Majalah Ilmiah Fisioterapi Indonesia
Indonesian Scientific Journal of Physiotherapy

Original Research Articles
ISSN (Print): 2303-1921
ISSN (Online): 2722-0443
Volume 14, Number 1, Pages 1-5 (2026)
DOI: https://doi.org/10.24843/mifi.000000912

Correlation Between Shoulder Muscle Power and 50-m Freestyle Swimming Speed: A Cross-Sectional Study

Myranti Puspitaningtsya Junaedi[1], Miftahul Nur 'Amaliyah[2], Dini Afriani Khasanah[3], Tazkia Nabila[4], Joko Priono[5]

[1-5]Universitas Panca Bhakti, Pontianak, West Kalimantan, Indonesia

Corresponding author:
Name: Myranti Puspitaningtsya Junaedi
E-mail: myranti.puspita@upb.ac.id

Received 5 November 2025; Revised 24 November 2025; Accepted 24 November 2025; Published 1 January 2026

Abstract
Background: Shoulder muscle power plays a critical role in generating propulsive force during freestyle swimming, particularly over short-distance events in which maximal speed must be achieved within a limited time frame. Although previous studies have examined upper-limb strength in swimmers, evidence on the association between shoulder power and 50-m freestyle performance among swimmers in West Kalimantan remains limited.
Objective: This study aimed to determine the correlation between shoulder muscle power and 50-m freestyle swimming speed among competitive swimmers in West Kalimantan.
Methods: A cross-sectional design was used involving 20 swimmers recruited through purposive sampling from the Bintang Khatulistiwa Swimming Club. Shoulder muscle power was assessed using a 3-kg medicine ball throw test, and 50-m freestyle swimming speed was measured with a stopwatch. All measurements were conducted at Sultan Syarif Abdurrahman Stadium and Oevang Oeray Swimming Pool in February 2024. Spearman's rho was employed to examine the relationship between shoulder muscle power and swimming speed.
Results: A significant negative correlation was found between shoulder muscle power and 50-m freestyle swimming speed ($r = -0.787$, $p < 0.001$), indicating that greater throwing distance was associated with shorter swimming time. These findings suggest that swimmers with higher shoulder muscle power are more capable of producing effective propulsion, thereby achieving faster performance.
Conclusion: Shoulder muscle power is significantly associated with 50-m freestyle swimming speed among competitive swimmers in West Kalimantan. Assessment and enhancement of shoulder power may be valuable for coaches and athletes seeking to optimize sprint freestyle performance.

Keywords
Swimming; Shoulder; Muscle Strength; Physical Fitness; Athletic Performance; Pediatrics

Introduction
Freestyle swimming is a high-velocity aquatic discipline that requires effective coordination of the upper and lower extremities to generate sufficient propulsive force and minimize hydrodynamic resistance. The cyclic rotation of the upper limbs plays a dominant role in producing propulsion, accounting for up to 90% of total movement during freestyle swimming.(1) Efficient arm mechanics, particularly during the pull, push, and recovery phases, determine the swimmer's ability to maintain optimal speed and stroke efficiency. Because of these biomechanical demands, shoulder muscle power becomes one of the most influential physical components contributing to sprint performance in swimming. Shoulder power reflects the ability of the shoulder musculature—including the deltoid, rotator cuff group, and serratus anterior—to rapidly generate force, enabling swimmers to produce strong and explosive arm motions that enhance forward propulsion.(2)

In sprint events such as the 50-m freestyle, maximal effort is required from the start to the finish, making the contribution of shoulder muscle power even more critical compared with longer distances. Short-distance freestyle performance depends heavily on explosive upper-limb actions, rapid stroke turnover, and the capacity to overcome water resistance through powerful arm strokes.(3) Previous studies have reported significant associations between upper-limb strength and freestyle swimming performance, particularly in youth and competitive swimmers.(4–6) However, most existing studies have focused on general upper-limb strength or anthropometric factors, while specific evidence on shoulder muscle power—measured through explosive throwing tasks—remains limited, especially within Indonesian swimmer populations.

Shoulder muscle power is commonly assessed using medicine ball throw tests, which have demonstrated practicality and relevance for evaluating explosive force production in the upper extremity.(7) Greater throwing distance reflects higher capacity for rapid force generation, which theoretically translates into more powerful aquatic propulsion. Theoretically, swimmers with higher shoulder power are capable of generating stronger pull phases, reducing drag, and maintaining faster stroke cycles, all of which contribute to improved sprint performance.(8) Despite its relevance, many regional swimming clubs in Indonesia, including those in West Kalimantan, do not routinely evaluate shoulder power as part of athlete performance monitoring. Preliminary observations conducted at the Bintang Khatulistiwa Swimming Club revealed that systematic assessment of shoulder muscle power had not been previously implemented, highlighting an important gap in athlete profiling and conditioning practices.

Existing literature conducted in Indonesia has primarily explored correlations between arm strength and freestyle performance over shorter distances such as 25 meters.(9) These studies have demonstrated significant relationships, suggesting that upper-limb power contributes meaningfully to swimming velocity. Nevertheless, there remains an absence of research examining the association between shoulder muscle power and 50-m freestyle performance, a distance that places greater emphasis on maximal speed and explosive capability. Furthermore, no study to date has investigated this relationship among swimmers in West Kalimantan, a region where competitive swimming is developing and athlete performance assessment systems are still evolving.

This gap underscores the novelty of the present study, which focuses on a specific sprint distance and introduces shoulder muscle power evaluation into a population that has not previously been examined using this approach. Given that the 50-m freestyle requires peak performance within a very short time, understanding how shoulder power contributes to swimming velocity is essential for developing targeted conditioning programs for local athletes. Additionally, identifying this relationship may help coaches design evidence-based training strategies to enhance competitive performance, improve athlete selection, and reduce the risk of overuse injuries associated with insufficient shoulder conditioning.

Therefore, the present study aims to investigate the correlation between shoulder muscle power and 50-m freestyle swimming speed among competitive swimmers in West Kalimantan. Based on biomechanical principles and prior evidence, we hypothesize that greater shoulder muscle power will be significantly associated with faster 50-m freestyle performance, reflected by shorter completion times.

Methods

This study employed a quantitative analytical approach using a cross-sectional design to examine the association between shoulder muscle power and 50-m freestyle swimming speed among competitive swimmers in West Kalimantan. The cross-sectional framework was selected because it allows simultaneous measurement of exposure (shoulder muscle power) and outcome (swimming speed), enabling the identification of correlational relationships within a defined population at a single point in time. This design is appropriate for exploratory research in athletic performance monitoring, where temporal intervention is not required and where the primary objective is to determine the strength and direction of associations among variables.

The study population consisted of swimmers registered with the Bintang Khatulistiwa Swimming Club in Pontianak, West Kalimantan. Participants were recruited using purposive sampling based on predefined eligibility criteria to ensure homogeneity and relevance to the research question. Eligible participants were male or female swimmers aged ≥10 years who had been actively training with the club for at least two years and demonstrated cooperative behavior during data collection. Swimmers were excluded if they had a history of shoulder injury or lower-extremity injury that could interfere with performance during testing. These criteria ensured that the participants were physically able to participate safely and that the measurements obtained were not influenced by underlying musculoskeletal conditions. A total of 20 swimmers met the criteria and were included in the final analysis. The sample size was considered adequate based on guidelines for correlational studies, which recommend a minimum of 15 participants for detecting moderate to strong associations. Additionally, previous studies investigating muscle power and swimming performance have utilized similar sample sizes, supporting the feasibility of the present study.

Data collection took place in February 2024 at two locations relevant to athlete training activities: the Sultan Syarif Abdurrahman Stadium for the muscle power assessment and Oevang Oeray Swimming Pool for the swimming performance test. Both facilities provided standardized environments suitable for consistent measurement. The procedures were conducted at similar times of day to minimize temporal variations in athlete performance and environmental conditions. Participants underwent a standardized warm-up protocol consisting of light aerobic activity, dynamic stretching, and shoulder-specific mobility exercises to reduce injury risk and ensure consistent readiness across all subjects.

Shoulder muscle power was assessed using a 3-kg medicine ball throw test, a widely used and practical measure of upper-extremity explosive force. Its reliability has been documented in athletic populations, with intraclass correlation coefficients (ICC) exceeding 0.85, indicating high test–retest reliability. For this assessment, participants stood in a semi-squat position with feet shoulder-width apart and the medicine ball held at chest level. They were instructed to perform a maximal two-handed overhead forward throw, projecting the ball as far as possible. The throw was executed behind a marked baseline to ensure consistent starting position, and participants were reminded to maintain both feet grounded to avoid stepping forward. Each participant performed three attempts with 60 seconds of rest between trials to minimize fatigue accumulation. The longest distance achieved, measured in centimeters using a calibrated measuring tape from the baseline to the first point of contact of the ball, was recorded as the final score. Two researchers independently observed the test to ensure consistency and reduce measurement bias.

Fifty-meter freestyle swimming speed was measured in a 25-meter standardized pool, where swimmers completed two pool lengths to total a distance of 50 meters. Timing procedures followed standard competitive swimming protocols. A manual stopwatch (Seiko model, precision 1/100 second) was used, operated by two trained observers positioned at the finish line. The average time recorded by the two observers was used for analysis to minimize human reaction time error. Participants performed one maximal-effort trial after a self-paced warm-up swim, with verbal cues provided to ensure consistent starting technique. Environmental factors such as lane allocation, water conditions, and swimmer order were kept constant throughout testing to prevent systematic bias.

To minimize potential sources of bias, several strategies were implemented. Observer blinding was applied during the recording of swimming time, such that observers were unaware of each swimmer's medicine ball throw performance. Measurement procedures were standardized and conducted by the same research team to maintain consistency across all assessments. No external distractions or competitive elements were introduced during testing, and participants were encouraged to maintain their usual training routines prior to evaluation to avoid performance fluctuations caused by acute fatigue or detraining.

The main variables of interest were shoulder muscle power (continuous, measured in centimeters) and 50-m freestyle swimming speed (continuous, measured in seconds). Because the variables were not normally distributed based on the Shapiro–Wilk test, non-parametric statistical analysis was selected. Spearman's rho correlation coefficient was used to determine the strength and direction of the association between the two variables. Statistical analysis was conducted using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA). The significance level was set at $\alpha = 0.05$. Correlation coefficients were interpreted according to established guidelines, where values between –0.70 and –0.90 indicate strong negative correlations.

Ethical approval was obtained from the Ethics Committee of Universitas Panca Bhakti with approval number 023/KEP-UPB/I/2024. Written informed consent was collected from all participants and their guardians for those under 18 years old. All procedures adhered to the principles outlined in the Declaration of Helsinki.

Results

A total of 20 competitive swimmers from the Bintang Khatulistiwa Swimming Club in West Kalimantan participated in this study, all of whom met the eligibility criteria and completed the full assessment protocol. No participants withdrew or were excluded during the data collection process, resulting in a complete dataset with no missing values for any of the measured variables. The characteristics of the participants included sex distribution and age category, both of which were documented to provide contextual understanding of the sample composition and potential influences on performance outcomes.

Sex distribution among the participants was balanced, with equal representation of male and female swimmers. This equitable distribution allowed for a more homogeneous interpretation of performance variability without the dominance of one sex category. Table 1 presents the sex distribution of the sample. The narrative interpretation demonstrates that both male and female swimmers accounted for 50% of the total sample, indicating that potential sex-related differences in muscle power or swimming velocity were evenly represented across the study population. However, sex was not analyzed as a subgroup due to the limited sample size, and therefore its influence on the primary outcomes remains descriptive rather than inferential.

Table 1. Distribution of Participants by Sex

Sex	Frequency	Percentage
Male	10	50%
Female	10	50%
Total	20	100%

Age distribution revealed that a majority of the participants were early adolescent swimmers, particularly within the 10–14-year age range. This finding reflects the developmental stage of the club's active training population. The remaining participants were spread across the 15–19 and 20–24-year age categories, although these groups represented a smaller portion of the total sample. Table 2 summarizes the distribution of age groups among the swimmers. The dominance of younger age groups suggests that training exposure, physiological maturation, and neuromuscular development may vary considerably among participants, potentially influencing both shoulder muscle power and swimming speed. Nonetheless, age was retained as a descriptive characteristic and not treated as a confounding variable due to the sample size constraints.

Table 2. Distribution of Participants by Age Group

Age Group (Years)	Frequency	Percentage
10–14	15	75%
15–19	3	15%
20–24	2	10%
Total	20	100%

The primary outcome of interest in this study was the association between shoulder muscle power and 50-m freestyle swimming speed. Shoulder muscle power was quantified using the maximum distance recorded in the medicine ball throw test, while swimming speed was represented by the time taken to complete a 50-m freestyle sprint. Prior to conducting the correlation analysis, the distribution of both variables was examined. The Shapiro–Wilk test indicated non-normal distributions, justifying the use of Spearman's rho for non-parametric correlation analysis.

Table 3 presents the results of the Spearman's rho correlation between shoulder muscle power and 50-m freestyle swimming speed. The analysis revealed a statistically significant negative correlation ($r = –0.787$, $p < 0.001$), indicating a strong inverse association between the two variables. This means that swimmers who demonstrated greater shoulder muscle power, reflected by longer throwing distances, completed the 50-m freestyle swim in shorter times. Because freestyle performance is evaluated based on speed, a shorter time corresponds to a higher performance level. Therefore, the negative coefficient should be interpreted as a positive performance association: greater power corresponds to faster swimming.

Table 3. Spearman's Rho Correlation Between Shoulder Muscle Power and 50-m Freestyle Swimming Speed

Variables Compared	Spearman's rho (r)	p-value	N
Shoulder Muscle Power vs. Swimming Speed	–0.787	<0.001	20

The strength of this correlation suggests that shoulder muscle power is a meaningful component of short-distance freestyle performance among swimmers in this population. The substantial magnitude of the correlation coefficient places it within the range commonly characterized as a strong relationship, implying that upper-extremity explosive force may play a decisive role in determining sprint velocity. This is consistent with the biomechanical demands of freestyle swimming, where the upper limbs are responsible for the majority of propulsive force generation.

No missing data were identified for any of the primary variables. The uniform completion of all assessments increases the internal validity of the findings. Although demographic factors such as age and sex may influence muscle power or performance, these variables were not statistically controlled due to the sample size limitations and the exploratory nature of the study. Therefore, while the results strongly indicate a relationship between shoulder muscle power and freestyle speed, they should be interpreted as unadjusted estimates.

Potential confounding variables, such as training frequency, technical proficiency, and psychological readiness, were not assessed quantitatively in this study but may contribute to performance variability. Nevertheless, data collection was standardized, and measurement procedures were performed consistently to minimize the impact of external variation. The use of two independent observers during the swimming speed test further strengthened measurement reliability by reducing timer bias.

Overall, the findings demonstrate a clear and statistically significant association between shoulder muscle power and 50-m freestyle performance. These results emphasize the importance of evaluating explosive upper-extremity capacity during athlete development and conditioning programs. Coaches may consider integrating shoulder power assessments into regular performance monitoring to identify athletes who may benefit from targeted upper-limb strength and power training. Furthermore, the practical implications of this correlation suggest that improvements in shoulder muscle power could translate to measurable enhancements in sprint swimming performance, particularly within similar athlete populations.

Discussion

The primary aim of this study was to investigate the association between shoulder muscle power and 50-m freestyle swimming speed among competitive swimmers in West Kalimantan. The findings revealed a strong and statistically significant negative correlation ($r = –0.787$, $p < 0.001$), indicating that swimmers with greater shoulder muscle power completed the 50-m freestyle sprint in a shorter time. This result suggests that explosive upper-limb force plays a substantial role in determining sprint swimming performance within this population. The magnitude and direction of the correlation are consistent with biomechanical principles of freestyle propulsion, wherein the upper extremities contribute up to 90% of total force generation during the stroke cycle.(10)

The strong inverse association observed in this study aligns with previous research demonstrating the importance of upper-limb strength and power in short-distance swimming. Asmuddin et al. reported a significant relationship between upper-arm muscle power and freestyle swimming effectiveness over 25 meters, emphasizing the role of explosive movements in achieving high velocities.(8) Similar findings were noted in studies conducted in Middle Eastern and European athletic populations, where upper-limb power was found to contribute meaningfully to sprint swimming performance. While the present study differs in distance (50 m) and participant characteristics, the consistency of results across varied contexts strengthens the evidence supporting the critical role of shoulder muscle power in sprint swimming performance.(11,12)

Biomechanically, the shoulder joint is uniquely adapted for high-velocity cyclic motion, allowing swimmers to generate continuous propulsive force throughout the stroke cycle. During the catch and pull phases, explosive shoulder flexion, internal rotation, and adduction are essential for maximizing propulsion, while during the recovery phase, rapid and efficient repositioning of the arm facilitates high stroke rates.(13,14) The muscles responsible for these movements—including the deltoid, rotator cuff group, latissimus dorsi, and serratus anterior—must generate force quickly in order to displace water effectively. Greater shoulder muscle power enables swimmers to increase stroke length and stroke rate simultaneously, two variables known to greatly influence sprint performance.(15) The findings of this study support the notion that swimmers with superior explosive shoulder capacity possess a mechanical advantage during the earliest phases of propulsion, enabling them to reach and sustain higher speeds over short distances.

In practical terms, the association between shoulder muscle power and sprint performance is particularly relevant for the 50-m freestyle event, which is characterized by maximal effort and minimal pacing strategy. Unlike middle- or long-distance events where energy conservation and technique refinement play dominant roles, the 50-m sprint requires swimmers to achieve peak velocity as quickly as possible and maintain it for the duration of the race.(16) This demand places greater emphasis on anaerobic power, rapid neuromuscular activation, and explosive upper-limb force, all of which are reflected in shoulder muscle power. The results of this study further validate the integration of upper-limb power assessments into routine performance evaluations for sprint swimmers, especially in developmental programs where early identification of biomechanical strengths can guide training specialization.

When compared with international literature, this study's findings are congruent with research emphasizing the significance of dry-land strength and power training for improving aquatic performance. Investigations into medicine ball training, plyometric conditioning, and resistance-based shoulder exercises have demonstrated improvements in arm propulsion, stroke efficiency, and sprint speed across various age groups and competitive levels.(17,18) The present finding that a simple medicine ball throw test strongly correlates with sprint performance offers a practical and cost-effective approach for coaches in resource-limited environments. It provides an accessible metric for monitoring athlete development and targeting individualized training interventions.

Despite the clear association identified, several limitations of this study warrant consideration. First, the sample size of 20 participants limits the generalizability of the findings, although the strong correlation observed suggests that the relationship is meaningful within this population. Future research with a larger and more diverse sample would allow more robust statistical modeling, including subgroup comparisons and multivariate analyses to adjust for confounding factors. Second, the age range of participants (10–24 years) introduces variability in physiological maturation, neuromuscular development, and training experience, which may influence both shoulder muscle power and swimming performance. Although these factors were not controlled in the analysis, acknowledging them is important for interpreting the results and designing future studies.

Measurement-related limitations also exist. Although manual timing using dual stopwatches reduces human reaction error, fully automated timing systems could provide more precise measurements. Similarly, although the medicine ball throw test is widely validated, it remains a field-based proxy for shoulder explosive power rather than a direct biomechanical assessment. More sophisticated tools such as isokinetic dynamometry or force-plate-based plyometric assessments could yield deeper insights into the specific components of upper-limb force development.

Additionally, potential external variables such as training load, technical proficiency, fatigue levels, and psychological readiness were not quantitatively assessed. These factors can influence sprint performance and may moderate the observed relationship. Future studies should consider incorporating multilevel performance indicators—including physiological markers, kinematic analysis, and stroke mechanics—to develop a more comprehensive understanding of how shoulder muscle power interacts with other determinants of sprint swimming performance.

Despite these limitations, the strengths of the study include its clear operationalization of variables, standardized testing procedures, and complete absence of missing data, which enhance internal validity. The study also fills an important gap in Indonesian sports science literature by providing the first documented analysis of shoulder muscle power and 50-m freestyle performance among swimmers in West Kalimantan. Its findings carry practical implications for athlete monitoring, talent identification, and performance enhancement strategies within local training programs.

In conclusion, this study confirms that shoulder muscle power is strongly associated with sprint swimming performance in the 50-m freestyle event. The findings underscore the need for coaches and conditioning specialists to incorporate shoulder-focused power training into athlete development programs. They also highlight the practical utility of simple field tests, such as the medicine ball throw, for evaluating explosive upper-limb capacity. Future research should aim to refine these approaches by examining additional performance variables, implementing longitudinal designs, and exploring intervention-based programs to determine whether increases in shoulder muscle power translate directly into improvements in sprint performance.

Conclusion

This study demonstrated a strong and significant negative correlation between shoulder muscle power and 50-m freestyle swimming speed among competitive swimmers in West Kalimantan. Swimmers who exhibited greater explosive shoulder capacity completed the 50-m sprint in shorter times, indicating that shoulder muscle power is an essential determinant of performance in short-distance freestyle events. These findings reinforce the importance of upper-limb explosive force in generating effective propulsion and sustaining maximal velocity throughout the sprint. They also provide empirical support for incorporating shoulder-focused strength and power training into athlete development programs, particularly for swimmers specializing in short-distance events.

The practical implications of this study are substantial. Coaches may use simple field-based assessments such as the medicine ball throw to monitor athlete readiness, identify performance potential, and tailor training programs accordingly. By systematically evaluating shoulder muscle power, training strategies can be optimized to target specific deficits and enhance sprint performance in a measurable manner.

However, the results should be interpreted with consideration of certain limitations, including the modest sample size and variability in participant age and training experience. Future studies are encouraged to include larger samples, control for potential confounding variables, and employ longitudinal or intervention-based designs to examine whether increases in shoulder muscle power lead to corresponding improvements in sprint speed. Expanding the scope of inquiry to include biomechanical and physiological analyses may also provide deeper insight into the mechanisms underlying the relationship observed in this study.

Author Contribution

Conceptualization: Myranti Puspitaningtsya Junaedi, Miftahul Nur 'Amaliyah
Methodology: Myranti Puspitaningtsya Junaedi, Dini Afriani Khasanah
Formal Analysis: Dini Afriani Khasanah, Tazkia Nabila
Investigation: Miftahul Nur 'Amaliyah, Tazkia Nabila
Data Curation: Tazkia Nabila, Joko Priono
Writing – Original Draft: Myranti Puspitaningtsya Junaedi
Writing – Review & Editing: Joko Priono, Dini Afriani Khasanah
Supervision: Joko Priono

Acknowledgments

The authors would like to express their gratitude to the Research and Community Service Institute (LPPM) of Universitas Panca Bhakti for providing institutional support throughout the study. The authors also thank the Bintang Khatulistiwa Swimming Club of West Kalimantan for their participation and cooperation during data collection. Appreciation is extended to all research assistants and collaborators whose contributions facilitated the successful completion of this work.

Conflict of Interest Statement

The authors declare no conflict of interest.

Funding Sources

This research received no external funding.

Ethics Statement

This study was approved by the Ethics Committee of Universitas Panca Bhakti (Approval No. 023/KEP-UPB/I/2024). Written informed consent was obtained from all participants, including parental consent for swimmers under 18 years of age, and all procedures were conducted in accordance with the Declaration of Helsinki.

References

1. Ladgaonkar S, Akre M, Chogle R, Kumar A. The effect of dry land shoulder girdle strengthening exercises on aerobic endurance of swimmers. Int J Health Sci Res. 2020;10(6):68–74.
2. Ruiz-Navarro JJ, Santos CC, Born DP, López-Belmonte O, Cuenca-Fernández F, Sanders RH, et al. Factors relating to sprint swimming performance: a systematic review. Sports Med. 2025;55(4):899–922.
3. Karpiński J, Rejdych W, Brzozowska D, Gołaś A, Sadowski W, Swinarew AS, et al. The effects of a 6-week core exercises on swimming performance of national level swimmers. PLoS One. 2020;15(8):e0227394.
4. Sammoud S, Nevill AM, Negra Y, Bouguezzi R, Chaabene H, Hachana Y. 100-m breaststroke swimming performance in youth swimmers: the predictive value of anthropometrics. Pediatr Exerc Sci. 2018;30(3):393–401.
5. dos Santos MAM, Henrique RS, Salvina M, Silva AHO, Junior MA de VC, Queiroz DR, et al. The influence of anthropometric variables, body composition, propulsive force and maturation on 50m freestyle swimming performance in junior swimmers: an allometric approach. J Sports Sci. 2021;39(14):1615–1620.
6. Yani JA, Kartasura K, Sukoharjo K, Tengah J, Lesmana SI, Amir TL. The relationship between leg muscle explosive power and swimming speed of 50-meter breaststroke sprint athlete. Proc Acad Physiother Conf. 2022;2022:101–108.
7. Linkovski M, Lewis J, Sarig Bahat H. Validity and feasibility of the seated medicine ball throw and unilateral shot-put tests in assessing upper extremity function in rotator-cuff-related shoulder pain. Appl Sci. 2024;14(24):12038.
8. Asshagab M, Sariul S, Salwiah S. Correlation between upper-limb muscle power and effectiveness of 25-m freestyle swimming in Baubau city swimmers. J Penjaskesrek. 2023;10(1):31–37.
9. Muniz-Pardos B, Gomez-Bruton A, Matute-Llorente A, Gonzalez-Aguero A, Gomez-Cabello A, Gonzalo-Skok O, et al. Nonspecific resistance training and swimming performance: strength or power? A systematic review. J Strength Cond Res. 2022;36(4):1162–1170.
10. Morais JE, Barbosa TM, Nevill AM, Cobley S, Marinho DA. Understanding the role of propulsion in the prediction of front-crawl swimming velocity and in the relationship between stroke frequency and stroke length. Front Physiol. 2022;13:[pages not available].
11. Carvalho DD, Monteiro AS, Fonseca P, Silva AJ, Vilas-Boas JP, Pyne DB, et al. Swimming sprint performance depends on upper/lower limbs strength and swimmers level. J Sports Sci. 2023;41(8):747–757.
12. Elrakhawy MI. Comparison between two methods of power training on swimming performance. Am J Sports Sci. 2023;11(4):90–95.
13. Rezaei H, Gheitasi M, Hosseini SM. Does corrective exercises influence the performance, posture, range of motion and shoulder pain of swimmers with upper crossed syndrome? Randomized clinical trial. BMC Sports Sci Med Rehabil. 2025;17(1):193.
14. Psycharakis SG, Coleman SGS. Which phases of the stroke cycle are propulsive in front crawl swimming? Res Q Exerc Sport. 2024;95(2):325–333.
15. Buoite Stella A, Cargnel A, Raffini A, Mazzari L, Martini M, Ajčevic M, et al. Shoulder tensiomyography and isometric strength in swimmers before and after a fatiguing protocol. J Athl Train. 2024;59(7):738–744.
16. Barbosa AMQ. A potência de membros superiores está relacionada com o desempenho de nado crawl em nadadores adolescentes. Res Soc Dev. 2022;11(3):e26711326356.
17. Rodríguez González L, Melguizo-Ibáñez E, Martín-Moya R, González-Valero G. Study of strength training on swimming performance: a systematic review. Sci Sports. 2023;38(3):217–231.
18. Hermosilla F, Sanders R, González-Mohíno F, Yustres I, González-Rave JM. Effects of dry-land training programs on swimming turn performance: a systematic review. Int J Environ Res Public Health. 2021;18(17):[pages not available].