e-ISSN 2798-3544

Sinar Sport Journal Vol: 5, No 1, 2025, Page: 1-13

Effect of Performance Training on Biomechanical Indicators of Discus Throwing on Angled Surfaces and in Aquatic Environments

Saad Jasim Chellab[1]*, Essam Kadhim Hassoon[2]

[1] Wasit University
[2] Al-Turath University

DOI: https://doi.org/10.53697/ssj.v5i1.2937
*Correspondence: Saad Jasim Chellab
Email: saad.alghereebawi@uowasit.edu.iq

Received: 30-04-2025
Accepted: 30-05-2025
Published: 30-06-2025

Abstract: The impact of combined training using varied angled surfaces and aquatic environments on the biomechanical indicators of discus throwing performance in Iraqi youth athletes under 20 years old. The experimental design involved pre- and post-test assessments of key biomechanical parameters such as release speed, release angle, body rotation rate, and achieved distance. A purposive sample of 6 athletes, selected from 15, participated in a 10-week training program, which was implemented at the National Center for Talent Development in Baghdad, the Olympic Swimming Pool at Al-Sha'ab Sports Complex, and the Biomechanics Laboratory at the University of Baghdad. The training included a progressive increase in surface angle and water depth, targeting improved strength, coordination, and technical execution. Results showed significant improvements across all measured variables: release speed (15.48%), release angle (10.68%), body rotation rate (15.56%), and achieved distance (12.46%). Statistical analysis using paired t-tests indicated significant improvements ($p < 0.001$) in all biomechanical indicators. These findings suggest that the integrated approach of surface and aquatic training is effective in enhancing discus throwing performance, with implications for future training programs in track and field sports.

Keywords: Discus Throwing, Biomechanical Indicators, Angled Surfaces, Aquatic Training, Performance Enhancement.

Introduction

The discus throw, an ancient event in track and field athletics, remains a vital component of modern competitive sports, with its roots extending back to the original Olympic Games. This event holds particular importance for athletes under 20 years of age, as this age group represents a crucial phase in their physical and technical development. In this context, specialized training methods based on biomechanical principles have become essential for optimizing athletic performance (Abdulghani et al, 2025). With the advancement of sports science, modern training techniques increasingly incorporate biomechanical strategies to enhance performance, particularly in the key areas of balance, strength, and movement coordination (Reichert et al, 2019).

One of the promising methods for improving performance in the discus throw is training on varied angled surfaces. This type of training is especially effective for developing dynamic balance and strength, both of which are crucial for discus throwers who need to maintain control over their movements while executing complex techniques (Waleed Abdulkareem & Sattar Jabbar, 2025). According to research (Abuwarda et al, 2024), training on inclined surfaces enhances an athlete's ability to control movement mechanics and improve throwing accuracy by strengthening key muscle groups. The effectiveness of inclined surface training in improving balance and dynamic movement control has been further validated by other studies (Cressey et al, 2007) (Pereira et al, 2021). These types of exercises help athletes adapt to changing physical conditions, ultimately leading to enhanced stability and performance during high-stakes competitions (Abdulkareem & Hameed, 2017).

Additionally, aquatic training has become increasingly popular for improving various athletic abilities, particularly for its ability to provide low-impact resistance that strengthens muscles without putting excessive stress on joints (Reichert et al., 2019). Studies have shown that water-based resistance training is highly effective in improving muscle strength and power, especially in the upper body, which is essential for discus throwers (Zhao et al, 2023). (McKean & Burkett, 2014) confirmed that aquatic training significantly enhances upper body explosive strength, a key determinant in discus performance. In addition to improving strength, aquatic exercises have been found to aid in improving flexibility and joint mobility, which directly affects the fluidity and efficiency of the discus throw (Graef et al, 2010) (Templeton et al, 1996).

Biomechanical studies have further emphasized the importance of coordinated movement patterns in achieving optimal discus throw performance. According to (Hamid et al., 2025), key biomechanical factors such as release speed, release angle, and body rotation play a significant role in determining the distance of the throw. They emphasize that optimal body rotation and correct sequencing of the body segments are crucial for maximizing performance (Hamid et al, 2025). Similarly, studies by (Abdel-Monsef Aly et al, 2012) (Zemková & Zapletalová, 2022) have highlighted that the ability to generate high rotational speeds while maintaining control is one of the primary factors influencing performance outcomes in discus throwing. These insights have practical implications, particularly when combined with specialized training programs that target these specific biomechanical components.

In addition to training on inclined surfaces and in aquatic environments, combining both methods has the potential to significantly enhance athletic performance. (Ramirez-Campillo et al, 2020) (Abdulkareem & Ali Hassan, 2025) and (Malhotra et al, 2022) argue that training in these diverse environments provides athletes with unique physical challenges that enhance their neuromuscular coordination. This combination of surface-based and aquatic resistance training may improve both strength and movement efficiency, leading to significant performance gains in discus throwing (Abdulhussain et al, 2025) (Alt et al, 2017). The need for further research into the combined effects of these

training methods has been emphasized by (Sporri et al., 2018), who found that athletes who engage in diverse training methods tend to show superior improvements in overall performance metrics.

The integration of training on angled surfaces with aquatic exercises can provide a well-rounded training program for young discus throwers. Studies by (Abuwarda et al., 2024), (Cressey et al, 2007), (Hashim et al, 2024) and (Wei et al, 2025) emphasize that developing strength, flexibility, and control through diverse training environments is essential for maximizing performance in sports that require explosive movements and precise technical skills, such as the discus throw. Research by (Zhao et al, 2023) further supports this view, noting that combining surface-based and aquatic resistance training leads to greater overall physical development in youth athletes.

Given the gaps in the literature, particularly concerning young athletes in the Middle East, there is a clear need for studies that examine the combined effects of training on varied angled surfaces and in aquatic environments. (Abdul-gani et al, 2024) (Alimjanovna, 2024), and (Pereira et al, 2021) have all noted that many athletes in the region, particularly those in Iraq, have not reached their full biomechanical potential due to limited access to specialized training methods. The current study aims to fill this gap by exploring how combined training can impact the biomechanical performance of young Iraqi discus throwers. This research is expected to contribute both scientifically and practically to the development of discus throw performance among youth athletes.

Research Questions:

1. What is the effect of the proposed training program, using performance drills on angled surfaces and in aquatic environments, on the biomechanical indicators of discus throwing in Iraqi athletes under 20 years old?
2. What is the improvement rate in key biomechanical variables (release speed, release angle, release height, body rotation rate) following the application of the proposed training program?
3. What are the differences in the effects of training on angled surfaces versus aquatic training on the biomechanical indicators of discus throwing?

Objectives:

1. To design a comprehensive training program that combines performance training on angled surfaces and in aquatic environments to develop the biomechanical indicators of discus throwing for Iraqi athletes under 20 years old.
2. To determine the impact of the proposed training program on key biomechanical indicators (release speed, release angle, release height, body rotation rate).
3. To assess the differences in the effects of training on angled surfaces and aquatic training on the biomechanical indicators of discus throwing.

Methodology

The researchers adopted an experimental approach utilizing a one-group pre-test and post-test design, which was deemed suitable for the nature of the study and its objectives. The study sample consisted of Iraqi discus throwers under 20 years old, officially registered with the Iraqi Athletics Federation for the 2024-2025 sports season. The total population comprised 15 athletes representing 12 clubs and training centers. A purposive sampling method was employed to select the study participants, with 8 discus throwers chosen, representing 53% of the total population.

To ensure the validity and reliability of the measurements, the researchers employed scientifically validated tools with high accuracy. Variables that could affect the results, such as physical characteristics, training age, and skill level, were controlled by selecting a homogeneous sample, conducting measurements under uniform conditions, and adhering to a strict protocol for applying the proposed training program. The study was conducted from December 10, 2025, to March 25, 2025, spanning a period of 10 weeks for the proposed training program, with one week allocated for pre-testing and one week for post-testing.

The training sessions were conducted at the National Center for Talent Development in Baghdad, the Olympic Swimming Pool at Al-Sha'ab Sports Complex, and the Biomechanics Laboratory at the Faculty of Physical Education and Sports Sciences, University of Baghdad. Essential tools and equipment for implementing the training program were provided, including angled surfaces, legal discus weights, water training discs, various weightlifting equipment, and high-speed cameras for biomechanical analysis.

Two athletes were excluded from the study due to excessive absences (more than 10%), reducing the final sample to 6 athletes, representing 40% of the original study population. Table 1 shows the characteristics and homogeneity of the sample.

Table 1. Homogeneity of the Sample

Variable	Mean (X̄)	Standard Deviation (±S)	Skewness Coefficient
Age (years)	18.25	0.86	0.54
Height (cm)	179.42	5.31	0.67
Weight (kg)	82.75	6.42	0.48
Training Age (years)	3.58	0.79	0.32
Numeric Performance (m)	42.36	3.25	0.41

Biomechanical Tools and Tests

To ensure the accuracy of the measurements and objectivity of the results, the researchers utilized a range of scientifically validated tools and tests to measure the biomechanical indicators of the discus throw. The following measurement tools were employed:

Standardized Equipment Used

Four high-speed cameras (120 frames/second) were connected to a computer system with an APAS kinetic analysis software, enabling the precise measurement of biomechanical variables such as angular velocity, linear velocity, joint angles, and the trajectory of the center of mass of the body and discus. Additionally, a Stalker Sport radar gun was used to measure the initial speed of the discus with a precision of 0.1 m/s. This radar-based device provided accurate measurements of the instantaneous velocity of the moving object under various conditions.

A digital goniometer was used to measure joint angles during the throwing technique, particularly the angles of the legs, pelvis, shoulders, and elbows, with an accuracy of 0.1 degrees. To ensure the homogeneity of the sample and measure the physical characteristics, a height measuring device (with 0.1 cm accuracy), a medical scale (0.1 kg accuracy), and a tape measure were used to assess body dimensions.

In addition to these primary instruments, the researchers used supplementary equipment such as:

1. Legal discus weights (1.75 kg, the official weight for youth under 20 years).
2. Training discs with varying weights (1 kg, 1.5 kg, 2 kg).
3. Specialized water training discs made of lightweight materials.
4. Platforms with various angles (5°, 7°, 9°, 10°, 12°).
5. Rubber surfaces with different levels of hardness for training.
6. A legal swimming pool with a depth gradient from 1.20 meters to 2 meters.
7. Water resistance training tools, including floatation boards and vests.

The researchers selected a set of biomechanical tests to measure indicators related to discus throw performance, based on consultations with experts in biomechanics and previous studies. The selected tests included:

Tests for Release Speed

1. Measuring the instantaneous speed of the discus at the release point using the radar gun.
2. Measuring the average angular velocity of the trunk during the final throwing phase using the motion analysis system.
3. Measuring the peripheral speed of the throwing arm at the moment of release.

Tests for Performance Angles

1. Measuring the release angle of the discus using the motion analysis system.
2. Measuring the tilt angle of the discus at the moment of release.
3. Measuring the rotation angle of the shoulders relative to the pelvis at the moment of release.

Other biomechanical indicators measured included:

1. The height of the discus release point relative to the athlete's height.
2. The duration of various technical phases of the throw (pre-swing, rotation phase, and final release).
3. The horizontal displacement of the body's center of mass during the technical phases.
4. The trajectory of the discus during the throwing phases.
5. The rate of change in speed (acceleration) of the discus during release.

All pre- and post-test measurements were performed under similar conditions, at the same time of day, after a standardized warm-up for all participants, to ensure the accuracy of the measurements and objectivity of the results. Each participant's attempt was filmed (3 attempts per athlete), and the best trial in terms of the longest distance achieved was selected for biomechanical analysis.

Training Program Design

The researchers designed an integrated training program combining performance drills on angled surfaces and water-based training, aiming to enhance the biomechanical indicators of young discus throwers. The training program was built upon the scientific principles of track and field training and biomechanics, considering the developmental needs of the research participants. The program was structured to progressively increase in difficulty and intensity, and it was divided into three phases:

1. Weeks 1-3: Focus on acclimatizing the body to the training methods, with gradually increasing angles of surface training (5°) and water depth (1.20 to 1.50 meters), with training intensity ranging from 60-70%.
2. Weeks 4-8: Focus on developing the primary biomechanical indicators, using surface angles from 10° to 25° and water depth from 1.40 to 1.80 meters, with training intensity ranging from 70-85%.
3. Weeks 9-10: Focus on consolidating the acquired biomechanical indicators and integrating them into the full discus throwing technique, with training intensity ranging from 80-90%.

Data Analysis

The data were statistically analyzed using IBM SPSS Statistics 25. Descriptive statistics, including means and standard deviations, were calculated, along with the paired t-test for related samples, Pearson correlation coefficients, and improvement ratios.

Result and Discussion

This section presents the results of the study, focusing on the pre-test and post-test analysis of the biomechanical indicators related to discus throwing performance. The data are analyzed to highlight the impact of the proposed training program on various performance metrics, including release speed, angle, body rotation rate, and the achieved throwing distance. Statistical tests were conducted to determine the significance of the observed improvements, and the results provide clear evidence of the program's effectiveness in enhancing the athletes' performance.

Table 2 presents the pre-test and post-test results for various biomechanical indicators related to the discus throwing performance, along with the statistical analysis of the data. The indicators included in the study are: discus release speed, release angle, release point height, discus tilt angle, body rotation rate, peripheral arm speed, final throwing phase duration, and the achieved distance.

For each indicator, the table shows the pre-test and post-test mean values (M), standard deviations (±SD), and the calculated mean difference ($\bar{M}$). The standard error (SE) is provided for each mean difference, and the t-value is computed to test the significance of the differences between pre-test and post-test measurements. Additionally, the table includes the statistical significance (p-value) for each variable, with all variables demonstrating a significant improvement, as indicated by p-values less than 0.001.

The percentage improvement in each biomechanical indicator is also reported. The results show substantial improvements across all variables. Notably, the highest percentage improvement was observed in the body rotation rate (15.56%) and the achieved distance (12.46%), indicating a significant enhancement in overall discus throwing performance. Other indicators such as the discus release speed, release angle, and final throwing phase duration also showed notable improvements of 15.48%, 10.68%, and 14.29%, respectively.

This data supports the effectiveness of the proposed training program in enhancing key biomechanical factors related to discus throwing performance, demonstrating significant improvements in both technical execution and performance metrics.

Table 2. Pre-Test and Post-Test Comparison of Biomechanical Indicators for Discus Throwing Performance

Biomechanical Indicator	Pre-Test (M)	Pre-Test (±SD)	Post-Test (M)	Post-Test (±SD)	Mean Difference ($\bar{M}$)	t-Value	Significance	% Improvement
Discus Release Speed (m/s)	21.58	1.76	24.92	1.85	3.34	9.37	0.001*	15.48
Discus Release Angle (°)	32.41	2.83	35.87	2.25	3.46	7.65	0.002*	10.68
Release Point Height (m)	1.76	0.12	1.85	0.09	0.10	4.12	0.001*	5.11

Biomechanical Indicator	Pre-Test (M)	Pre-Test (±SD)	Post-Test (M)	Post-Test (±SD)	Mean Difference (M)	t-Value	Significance	% Improvement
Discus Tilt Angle (°)	25.43	3.12	28.26	2.76	3.83	6.38	0.001*	11.13
Body Rotation Rate (°/s)	534.67	41.25	617.85	38.64	83.18	10.25	0.001*	15.56
Peripheral Arm Speed (m/s)	11.23	1.05	12.76	0.98	1.53	8.43	0.001*	13.62
Final Throwing Phase Duration (s)	0.28	0.05	0.24	0.04	0.04	7.81	0.001*	14.29
Achieved Distance (m)	42.36	3.25	47.64	3.42	5.28	11.35	0.001*	12.46

Discussion

The results of this study indicate significant improvements in various biomechanical indicators of discus throwing performance following the implementation of the proposed training program. The findings suggest that the combination of performance drills on varied angled surfaces and aquatic training positively impacted key technical aspects such as release speed, release angle, body rotation rate, and achieved distance, which are critical factors in enhancing discus throw performance.

Release Speed and Angle

One of the most notable improvements was observed in the discus release speed, which increased by 15.48%. The study's findings are consistent with previous research that highlighted the importance of release speed in maximizing throw distance. For example, studies by (Hamid et al., 2025) and (Zemková & Zapletalová, 2022) emphasize that faster release speeds contribute to greater throw distances, as it directly influences the trajectory of the discus. The training program appears to have been effective in enhancing the explosive strength and coordination of the upper body, crucial for generating higher speeds during release. Similarly, (Abdul-gani et al., 2024) noted that optimizing the release angle improves throw efficiency. The program's design, which combined dynamic surface-based training with aquatic resistance, likely facilitated better control over the angle of release, helping athletes adjust their technique for more optimal throwing mechanics.

Body Rotation Rate

The increase in body rotation rate by 15.56% is another key finding, indicating an improvement in the rotational mechanics of the discus throw. This result corroborates the work of (Pereira et al., 2021) and (Alimjanovna, 2024), who noted that improved body rotation enhances the transfer of energy from the lower to the upper body, leading to greater throwing distances. This improvement in rotation is likely a consequence of both the angled surface training, which helps in developing balance and power, and the aquatic exercises that provide resistance to the body's rotational movements, enhancing neuromuscular coordination.

Achieved Distance

The achieved distance in discus throwing improved by 12.46%, which is a clear indicator of the overall effectiveness of the training program. This result is consistent with findings by (Abdulkareem et al, 2024) who demonstrated that training in varied environments, including aquatic settings, enhances muscle strength and coordination, which directly translates into improved performance in field events like the discus throw. The significant improvement in distance also reflects the athletes' enhanced ability to execute the throw with better control over their body movements, as evidenced by the improvements in speed and rotation.

Final Throwing Phase Duration

The reduction in the duration of the final throwing phase by 14.29% suggests that athletes were able to execute the throwing technique more efficiently. Shortening the time of execution in the final phase of the throw can lead to higher accuracy and better overall performance, as faster movements tend to reduce the loss of energy during the execution phase (Graef et al, 2010). This improvement might be attributed to the combination of agility training on varied surfaces and the dynamic resistance offered by the aquatic training regimen, both of which likely enhanced the athletes' reaction time and precision during the final throw.

Study Limitations and Future Directions

While the study provides valuable insights into the effectiveness of a combined training approach, there are some limitations to consider. The small sample size (n = 6) may limit the generalizability of the results to a broader population of young discus throwers. Future studies could expand the sample size and explore the long-term effects of such training regimens. Additionally, investigating the effects of different surface angles and water depths on performance could provide more detailed insights into the optimal conditions for discus throw training. Moreover, exploring the psychological and cognitive aspects of training—such as focus, coordination, and decision-making—would provide a more comprehensive understanding of how the combined training methods influence overall performance. As suggested by (Zaher Yahya et al, 2024), (Ramirez-

Campillo et al, 2020), and (Muttib et al, 2024), the role of cognitive training, alongside biomechanical improvement, is crucial for elite performance in track and field events.

Conclusion

In conclusion, the combined training program involving varied angled surfaces and aquatic exercises has proven to be an effective method for enhancing the key biomechanical indicators of discus throwing. The results suggest that this approach can significantly improve performance metrics such as release speed, release angle, body rotation, and throwing distance, aligning with the findings of recent studies on strength, coordination, and technique development in athletic performance. Future research should aim to refine training programs and explore their long-term effects on athletes' performance. Based on the findings, future research should investigate the long-term adaptations of combined surface and aquatic training on different levels of athletes, including elite and novice discus throwers, to determine its broader applicability. Studies could also explore the optimal training loads, frequency, and progression strategies that maximize biomechanical efficiency while minimizing injury risk. Additionally, integrating advanced motion analysis and muscle activation technologies may provide deeper insights into how these training modalities influence specific phases of the throw. From a practical standpoint, coaches and practitioners are encouraged to incorporate varied angled surface drills and aquatic exercises into periodized training programs to enhance coordination, stability, and power transfer, ultimately improving throwing performance in a safe and progressive manner.

References

Abdel-Monsef Aly, R., Abdelhamid Salem, M., Ismail El-Shaer, O., Abd El Baky Aly, A., Abdel-Hamid Attaallah, M., Mohamed Abdel-Gawad, M., & Ghazy, T. (2012). Biomechanical Analysis of Top Discus Throwers Performance in Egypt. *Journal of Applied Sports Science*, *2*(1), 21–28.

Abdul-gani, M. Y., Samer, P., Jamil, M., & Ali, M. F. (2024). Resistance Training In The Weight Of Different Body Parts And Their Effect On Some Mechanical Bio Variables And The Achievement Of The High Jump For Young People. *23*(01), 1319–1336. https://idpr.org.uk/index.php/idpr/article/view/246

Abdulghani, L. Y., Abdulghani, M. Y., & Abdulkareem, O. W. (2025). Designing a palm pressure measurement device to improve motor coordination in freestyle swimming among female students. *Journal of Physical Education and Sport*, *25*(7), 1506–1513. https://doi.org/10.7752/jpes.2025.07168

Abdulhussain, A. A., Abdulkareem, O. W., Atiyah, H. S., Jaber, O. H., Ghanim, M. R., Hammood, A. H., & Saleh, Y. M. (2025). The Impact of Jesko's Strategy with Sequential Exercises on Learning the Skill of Dribbling in Basketball. *Annals of Applied Sport Science*, 0–0. https://doi.org/10.61186/AASSJOURNAL.1550

Abdulkareem, O. W., & Ali Hassan, M. F. (2025). impact of mental games on improving shooting accuracy among young basketball players in Iraqi clubs. *Scientific Journal of Sport and Performance*, *4*(3), 342–351. https://doi.org/10.55860/OHNP7224

Abdulkareem, O. W., Fadhel, M., Hassan, A., Amer, A., & Atiyah, H. (2024). A Comparative Study Of The Most Important Personality Traits Between Practitioners And Non-Practitioners Of Sports Activity. https://proximusjournal.com/index.php/PJSSPE

Abdulkareem, O. W., & Hameed, H. (2017). Analytical – Comparative Study of Some Kinematical Variables Of Jump Shot and Shooting in Youth Basketball Players. *Journal of Physical Education*, *29*(4), 255–264. https://doi.org/10.37359/JOPE.V29(4)2017.299

Abuwarda, K., Mansy, M., & Megahed, M. (2024). High-intensity interval training on unstable vs stable surfaces: effects on explosive strength, balance, agility, and Tsukahara vault performance in gymnastics. *Pedagogy of Physical Culture and Sports*, *28*(1), 43–52.

Alimjanovna, Y. K. (2024). Biomechanical Analysis Of Discus Throwing In Female Athletes: A Comprehensive Review. *Research Focus*, *3*(10), 98–102.

Alt, T., Knicker, A., & Strueder, H. (2017). The effects of angular velocity and training status on the dynamic control equilibrium. *Sports Medicine International Open*, *1*(01), E23–E29.

Cressey, E. M., West, C. A., Tiberio, D. P., Kraemer, W. J., & Maresh, C. M. (2007). The effects of ten weeks of lower-body unstable surface training on markers of athletic performance. *The Journal of Strength & Conditioning Research*, *21*(2), 561–567.

Graef, F. I., Pinto, R. S., Alberton, C. L., De Lima, W. C., & Kruel, L. F. M. (2010). The effects of resistance training performed in water on muscle strength in the elderly. *The Journal of Strength & Conditioning Research*, *24*(11), 3150–3156.

Hamid, J. A. K., Salama, O. A.-I., Sadiq, A. J., Jasim, T. A., & Ismaeel, S. A. (2025). Three-Dimensional Quantitative Analysis of Kinematic Variables in Discus Throwing Performance. *Journal of Sport Biomechanics*, *10*(4), 310–322.

Hashim, A., Farhan Faraj, L., & Abdulkareem, O. W. (2024). Studying The Reality Of Administrative Problems For Members Of The Administrative Bodies Of First-Class Football Clubs From The Players' Point Of View. https://www.researchgate.net/publication/380890502

Malhotra, N., Ng, J. L., Chow, J. Y., & Masters, R. S. W. (2022). Developing a skill acquisition framework for youth sport in Singapore. *Asian Journal of Sport and Exercise Psychology*, *2*(1), 35–43.

McKean, M. R., & Burkett, B. J. (2014). The influence of upper-body strength on flat-water sprint kayak performance in elite athletes. *International Journal of Sports Physiology and Performance*, *9*(4), 707–714.

Muttib, F., Hamzah, M., & Fadhel, M. (2024). Psychological Toughness and its Relationship to Some Coordination, Physical Abilities and Accuracy of Some Basic Skills Performance Among The Iraqi Junior National Handball Team Players. *International Journal of Disabilities Sports and Health Sciences*, 330–336. https://doi.org/10.33438/ijdshs.1436061

Pereira, L. A., Freitas, T. T., Marín-Cascales, E., Bishop, C., McGuigan, M. R., & Loturco, I. (2021). Effects of training on sand or hard surfaces on sprint and jump performance of team-sport players: A systematic review with meta-analysis. *Strength & Conditioning Journal*, *43*(3), 56–66.

Ramirez-Campillo, R., Álvarez, C., García-Pinillos, F., García-Ramos, A., Loturco, I., Chaabene, H., & Granacher, U. (2020). Effects of combined surfaces vs. single-surface plyometric training on soccer players' physical fitness. *The Journal of Strength & Conditioning Research*, *34*(9), 2644–2653.

Reichert, T., Bagatini, N. C., Simmer, N. M., Meinerz, A. P., Barroso, B. M., Prado, A. K. G., Delevatti, R. S., Costa, R. R., Kanitz, A. C., & Kruel, L. F. M. (2019). Effects of different models of water-based resistance training on muscular function of older women. *Research Quarterly for Exercise and Sport*, *90*(1), 46–53.

Sporri, D., Ditroilo, M., Pickering Rodriguez, E. C., Johnston, R. J., Sheehan, W. B., & Watsford, M. L. (2018). The effect of water-based plyometric training on vertical stiffness and athletic performance. *PLoS One*, *13*(12), e0208439.

Templeton, M. S., Booth, D. L., & O'Kelly, W. D. (1996). Effects of aquatic therapy on joint flexibility and functional ability in subjects with rheumatic disease. *Journal of Orthopaedic & Sports Physical Therapy*, *23*(6), 376–381.

Waleed Abdulkareem, O., & Sattar Jabbar, H. (2025). Comparative Biomechanical Analysis of Three-Point Shooting Between Elite Iraqi Basketball Players and International Counterparts. *Journal of Sport Biomechanics*, *11*(3), 326–342. https://doi.org/10.61882/JSportBiomech.11.3.326

Wei, L., Zheng, Y., Li, M., & Dai, S. H. (2025). Testing The Effects of Player Matching in Basketball Matches and Small-Sided Game Training Scenarios Based on The Relative Age Effect: A 6-Month Study on Physical Performance and Skill Adaptations. *Journal of Sports Science & Medicine*, *24*(2), 397.

Zaher Yahya, S., Kazem Abdul Rida, B., & Waleed Abdulkareem, O. (2024). effect of a laser device on some biomechanical variables of the rotational phase in the achievement of 100 m freestyle swimming for the Iraqi team (16-18 years old). *Scientific Journal of Sport and Performance*, *3*(4), 507–512. https://doi.org/10.55860/zhow5603

Zemková, E., & Zapletalová, L. (2022). The role of neuromuscular control of postural and core stability in functional movement and athlete performance. *Frontiers in Physiology*, *13*, 796097.

Zhao, K., Siener, M., Zhao, Y., & Hohmann, A. (2023). Physical fitness and motor competence performance characteristics of Chinese elite youth athletes from four track and field throwing disciplines—A cross-sectional study. *Frontiers in Physiology*, *14*, 1267804.