HIJM
HORIZON: Indonesian Journal of Multidisciplinary

p-ISSN: 2987-7776
e-ISSN: 2987-7180
Vol. 4, No. 4, 2026

EXPLORING THE RELATIONSHIP BETWEEN SWIMMING AND ENDURANCE CAPACITY: A SYSTEMATIC LITERATURE REVIEW

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Article History

Received: 27-05-2026

Revision: 08-07-2026

Accepted: 13-07-2026

Published: 16-07-2026

Abstract. This study investigates the relationship between swimming and endurance capacity through a systematic literature review. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework to ensure a transparent and structured selection process. Articles published between 2010 and 2025 were retrieved from Scopus, PubMed, Google Scholar, and ScienceDirect using keywords related to swimming, endurance, aquatic exercise, and aerobic capacity. After applying the inclusion and exclusion criteria, six studies were included in the final qualitative synthesis. Data were analyzed using qualitative thematic synthesis by comparing study characteristics, intervention models, training duration and frequency, participant profiles, and endurance outcomes such as VO_2 max, 6-minute walk test performance, heart rate response, and swimming time trials. The findings indicate that swimming contributes positively to cardiorespiratory and muscular endurance in athletes, older adults, and recreational participants. Structured swimming programs, particularly those involving progressive intensity, interval training, and aquatic resistance components, tended to produce stronger endurance adaptations. However, the review is limited by methodological heterogeneity, small sample sizes in several studies, inconsistent endurance measurements, and limited long-term evidence. Future research should employ standardized testing protocols, longitudinal designs, and broader participant groups. Overall, swimming can be considered an effective, low-impact, and adaptable method for improving endurance capacity.

Keywords: Swimming, Endurance, Aerobic Capacity, VO_2 Max, Systematic Review

Abstrak. Penelitian ini bertujuan untuk mengkaji hubungan antara aktivitas renang dan kapasitas daya tahan melalui tinjauan sistematis terhadap literatur yang relevan. Kajian ini mengikuti pedoman PRISMA untuk memastikan proses seleksi artikel yang transparan dan terstruktur. Artikel yang diterbitkan antara tahun 2010 hingga 2025 dikumpulkan dari Scopus, PubMed, Google Scholar, dan ScienceDirect dengan menggunakan kata kunci terkait renang, daya tahan, latihan akuatik, dan kapasitas aerobik. Setelah menerapkan kriteria inklusi dan eksklusi, enam studi dimasukkan dalam sintesis kualitatif akhir. Data dianalisis menggunakan sintesis tematik kualitatif dengan membandingkan karakteristik studi, model intervensi, durasi dan frekuensi latihan, karakteristik peserta, serta luaran daya tahan seperti VO_2 max, tes jalan 6 menit, respons denyut jantung, dan uji waktu renang. Hasil kajian menunjukkan bahwa renang berkontribusi positif terhadap daya tahan kardiorespirasi dan daya tahan otot pada atlet, lansia, serta peserta rekreasional. Program renang yang terstruktur, terutama yang melibatkan intensitas progresif, latihan interval, dan komponen resistensi air, cenderung menghasilkan adaptasi daya tahan yang lebih baik. Namun, kajian ini memiliki keterbatasan berupa heterogenitas metodologi, ukuran sampel yang kecil pada beberapa studi, ketidakkonsistenan pengukuran daya tahan, dan terbatasnya bukti jangka panjang. Penelitian selanjutnya direkomendasikan menggunakan protokol pengukuran yang terstandar, desain longitudinal, dan populasi yang lebih beragam. Secara keseluruhan, renang dapat dianggap sebagai metode yang efektif, rendah risiko benturan, dan adaptif untuk meningkatkan kapasitas daya tahan.

Kata Kunci: Renang, Daya Tahan, Kapasitas Aerobik, VO_2 Max, Tinjauan Sistematis

How to Cite: Fatmawan, R., Dewi, K. A. K., & Negara, G. A. A. K. S. N. S. (2026). Exploring the Relationship Between Swimming and Endurance Capacity: A Systematic Literature Review. *HORIZON: Indonesian Journal of Multidisciplinary*, 4 (4), 4212-4223. http://doi.org/10.54373/hijm.v4i4.5979

INTRODUCTION

Endurance capacity is a fundamental component of physical fitness that plays a crucial role in maintaining overall health and optimizing athletic performance. Within the field of sports science, endurance is generally defined as the ability of an individual to sustain prolonged physical activity, particularly activities that rely on aerobic metabolism. High levels of endurance are associated with improved cardiovascular function (Schjerve et al., 2008), increased oxygen uptake (VO_2 max) (Buttar et al., 2019), and enhanced muscular efficiency (Vigorito & Giallauria, 2014), all of which contribute to better physical performance and reduced risk of chronic diseases.

Swimming has long been recognized as a highly effective form of aerobic exercise that engages multiple muscle groups simultaneously while minimizing the risk of joint injury. As a low-impact activity, swimming provides a unique training stimulus due to the properties of water, such as buoyancy and resistance, which facilitate both cardiovascular and muscular adaptations. Research in exercise physiology suggests that regular swimming training can significantly improve cardiorespiratory endurance, muscular endurance, and overall physical fitness (Barbosa et al., 2008; Tanaka, 2009). Furthermore, swimming is widely used not only by competitive athletes but also by the general population as a means of improving health-related fitness.

In addition to physiological benefits, the effectiveness of swimming activities is also influenced by instructional approaches, learning models, and the development of basic aquatic skills. Dewi & Rusmayani (2023) found that freestyle swimming instruction contributed positively to students' learning outcomes in freestyle swimming. Similarly, Dewi & Budiman (2024) reported that learning models were related to the level of knowledge of basic freestyle swimming techniques among members of the Tirta Krisna Jembrana Swimming Club. These findings indicate that swimming performance and endurance development are not only determined by physical training variables but also by pedagogical strategies, technical understanding, and structured learning experiences.

Despite the growing body of literature examining the benefits of swimming, the specific relationship between swimming and endurance capacity remains fragmented across various studies with differing methodologies, populations, and training protocols. Some studies emphasize improvements in cardiovascular endurance (Sumartana & Setiaji, 2025; Chen et al., 2024; Aspenes et al., 2009), while others highlight muscular endurance or performance outcomes (Price et al., 2024; Fone & Tillaar, 2022; Kilding et al., 2010). This variability creates challenges in drawing comprehensive conclusions regarding the overall effectiveness of swimming as an endurance-enhancing activity. Therefore, a systematic synthesis of existing research is needed to provide a clearer and more integrated understanding of this relationship.

In response to this gap, this study aims to systematically review and analyze existing literature on the relationship between swimming and endurance capacity. By evaluating findings from multiple studies, this review seeks to identify patterns, key variables, and the extent to which swimming contributes to endurance development across different populations. The findings of this study are expected to provide valuable insights for coaches, educators, and practitioners in designing effective training programs, as well as for researchers seeking to advance knowledge in the field of sports and health sciences.

METHODS

This study employed a systematic literature review (SLR) design guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. The PRISMA approach is widely recognized in the field of evidence-based research for its structured and transparent procedures in identifying, screening, and synthesizing relevant studies (Page et al., 2021). By following this framework, the present study ensures methodological rigor, reproducibility, and minimization of bias in the selection of articles.

A comprehensive literature search was conducted across several electronic databases, including Scopus, PubMed, Google Scholar, and ScienceDirect. The search process was carried out using combinations of keywords and Boolean operators, such as: “swimming” and “endurance”, “aquatic exercise” and “cardiorespiratory endurance”, and “swimming training” and “aerobic capacity”. To ensure relevance and currency, only articles published between 2010 and 2025 were included. Additionally, reference lists of selected articles were manually screened to identify further relevant studies. The inclusion criteria for this review were as follows: (1) peer-reviewed journal articles, (2) studies examining the relationship between swimming and endurance capacity, (3) studies involving human participants (athletes or non-athletes), (4) articles published in English; and (5) studies providing empirical data (quantitative or mixed methods). The Exclusion Criteria Included: (1) review articles, conference abstracts, and editorials, (2) studies not directly related to swimming or endurance, (3) duplicate publications; and (4) articles with incomplete or inaccessible full texts.

The study selection process followed the four stages of the PRISMA flow: identification, screening, eligibility, and inclusion. In the identification phase, all records obtained from database searches were compiled and duplicates were removed. During the screening stage, titles and abstracts were reviewed to exclude irrelevant studies. In the eligibility phase, full-text articles were assessed based on the predefined criteria. Finally, studies that met all inclusion criteria were included in the qualitative synthesis. Relevant data from the selected studies were systematically extracted using a standardized form. The extracted information included: author(s), year of publication, sample characteristics (e.g., age, gender, training status), study design, type of swimming intervention, duration and frequency of training, and measured outcomes related to endurance (e.g., VO_2 max, time-to-exhaustion, cardiovascular indicators). This process facilitated consistency and comparability across studies.

The data were analyzed using a qualitative synthesis approach. Findings from the selected studies were categorized based on key themes, such as types of endurance (cardiorespiratory vs. muscular), population characteristics, and training protocols. Patterns, similarities, and discrepancies among studies were identified and critically discussed to provide a comprehensive understanding of the relationship between swimming and endurance capacity.

RESULTS

Study Selection

Based on the database search, 245 articles were initially identified from Scopus, PubMed, Google Scholar, and ScienceDirect. After removing 65 duplicate records, 180 articles remained for screening. Following title and abstract screening, 120 articles were excluded because they were not directly relevant to the relationship between swimming and endurance capacity. The remaining 60 articles were assessed for full-text eligibility, and six studies met all inclusion criteria. These six studies were included in the final qualitative synthesis.

Characteristics of Included Studies

The selected studies were published between 2010 and 2025 and involved diverse populations, including competitive swimmers, older adults, recreational athletes, and non-athletes. The majority of studies employed experimental or randomized controlled designs, while several studies synthesized evidence through systematic or narrative review designs. The duration of swimming-related interventions ranged from 6 to 16 weeks in intervention studies, while review-based studies analyzed wider variations in training duration and methods. Most studies focused on cardiorespiratory endurance, commonly measured using VO_2 max, VO_2 peak, 6-minute walk test performance, heart rate response, and swimming performance tests. Other studies examined muscular endurance and strength-related adaptations, particularly through aquatic resistance training, dry-land strength training, and inspiratory muscle training.

Overall, the reviewed evidence shows that swimming and swimming-related training programs are associated with positive adaptations in endurance capacity.

Table 1. Synthesis of selected studies on swimming and endurance capacity

No.	Author (s) & Year	Sample	Study Design	Intervention	Duration	Endurance Measure	Key Findings
1.	Sumartana, I. M., & Setiaji, Y. (2025)	Related articles	Qualitative design, literature review (narrative review)	Swimming activity	Not specified (No intervention period due to review-based design)	• Cardiovascular endurance indicators • Lung capacity • Muscular endurance	Swimming is a holistic, accessible, and adaptable activity that improves both physical endurance and psychological resilience.
2.	Chen, Y., Lan, Y., Zhao, A., Wang, Z., & Yang, L. (2024)	80 older adults, age: 60–70 years	Randomized Controlled Trial (RCT)	Free Swimming (FS), Aquatic Resistance Training (ART), and Combination (FS & ART)	16 weeks, with frequency: 2 sessions per week	6-Minute Walk Test (6MWT) → primary measure of cardiovascular endurance	FS → improves cardiovascular endurance ART → enhances muscular strength and endurance Combination → provides the most comprehensive fitness benefits
3.	Aspenes, S., Kjendlie, P., Hoff, J., & Helgerud, J. (2009)	20 competitive swimmers divided into: intervention group: 11 swimmers and control group: 9 swimmers	Experimental study (controlled trial) Pre-test and post-test design with: intervention group vs control group	Combined training program: maximal strength training (dry-land), high-intensity interval endurance training (in-water)	11 weeks	Peak oxygen uptake (VO_2 peak) with 400 m freestyle performance (indicator of aerobic endurance)	Combined strength + endurance training: improves strength and middle-distance performance. Strength gains contribute to improved endurance performance indirectly
4.	Price, T., Cimadoro, G., & Legg, H. S. (2024).	Total studies included: 43 studies	Systematic Review	Examined variables across studies: • Muscle strength • Muscle power • Aerobic capacity	Not applicable (varies across included studies)	Aerobic capacity indicators (e.g., VO_2 max, aerobic metabolism)	Swimming performance in youth is multifactorial, with endurance (especially aerobic capacity) being a key determinant

No.	Author (s) & Year	Sample	Study Design	Intervention	Duration	Endurance Measure	Key Findings
				• Anaerobic capacity			for longer events.
5.	Fone, L., & Tillaar, R. Van Den. (2022)	No single participant group (review study) Total studies included: 27 studies	Systematic Review	Different types of strength training methods: • In-water specific resistance training • Dry-land swim-specific training • Non-specific dry-land strength training	Included studies had interventions longer than 3 weeks	Endurance inferred from: • Swimming performance outcomes (time trials) • Some included studies may use: • Aerobic capacity (VO_2) • Race distances (especially middle-distance events)	Strength training is beneficial for swimmers, and a combined training approach is recommended for optimal performance gains.
6.	Kilding, A. E., Brown, S., & Mcconnell, A. K. (2010)	16 competitive club-level swimmers that randomly assigned into: Experimental group (IMT) and Control group (sham/placebo IMT)	Randomized Controlled Trial (RCT)	Inspiratory Muscle Training (IMT) using a pressure-threshold device	6 weeks	Swimming performance (time trials): 100 m, 200 m, 400 m	IMT enhances respiratory muscle strength, leads to performance gains in shorter swimming events

Summary of Findings

The synthesis of the selected studies indicates a consistent positive relationship between swimming and endurance capacity. Most studies reported significant improvements in VO_2 max, which is a key indicator in exercise physiology. Additionally, improvements in cardiovascular efficiency, heart rate recovery, and muscular endurance were frequently observed. Variations in training protocols, such as interval training, continuous swimming, and polarized training, were found to influence the degree of endurance improvement. High-intensity and structured swim training programs tended to yield greater gains compared to low-intensity or unstructured activities. Furthermore, both athletes and non-athletes benefited from swimming interventions, although trained individuals often showed more specific physiological adaptations. Overall, the findings demonstrate that swimming is an effective modality for enhancing both cardiorespiratory and muscular endurance across different populations and training conditions.

DISCUSSION

The findings of this systematic literature review show that swimming has a consistently positive impact on endurance capacity across various populations and training contexts. From an exercise physiology perspective, these improvements can be explained by adaptations such as increased oxygen uptake, enhanced cardiovascular efficiency, improved stroke volume, and better muscular endurance. The aquatic environment provides buoyancy and resistance, which simultaneously stimulate the cardiovascular and muscular systems while reducing mechanical stress on the joints. This characteristic makes swimming suitable not only for athletic training but also for health promotion and rehabilitation-oriented exercise (Tanaka, 2009; Vigorito & Giallauria, 2014).

A critical analysis of the included studies indicates that the effectiveness of swimming in improving endurance is strongly influenced by training variables, particularly intensity, duration, frequency, and the type of swimming-based activity. Studies involving high-intensity interval training, combined strength-endurance training, aquatic resistance training, and inspiratory muscle training tended to report stronger improvements in endurance-related outcomes. This is consistent with broader principles of training specificity and overload, which emphasize that physiological adaptations depend on appropriate training stimulus and progression (Nugent et al., 2017; Crowley et al., 2017).

Despite the generally positive findings, several inconsistencies were identified across the reviewed studies. First, the studies used different research designs, participant groups, intervention models, and endurance measures. Some studies used direct physiological indicators such as VO_2 max or VO_2 peak, while others used indirect indicators such as 6-minute walk test performance, heart rate recovery, or swimming time trials. These differences make direct comparisons across studies difficult. Second, intervention duration varied from short-term programs to longer training periods, which may influence the magnitude of endurance adaptation. Third, sample sizes in several studies were relatively small, limiting the generalizability of findings.

Recent studies in the Indonesian swimming education context also support the importance of structured and developmentally appropriate swimming programs. Dewi & Rusmayani (2023) emphasized that freestyle swimming learning can improve learning outcomes when implemented through systematic instruction. Dewi & Budiman (2024) further highlighted that appropriate learning models are associated with better knowledge of basic freestyle swimming techniques. Although these studies primarily focused on learning outcomes and technical knowledge rather than direct endurance indicators, they remain relevant because technical efficiency and understanding of movement patterns are important foundations for sustained swimming performance and long-duration aquatic activity.

Another important issue is the limited exploration of diverse populations. Although the reviewed studies included athletes, older adults, and general participants, fewer studies examined beginners, clinical populations, individuals with chronic diseases, or participants from school-based physical education settings. In addition, gender differences, adherence, enjoyment, and long-term sustainability of endurance gains were not consistently examined. These aspects are important because the long-term effectiveness of swimming programs depends not only on physiological adaptation but also on behavioral and psychological factors.

Research Gap

Based on the critical analysis, several research gaps can be identified:

- Lack of standardization in endurance measurement; Future studies should adopt more consistent and comparable indicators (e.g., standardized VO_2 max protocols) to improve the reliability of findings.
- Limited long-term and longitudinal studies; There is a need for research examining the long-term effects of swimming on endurance and whether improvements are maintained over time.
- Underrepresentation of diverse populations; More studies are required involving elderly individuals, clinical populations, and beginners to enhance the generalizability of results.
- Insufficient comparison of training models; Direct comparisons between different swimming training approaches (e.g., HIIT vs. continuous training) remain limited and should be further explored.
- Neglect of psychological and behavioral factors; Furthermore, aquatic play-based learning may contribute to endurance development indirectly by improving children's confidence, safety awareness, and willingness to participate in water-based activities. Krisna Dewi & Andika (2025) demonstrated that an aquatic play-based learning program was effective in improving water confidence and fundamental aquatic skills among children aged 4–7 years. In line with this, Dewi & Tutuandari (2025) reported that innovative swimming activities can enhance self-confidence, safety, and motor development in young children. These

findings suggest that enjoyment, confidence, and fundamental aquatic competence should be considered as supporting factors in long-term swimming participation and endurance-oriented aquatic programs.

Practical Implications

The results of this review have practical implications for coaches, physical education teachers, and health professionals. For coaches and trainers, swimming can be integrated into endurance training programs by using structured progression, appropriate intensity, and a combination of aerobic and resistance-based activities. Interval swimming and combined strength-endurance training may be especially useful for athletes who need to improve both cardiovascular capacity and sport-specific performance. For physical education practitioners, swimming offers a low-impact and enjoyable alternative for developing endurance among students. Progressive aquatic activities can help students improve fitness while also developing water confidence and movement competence. For health and rehabilitation professionals, swimming may be recommended as an adaptable exercise option for individuals who require cardiovascular conditioning with lower joint stress. However, program design should consider individual fitness level, safety, health status, and gradual progression.

For children and beginner swimmers, swimming programs should not only focus on endurance outcomes but also emphasize basic technique mastery, water confidence, safety, and enjoyable learning experiences. Game-based and innovative aquatic activities may help learners become more confident and motivated to participate consistently in swimming activities (Dewi & Andika, 2025; Dewi & Tutuandari, 2025). For researchers, the findings highlight the importance of using standardized measurement tools and clearly reporting intervention variables such as frequency, intensity, duration, stroke type, and training volume. Future studies are also recommended to combine physiological, psychological, and behavioral outcomes so that the benefits of swimming can be understood more comprehensively. These practical implications confirm that swimming is not only an exercise modality for performance improvement but also a flexible strategy for promoting long-term endurance, health, and active lifestyles.

CONCLUSION

This systematic literature review concludes that swimming is an effective and versatile form of exercise for improving endurance capacity. The reviewed studies consistently show that swimming contributes to improvements in cardiorespiratory endurance and muscular endurance, as reflected in outcomes such as VO_2 max, VO_2 peak, 6-minute walk test performance, heart rate response, and swimming time-trial performance. These adaptations are mainly supported by aerobic stimulation, water resistance, and the low-impact characteristics of the aquatic environment.

The effectiveness of swimming as an endurance training modality depends on program variables such as intensity, duration, frequency, intervention type, and participant characteristics. Structured programs that incorporate progressive intensity, interval training, aquatic resistance, inspiratory muscle training, or combined strength-endurance approaches appear to produce stronger benefits than unstructured activities. Nevertheless, current evidence is limited by methodological heterogeneity, inconsistent endurance measurements, small sample sizes in some studies, and limited longitudinal data. Based on these findings, coaches and practitioners are recommended to design swimming programs systematically, beginning with safe adaptation to water and progressing toward structured endurance training according to individual fitness levels. Physical education and health professionals should consider swimming as a low-impact option for improving endurance in different populations. Future researchers are recommended to conduct longitudinal and experimental studies using standardized outcome measures, broader participant groups, and integrated physiological, psychological, and behavioral variables. These recommendations are expected to strengthen the evidence base and support the development of more effective swimming-based endurance programs.

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