Perform*. 2020;15(9):1272-1280. doi:10.1123/IJSPP.2019-0715

23) Genc H, Cigerci AE, Üniversitesi K, Genç H, Ciğerci AE. The Effect of the Core Exercises on Body Composition, Selected Strength and Performance Skills in Child Soccer Players The Evaluation of Some Physical and Motor Features of The Female and Male Students Aged 12-14 Who Participated in Sports or Not View pro. *Int J Appl Exerc Physiol www.ijaep.com*. 2020;9(6):108-116.

24) Ihsan N, Bafirman, Sujana A, Permana AY. Design of Instrument Explosive Power Leg Muscles Sensor Based. *J Phys Conf Ser*. 2020;1594(1). doi:10.1088/1742-6596/1594/1/012038

25) Crowley E, Lyons M, Harrison AJ. The Specificity of Dry-land Resistance Training Exercises to Swimming Performance. Published online 2022.

26) Feijen S, Tate A, Kuppens K, Struyf T, Claes A, Struyf F. Intrarater and interrater reliability of a passive shoulder flexion range of motion measurement for latissimus dorsi flexibility in young competitive swimmers. *J Sport Rehabil*. 2020;29(6):855-858.

27) Matsuura Y, Fujimoto T, Koizumi K, Mise T, Edama M, Shimoyama Y. Posterior deltoid shoulder tightness and greater contralateral lower limb muscle strength are associated with swimmers' shoulder pain. *J Sci Med Sport*. 2023;26(12):694-699.

28) Lim B, Swafford AP, Conroy KE, Mercer JA. Shoulder Muscle Activity While Swimming in Different Wetsuits and Across Different Paces. *Int J Exerc Sci*. 2023;16(1):172.

29) Cañas-Jamett R, Figueroa-Puig J, Ramirez-Campillo R, Tuesta M. Plyometric training improves swimming performance in recreationally-trained swimmers. *Rev Bras Med do Esporte*. 2020;26:436-440.

30) Takahisa Ide MA, Johnson WF, Takise S, et al. The Effects of Breaststroke Kick Electromyography Muscle Activity. *Psychology*. 2021;11(8):363-368.

31) Button C, Button AJ, Jackson A marie, Cotter JD, Maraj B. Teaching Foundational Aquatic Skills to Children in Open Water Environments Teaching Foundational Aquatic Skills to Children in Open Water Environments. 2020;13(1).

32) Zemková E. Strength and Power-Related Measures in Assessing Core Muscle Performance in Sport and Rehabilitation. *Front Physiol*. 2022;13(May):1-15. doi:10.3389/fphys.2022.861582

33) Cengizel E, Dölek BE. Investigation of the Relationship between Maximal Strength and Swimming Performance in Adolescent Swimmers. *Int J Appl Exerc Physiol*. 2020;9(3):89-97.

34) Morais JE, Forte P, Nevill AM, Barbosa TM, Marinho DA. Upper-limb kinematics and kinetics imbalances in the determinants of front-crawl swimming at maximal speed in young international level swimmers. *Sci Rep*. 2020;10(1):11683.

35) Okada T, Huxel KC, Nesser TW. Relationship between core stability, functional movement, and performance. *J Strength Cond Res*. 2011;25(1):252-261.

36) Ji MY, Yoon JH, Song KJ, Oh JK. Effect of dry-land core training on physical fitness and swimming performance in adolescent elite swimmers. *Iran J Public Health*. 2021;50(3):540-549. doi:10.18502/ijph.v50i3.5595

37) Gemaini A, Kiram Y, Komaini A, et al. The influence of IQ, emotional and spiritual perceptions on sports participation in an effort to improve physical health. *Sport TK-EuroAmerican J Sport Sci*. 2024;13(SE-). doi:10.6018/sportk.579071

38) Oliveira M, Henrique RS, Queiroz DR, Salvina M, Melo W V., Moura dos Santos MA. Anthropometric variables, propulsive force and biological maturation: A mediation analysis in young swimmers. *Eur J Sport Sci*. 2021;21(4):507-514. doi:10.1080/17461391.2020.1754468

39) Zemková E, Zapletalová L. The role of neuromuscular control of postural and core stability in functional movement and athlete performance. *Front Physiol*. 2022;13:796097.

40) Gülbin C, Mardin E, Üniversitesi A, et al. The Effect of 8-Week Core Exercises Applied to 10-12 Age Male Swimmers on Swimming Performance. *Int J Appl Exerc Physiol*. 2020;9(3):2322-3537. doi:10.26655/IJAEP.2020.3.22