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Strength and conditioning programs for improving swimming performance in competitive swimmers: a systematic review

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ABSTRACT

Strength and conditioning (S&C) are commonly integrated into competitive swim coaching but questions regarding, which type of strength exercises result in the optimal improvements of underwater skills, the appropriate progression of the exercises remain unresolved. This systematic review merges the experimental findings where the main goal of S&C interventions was to enhance the performance of the swimmers. The review procedures conformed with the PRISMA 2020 statement requirements. First, Scopus was the search engine, which by a Boolean search was the first to provide 699 records, after that, 127 were the next ones to be left and from these, 20 were actually the intervention studies, which have been selected after the duplicates were removed in addition to filtering out the document type, the language, publication year, area, and also title and abstract screening. Eligible articles reported various S&C methods such as dry-land, in-water, resisted, plyometric, concurrent, or acute-potentiation as the swimmers were exposed to these and the swimming data were given. High-repetition low-relative-load and velocity-oriented protocols, short-term (6-12 week) mesocycles, and swimming-specific prescribing of the force vector turned out to be the most important elements in programming. As stated, the paper urges the implementation of swim training plans by means of S&C that is highly targeted and transfer oriented, at the same time, the authors point out the necessity for conducting the researches of a larger sample size and a longer time duration with a control of variables better as means to verify the conclusions of this study and to expand its scope.

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Introduction

In competitive swimming, races are won and lost by hundredths of a second, so there is no room for wasted effort. Outcomes hinge on propulsive forces, the power generated in starts and turns, and how efficiently each stroke is executed (Keating et al., 2025; Thng et al., 2024). Water resists movement but does not bear the swimmer's weight, which makes the ability to produce and apply force quickly a central goal. Strength and conditioning have moved accordingly, from a supporting role to a core part of modern swimming programs (Wirth et al., 2022; Raineteau et al., 2023). It is little wonder, then, that coaches, sport scientists, and performance staff around the world keep asking whether land-based or in-water resistance work actually produces better swimmers. The question at the center of this review is a familiar one: how well do the adaptations from dry-land training or resisted swimming carry over to competitive performance in the water? Swimmers commonly do resistance, plyometric, and power work in the belief that added strength and explosiveness will produce faster starts, higher underwater velocity, and sharper sprint times (Amara et al., 2022; Fernandes et al., 2025). Yet the relationship between force and velocity does not transfer from land to water in any simple or universal way. Several studies (Norberto et al., 2023; Sorgente et al., 2023) have shown that large gains on land can leave free-swimming performance largely unchanged. That tension, between clear neuromuscular adaptations and unreliable competitive transfer, is what drives the core question of this review.

Research on what shapes swimming performance has grown considerably. Some work centers on dry-land strength-power, anthropometrics, and joint range of motion (Nicol et al., 2022; Illera-Delgado et al., 2022). Other studies examine the mechanics of the start and the factors that predict swim block performance (Thng et al., 2022; Thng et al., 2024), or map power-velocity curves across different strokes and race distances (Sorgente et al., 2023; Raineteau et al., 2026). Repeated correlational findings link upper and lower limb strength, dry-land strength tests, and force-velocity profiles to start ability and sprint performance (Fernandes et al., 2025; Amara et al., 2026; Hołub et al., 2025). For a long time, the theoretical literature has treated strength training as one of the most important ingredients in a successful swimming career (Wirth et al., 2022). There are also adjacent lines of inquiry: the biomechanics of starts and underwater swimming (de Jesus et al., 2023; Chen et al., 2022; Wang et al., 2025), the physiological and metabolic factors behind different segments of a race (Keller et al., 2025; Almeida et al., 2023; Li et al., 2023), and the endurance qualities that support repeated efforts and how to measure them (da Silva et al., 2022). Useful as these findings are for describing the situation, they cannot on their own demonstrate that training improvements carry over into better performance.

Methodological advances in recent years have made it easier to see how swimmers actually perform and monitor strength and conditioning. Newer methods emphasize velocity, intensity, load management, velocity profiling, and applying force along specific directions, all of which permit precise, highly individualized prescription (Keating et al., 2025; Chen et al., 2025). Load equalization based on session rating of perceived exertion (sRPE) now allows different conditioning tools to be compared fairly in potentiation research (Ma et al., 2026). Meanwhile, new equipment for underwater resistance has reshaped swimming technology, blurring the old dividing line between pool work and gym work (Coloretti et al., 2025; Ruiz Navarro et al., 2024). Core training and breathing-enhanced regimens have added further possibilities (Jia et al., 2022; Cui et al., 2023; Fan et al., 2024; Xu et al., 2026). Despite all this activity, gaps remain. The evidence sits scattered across training modalities: maximal strength, plyometric, concurrent, blood-flow-restricted, and aquatic resistance training, each evaluated with very different outcome measures (Yang et al., 2025; Wang et al., 2023). With that kind of fragmentation, it is hard to tell which programs most reliably improve performance. Reviews of performance determinants do exist (Price et al., 2024), yet very few systematic reviews focus specifically on the effectiveness of S&C interventions in competitive swimmers. Practically none combine the recent velocity-based and force-vector approaches with the traditional strength and plyometric methods.

Second, the field is full of methodological and programming limitations. Many experiments are short, underpowered, single-sex, or run without tightly controlled conditions. Age-group and club samples are the norm, which limits how far the results can be applied to elite competition (Gemaini et al., 2023; Pereira et al., 2023; Permana et al., 2022; Gao et al., 2026). Programming variables, such as training frequency, intensity, duration, exercise selection, and periodisation, are rarely described in adequate detail, let alone compared against one another. Coaches therefore get little practical direction (Chaabene et al., 2025; Saeterbakken et al., 2025). A synthesis that highlights these variables is clearly needed. The pace and nature of new publications have made this review all the more necessary. S&C consumes a significant share of training hours, often at the expense of technical and aerobic work. Without transfer evidence showing it works, prescribing it may waste time and produce maladaptive fatigue (Tsoltos et al., 2023; Mujika et al., 2024). The recent S&C literature is growing quickly, and its methodology has improved, mostly within the last five years. A well-organized PRISMA-based synthesis therefore offers a way to turn a scattered body of studies into practical, evidence-based recommendations for competitive swimmers. With that in mind, this systematic review has three aims: to catalogue the S&C program types used with competitive swimmers, to appraise how effective they are for swimming performance, and to identify which programming characteristics are associated with the greatest improvements. These aims translate into three research questions: RQ1: What types of strength and conditioning programs have been implemented to improve swimming performance among competitive swimmers?; RQ2: How effective are strength and conditioning interventions in improving swimming performance outcomes, including swimming speed, power, strength, endurance, and race performance?; RQ3: What training characteristics (e.g., frequency, intensity, duration, exercise modality, and periodization) are associated with the greatest improvements in swimming performance? By synthesising twenty recent intervention studies within a transparent PRISMA 2020 framework and organising the evidence around modality, effectiveness, and programming, this review offers an integrated and practically oriented account of S&C for competitive swimming that extends beyond existing determinant-focused reviews.

Method

A systematic review of the literature design was done to locate, evaluate, and synthesise the available experimental literature in a way that is both transparent and reproduce-able. This method of literature review is good when the aim is to gather together primary research studies that address your research questions and at the same time reduce selection and reporting biases as far as possible (Tranfield et al., 2003; Liberati et al., 2009). Reporting and implementation were done in line with the PRISMA (Preferred) Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement that offers an updated, item- by-item guideline for different steps including identification, screening, eligibility, and inclusion, as well as providing template for the diagram illustrating the flow of a study selection (Page et al., 2021).

Before building the search string, the review questions were broken down using the PICO (Population, Intervention/Interest, Comparison, Outcome) framework in order to make sure that the main concepts were identified systematically (Table 1). Each of the four PICO components was expressed as a set of synonymous words and these were put together using logical connectors to form the search strategy.

Table 1. PICO framework used to structure the search strategy.

PICO element	Operationalisation for this review
Population (P)	Competitive, trained, or elite swimmers (including age-group and collegiate swimmers)
Intervention (I)	Strength and conditioning programmes - resistance/strength, plyometric, concurrent, in-water resisted, force-vector, and acute potentiation training
Comparison (C)	Control/usual training, an alternative S&C modality, or a within-subject pre-post comparison (comparator not mandatory)
Outcome (O)	Swimming performance outcomes - swim/sprint time, start and turn, underwater/stroke velocity, and neuromuscular strength or power transferable to swimming

The Boolean search string combined the population and intervention clusters with an outcome cluster and was applied to the title, abstract, and keyword fields: TITLE-ABS-KEY ((swimmer* OR swimming) AND ("strength training" OR "resistance training" OR "strength and conditioning" OR plyometric* OR "dry-land" OR "dryland" OR "power training" OR "concurrent training") AND (performance OR sprint OR speed OR "start" OR power OR velocity OR "race"))

Truncation (asterisk) captured lexical variants such as swimmer/swimmers and plyometric/plyometrics, while the TITLE-ABS-KEY field code restricted retrieval to the title, abstract, and indexed keywords. Limiters were applied for document type (article), language (English), publication window, and sport-relevant Scopus subject areas. The string was piloted and refined iteratively: an initial, broader version returned a large volume of clinical, animal, and non-swimming records, prompting the addition of the performance-outcome cluster to improve precision.

Scopus was chosen as the primary and authoritative bibliography source for several grounds: (1) it was considered as a very comprehensive database of sport science, kinesiology, and physiology literature (2) it is known for offering exportable structured metadata. An entire day's work was spent executing a single search and exporting metadata as was part of this review. The set of selected manuscripts, the selection flow diagram, as well as descriptive synthesis tables, were made from the same file of Scopus output. The primary selection process did not include the use of any additional databases. Eligibility criteria were defined a priori and are summarised in Table 2.

Table 2. Inclusion and exclusion criteria.

Criterion	Inclusion	Exclusion
Language	English	Non-English
Document type	Peer-reviewed article	Conference paper, book chapter, editorial, erratum
Publication period	2022-2026	Before 2022
Population	Competitive/trained/elite swimmers	Non-swimmers; other sports; clinical or animal samples
Intervention	Strength & conditioning / resistance / plyometric / in-water resisted / concurrent / acute potentiation	Non-S&C interventions; electrostimulation-only; respiratory-muscle-only; nutrition/recovery-only
Outcome	Swimming performance and/or transferable neuromuscular outcomes	Injury/pain outcomes only; no performance outcome

Design	Experimental / quasi-experimental intervention study	Cross-sectional/correlational; reviews; protocols; case reports without intervention

Screening was done in stages, following PRISMA 2020. First, the Scopus records were extracted, de-duplicated, and checked against the automated eligibility limiters. What remained then went through title-plus-abstract screening against three main themes: population, intervention, and outcome. Anything that failed to fit the population-intervention scope was dropped at that point. This included studies on non-swimming sports and populations, descriptive or correlational research with no intervention, clinical or animal work, and studies on nutrition, recovery, or monitoring. The studies still standing went to full-text inspection, where final eligibility was decided. Every screening decision at each phase was recorded. Whenever a judgment call came up, the paper was referred back for rereading with the checklist in Table 2, and this continued until every full-text exclusion could be explained.

Methodological quality was assessed separately from the PICO-based search formulation, using the Mixed Methods Appraisal Tool (MMAT), Version 2018 (Hong et al., 2018). That tool fits heterogeneous designs, which is exactly the situation here. For each study, the first step was classifying the design category: predominantly quantitative randomized controlled trials or quantitative non-randomized studies, with a single quantitative descriptive single-case study in the mix. From there, the relevant five-item checklist was applied, rating each item as Yes (1), Can't tell/Partial (0.5), or No (0). Studies reaching at least 60% of the criteria, ≥3 of 5, were kept for synthesis. Quality score alone never disqualified a study, in line with MMAT developer guidance. Table 3 lays out the appraisal results.

Table 3. Quality assessment summary (MMAT 2018). Q1-Q5 correspond to the five design-specific criteria; category thresholds: High ≥80%, Medium 60-79%, Low <60%.

Author(s), Year	Design (MMAT)	Q1	Q2	Q3	Q4	Q5	Total /5	%	Category
Silva et al. (2022)	Quant. RCT	1	1	0.5	1	1	4.5	90%	High
Amara et al. (2022)	Quant. RCT	1	1	1	1	1	5	100%	High
Gussakov et al. (2023)	Quant. non-randomized	1	0.5	0.5	0.5	1	3.5	70%	Medium
Gemaini et al. (2023)	Quant. non-randomized	1	0.5	1	0.5	1	4	80%	High
Amara et al. (2023)	Quant. RCT	1	1	1	1	1	5	100%	High
Tsoltos et al. (2023)	Quant. non-randomized	1	1	0.5	1	1	4.5	90%	High
Wang et al. (2023)	Quant. RCT	1	1	0.5	1	0.5	4	80%	High
Pereira et al. (2023)	Quant. non-randomized	1	0.5	0.5	0.5	1	3.5	70%	Medium
Norberto et al. (2023)	Quant. non-randomized	1	1	1	1	0.5	4.5	90%	High
Hill et al. (2024)	Quant. RCT	1	1	1	1	1	5	100%	High
Pocaan (2024)	Quant. non-randomized	1	1	1	0.5	1	4.5	90%	High
Ruiz-Navarro et al. (2024)	Quant. non-randomized	1	1	0.5	1	1	4.5	90%	High
Hartoto et al. (2025)	Quant. non-randomized	1	0.5	1	0.5	1	4	80%	High
Keating et al. (2025)	Quant. descriptive	1	0.5	1	0.5	1	4	80%	High
Yang et al. (2025)	Quant. RCT	1	1	1	1	1	5	100%	High
Chen et al. (2025)	Quant. non-randomized	1	1	1	0.5	1	4.5	90%	High
Pradittakarn et al. (2025)	Quant. RCT	1	1	1	0.5	1	4.5	90%	High
Ma et al. (2026)	Quant. RCT	1	1	1	1	1	5	100%	High
Rodríguez-Rosell et al. (2026)	Quant. RCT	1	1	1	1	1	5	100%	High
Yang et al. (2026)	Quant. RCT	1	1	1	1	1	5	100%	High

Out of the twenty studies, eighteen were rated High and the remaining two Medium. So the overall evidence base held up reasonably well, even though there's clearly room for it to be stronger. The most common constraints we ran into included the absence of real control groups in single-arm designs, plus insufficient disclosure of allocation and blinding. An independent double-appraisal with a Cohen's kappa coefficient in the substantial range (κ = 0.61-0.80) would have been a reasonable target here, but that wasn't what happened. A single reviewer appraised the studies instead, inter-rater reliability was never calculated, and we acknowledge that as a limitation.

For every study that made it into the review, a standardised extraction form captured the author(s) and year, study location, design, sample characteristics, the S&C intervention with its modality, frequency, intensity, and duration, the outcome measures, and the principal findings. On the swimming side, we pulled out sprint and race times, start and turn performance, underwater and stroke velocities, and transferable neuromuscular measures like one-repetition-maximum strength, jump performance, and medicine-ball throw. To keep the data honest, each extracted value was checked against the source abstract. Anything the original paper didn't explicitly report was recorded as not reported, never inferred.

Alongside the article synthesis, we ran a simple descriptive bibliometric analysis. Publication year was tallied in a table to show the temporal distribution, and geographic distribution was worked out from the study location where that was stated, or from the corresponding author's address when it wasn't. Author keywords across the included studies were aggregated to identify the main conceptual groups. Those clusters then got bundled into type-program themes so they could be presented graphically. Since the main concern here was combined interventions rather than full bibliometric mapping, we didn't attempt formal co-authorship or co-citation network mapping, for instance with VOSviewer.

Because the included studies varied quite a lot in modalities, doses, and outcomes, a narrative thematic synthesis made more sense than a meta-analysis (Thomas & Harden, 2008). Themes around program types were identified first, in line with research question 1. From there we dug into effectiveness (RQ2) and programming characteristics (RQ3), coding the findings inductively, grouping them, and then comparing agreements, contradictions, and dose-response patterns across studies. Each conclusion was weighted according to the study design and its methodological quality. The review follows the PRISMA 2020 checklist and flow diagram guidelines (Page et al., 2021, BMJ, 372, n71). Selection and exclusion stages, along with the final counts, are captured in the flow diagram (Figure 1) and explained in Section 5.1. That way the diagram, the Methods, and the Results all stay numerically consistent.

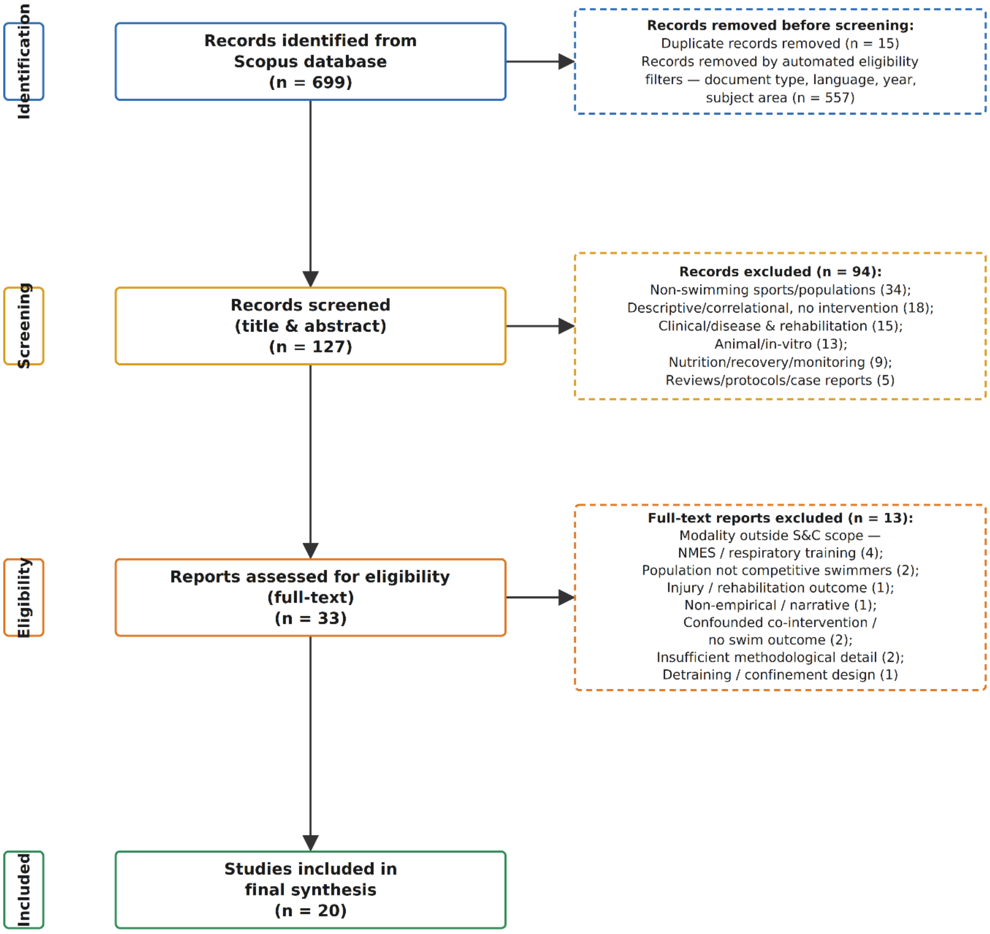

Figure 1. PRISMA 2020 flow diagram of the study selection process. Diagram template adapted from Page et al. (2021).

Results and Discussions

A Scopus search turned up 699 articles in total. Before anything was screened, the authors removed 15 duplicate records and then 557 more via automated eligibility limiters. Those limiters worked on document type, language, publication window, and subject area, which left 127 studies to move into title-and-abstract screening. From there, 34 studies were set aside because they discussed non-swimming sports and populations. Another 18 went out for being descriptive or correlational work without any intervention. Clinical, disease, and rehabilitation studies accounted for 15, animal or in-vitro research for 13, and 9 covered areas like nutrition, recovery, or monitoring. The remaining 5 were reviews, protocols, or case reports. Thirty-three reports made it through to full-text assessment, and 13 of those were excluded too. The reasons varied. Four studies featured intervention modalities outside the scope of sports coaching and conditioning, such as electrostimulation or respiratory-muscle training. Two had populations that did not consist of competitive swimmers. One looked at injury or rehabilitation outcomes, and one was a non-empirical or narrative article. Two had confounded co-interventions or lacked any swim-performance outcome measurement, while two more fell short on methodological detail. In the end, twenty (20 studies) fulfilled every criterion the authors set and were included in the final synthesis.

All twenty studies appeared between 2022 and 2026, with 2023 standing out as the most productive year by far. That single year produced more articles than all the others combined. At least fourteen different nationalities were involved across the sample. China was the main host country, and Indonesia, Tunisia, and Spain also contributed; the remaining studies formed a nearly worldwide circle (Figure 3). On the design side, randomized controlled trials and quasi-experimental intervention studies dominated. One paper, however, was a single-athlete case study. Swimmer numbers were generally quite limited (8 60 swimmers), and the groups ranged from age-group and Collegiate level swimmers up to national teams and Olympic-level athletes. Table 4 lays out the key characteristics of the included studies, and Table 5 presents their classification by themes and methods.

Table 5. Summary of included studies (full titles retained).

Title	Author(s), Year	Country	Design / Method	Key findings
Effects of a 10-week dry-land strength and conditioning program in physical capacities and start of previously federated and regular swimming practitioners	Silva et al. (2022)	Portugal	RCT	A 10-week dry-land S&C program significantly improved flexibility, strength and muscular power and enhanced swim-start flight-phase variables versus controls, although 15-m time gains were not strictly linear.
Effect of Concurrent Resistance Training on Lower Body Strength, Leg Kick Swimming, and Sport-Specific Performance in Competitive Swimmers	Amara et al. (2022)	Tunisia	RCT	Nine weeks of combined aquatic and dry-land resistance training produced large increases in 1RM back squat (~15%), 30-m leg-kick speed (~6%) and 100-m front-crawl start and turn performance; controls were unchanged.
Optimization of the speed-strength training technique for highly qualified swimmers	Gussakov et al. (2023)	Kazakhstan	Quasi-experimental	A phased speed-strength methodology using in-water resistance equipment improved speed-power qualities and stroke stability across speed modes in highly qualified national-team swimmers.
Plyometric training method potentially increasing explosive power of swimmer's leg muscles compared to untrained swimmer's	Gemaini et al. (2023)	Indonesia	Quasi-experimental (2-group)	Eighteen plyometric sessions significantly increased lower-limb explosive power in swimmers relative to a control group that received no land-based training.
The effect of combining HIIT and dry-land training on strength, technique, and 100-m butterfly swimming performance in age-group swimmers: a randomized controlled trial	Amara et al. (2023)	Tunisia	RCT	Eight weeks of combined HIIT and maximum-strength dry-land training substantially improved maximum strength (22-28%), stroke technique, and 100-m butterfly performance (~3.5%) versus usual training.
Delayed Effect of Dry-Land Strength Training Sessions on Swimming Performance	Tsoltos et al. (2023)	Greece	Crossover (quasi-exp.)	Dry-land maximum-strength or strength-endurance sessions performed the previous evening neither impaired nor enhanced next-day 100-m front-crawl time; only upper-body medicine-ball throw was transiently reduced after maximum-strength work.
Effects of 4-Week Low-Load Resistance Training with Blood Flow Restriction on Muscle Strength and Left Ventricular Function in Young Swimmers: A Pilot Randomized Trial	Wang et al. (2023)	China	Pilot RCT	Four weeks of low-load resistance training with blood-flow restriction increased 1RM back squat comparably to conventional high-load training in young swimmers, with only minor left-

Title	Author(s), Year	Country	Design / Method	Key findings
				ventricular structural change and no adverse cardiac effect.
Plyometric exercises to develop the muscular power of the swimmer's lower limbs in the start technique	Pereira et al. (2023)	Ecuador	Pre-experimental	A 12-week plyometric-exercise system significantly increased lower-limb muscular power and the flight distance achieved before water entry during the start technique.
Two Different Approaches to Dry-land Training Do Not Improve the Water Performance of Swimmers	Norberto et al. (2023)	Brazil	Controlled trial (3-group)	Both dry-land models (strength-only and combined strength-power) improved dry-land and tethered-swimming force but did not improve free-swimming 50-, 100- or 200-m performance beyond the control group.
The Acute Effects of a Preload Upper-Body Power Exercise on 50-m Freestyle Performance in Youth Swimmers	Hill et al. (2024)	United Kingdom	Randomized crossover	A pre-load upper-body power exercise (3×5 medicine-ball slams) induced post-activation performance enhancement, improving 50-m freestyle time by ~1.6% (0.47 s) after 4 min of recovery, with larger effects in females (~2%).
Effect of Tabata resistance training program on body capacities and 50m sprint performance of intermediate swimmers	Pocaan (2024)	Philippines	Quasi-experimental (2-group)	A Tabata resistance-training program outperformed conventional training, producing large gains in anaerobic capacity (1RM, peak and average power), VO_2max and 50-m sprint times across all four competitive strokes.
The Effects of Eccentric Training on Undulatory Underwater Swimming Performance and Kinematics in Competitive Swimmers	Ruiz-Navarro et al. (2024)	Spain	Controlled trial (2-group)	Five weeks of combined water and dry-land eccentric training (conical pulleys) improved undulatory-underwater-swimming velocity and kick kinematics, whereas water-only training improved only countermovement-jump height.
Improvement in 50-Meter Freestyle Swimming Speed Following 6 Weeks of Plyometric Training in 12-13 Years Old	Hartoto et al. (2025)	Indonesia	Pre-experimental (one-group)	Six weeks of plyometric training significantly reduced 50-m freestyle time in 12-13-year-old male swimmers (50.15 s → 49.26 s; $p < 0.01$).
Applying Load-Velocity Profiling to Guide In-Water Resistance Training in an Olympic-Level Swimmer: A Case Study	Keating et al. (2025)	Ireland	Single-case study	An individualized six-week in-water resisted-swim intervention guided by load-velocity profiling improved maximal swim speed (+3.4%) and competition time (+1.3%) in an Olympic-level 50-m freestyle swimmer.
Comparing The Effects of Maximal Strength Training, Plyometric Training, and Muscular Endurance Training on Swimming-Specific Performance Measures: A Randomized Parallel Controlled Study in Young Swimmers	Yang et al. (2025)	China	RCT (parallel)	Over six weeks, maximal strength training was superior to muscular-endurance training for start distance and time and for 25-50-m freestyle; plyometric training also outperformed endurance training on several swimming-specific measures.
Effects of Horizontal and Vertical Vector Resistance Training on Swim Start Performance: An Eight-Week Intervention in Division One Collegiate Swimmers in Taiwan	Chen et al. (2025)	Taiwan	Quasi-experimental (2-group)	Eight weeks of both horizontal- and vertical-vector resistance training improved swim-start flight distance and time and 15-25-m speed; horizontal-vector training showed more favorable within-group start and concentric-jump trends.
The Effect of Speed, Agility, and Quickness Training on Backstroke Performance in 12-15-Year-Old Students	Pradittakarn et al. (2025)	Thailand	RCT	Twelve weeks of speed-agility-quickness training significantly improved backstroke speed, stroke rate and coordination in 12-15-year-old swimmers relative to regular practice.
Comparing acute effects of heavy resistance, plyometric,	Ma et al. (2026)	China	RCT	When conditioning loads were equalized by session-RPE, heavy-

Title	Author(s), Year	Country	Design / Method	Key findings
and complex training on post-activation performance enhancement in elite swimmers: a randomized controlled trial				resistance, plyometric and complex protocols all elicited post-activation performance enhancement of 15-m swim-start time and lower-body power in elite swimmers, with peak effects several minutes post-conditioning.
Improved Neuromuscular Performance in Low-Load vs. Moderate-Load Resistance Training Among Young Elite Swimmers	Rodríguez-Rosell et al. (2026)	Spain	RCT	Eight weeks of velocity-based land resistance training at both low and moderate loads improved strength and 50-m freestyle time; only the low-load condition additionally improved countermovement jump and pull-up performance.
Responder signatures and predictors of upper- and lower-limb power responsiveness to maximal strength versus plyometric dry-land training in swimmers	Yang et al. (2026)	China	RCT	Both maximal-strength and plyometric dry-land training improved upper- and lower-limb power versus control; maximal-strength training elicited greater upper-limb responsiveness, and responder signatures were stable and strongly aligned with training modality.

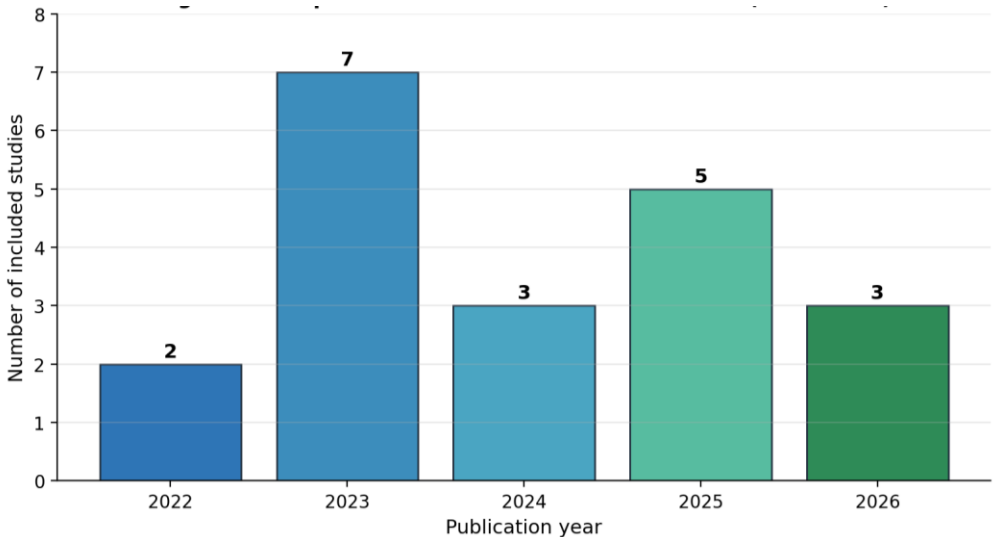

Figure 2. Temporal distribution of the 20 included studies by publication year.

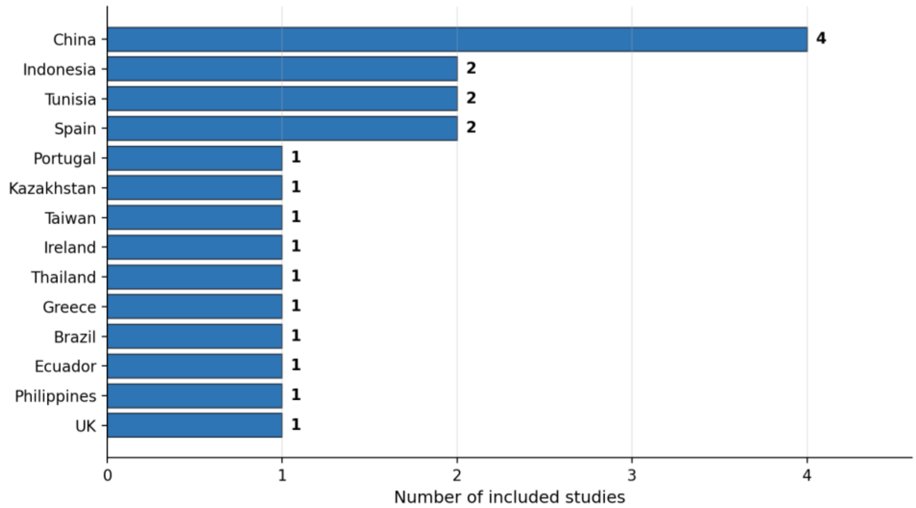

Figure 3. Geographic distribution of the included studies, by reported study location or corresponding-author affiliation.

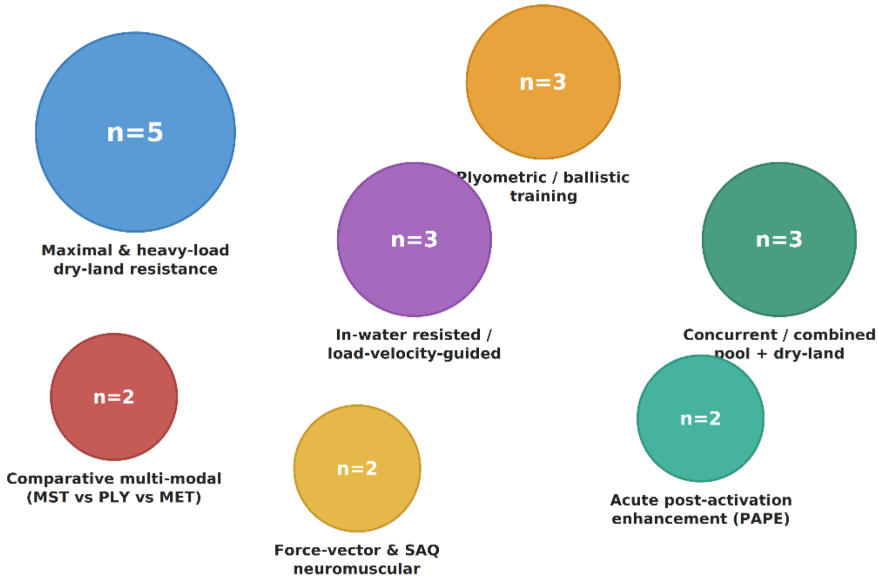

Figure 4. Thematic clustering of strength and conditioning program types across the included studies.

Table 5. Classification of included studies by theme, design, modality, and primary outcome.

Author(s), Year	Country	Research design	Theme / focus	Intervention / modality	Primary outcome
Silva et al. (2022)	Portugal	RCT	Concurrent / combined	10-wk dry-land S&C (2×/wk)	Start kinematics, strength, power
Amara et al. (2022)	Tunisia	RCT	Concurrent / combined	9-wk aquatic + dry-land resistance	1RM squat, 30-m leg kick, 100-m start/turn
Gussakov et al. (2023)	Kazakhstan	Quasi-experimental	In-water resisted / speed-strength	Phased in-water resistance (flippers, paddles)	Speed-power, technique stability
Gemaini et al. (2023)	Indonesia	Quasi-experimental (2-group)	Plyometric / ballistic	Plyometric (18 sessions, 4×/wk)	Lower-limb explosive power
Amara et al. (2023)	Tunisia	RCT	Concurrent / combined	8-wk HIIT + maximum-strength	Strength, technique, 100-m butterfly
Tsoltos et al. (2023)	Greece	Crossover (quasi-exp.)	Maximal & heavy resistance	Evening dry-land MS / SE session	Next-day 100-m front crawl
Wang et al. (2023)	China	Pilot RCT	Maximal & heavy resistance	4-wk low-load RT + blood-flow restriction	1RM squat, LV function
Pereira et al. (2023)	Ecuador	Pre-experimental	Plyometric / ballistic	12-wk plyometric exercise system	Start flight distance, muscular power
Norberto et al. (2023)	Brazil	Controlled trial (3-group)	Maximal & heavy resistance	6-wk dry-land strength / strength+power	50/100/200-m free, tethered force
Hill et al. (2024)	United Kingdom	Randomized crossover	Acute PAPE / potentiation	Medicine-ball slam (acute conditioning)	50-m freestyle time

Author(s), Year	Country	Research design	Theme / focus	Intervention / modality	Primary outcome
Pocaan (2024)	Philippines	Quasi-experimental (2-group)	Maximal & heavy resistance	Tabata resistance training	50-m sprint (4 strokes), power, VO_2max
Ruiz-Navarro et al. (2024)	Spain	Controlled trial (2-group)	In-water resisted / eccentric	5-wk water + dry-land eccentric (conical pulley)	UUS velocity & kinematics
Hartoto et al. (2025)	Indonesia	Pre-experimental (one-group)	Plyometric / ballistic	6-wk plyometric (3×/wk)	50-m freestyle time
Keating et al. (2025)	Ireland	Single-case study	In-water resisted / LV-guided	6-wk LV-profiled resisted swim	Max swim speed, competition time
Yang et al. (2025)	China	RCT (parallel)	Comparative multi-modal	6-wk MST vs PLY vs MET	Start, 25/50-m freestyle
Chen et al. (2025)	Taiwan	Quasi-experimental (2-group)	Force-vector & SAQ	8-wk horizontal vs vertical vector RT	Swim-start, 15/25-m speed
Pradittakarn et al. (2025)	Thailand	RCT	Force-vector & SAQ	12-wk speed-agility-quickness training	Backstroke speed, stroke rate
Ma et al. (2026)	China	RCT	Acute PAPE / potentiation	Acute heavy-resistance vs plyometric vs complex	15-m swim start, lower-body power
Rodríguez-Rosell et al. (2026)	Spain	RCT	Maximal & heavy resistance	8-wk velocity-based low vs moderate load	Strength, 50-m freestyle
Yang et al. (2026)	China	RCT	Comparative multi-modal	6-wk maximal-strength vs plyometric	Upper/lower-limb power responsiveness

Thematic Synthesis

Findings for RQ1 - Types of S&C programs implemented

The selected articles group around seven overlapping program types (Figure 4). Most studies describe maximal and heavy-load dry-land resistance training (Pocaan, 2024; Wang et al., 2023; Rodríguez-Rosell et al., 2026; Tsoltos et al., 2023; Norberto et al., 2023). Within that cluster sit the main forms of conventional/strength training, velocity-based strength work, and the bloodflow-restricted version. A second cluster centers on plyometric and ballistic training, with a clear focus on lower-limb explosive and start performance (Gemaini et al., 2023; Hartoto et al., 2025; Pereira et al., 2023). The third type combines pool-based and dry-land training alongside the usual resistance or maximal strength work, sometimes paired with swimming or HIIT (Silva et al., 2022; Amara et al., 2022; Amara et al., 2023).

A fourth group came from training that combines resisted exercises during the swimming movement itself, plus velocity-load-guided training. These programs include conical-pulley concentric work, specialty aquatic resistance equipment, and personal resistance swimming prescription (Ruiz-Navarro et al., 2024; Gussakov et al., 2023; Keating et al., 2025). Two further clusters reflect shifts in methodology within this field. One covers acute post-activation performance enhancement protocols used before competition (Hill et al., 2024; Ma et al., 2026). The other consists of comparative multi-modal designs that pit maximal strength training, plyometrics, and muscular endurance training against one another in the same experiment (Yang et al., 2025; Yang et al., 2026). Finally, vector-specific and speed-agility methods exemplify the swimming-specific neuromuscular modes that are only just drawing attention (Chen et al., 2025; Pradittakarn et al., 2025). Put together, these clusters answer RQ1. They show that S&C for swimmers now involves in-water resistance, potentiation, and direction-specific loading, not just traditional gym-based strength work.

The delivery context across each cluster also matters. Dry-land training was used mainly to build maximal force, power, and jump development. In-water resistance methods, by contrast, allowed swimmers to retain stroke technique while adding propulsion overload (Gussakov et al., 2023; Keating et al., 2025). Concurrent training models came closest to real-life swimming within daily training programs, since these sessions simply included the pool time already set aside for swim work (Silva et al., 2022; Amara et al., 2023). That breadth of methods is an essential quality of the current evidence base. It also sets the premise for the next discussion, which takes up the question of effectiveness.

Findings for RQ2 - Effectiveness for swimming performance

Start and short-sprint performance produced the most striking and consistent gains. Start flight distance and time both improved thanks to joint maximal-strength programs and isolated-strength training, which also yielded meaningful gains in 15-50 metre swim sprints, with effects ranging from modest to large (Amara et al., 2022; Silva et al., 2022; Yang et al., 2025). Plyometric interventions, meanwhile, reliably boosted lower-leg explosiveness and trimmed 50m freestyle times among younger swimmers (Hartoto et al., 2025; Gemaini et al., 2023; Pereira et al., 2023). Acute potentiation protocols delivered smaller but still meaningful effects, roughly a 1.6-2% improvement in 50m freestyle time when the conditioning stimulus targeted the upper limbs (Hill et al., 2024; Ma et al., 2026). In-water training combined with resistance and velocity-controlled loading had a significant influence on maximal swim speed in elite competitors and on race time in younger swimmers respectively (Keating et al., 2025; Ruiz-Navarro et al., 2024). Even so, outcomes varied across modalities, and the lack of transfer flagged in the introduction kept showing up in the data.

Two ground sessions improved both dry-land and tethered-swim power but left free-swimming times unchanged across the 50-, 100-, and 200-metre races (Norberto et al., 2023). Similarly, evening ground-strength exercises done at competitive intensity did not alter 100-m freestyle performance the following day (Tsoltos et al., 2023). Middle-distance races were noticeably less responsive to training than starts and sprints (Silvas et al., 2022; Ylangs et al., 2025), and that gap in results carries an important implication. Neuromuscular adaptation alone will not guarantee competitive transfer. What seems to matter is how specific the load is, how closely it matches the demands of the event, and the degree to which physical work is paired with skill-related tasks. Head-to-head comparisons are useful when choosing between methods, and overall strength training matched or outperformed plyometric and muscular-endurance training in terms of start and sprint outcomes.

Starts and sprints, by contrast, responded to both families of training: strength work and plyometric work alike (Yang, 2025, Yang 2026). High-velocity, low-load resistance training with movement speed as the key variable improved several physical qualities at once, including strength, 50m freestyle speed, jumping, and pulling. That points to an interesting possibility, that limb movement speed and the degree of muscular fatigue may matter just as much as total muscular loading (Rodríguez-Rosell et al., 2026). Low-load blood-flow-restriction training is another option, producing strength gains comparable to high-load work without raising cardiac concerns, which makes it attractive for fatigue-sensitive swimmers (Wang et al., 2023). So in answer to RQ2, S&C interventions do help, particularly for starts, sprints, and neuromuscular power, yet their effect on free-swimming time varies and depends on a range of factors.

Findings for RQ3 - Programming characteristics linked to the biggest improvements

On dose, the effective programs were short and focused. Mesocycles lasting six to twelve weeks, delivered two to four times a week, were enough to produce measurable changes in performance (Amara et al., 2022; Chen et al., 2025; Pradittakarn et al., 2025). On intensity and modality, higher-velocity execution combined with heavy or maximal loads transferred best to starts and sprints. Endurance-oriented, low-intensity resistance work was the weakest comparator (Yang et al., 2025; Rodríguez-Rosell et al., 2026). Force-vector-specific loading, meaning the direction of resistance mirrors the horizontal demands of the start, also emerged as a promising refinement in exercise selection (Chen et al., 2025).

Integration and specificity kept coming up as programming levers. Programs that paired dry-land strength with in-water or resisted-swim work, or that individualised prescription through load-velocity profiling, translated into competitive outcomes more reliably than isolated gym sessions (Keating et al., 2025; Amara et al., 2023; Ruiz-Navarro et al., 2024). Fatigue management played a role too. Low-relative-load and blood-flow-restriction strategies kept swimmers fresh while still driving adaptation, though the residual effects of heavy sessions on subsequent swimming depended on the modality and the timing (Wang et al., 2023; Tsoltos et al., 2023). To summarize RQ3, the biggest gains came from short, high-quality, velocity-oriented programmes, swimming-specific in nature, that were deliberately integrated with pool training rather than done in isolation.

Comparative and Critical Analysis

Controlled trials and quasi-experimental designs remain the leading approach in the field, and the methodology has generally been sound. Yet room for improvement is still visible (Table 3). Randomized designs became more frequent in recent work, which nudged methodological standards upward. Single-arm and pre-experimental designs, more exposed to expectancy and maturation effects, were largely kept to smaller club samples (Hartoto et al., 2025; Pereira et al., 2023). Overall sample sizes stayed modest. Single-sex cohorts were widespread.

Interventions lasting longer than twelve weeks were uncommon, which added another constraint to any long-term periodisation inference. Multi-modal and responder-analysis designs, by contrast, read as genuine methodological innovations. They redirect the research question from "can S&C improve performance?" to "which S&C and for whom?" (Yang et al., 2025; Yang et al., 2026).

The absence of certain designs is itself informative. Long-term, multi-season interventions were rare. Head-to-head modality comparisons with enough statistical power were almost nowhere to be found, and studies separating athletes by sex or event distance were equally scarce. Outcome heterogeneity did not help. Tethered force, load-velocity profiles, start kinematics, and race times all appeared as outcome measures, and with that much variation, comparing studies and running a meta-analysis became impossible. The most illuminating work paired an in-water performance outcome with a neuromuscular measure that had clear transfer potential. That setup exposes the transfer pathway directly instead of leaving us to rely on assumptions (Amara et al., 2022; Keating et al., 2025).

Combine these findings and a consistent picture emerges. Strength and conditioning delivers the greatest benefit in the phases that depend on explosive force: the start, the underwater section, and short sprints. Its influence on free-swimming velocity over longer distances is smaller. That fits the underlying mechanics. Starts and sprints rely heavily on power and rate of force development, qualities most affected by heavy, ballistic, and velocity-based training respectively (Ma et al., 2026; Rodríguez-Rosell et al., 2026). The result also aligns with the force-velocity theory of swimming. A stronger dry-land force capacity raises the ceiling for underwater propulsion, but it does not guarantee that a swimmer will actually reach that ceiling (Sorgente et al., 2023; Raineteau et al., 2026).

Conceptually, this work adds to the specificity principle rather than overturning it. Land-based adaptations appear to be a facilitating condition, not the deciding one. Two athletes could show identical strength gains and still achieve very different competitive outcomes, depending on how they blend technique and propulsive mechanics with that strength (Norberto et al., 2023; Silva et al., 2022). A closer look through comparative and respondent analysis shows that some people respond systematically to a maximum strength stimulus, while others respond to a plyometric one. Individual response signatures and programme design therefore both matter (Yang et al., 2026).

Overall, the findings translate into practical guidance for coaches and performance specialists. Priority one is to emphasise strength and power over endurance. The work should then be organised in six-to-twelve-week blocks, delivered two to four times a week. Loading direction should be aligned with the horizontal demands of the start, and dry-land training should be paired with resisted elements or load/velocity guidance. Confidence in these performance factors as levers is high. Fatigue-sensitive methods such as low-load work with blood flow restriction can still generate adaptations while leaving the swimmer relatively fresh in the water, because interference stays minimal. In a pre-competition window, the acute benefit is probably small and the risk modest when timing is perfect (Hill et al., 2024). These levers work best alongside recovery and injury prevention strategies that keep athletes training, for example post-workout recovery techniques and a programme that specifically targets the shoulders. With that in view, this synthesis does not simply repeat what previous reviews concluded about influences on swimming abilities (Price et al., 2024; Thng et al., 2024). The emphasis here is different: how different exercise types produce change, to what extent, and how they can be programmed.

The findings partly confirm the narrative in favour of maximal strength training, then extend it by showing where the argument loses force. Transfer failures (Norberto et al., 2023) and modality-based results from controlled experiments limit how far that argument reaches. A persistent discrepancy runs through the literature: substantial gains on dry-land training, yet no corresponding improvement in free-swimming ability. That contradiction most likely reflects excessive interference and fatigue, a poor match with technical development, or insufficient focus on specificity, rather than any failure of strength training itself (Tsoltos et al., 2023; Silva et al., 2022). Additional context comes from research on dual-purpose and height training (Tomazin et al., 2022), the quick fade of detraining effects (Głyk et al., 2022), and the clear need to track training load closely as competition approaches (Marinof et al., 2026). Together, these strands support the conclusion that interference and workload management are what decide whether improvements actually surface in the water.

Future investigation should target several gaps. Adequately powered, long-term, multi-season experiments with genuine control conditions are needed to verify the enduring effects of periodisation. Separate analyses by sex and event are also warranted, since Hill et al. (2024) and Yang et al. (2025) reported differences in response based on both. Related aquatic sports offer another caution. Strength-performance correlations in water-polo players, for instance, should not be assumed to apply directly to competitive swimmers, a long-standing concern (Ren et al., 2025; Malliaros et al., 2025; Barrenetxea-Garcia et al., 2023). There is also a demand for standardised in-water performance outcomes and neuromuscular measurements that transfer easily, which would enable meta-analysis and a direct examination of the transfer mechanism (Keating et al., 2025). This study has limitations. It rests mainly on one database, Scopus. Restricting articles to English may have excluded relevant evidence. The narrow publication range favoured recently published studies over older classics, a choice that could bias how certain interventions are judged over time. Quality rating was completed by one person rather than two independent raters using the Kappa statistic. Methods and outcome types were so heterogeneous that numerical comparison was impossible, leaving a narrative summary whose conclusions are heavily influenced by research method and its soundness. Where the study location was not stated, country attributions were inferred from corresponding author affiliations, which is an imperfect proxy. Looking ahead, the research effort should focus on large-scale, randomised, multi-centre trials comparing maximal-strength, plyometric, and velocity-based programmes against one another across an entire season; on studies that manipulate the direction of force application or the degree of swim resistance to test transferability to the water; and on responder profiles, built from athletes showing the largest changes under each mode, to guide individually tailored training.

To close, the research questions can be answered directly. Contemporary strength and conditioning for competitive swimmers includes dry-land, in-water, resisted, plyometric, concurrent, and potentiation modalities (RQ1). These strategies are effective for enhancing sprint performance and neuromuscular power during the start, although their effect depends on moderating factors, and the main performance criterion remains the time taken to swim a given distance without constraints (RQ2). The most substantial changes appear when programmes are relatively short, highly intense, aimed at increasing velocity, swimming specific, and carried out in the pool alongside pool activities (RQ3).

Conclusions

Based on a review of 20 current interventional studies, the strength and conditioning picture cover five modes: dry-land, in-water resisted, plyometric, concurrent, and acute potentiation training. Swimmers who follow these interventions consistently improve their starts, sprints, and neuromuscular power. Whether that improvement carries over to a faster free-swimming race time is another matter; it depends heavily on the modality used and only materializes under certain conditions (RQ1, RQ2). The most significant gains come from short-term, intensive, velocity-focused programmes. These usually last six to twelve weeks, with two to four sessions per week, and are combined with pool sessions rather than treated as a separate mode. The main contribution of the paper is shifting the evidence from performance-determining factors to how effective interventive programmes are, and how they are programmed. Coaches get a set of guidelines with a clear focus on translating the training back to the pool. The authors are upfront about the limitations: small samples, short study periods, reliance on a single database, and variation between study results. They recommend adequately controlled, long-term trials that cover different competition types and events for both male and female swimmers. Using consistent in-water race results as indicators would help confirm and extend these findings.

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