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50-meter freestyle performance: a systematic review of upper limb strength, lower limb explosive power, and swimming technique determinants (2020–2026)

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ABSTRACT

The review followed the PRISMA 2020 framework and was conducted using Scopus as the primary information source, applying a Boolean strategy combining swimming, strength, explosive-power, and technique constructs within title, abstract, and keyword fields. The search returned 183 records, which were screened against predefined eligibility criteria restricting inclusion to English-language original articles and reviews directly addressing strength, power, or technical determinants of swimming performance. After title and abstract screening and full-text assessment, 50 studies were retained for qualitative and thematic synthesis. Included studies were evaluated by the FICO framework (Focus, Information, Context, Outcome); As the designs and outcome measures of the studies were highly different, no meta-analyses effect sizes are reported and the findings are combined narratively. Three thematic findings emerged. First, upper limb and trunk strength, expressed through tethered force and dry-land resistance capacity, are consistently associated with stroke propulsion and sprint velocity, although the strength-performance relationship is moderated by competitive level. Second, lower limb explosive power, assessed through jump and force-plate measures, is a robust determinant of start and turn performance, phases that contribute disproportionately to total 50-m time. Third, technical variables, particularly stroke length and stroke-rate regulation, mediate the translation of physical capacity into measurable velocity. Across studies, maximal-strength, plyometric, and complex training emerged as the most effective dry-land modalities. The review indicates that sprint freestyle performance is best modelled as an integrated outcome of force production, explosive power, and technical efficiency rather than any single capacity. Practically, the findings support multimodal conditioning that couples heavy resistance and plyometric work with technique-focused practice. Methodological heterogeneity and a scarcity of longitudinal designs are identified as priorities for future research.

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Introduction

The world of competitive swimming holds a significant place among different types of aquatic sports, with sprint races that cover short distances attracting attention from scientists for a long time. The reason is that such races abridge the factors that determine athletic performance to a moment of short and very intense physical activity. The 50-meter freestyle is the shortest Olympic swimming event and is considered the best showcase of swimming speed, requiring almost maximum neuromuscular effort right from the start signal.

So, it is a combination of physical and technical characteristics that separate faster from slower sprinters which matter the most for identifying talent and designing training. Reviews of competitive youth and adult swimmers point out that performance in such events is due to a combination of anthropometric, physiological, biomechanical, and technical factors rather than any single characteristic (Price et al., 2024); (Carvalho et al., 2023).

In this multifactorial scenario, three factors have been showing up repeatedly in the empirical literature: upper limb strength, lower limb explosive power, and swimming technique. Most of the force for propulsion during front-crawl swimming is produced by the musculature of the upper limb and trunk, power of the lower limb controls the explosive start and turn, and technique is the main factor for deciding how efficiently that force is changed into forward velocity. Although conceptually our understanding of the behavior of these determinants assumes their interdependence, still they have frequently been studied independently, and by doing so the information regarding how they collectively shape the sprint outcomes has been limited (Jin et al., 2024); (Amara et al., 2021).

This review is focused on adolescent and adult swimmers in competitive 50-m freestyle events in the pool. While Jin et al. (2024) only focused on resistance-training methods and Amara et al. (2021) only tested concurrent training within a single cohort, this review combines strength, power, and technique evidence from different studies to assess whether their combined effect is better than any single factor explanation of sprint performance.

Considerable research has focused on the relationship between strength and performance in swimming. Using dry-land and tethered testing modes of measuring upper-body strength, cross-sectional and interventional studies have found sprint velocity and stroke propulsion to be directly linked with these measures. Also, resistance-training programmes are capable of improving short-to-middle-distance front-crawl performance (Jin et al., 2024). Another strand of research has highlighted how lower limb strength and explosive power could enhance start and turn phases, which contribute a significant portion of total time in short-course sprint events (Thng et al., 2020); (Sokolowski et al., 2023). Methodologically, the field experienced a significant leap when various new instruments that allow for better and more accurate analysis of force-time characteristics and their transfer to water were adopted, including force-plate analysis, tethered-swimming ergometry and velocity-based testing (Thng et al., 2020); (Ozturk et al., 2024). Training-related studies have also shifted from general resistance practices to specific kinds like plyometric, complex, and velocity-based training modalities, with numerous studies comparing their effects on power development (Yang et al., 2025); (Wang et al., 2023); (Ma et al., 2026). Not only have these developments enhanced the capacity to measure the factors, but they have also revealed the diversity in how outcomes are conceptualised.

The first shortcoming in the area is integration. Even though the main factors of a person are explored quite in detail, only a few consolidated studies compare how arm strength, leg power, and swimming technique together fulfill the requirements of the 50-m freestyle swimming. Generally, current reviews are centered on strength training in swimming at a broader level (Wirth et al., 2022) or a single ability such as lower-limb explosive power (Wang et al., 2023) and so the question of the integration of these components is left unexplored. Another gap is methodological. Cross-sectional and short-term intervention designs with inconsistent control of competitive level, maturation, and sex largely characterize the literature. Strength-performance association seems to be dependent on the swimmer level (Yang et al., 2025) and biological maturation of younger age groups (DE ALMEIDA-NETO et al., 2023). Therefore, results obtained from samples of different kinds are quite difficult to generalize, and to some extent, the causal mechanisms connecting physical capacity to sprint velocity are still inferred. These discrepancies highlight the need to conduct a targeted systematic review. The international sprint freestyle level is becoming more and more competitive, and the slightest improvements in the start, mid-pool, and turn phases can make all the difference. A review that clearly shows the interplay of strength, power, and technique is not only appropriate at this time for consolidating the current evidence but also helpful in planning the integrated conditioning programs for sprint swimmers (Jin et al., 2024); (Diu & Thuc, 2024).

Therefore, the first objective of this review is to identify how much upper-limb strength contributes to sprint freestyle swimming performance. This issue is being explored, as efforts to move forward in front crawl are mainly produced by the upper limbs along with the trunk, and understanding this link will lead to direct consequences on how resistance training is prescribed.

RQ1: What is the role of upper limb (and trunk) strength in 50 m freestyle swimming?. The second goal is related to the explosive power of lower limbs. In sprinting, the start and turn are two of the most explosive, ballistic actions. Therefore, the review investigates the correlation of lower-limb power with these phases and with overall sprint time. In doing so, it provides a clearer evidence base for plyometric and power-oriented training. RQ2: What extent does lower limb explosive power contribute to the start, turn, and overall 50-m freestyle performance?. The third aim discusses technique as the mechanism that connects a swimmer's physical capacity to their swimming speed. Through combining research on stroke length, stroke rate, and kinematic efficiency, this review explains the role of technical variables in the interplay of strength-power-performance. The unique aspect of this review is that it incorporates the three factors in a single PRISMA-based sprint freestyle analysis instead of viewing them as distinct research avenues. RQ3: To what extent is the effect of physical capacities (strength and power) on 50-m freestyle performance explained by swimming technique?

Method

Research Design and Framework

Firstly, this research is a systematic literature review (SLR) a precise, clear, and well-ordered way of figuring out, examining, and combining already established facts about a certain question. The reason for choosing the SLR method is that it lessens the chance of introducing selection bias and also makes the research more reproducible as compared to narrative reviews. Both the decisions related to reporting and the procedure were in accordance with PRISMA 2020 statement that offers a standardised framework for recording identification, screening, eligibility and inclusion. Moreover, the synthesis' thematic approach matches the evidence structuring of recent swimming reviews (Jin et al., 2024); (Wang et al., 2023); (Chaabene et al., 2025).

Search Strategy

A Boolean search string was put together to capture the overlap of swimming performance, strength, explosive power, and technique constructs. The search was conducted in the fields of title, abstract, and keyword (TITLE-ABS-KEY) and used truncation to cover lexical variants (e.g., swim*, strength, power). The string used was:

> TITLE-ABS-KEY(("swim" OR "freestyle" OR "front crawl")AND ("strength" OR "resistance training" OR "muscle force")AND ("explosive power" OR "plyometric" OR "jump")AND ("technique" OR "kinematic" OR "stroke" OR "performance"))

Truncation (the asterisk) managed to get morphological variants like swim, swimmer and swimming, on the other hand, field codes restricted hits to the most semantically relevant metadata. Limiters for language and document type were applied at the screening stage rather than the search stage.

Database and Information Sources

Scopus was used as the main and official source of information for this review. It was chosen because it covers a wide range of disciplines in peer-reviewed sports science journals and its organized metadata allow reproducible export and bibliometric processing. The search was conducted on 29 June 2026. There were no other databases. Accordingly, the synthesis is solely based on the Scopus-indexed corpus which is a limitation that is recognized in the limitations section.

Table 1. Inclusion and Exclusion Criteria

Criterion	Inclusion	Exclusion
Language	English-language documents	Non-English (Spanish, Chinese, Russian, Persian)
Document type	Original article, Review	Book, book chapter, short survey, retracted, editorial
Publication period	2020–2026	Published before 2020
Subject area	Sport science, exercise physiology, biomechanics, human movement	Unrelated disciplines
Accessibility	Verifiable record with DOI	No DOI / not retrievable
Relevance	Directly addresses strength, power, or technique in swimming performance	Tangential or incidental mention only

Study Selection Process

Study selection was done in three consecutive steps. First, the titles and abstracts of 183 records discovered through the search were compared to the inclusion criteria in order to also exclude the records which were clearly not related to the topic. Next, the complete manuscripts of the remaining records were checked for eligibility in terms of language, type of document, availability, and direct connection to the strength-power-technique area. In the third step, studies that met the criteria were taken forward for review. The process of screening records against the criteria was done in a very systematic way, and cases that were not clear were decided after looking again at the full record metadata and abstract content for better understanding.

The exact number of records at each screening stage are given in the PRISMA 2020 flow diagram (see Figure 1) below. The single-database (Scopus) approach was chosen for the sake of consistency and reproducible export, and this selection is also recognized as a limitation without any multi-database triangulation to offset it.

Quality Assessment — FICO Framework

The FICO framework was the tool used to evaluate the methodological quality and relevance of studies. This framework assesses each study on 4 dimensions: Focus (how clear and relevant to sprint swimming determinants is the research question?), Information (how well the sample description, instrumentation, and data reporting are done), Context (whether the population, setting, and competitive level are appropriate), and Outcome (how valid and interpretable the performance or capacity measures reported). Each dimension was rated on a three-point scale with 0 meaning not met, 1 partially met, and 2 fully met. The maximum score a study can get is 8. Synthesis inclusion was based on the studies that scored at least 5 out of 8. In fact, all 50 studies that were retained met this threshold.

Data Extraction Procedure

We used a standardized data extraction sheet for all the studies we included. This sheet helped us collect the necessary information, such as the author(s), publication year, country of the lead affiliation, study design, sample characteristics, the intervention or determinant examined, outcome measures, and key findings. Extraction was done straight from the Scopus metadata and abstracts to keep the closeness to the source records intact. The extracted fields were then used to prepare the descriptive tables and thematic synthesis.

Network and Bibliometric Analysis Methodology

Descriptive bibliometric analysis of the included corpus was conducted to complement the qualitative synthesis. Co-occurrence frequencies of author keywords were computed, the dominant conceptual clusters were identified, and the temporal and geographic distribution of the studies was tabulated. The visualisation of keyword co-occurrence (Figure 4) was created to portray the conceptual structure of the field, following the rationale of co-occurrence analysis used by tools like VOSviewer, with frequency thresholds set to keep the most prominent terms.

Data Analysis and Synthesis

We used a thematic synthesis approach for the organisation of finding. After the coding or labelling process, the findings were grouped into descriptive themes that came from the three determinants that are under research the strength of upper limb, explosive power of the lower limb, and technique. Later on, these descriptive themes were used to answer the three research questions resulting in analytical conclusions. At the same time, agreements, contradictions, and moderating factors (like competition level, and maturation) were explicitly analysed rather than being blindly combined or ignored.

Reporting and Documentation

The review was recorded following the PRISMA 2020 reporting template, and the process of records from identification to inclusion is shown in the PRISMA 2020 flow diagram. Numbers are consistently reported in the Abstract, Methods, Results, and flow diagram to maintain internal coherence and reproductivity of the screening pathway.

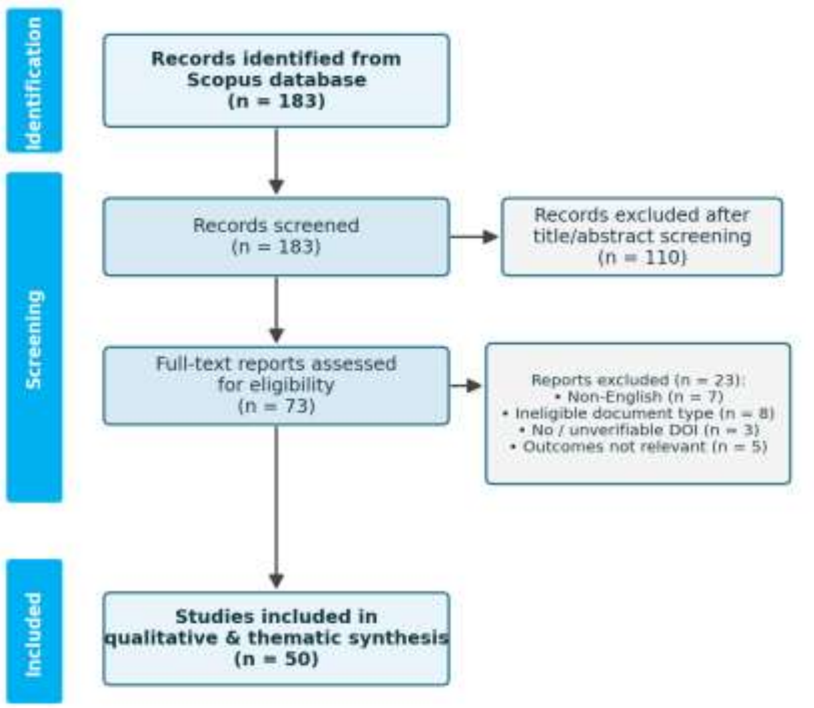

Figure 1. PRISMA 2020 flow diagram of the study identification, screening, eligibility, and inclusion process.

Results and Discussions

Study Selection Results

Scopus returned 183 search results. Since the text was taken from a single deduplicated database export, there was no need to remove duplicate records, so 183 records were left for screening. 110 records were discarded after title and abstract screening because they did not directly discuss strength, power, or technical determinants of swimming performance, 73 full-text records were left for eligibility assessment. 23 of these were excluded for the following reasons: non-English language (n = 7), ineligible document type such as books, book chapters, short surveys, or retracted items (n = 8), unable to find/access or absence of a verifiable DOI (n = 3), and the main outcomes were not relevant to the review (n = 5). This method led to the inclusion of 50 papers in the final qualitative and thematic synthesis that is in line with the PRISMA flow diagram.

Descriptive Characteristics

The 50 studies selected publication dates ranges from 2020 to 2026, and the number of publications focuses mainly on recent years having an upward trend (Figure 2). Besides China, Tunisia, Brazil, Spain, Portugal, and the UK, research was so varied in different parts of the world (Figure 3). Author-keyword co-occurrence (Figure 4) showed swimming performance, resistance training, power, and stroke parameters are the major thematic clusters of the collection. Table 2 presents tenfold representative samples of the included studies, and Table 3 depicts their themes and methodological types.

Table 2. Summary of Representative Included Studies (n = 10)

Title	Author(s)	Year	Country / Method	Key Findings
The prediction of swim start performance based on squat jump force-time characteristics	Thng S. et al.	2020	Australia — Cross-sectional; squat-jump force-time analysis (n=38 swimmers)	Squat-jump force-time variables significantly predicted swim-start (15 m) performance, linking lower-limb explosive power to starts.

Title	Author(s)	Year	Country / Method	Key Findings
Synbiotic Supplementation with Probiotics and Omega-3 Fatty Acids Enhances Upper-Body Muscle Strength in Elite Swimmers	Imanian B. et al.	2025	Iran — Randomized double-blind trial; 8-week synbiotic supplementation	Probiotic + omega-3 supplementation enhanced upper-body muscular strength and power outputs in trained swimmers.
The methodology of resistance training is crucial for improving short-medium distance front crawl performance	Jin G. et al.	2024	China — Systematic review of dry-land resistance-training methods	Structured resistance training is decisive for improving short-to-middle-distance front-crawl performance.
Swimming sprint performance depends on upper/lower limbs strength and swimmers level	Carvalho D.D. et al.	2023	Portugal — Cross-sectional; tethered-force & dry-land strength testing by level	Sprint performance depended jointly on upper- and lower-limb strength, moderated by swimmer level.
Comparing the Effects of Maximal Strength, Plyometric, and Muscular Endurance Training on Swimming-Specific Performance	Yang L. et al.	2025	China — Randomized trial comparing maximal-strength, plyometric & endurance training	Maximal-strength and plyometric programs produced the largest gains in sprint and power-related outcomes.
Underwater and surface tethered swimming, lower limb strength, and somatic traits as indices of sprint performance	Sokolowski K. et al.	2023	Poland — Cross-sectional; underwater/surface tethered swimming + lower-limb strength	Lower-limb strength and somatic traits were key determinants of sprint front-crawl and dolphin-kick velocity.
The effect of concurrent resistance training on upper body strength, sprint swimming performance and kinematics	Amara S. et al.	2021	Tunisia — Controlled trial; concurrent dry-land resistance + swim training	Concurrent resistance training improved upper-body strength and sprint swimming without impairing technique.
Comparing acute effects of heavy resistance, plyometric, and complex training on post-activation performance enhancement	Ma Z. et al.	2026	China — Crossover; heavy-resistance vs plyometric vs complex conditioning	Complex and heavy-resistance protocols acutely enhanced post-activation performance and subsequent sprint output.
Effect of Dynamic Resistance Training on Isometric Strength, Architecture, and Biomechanical Efficiency of Muscles	Koryak Y.A. et al.	2025	Russian Federation — Intervention; dynamic resistance training, ultrasound + dynamometry	Dynamic resistance training increased isometric strength and altered muscle architecture and biomechanics.
Effectiveness of plyometric training vs. complex training on the explosive power of lower limbs	Wang X. et al.	2023	Malaysia — Systematic review; plyometric vs complex training	Both plyometric and complex training improved lower-limb explosive power, with complex training showing added benefit.

Table 3. Classification of Representative Studies by Theme and Method (n = 10)

Author(s)	Year	Country	Research Design	Theme / Focus	Intervention
Thng S. et al.	2020	Australia	Cross-sectional	Lower-limb power / start	Squat-jump testing
Imanian B. et al.	2025	Iran	RCT	Upper-limb strength	Synbiotic supplement
Jin G. et al.	2024	China	Systematic review	Upper-limb strength / technique	Dry-land resistance
Carvalho D.D. et al.	2023	Portugal	Cross-sectional	Integrated strength	Tethered + dry-land
Yang L. et al.	2025	China	Randomized trial	Power / strength training	Maximal/plyometric
Sokolowski K. et al.	2023	Poland	Cross-sectional	Lower-limb power	Tethered swimming
Amara S. et al.	2021	Tunisia	Controlled trial	Concurrent strength	Concurrent resistance
Ma Z. et al.	2026	China	Crossover	Lower-limb power (PAPE)	Heavy/plyometric/complex
Koryak Y.A. et al.	2025	Russian Federation	Intervention	Strength / architecture	Dynamic resistance
Wang X. et al.	2023	Malaysia	Systematic review	Lower-limb power	Plyometric vs complex

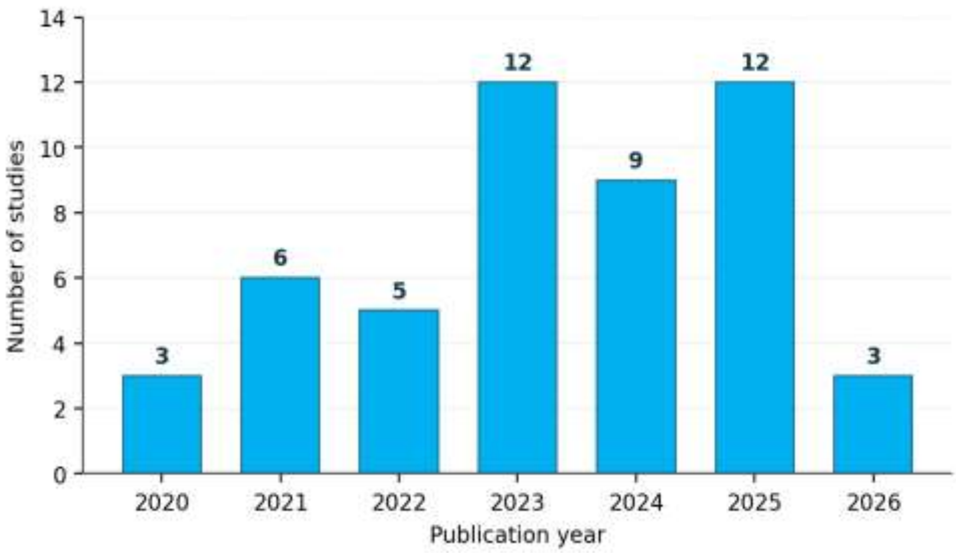

Figure 2. Annual distribution of the 50 included studies (2020–2026).

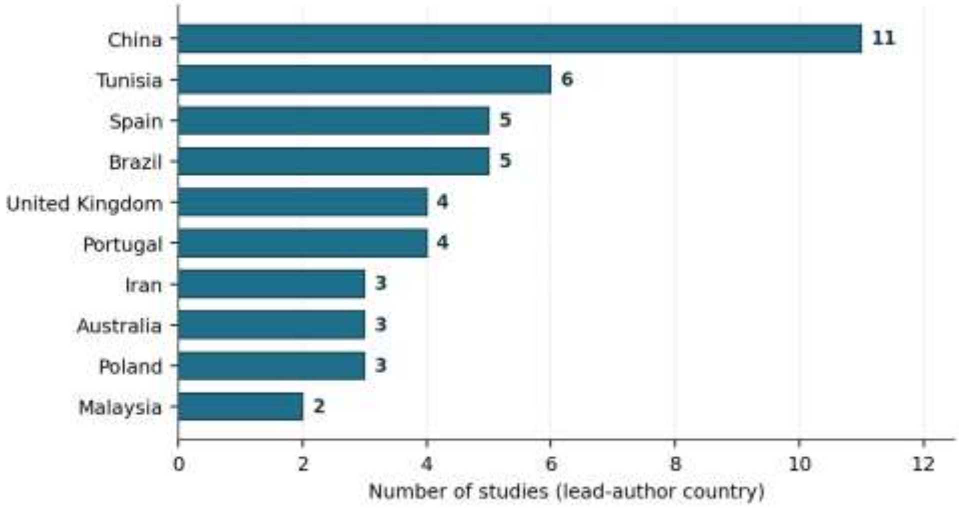

Figure 3. Geographic distribution of included studies by lead-author country (top 10).

Figure 4. Author-keyword co-occurrence map; bubble size reflects keyword frequency.

Thematic Synthesis

Findings for RQ1 — Upper Limb Strength

The research always points to the fact that strength in the upper limbs and trunk is a major factor influencing sprint freestyle swimming performance. For instance, Yang et al. (2025) revealed that both upper- and lower-limb strength contribute to sprint performance, however, the level of the swimmer determines the extent to which strength is a factor, implying that as a swimmer becomes more skilled, strength is more of a differentiator. In addition to that, Jin et al. (2024) after a methodological review came to the conclusion that resistance training is the main factor for improving front-crawl performance over short-to-middle distances, which strongly supports the cause-effect relation between strength and velocity.

Interventional studies are a step further than these cross-sectional studies. According to Amara et al. (2021), concurrent dry-land resistance training led to improvements in upper-body strength and sprint swimming, and technique was not compromised. On the other hand, Amara et al. (2022) found that concurrent training, especially the one focusing on the upper body, resulted in similar gains. Supplementation studies have also demonstrated that by means of nutrition, muscular capacity can be enhanced so that it increases upper-body strength and power in trained swimmers (Imanian et al., 2025), which clearly indicates that the production of force by upper limbs is a modifiable factor for performance. Tethered-force instruments have a role in defining this relationship even more by correlating propulsive impulse with a quantifiable sprint capacity (Marinho et al., 2021); (Oliveira et al., 2020).

Still, the connection doesn't quite follow a straight line. Many researchers advise that the transfer of dry-land strength to a swimmer's velocity in the pool is highly dependent on the mechanics of the stroke and the specificity of the resistance stimulus (Saeterbakken et al., 2022); (Arsoniadis et al., 2025). Hence, the review is in favour of a tempered version in which upper-limb strength is a requirement but on its own it is not enough; the manifestation of it depends on technical skills and level of competition. So, to RQ1 upper limb and trunk strength through their primary effect of increasing stroke propulsion, top-level swimmers increased effective 50-m freestyle by integrating strength training with technical practice.

Findings for RQ2 — Lower Limb Explosive Power

Lower-limb explosive power was identified as main factor behind start and turn, the phases that heavily influence 50-m time. Thng et al., (2020) demonstrated that squat-jump force-time parameters could predict swim-start performance to a great extent. The study thereby offered a direct mechanical explanation of how lower-limb power influences block performance. In the same manner, Sokolowski et al. (2023) pointed out lower-limb strength and body structure as the main factors responsible for speed in sprint front-crawl and underwater dolphin-kick.

Training studies agree on plyometric and power-oriented exercises as the effective ways to develop this capacity. For instance, Wang et al. (2023) revealed that both plyometric and complex trainings led to an increase in lower-limb explosive power, and complex training provided even more benefit; similarly, Yang et al. (2025) showed that the programmes of maximal-strength and plyometrics resulted in the biggest improvements in sprint and power performances. On the other hand, acute potentiation research gives more details: for instance, Ma et al. (2026) showed that heavy-resistance as well as complex protocols can instantly boost post-activation performance and the following sprint output, whereas Koryak et al. (2025) associated dynamic resistance training with the changes in muscle architecture and isometric strength that support the ability to be explosive.

There is some variation in how big and when these changes happen, and that these factors change with a person's age, whether they are a trained athlete, and how the programme is done (Chaabene et al., 2025); (Dhote et al., 2024). The fact that the effectiveness of plyometric training changes with age hints that the period during which one can develop power may be limited by one's stage of development (Chaabene et al., 2025). To address RQ2, explosive power of the lower limbs is a very important factor in determining the performance in the start, turn, and overall sprint. It has been found that plyometric and complex training, as well as velocity-based training, are the best ways to develop this power. However, the size of the effects also depends on the level of physical maturation and training history.

Findings for RQ3 — Technique as Mediator

This method is a central theme throughout the works as the way to turn physical ability into speed. Research on swimming movements show that the length and frequency of strokes are important factors that connect the exertion of force to the resulting speed (Marinho et al., 2021); (Alawamleh & Alkasasbeh, 2024). Carvalho et al. (2023) demonstrated that the performance in sprinting is a reflection of both physical strength and swimming techniques, indicating that two equally strong swimmers may have different swimming speeds due to their level of technical efficiency.

Biological maturation and anthropometry still shape this mediation. DE ALMEIDA-NETO et al. (2023) and Oliveira et al. (2020) found that propulsive force and its conversion into velocity are influenced by the maturational status and body segment dimensions, especially in youth cohorts. This means that technical changes have to be adjusted according to the developmental level, and that strength improvements may be only partially realized if the stroke technique is not optimal (Nakatani et al., 2024); (Carrasco-Fernandez et al., 2025).

Most importantly, the studies even point to a two-way street: better strength can support achieving higher sustainable stroke rates, on the other hand, better swimming technique makes it possible to direct a bigger share of produced force into propulsion (Saeterbakken et al., 2022); (Diu & Thuc, 2024). Besides the above, to respond to the third research question, the swim technique affects the strength-power-performance chain by determining the level of conversion of produced force and power into swimming velocity. Thus, the technical proficiency is the one who opens the door through which the physical capability is experienced. So, without it, one cannot get the best out of strength and power training.

Comparative and Critical Analysis

Methodologically speaking, most of the corpus consists of cross-sectional studies and short-term intervention studies. Cross-sectional research identifies links between strength, power, and performance (Yang et al., 2025); (Sokolowski et al., 2023) while controlled and randomized trials offer stronger causal evidence of the effects of training (Yang et al., 2025); (Ma et al., 2026). Systematic reviews in the corpus summarize these results at a much more conceptual level (Jin et al., 2024); (Wang et al., 2023); (Chaabene et al., 2025), but the few long-term longitudinal studies severely restrict our understanding of the long-term adaptations.

A change in approach can be seen along the review period: older studies were based mainly on anthropometric and gross strength measurements (Oliveira et al., 2020; San Juan et al., 2020), while recent research makes use of force-plate, tethered-ergometry, and velocity-based devices (Thng et al., 2020; Ozturk et al., 2024; Price et al., 2024). This adjustment not only raised the measurement accuracy but also increased the diversity in the outcome definition, making direct comparison of studies more difficult. The designs that are rarely used are multi-season cohort studies and mechanistic works that integrate in-water kinetics with dry-land capacity.

Besides the fundamental determinant investigations, a methodological work has been done examining the measurement reliability and the coaching practice that is applied. For instance, Salter et al. (2025) have shown the reliability and sensitivity of isometric strength and sprint-speed tests in adolescent athletes. Similarly, Raineteau et al. (2023) have probed the dry-land training and testing methods of strength-and-conditioning coaches, revealing the wide-ranging variability of field application. Mechanistic research has explained the dry-land foundation of power: For example, Thompson et al. (2023) have studied the kinetics and kinematics of the free-weight back squat and loaded jump squat, and Jaen-Carrillo et al. (2026) have discovered that submaximal back-squat mechanical variables are directly linked to performance. Besides that, Ashworth et al. (2025) have elaborated on the muscle activity of shoulder internal- and external-rotation which is quite relevant to upper-limb propulsion, and Argun et al. (2023) have analyzed grab and track starts with respect to lower-extremity strength characteristics.

Intervention research has highlighted the importance of resistance and plyometric stimuli in training protocols. According to Zouita et al. (2023), resistance training is effective in boosting muscular fitness, muscle morphology, and body composition. Silva et al. (2022) demonstrated that a 10-week dry-land strength-and-conditioning program was able to improve various physical capacities and start performance. However, da Silva et al. (2022) emphasized that the fat-free-mass gains resulting from resistance periodization may not always translate to improved in-water performance. Almeida et al. (2021) reported that power-oriented resistance training during an altitude camp led to enhancements in strength and technical aspects of the sport. At the same time, Gemaini et al. (2023) and Ojeda-Aravena et al. (2023) independently supported the effectiveness of plyometric-jump training in raising lower-limb explosive power and general physical fitness. Keller et al. (2023) followed the interplay of metabolic and mechanical factors throughout an annual training cycle and interpreted these changes as adaptations made during periodized preparation. Randomized studies on training load further elaborate that an optimal resistance dose is necessary to achieve improvements in swimming performance (Amara et al., 2021).

Neuromuscular and ancillary streams are added to complete the picture. Gomes et al. (2025) researched the impact of concurrent-training on the H reflex, V wave, and contractile properties of plantar flexors, thereby identifying lower limb adaptations as the source of explosive power. On the other hand, Fortes et al. (2024) found that cognitive effort elevated to an extreme level right before velocity-based training sessions negatively affects the rate of force production, thus highlighting the importance of neuromuscular readiness for power expression. Symons et al. (2023) demonstrated that sprint-interval training increases the rate of torque development, a reliable and transferable measure of the ability to produce an explosive movement. On the other hand, Miro et al. (2021) found that a customized bite-aligning mouthguard influenced the powerful movements of highly trained swimmers. Chmiel & Kurpas (2026) ergogenic research, just published, has taken the lead in revealing that the transcranial direct-current stimulation can be considered as a performance enhancer in swimming. Altogether, these research articles not only expand the evidential basis supporting the integrated determinant model but also vividly demonstrate the wide range of factors that influence the strength-power-technique relationship.

Discussion

Taken together, the results show that 50-m freestyle performance depends on an integration of strength, power, and stroke technique rather than the output of one single factor. The repeated moderation of strength's influence by swimmer level and maturation (Yang et al., 2025); (DE ALMEIDA-NETO et al., 2023) points to the fact that these determinants are part of a dynamic system which undergoes rebalancing along the development and competition process.

In theory, the synthesis lends support to an integrated determinant system where technique serves as the medium that physically links the capacity with velocity. Such a system essentially describes a sport performance model based on physiological factors only (Carvalho et al., 2023), (Diu & Thuc, 2024). In practice, the findings support a method in which a multimodal conditioning that couples heavy resistance and plyometric training with technique-based practice is used; coaches should phase dry-land power work with in-water technical refinement rather than consider them as separate domains (Jin et al., 2024), (Wang et al., 2023), (Ma et al., 2026).

Relative to previous reviews which generally looked at strength training in swimming (Wirth et al., 2022) or the isolated capacities like lower-limb power (Wang et al., 2023), the current review unfolds a direct integrative narrative centered on sprint freestyle. Discrepancies in literature, mainly the inconsistent size of strength translation to swimming speed (Saeterbakken et al., 2022); (Arsoniadis et al., 2025), are logically accounted for by variations in sample level, equipment, and extent of technique control.

Three main research gaps can be identified. First, only a handful of studies consider the three determinants together in a single sprint-freestyle sample. Second, longitudinal and multi-season studies are almost non-existent, thereby making the understanding of continuous adaptation very limited. Third, sex- and maturation-specific responses are still largely unknown (Ma et al., 2026); (DE ALMEIDA-NETO et al., 2023). The review itself is not flawless: the exclusive use of one database (Scopus) could have left out relevant records; the limitation to English-language articles and reviews carries the risk of both language and publication biases; the qualitative nature of the synthesis makes it impossible to have meta-analytic features and therefore, no pooled effect estimates can be given. Hence, heterogeneity statistics like I^2 or τ^2 were not calculated because these refer to meta-analytical frameworks in contrast to narrative synthesis.This implementation also omits a formal separate Discussion subsection after synthesis and interpretative discussion is carried out in this Results and Discussions section.

Thus, future investigations should focus on multifactorial, longitudinal studies that also include dry-land capacity as well as in-water kinetics; standardise outcome measures for meta-analysis possibility; and look at sex- and maturation-specific training responses. To sum up, RQ1 is fulfilled through the significant impact of upper-limb strength on propulsion; RQ2, through the important function of lower-limb explosive power in start, turn, and sprint phases; and RQ3, through the role of technique as a bridge between physical capacity and velocity.

Conclusions

This systematic review synthesized evidence from 50 Scopus-indexed studies on the roles of upper limb strength, lower limb explosive power, and swimming technique in 50-m freestyle performance. The findings indicate that upper limb strength enhances stroke propulsion, lower limb explosive power is essential for effective starts and turns, and swimming technique serves as the key factor in translating physical capacity into swimming speed. Together, these components form an integrated framework for optimizing sprint freestyle performance. The review highlights the importance of combining strength, power, and technical training within a periodized program tailored to athletes' competitive level and maturation. Although limited to English-language studies indexed in Scopus and a qualitative synthesis, this review provides a comprehensive evidence base for coaches and practitioners. Future research should employ longitudinal and multifactorial designs with standardized outcome measures to strengthen evidence for integrated training strategies in sprint swimming

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