Supplementary Material

From Start to Breakout in Competitive Swimming: A Systematic Review of Biomechanical Links Across the Start and Underwater Phases

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Table S1. Synthesis Without Meta-analysis (SWiM) reporting checklist [14].

Item	SWiM reporting item	Location in the manuscript
1a	Grouping studies for synthesis: provide a description of, and rationale for, the groups used in the synthesis	Section 2.7, Section 3.3 (subsections 3.3.1–3.3.4), Table 4
1b	Detail and provide rationale for any changes made subsequent to the protocol in the groups used in the synthesis	Section 2 (first paragraph) and Section 2.6 (grouping of reports from the same study)
2	Standardised metric and transformation methods used: describe the standardised metric for each outcome, explain why it was chosen and describe any methods used to transform the intervention effects to it	Section 2.7: no standardised metric, direction of effect and reported statistics (r, β, p, mean differences) extracted as reported, Table 4
3	Synthesis methods: describe and justify the methods used to synthesise the effects for each outcome when it was not possible to undertake a meta-analysis	Section 2.7 (vote-counting avoided, structured narrative synthesis by type of evidence and start type, effect-direction table, Table 5)
4	Criteria used to prioritise results for summary and synthesis	Section 2.7, Section 3.3 (direct associations prioritised over condition comparisons and race analyses, overlapping intervals flagged in Table 4)
5	Investigation of heterogeneity in reported effects: state the method(s) used to examine heterogeneity	Section 3.3.6 (sex, technique and performance level), Section 3.3.2 (start type and device)
6	Certainty of evidence: describe methods used to assess certainty of the synthesis findings	Sections 2.6 and 3.1 and Table S3 describe the appraisal of individual studies. The Limitations discuss confidence in the synthesis in light of study design and reporting.
7	Data presentation methods: describe the graphical and tabular methods used to present the effects	Tables 2–5 (Table 5 is the effect-direction table) and Figure 2
8	Reporting results: for each comparison and outcome, provide a description of the synthesised findings and the certainty of the findings	Section 3.3, Table 4
9	Limitations of the synthesis: report the limitations of the synthesis methods and/or the groupings used in the synthesis	Section 5

Table S2. Records removed after full-text screening and respective reasons for exclusion.

Record	Reason for exclusion
1. Alptekin, 2014	No underwater variable
2. Alves et al., 2006 [23]	No start variable
3. Arellano et al., 2000 [21]	No underwater variable
4. Barany, Barabas & Moravecz, 1993	No underwater variable
5. Barkwell & Dickey, 2018 [82]	No underwater variable
6. Barkwell & Dickey, 2020 [84]	No underwater variable
7. Born et al., 2024 [4]	No underwater variable
8. Breed & McElroy, 2000	Population (non-competitive swimmers)
9. Carvalho et al., 2017 [19]	No underwater variable
10. de Jesus et al., 2016a [83]	No underwater variable (variables only up to full immersion)
11. Duarte et al., 2017 [25]	No underwater variable
12. Elipot et al., 2010	No start variable
13. Fattah & Tarawneh, 2020	Breaststroke only
14. García-Ramos et al., 2016	No underwater variable
15. Gil-Calvo et al., 2024	No underwater variable
16. Hamidi Rad et al., 2021	No start variable
17. Hamidi Rad et al., 2022a	No start variable
18. Hamidi Rad et al., 2022b	No start variable
19. Houel et al., 2013 [26]	No start variable
20. Jin et al., 2025 [90]	No start variable
21. Kibele et al., 2011	Publication type (not a peer-reviewed article or eligible proceedings)
22. Madureira et al., 2023	Study design (no original data)
23. McLean et al., 2022	No underwater variable
24. Nara et al., 2024 [85]	No underwater variable
25. Ozeki et al., 2017 [24]	No underwater variable
26. Ozeki et al., 2018	No underwater variable
27. Ozeki et al., 2025	No underwater variable
28. Peterson Silveira et al., 2018	No underwater variable (entry phase and time to 5 m only)
29. Ruiz-Navarro et al., 2024	No start variable
30. Seifert et al., 2010 [81]	No underwater variable
31. Slawson et al., 2013	No underwater variable
32. Stosic et al., 2023	No start variable
33. Takeda et al., 2014 [86]	No underwater variable
34. Takeda et al., 2022	No start variable
35. Taladriz et al., 2015 [22]	No underwater variable
36. Taladriz et al., 2016	No underwater variable
37. Thanopoulos et al., 2012	No underwater variable
38. Thng et al., 2022	Breaststroke starts not separable (2 of 5 swimmers)
39. Thow et al., 2012	No start variable
40. Tor et al., 2013 [20]	No start variable
41. van Dijk et al., 2020	No underwater variable
42. Veiga et al., 2025 [87]	No start variable
43. Wang, 2022	No start variable
44. Yamakawa et al., 2022	No start variable
45. Yamakawa et al., 2025	No start variable
46. Đurović et al., 2019	Publication type (not a peer-reviewed article or eligible proceedings)
47. Đurović et al., 2022	No underwater variable

Note: Not retrieved: Le Sage et al., 2013; Pearson et al., 1998; Nicholas & Watkins, 2006.

Table S3. Studies excluded through **r**eference lists of the included studies and snowballing citation tracking (OpenAlex, 27 October 2026).

Record	Reason for exclusion
1. Veiga et al., 2014	No start variable
2. Staunton et al., 2024	No start variable
3. Xu et al., 2026	No start or underwater variable
4. Sakai et al., 2017	No underwater variable
5. Galbraith et al., 2008	No underwater variable
6. Nguyen et al., 2014	No underwater variable (split times only)
7. Rudnik et al., 2023	No underwater variable (split times and mean velocity 5–15 m)
8. Beretić et al., 2013	No start or underwater variable (time to 10 m only)
9. Barlow et al., 2014	No underwater variable (mean velocity 4.5–5.5 m only)
10. Akashi & Matsuda, 2022	No underwater variable (mean velocity 4–5 m only)
11. Thng et al., 2021	No underwater variable
12. Coşkun et al., 2026	No underwater variable (analysis up to hand entry)
13. Wądrzyk & Staszkiewicz, 2018b	No underwater variable
14. Jorgić et al., 2010	No underwater variable
15. Ozeki et al., 2012	No underwater variable
16. Formicola & Rainoldi, 2015	No underwater variable
17. Benjanuvatra et al., 2007	No underwater variable
18. de Jesus et al., 2012	No start variable

Note: Reports not retrieved: Welcher et al., 2008; Takeda et al., 2011; Guimarães & Hay, 1985; de Jesus et al., 2013; Honda et al., 2012; Ikeda et al., 2025; Cuenca-Fernández et al., 2014; Blitvich et al., 2000.

Table S4. Methodological quality of the included studies (AXIS tool [13] with five additional items for within-swimmer designs).

Study	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	E1	E2	E3	E4	E5
Direct associations																									
Tor et al., 2015a [27], Tor et al., 2014 [28]	Y	Y	N	Y	Y	Y	NA	Y	Y	Y	Y	Y	NA	NA	Y	Y	Y	DK	DK	Y	NA	Y	DK	DK	NA
Ruschel et al., 2007 [29], Pereira et al., 2006 [30]	Y	DK	N	Y	DK	N	NA	Y	DK	Y	DK	Y	NA	NA	N	Y	DK	N	DK	N	NA	DK	Y	NA	DK
Gonjo & Olstad, 2020 [68]	Y	Y	N	Y	Y	N	NA	Y	Y	Y	Y	Y	NA	NA	Y	Y	Y	DK	Y	Y	NA	Y	NA	NA	NA
Matúš et al., 2021a [5], Matúš & Kandráč, 2020 [37], Matúš et al., 2020 [38] (appraised from [5])	Y	Y	N	Y	Y	DK	NA	Y	DK	Y	Y	Y	NA	NA	DK	Y	DK	N	Y	Y	Y	Y	Y	DK	DK
Hermosilla et al., 2022 [45]	Y	Y	N	Y	Y	DK	NA	Y	DK	Y	Y	Y	NA	NA	Y	Y	DK	Y	DK	Y	NA	Y	Y	Y	N
de Jesus et al., 2011 [48]	Y	Y	N	Y	Y	DK	NA	Y	Y	Y	Y	Y	NA	NA	DK	Y	DK	DK	DK	Y	Y	Y	Y	Y	N
Takagi et al., 2017 [54]	Y	Y	N	Y	Y	DK	NA	Y	Y	Y	Y	Y	NA	NA	Y	Y	Y	DK	DK	DK	NA	DK	DK	Y	NA
Elipot et al., 2009 [49]	Y	Y	N	Y	DK	DK	NA	Y	Y	Y	Y	Y	NA	NA	Y	Y	DK	DK	Y	Y	NA	Y	DK	DK	DK
Born et al., 2026 [62]	Y	Y	N	Y	Y	Y	NA	Y	Y	Y	Y	Y	NA	NA	Y	Y	DK	N	Y	Y	NA	Y	Y	Y	DK
Burkhardt et al., 2023 [69]	Y	Y	N	Y	Y	N	NA	Y	Y	Y	Y	Y	NA	NA	Y	Y	Y	DK	N	Y	Y	Y	Y	DK	Y
Fischer & Kibele, 2016 [70]	Y	Y	N	Y	Y	DK	NA	Y	DK	Y	Y	Y	NA	NA	DK	DK	DK	N	DK	Y	NA	Y	Y	Y	Y
Xie et al., 2024 [15]	Y	Y	N	Y	DK	DK	NA	Y	DK	DK	Y	DK	NA	NA	Y	Y	DK	DK	Y	N	NA	DK	DK	Y	N
Within-swimmer comparisons																									
Vantorre et al., 2010c [44]	Y	Y	N	Y	DK	N	NA	Y	Y	Y	DK	Y	NA	NA	DK	Y	DK	N	DK	N	DK	Y	DK	NA	N
Tor et al., 2015b [71]	Y	Y	N	Y	Y	N	NA	Y	Y	Y	Y	Y	NA	NA	Y	Y	Y	Y	DK	Y	DK	DK	Y	DK	Y
Cicenia Achurra et al., 2020 [72]	Y	Y	N	Y	Y	N	NA	Y	DK	Y	Y	Y	NA	NA	N	Y	DK	Y	DK	N	Y	N	N	N	DK
Cicenia Achurra et al., 2019a [31], Cicenia et al., 2019b [32]	Y	Y	N	Y	Y	N	NA	Y	DK	Y	Y	Y	NA	NA	Y	Y	Y	Y	DK	Y	Y	DK	N	N	DK
Sato et al., 2025 [42]	Y	Y	Y	Y	Y	N	NA	Y	Y	Y	Y	Y	NA	NA	Y	Y	Y	Y	DK	Y	Y	Y	DK	DK	DK
Sato et al., 2024 [66]	Y	Y	N	Y	Y	DK	NA	Y	DK	Y	Y	Y	NA	NA	Y	Y	Y	Y	Y	Y	Y	Y	DK	DK	DK
Manz et al., 2019 [65]	Y	Y	N	Y	Y	N	NA	Y	DK	Y	Y	Y	NA	NA	DK	Y	Y	Y	DK	Y	N	N	DK	Y	Y
Ikeda et al., 2017 [63]	Y	Y	N	Y	Y	DK	NA	Y	DK	Y	Y	Y	NA	NA	Y	Y	DK	DK	Y	Y	DK	N	DK	DK	DK
Szczepan et al., 2026 [73]	Y	Y	DK	Y	Y	N	NA	Y	Y	Y	Y	Y	NA	NA	Y	Y	Y	Y	Y	Y	Y	Y	Y	DK	DK
Qiu et al., 2024 [74]	Y	Y	N	Y	Y	N	NA	Y	Y	Y	Y	Y	NA	NA	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N
Matúš et al., 2024a [51]	Y	Y	N	Y	Y	DK	NA	Y	DK	Y	Y	Y	NA	NA	DK	Y	DK	Y	Y	Y	Y	Y	Y	DK	DK
Matúš et al., 2025b [16]	Y	Y	N	Y	Y	DK	NA	Y	Y	Y	Y	Y	NA	NA	DK	Y	Y	Y	Y	Y	Y	Y	Y	DK	DK

Study	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	E1	E2	E3	E4	E5
Abo-Touq & Abdel-Fattah, 2020 [46]	Y	Y	N	Y	Y	N	NA	Y	DK	Y	DK	Y	NA	NA	N	Y	DK	DK	DK	DK	DK	DK	DK	DK	N
Agopyan et al., 2026 [43]	Y	Y	Y	Y	Y	DK	Y	Y	DK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	DK	N
Iizuka et al., 2016 [67]	Y	DK	N	Y	Y	N	NA	Y	DK	Y	Y	Y	NA	NA	Y	Y	DK	Y	DK	Y	N	Y	DK	NA	N
Matúš et al., 2021b [50]	Y	Y	N	Y	Y	N	NA	Y	DK	Y	Y	Y	NA	NA	Y	Y	DK	DK	Y	Y	Y	Y	Y	DK	DK
Matúš et al., 2026 [53]	Y	Y	N	Y	Y	N	NA	Y	DK	Y	Y	Y	NA	NA	Y	Y	DK	Y	Y	Y	Y	DK	Y	DK	DK
de Jesus et al., 2016 [64]	Y	Y	N	Y	Y	N	NA	Y	Y	Y	Y	Y	NA	NA	Y	Y	Y	DK	DK	Y	Y	Y	Y	DK	DK
Between-group comparisons and training studies																									
Vantorre et al., 2010b [75]	Y	Y	N	Y	DK	N	NA	Y	Y	Y	Y	Y	NA	NA	DK	Y	Y	DK	DK	Y	NA	Y	DK	DK	DK
Wądrzyk et al., 2022 [76]	Y	Y	N	Y	Y	N	NA	Y	Y	Y	Y	Y	NA	NA	DK	Y	DK	Y	Y	Y	NA	Y	Y	Y	DK
Lin et al., 2025 [77]	Y	Y	N	Y	Y	N	NA	Y	Y	Y	Y	Y	NA	NA	Y	Y	DK	Y	Y	Y	NA	Y	Y	Y	DK
Rejman et al., 2017 [47]	Y	DK	N	Y	Y	N	NA	Y	DK	DK	DK	Y	NA	NA	DK	DK	DK	Y	DK	Y	NA	Y	Y	DK	N
Chen et al., 2025a [35], Chen et al., 2023 [36]	Y	DK	N	Y	DK	N	NA	Y	Y	Y	Y	Y	NA	NA	Y	Y	DK	N	Y	Y	Y	Y	Y	Y	DK
Born et al., 2020 [78]	Y	Y	N	Y	Y	DK	Y	Y	Y	Y	Y	Y	NA	Y	Y	Y	DK	Y	Y	Y	NA	Y	Y	Y	DK
Chen et al., 2025b [79]	Y	DK	N	Y	Y	N	NA	Y	DK	Y	Y	Y	NA	NA	Y	Y	DK	Y	Y	Y	NA	Y	Y	Y	DK
Tor et al., 2018 [18]	Y	Y	N	Y	Y	DK	NA	Y	DK	Y	Y	Y	NA	NA	DK	Y	Y	Y	DK	Y	NA	NA	Y	Y	Y
Nosiadek et al., 2024 [39], Wądrzyk & Staszkiewicz, 2018a [40]	Y	Y	N	Y	Y	N	NA	Y	DK	Y	Y	Y	NA	NA	Y	Y	Y	Y	DK	Y	NA	Y	Y	DK	DK
Race analyses and descriptive studies																									
Vantorre et al., 2010a [80]	Y	Y	N	Y	DK	N	NA	Y	DK	Y	Y	Y	NA	NA	Y	Y	Y	DK	DK	Y	NA	Y	DK	Y	DK
Burkett et al., 2010 [41]	Y	Y	Y	Y	Y	N	NA	Y	Y	Y	Y	Y	NA	NA	Y	Y	DK	Y	DK	Y	NA	Y	DK	Y	Y
Cossor & Mason, 2001 [57]	Y	Y	N	Y	Y	DK	NA	Y	DK	Y	DK	N	NA	NA	Y	N	DK	DK	DK	N	NA	NA	NA	DK	NA
Marinho et al., 2021 [55]	Y	Y	DK	Y	Y	Y	NA	Y	DK	Y	Y	DK	NA	DK	Y	Y	Y	DK	Y	Y	NA	NA	NA	DK	NA
Morais et al., 2022 [56]	Y	Y	DK	Y	Y	Y	NA	Y	Y	Y	Y	DK	NA	Y	Y	Y	Y	DK	Y	Y	NA	NA	NA	DK	NA
Arellano et al., 2022 [59]	Y	Y	DK	Y	Y	Y	NA	Y	Y	Y	Y	Y	NA	NA	Y	Y	DK	DK	DK	Y	NA	NA	NA	Y	NA
Qiu et al., 2021 [33], Qiu et al., 2020 [34]	Y	Y	DK	Y	Y	Y	NA	Y	Y	Y	Y	DK	NA	NA	Y	Y	Y	DK	Y	Y	NA	NA	DK	DK	NA
Gao et al., 2025 [60]	Y	Y	N	Y	Y	DK	NA	Y	DK	Y	Y	DK	NA	NA	DK	Y	DK	Y	Y	Y	NA	NA	NA	DK	NA
Grznár et al., 2019 [58]	Y	Y	N	Y	Y	Y	NA	DK	DK	Y	DK	Y	NA	NA	Y	Y	DK	N	DK	NA	NA	NA	NA	NA	NA
Matúš et al., 2024b [61]	Y	Y	DK	Y	Y	Y	NA	Y	DK	Y	Y	DK	NA	NA	Y	Y	DK	N	DK	N	NA	NA	NA	Y	NA

Study	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	E1	E2	E3	E4	E5
Matúš et al., 2025a [52]	Y	Y	N	Y	Y	DK	NA	Y	Y	Y	Y	Y	NA	NA	Y	Y	Y	Y	Y	Y	DK	Y	Y	Y	Y
Born et al., 2024 [17]	Y	Y	N	Y	Y	DK	NA	Y	Y	Y	Y	DK	NA	NA	DK	Y	Y	Y	Y	Y	NA	NA	Y	DK	DK

Y, yes. N, no. DK, don't know (unclear or not reported), the third response option of the AXIS tool. NA, not applicable. Items 7, 13 and 14 concern non-responders and were not applicable to these designs. E1–E5 were recorded only where trials or conditions were repeated within swimmers and were not added to any score.

Table S5. Reasons for negative (N) and don't know (DK) judgements of the AXIS tool.

Study	AXIS item	Rating	Reason
Tor et al., 2015a [27], Tor et al., 2014 [28]	3. Sample size justified	N	Not justified
Tor et al., 2015a [27], Tor et al., 2014 [28]	18. Limitations discussed	DK	No limitations section found
Tor et al., 2015a [27], Tor et al., 2014 [28]	19. Funding/conflicts acceptable	DK	No statement found
Tor et al., 2015a [27], Tor et al., 2014 [28]	E3. Rest/fatigue controlled	DK	Not reported
Tor et al., 2015a [27], Tor et al., 2014 [28]	E4. Trial selection pre-specified/objective	DK	Criterion for selecting trials from the database unclear
Ruschel et al., 2007 [29], Pereira et al., 2006 [30]	2. Appropriate design	DK	Correlations on 24 trials from 4 swimmers treated as independent (pseudo-replication)
Ruschel et al., 2007 [29], Pereira et al., 2006 [30]	3. Sample size justified	N	Not justified, n = 4
Ruschel et al., 2007 [29], Pereira et al., 2006 [30]	5. Appropriate sample frame	DK	One club
Ruschel et al., 2007 [29], Pereira et al., 2006 [30]	6. Selection likely representative	N	Purposive selection
Ruschel et al., 2007 [29], Pereira et al., 2006 [30]	9. Measurement valid/reliable	DK	Four 30 Hz VHS cameras, calibration and reliability not described
Ruschel et al., 2007 [29], Pereira et al., 2006 [30]	11. Methods replicable	DK	Little detail on digitising

Study	AXIS item	Rating	Reason
Ruschel et al., 2007 [29], Pereira et al., 2006 [30]	15. Results internally consistent	N	Discussion interprets the negative correlation between underwater velocity and time to 15 m in the opposite direction ('slower starts')
Ruschel et al., 2007 [29], Pereira et al., 2006 [30]	17. Conclusions justified	DK	n = 4, general conclusions
Ruschel et al., 2007 [29], Pereira et al., 2006 [30]	18. Limitations discussed	N	No limitations
Ruschel et al., 2007 [29], Pereira et al., 2006 [30]	19. Funding/conflicts acceptable	DK	Not reported
Ruschel et al., 2007 [29], Pereira et al., 2006 [30]	20. Ethics/consent	N	Ethics not reported
Ruschel et al., 2007 [29], Pereira et al., 2006 [30]	E2. Familiarisation	DK	Not reported
Ruschel et al., 2007 [29], Pereira et al., 2006 [30]	E5. Repeated trials handled	DK	6 trials per swimmer without handling dependence
Gonjo & Olstad, 2020 [68]	3. Sample size justified	N	Not justified
Gonjo & Olstad, 2020 [68]	6. Selection likely representative	N	Volunteers
Gonjo & Olstad, 2020 [68]	18. Limitations discussed	DK	No limitations section found
Matúš et al., 2021a [5], Matúš & Kandráč, 2020 [37], Matúš et al., 2020 [38] (appraised from [5])	3. Sample size justified	N	Not justified, n = 18 for multiple regression
Matúš et al., 2021a [5], Matúš & Kandráč, 2020 [37], Matúš et al., 2020 [38] (appraised from [5])	6. Selection likely representative	DK	Selection not described
Matúš et al., 2021a [5], Matúš & Kandráč, 2020 [37], Matúš et al., 2020 [38] (appraised from [5])	9. Measurement valid/reliable	DK	SwimPro 50 Hz + Dartfish, validity by reference
Matúš et al., 2021a [5], Matúš & Kandráč, 2020 [37], Matúš et al., 2020 [38] (appraised from [5])	15. Results internally consistent	DK	Multiple regression with n = 18 and many predictors, overlapping intervals (time to 2 m and to 5 m)
Matúš et al., 2021a [5], Matúš & Kandráč, 2020 [37], Matúš et al., 2020 [38] (appraised from [5])	17. Conclusions justified	DK	'Contribution' of 64–65% to time to 5 m with overlapping intervals

Study	AXIS item	Rating	Reason
Matúš et al., 2021a [5], Matúš & Kandráč, 2020 [37], Matúš et al., 2020 [38] (appraised from [5])	18. Limitations discussed	N	No limitations
Matúš et al., 2021a [5], Matúš & Kandráč, 2020 [37], Matúš et al., 2020 [38] (appraised from [5])	E4. Trial selection pre-specified/objective	DK	Does not state whether the mean or the best trial was used
Matúš et al., 2021a [5], Matúš & Kandráč, 2020 [37], Matúš et al., 2020 [38] (appraised from [5])	E5. Repeated trials handled	DK	45 starts per swimmer, correlations computed on the 18 swimmers, handling of the repeated trials not described
Hermosilla et al., 2022 [45]	3. Sample size justified	N	Not justified, 16 swimmers
Hermosilla et al., 2022 [45]	6. Selection likely representative	DK	Selection not described
Hermosilla et al., 2022 [45]	9. Measurement valid/reliable	DK	Five calibrated 60 Hz cameras, reliability not reported
Hermosilla et al., 2022 [45]	17. Conclusions justified	DK	Regression on 48 starts from 16 swimmers (non-independent trials)
Hermosilla et al., 2022 [45]	19. Funding/conflicts acceptable	DK	No conflicts declared, funding not stated
Hermosilla et al., 2022 [45]	E5. Repeated trials handled	N	3 trials per swimmer treated as independent
de Jesus et al., 2011 [48]	3. Sample size justified	N	Not justified, n = 6
de Jesus et al., 2011 [48]	6. Selection likely representative	DK	Selection not described
de Jesus et al., 2011 [48]	15. Results internally consistent	DK	Correlations used repeated trials from six swimmers. The reported p-values are consistent with 24 observations.
de Jesus et al., 2011 [48]	17. Conclusions justified	DK	Conclusions on the glide with n = 6
de Jesus et al., 2011 [48]	18. Limitations discussed	DK	Unclear
de Jesus et al., 2011 [48]	19. Funding/conflicts acceptable	DK	Not reported in the text read
de Jesus et al., 2011 [48]	E5. Repeated trials handled	N	Correlations treated repeated trials from the same swimmers as independent observations.
Takagi et al., 2017 [54]	3. Sample size justified	N	Not justified, n = 10
Takagi et al., 2017 [54]	6. Selection likely representative	DK	Selection not described
Takagi et al., 2017 [54]	18. Limitations discussed	DK	Short format
Takagi et al., 2017 [54]	19. Funding/conflicts acceptable	DK	Not reported
Takagi et al., 2017 [54]	20. Ethics/consent	DK	Not reported
Takagi et al., 2017 [54]	E2. Familiarisation	DK	Not stated
Takagi et al., 2017 [54]	E3. Rest/fatigue controlled	DK	Not stated
Elipot et al., 2009 [49]	3. Sample size justified	N	Not justified, n = 8

Study	AXIS item	Rating	Reason
Elipot et al., 2009 [49]	5. Appropriate sample frame	DK	National-team swimmers, recruitment not described
Elipot et al., 2009 [49]	6. Selection likely representative	DK	Selection not described
Elipot et al., 2009 [49]	17. Conclusions justified	DK	The optimal instant for initiating lower-limb actions is inferred from a velocity range taken from earlier work
Elipot et al., 2009 [49]	18. Limitations discussed	DK	Only notes that the distances depend on proficiency in the underwater lower-limb actions
Elipot et al., 2009 [49]	E3. Rest/fatigue controlled	DK	Rest not reported
Elipot et al., 2009 [49]	E4. Trial selection pre-specified/objective	DK	Best start analysed, criterion not defined
Elipot et al., 2009 [49]	E5. Repeated trials handled	DK	Only the best of three starts analysed
Born et al., 2026 [62]	3. Sample size justified	N	No sample-size calculation (exploratory, low KMO accepted)
Born et al., 2026 [62]	17. Conclusions justified	DK	'KPIs' derived from cross-sectional PCA and regression presented in almost causal terms
Born et al., 2026 [62]	18. Limitations discussed	N	No limitations section found
Born et al., 2026 [62]	E5. Repeated trials handled	DK	2 trials, best analysed, reliability cited (Tor et al.), not calculated
Burkhardt et al., 2023 [69]	3. Sample size justified	N	No sample-size calculation
Burkhardt et al., 2023 [69]	6. Selection likely representative	N	Convenience
Burkhardt et al., 2023 [69]	18. Limitations discussed	DK	No explicit limitations section found
Burkhardt et al., 2023 [69]	19. Funding/conflicts acceptable	N	Funded by Kistler Instruments AG, manufacturer of the system evaluated (potential conflict despite 'no conflicts' statement)
Burkhardt et al., 2023 [69]	E4. Trial selection pre-specified/objective	DK	5 trials per session, mean of 5 used (fastest also shown) – which enters the analysis to be confirmed
Fischer & Kibele, 2016 [70]	3. Sample size justified	N	Not justified, n = 46 for structural equation models with many parameters, split into 21 and 25
Fischer & Kibele, 2016 [70]	6. Selection likely representative	DK	Selection of swimmers not described
Fischer & Kibele, 2016 [70]	9. Measurement valid/reliable	DK	Three cameras (frequency not stated), manual digitising (Simi), instrumented block, reliability not reported
Fischer & Kibele, 2016 [70]	15. Results internally consistent	DK	Poor model fit ($\chi^2 = 1101.6$, df = 272) presented as significant, RMSEA announced but not reported
Fischer & Kibele, 2016 [70]	16. All analyses reported	DK	Only the most important predictors reported
Fischer & Kibele, 2016 [70]	17. Conclusions justified	DK	Explained variance of ~100% by construction (start time is the sum of its phases) interpreted as importance of the water phase
Fischer & Kibele, 2016 [70]	18. Limitations discussed	N	No limitations section

Study	AXIS item	Rating	Reason
Fischer & Kibele, 2016 [70]	19. Funding/conflicts acceptable	DK	Funding and conflicts of interest not reported
Xie et al., 2024 [15]	3. Sample size justified	N	Not justified, n = 10
Xie et al., 2024 [15]	5. Appropriate sample frame	DK	National-level swimmers, recruitment not described
Xie et al., 2024 [15]	6. Selection likely representative	DK	Selection not described
Xie et al., 2024 [15]	9. Measurement valid/reliable	DK	Reliability cited from earlier work, not assessed in this sample
Xie et al., 2024 [15]	10. Significance/precision stated	DK	Goodness of fit (R^2) reported without p values or confidence intervals
Xie et al., 2024 [15]	12. Basic data described	DK	Age not reported
Xie et al., 2024 [15]	17. Conclusions justified	DK	The optimal breakout position is predicted by the model and checked against the same data
Xie et al., 2024 [15]	18. Limitations discussed	DK	Limitations barely discussed
Xie et al., 2024 [15]	20. Ethics/consent	N	Ethical approval and consent not reported
Xie et al., 2024 [15]	E2. Familiarisation	DK	Not reported
Xie et al., 2024 [15]	E3. Rest/fatigue controlled	DK	Not reported
Xie et al., 2024 [15]	E5. Repeated trials handled	N	50 starts from 10 swimmers (3–8 each) pooled as independent observations
Vantorre et al., 2010c [44]	3. Sample size justified	N	Not justified, n = 7
Vantorre et al., 2010c [44]	5. Appropriate sample frame	DK	Origin not described
Vantorre et al., 2010c [44]	6. Selection likely representative	N	Convenience
Vantorre et al., 2010c [44]	11. Methods replicable	DK	Short paper (3 pages), little detail on calibration/digitising
Vantorre et al., 2010c [44]	15. Results internally consistent	DK	Degrees of freedom F(1,41) indicate 42 trials treated as independent (7 swimmers × 3 × 2)
Vantorre et al., 2010c [44]	18. Limitations discussed	N	No limitations
Vantorre et al., 2010c [44]	19. Funding/conflicts acceptable	DK	Not reported
Vantorre et al., 2010c [44]	20. Ethics/consent	N	Ethics/consent not reported
Vantorre et al., 2010c [44]	E1. Condition order randomised/counterbalanced	DK	Order of techniques not reported
Vantorre et al., 2010c [44]	E3. Rest/fatigue controlled	DK	Rest not reported
Vantorre et al., 2010c [44]	E5. Repeated trials handled	N	42 trials from 7 swimmers analysed as independent observations (F(1,41))
Tor et al., 2015b [71]	3. Sample size justified	N	Not justified
Tor et al., 2015b [71]	6. Selection likely representative	N	Convenience
Tor et al., 2015b [71]	19. Funding/conflicts acceptable	DK	Not found
Tor et al., 2015b [71]	E1. Condition order randomised/counterbalanced	DK	Order of trajectories unclear
Cicenia Achurra et al., 2020 [72]	3. Sample size justified	N	No sample-size justification

Study	AXIS item	Rating	Reason
Cicenia Achurra et al., 2020 [72]	6. Selection likely representative	N	Volunteers (convenience sample)
Cicenia Achurra et al., 2020 [72]	9. Measurement valid/reliable	DK	2D video at 120 Hz + Dartfish, reliability not reported, authors acknowledge the sampling-frequency limitation
Cicenia Achurra et al., 2020 [72]	15. Results internally consistent	N	Angles reported for n = 13 (vs n = 20) without explanation, abstract states block time differed between kick-plate positions, but post hoc tests show no difference
Cicenia Achurra et al., 2020 [72]	17. Conclusions justified	DK	Concludes that shin length 'optimises' the start on the basis of 0.007–0.024 s differences in block time only
Cicenia Achurra et al., 2020 [72]	19. Funding/conflicts acceptable	DK	Funding and conflicts of interest not reported
Cicenia Achurra et al., 2020 [72]	20. Ethics/consent	N	Ethical approval/consent not reported in this report
Cicenia Achurra et al., 2020 [72]	E2. Familiarisation	N	Familiarisation not reported
Cicenia Achurra et al., 2020 [72]	E3. Rest/fatigue controlled	N	Rest intervals not reported (9 starts)
Cicenia Achurra et al., 2020 [72]	E4. Trial selection pre-specified/objective	N	Analysed trial chosen subjectively by the swimmer (the one 'felt' to be best)
Cicenia Achurra et al., 2020 [72]	E5. Repeated trials handled	DK	3 trials per condition, only 1 analysed, between-trial reliability not reported
Cicenia Achurra et al., 2019a [31], Cicenia et al., 2019b [32]	3. Sample size justified	N	No sample-size justification
Cicenia Achurra et al., 2019a [31], Cicenia et al., 2019b [32]	6. Selection likely representative	N	Convenience sample
Cicenia Achurra et al., 2019a [31], Cicenia et al., 2019b [32]	9. Measurement valid/reliable	DK	2D video at 120 Hz, Dartfish, 1 m reference, reliability not reported
Cicenia Achurra et al., 2019a [31], Cicenia et al., 2019b [32]	19. Funding/conflicts acceptable	DK	Not reported
Cicenia Achurra et al., 2019a [31], Cicenia et al., 2019b [32]	E2. Familiarisation	DK	Eligibility required familiarity with the start, no familiarisation session
Cicenia Achurra et al., 2019a [31], Cicenia et al., 2019b [32]	E3. Rest/fatigue controlled	N	Rest between starts not reported
Cicenia Achurra et al., 2019a [31], Cicenia et al., 2019b [32]	E4. Trial selection pre-specified/objective	N	Trial chosen subjectively by the swimmer
Cicenia Achurra et al., 2019a [31], Cicenia et al., 2019b [32]	E5. Repeated trials handled	DK	3 trials per condition, 1 analysed
Sato et al., 2025 [42]	6. Selection likely representative	N	Convenience
Sato et al., 2025 [42]	19. Funding/conflicts acceptable	DK	Funding reported, conflicts of interest not found

Study	AXIS item	Rating	Reason
Sato et al., 2025 [42]	E3. Rest/fatigue controlled	DK	Rest not found
Sato et al., 2025 [42]	E4. Trial selection pre-specified/objective	DK	Swimmers could repeat a start they did not feel was their best (subjective selection)
Sato et al., 2025 [42]	E5. Repeated trials handled	DK	Unclear
Sato et al., 2024 [66]	3. Sample size justified	N	Not justified, n = 10
Sato et al., 2024 [66]	6. Selection likely representative	DK	Selection not described
Sato et al., 2024 [66]	9. Measurement valid/reliable	DK	120 Hz video, calibration described, digitising reliability not reported
Sato et al., 2024 [66]	E3. Rest/fatigue controlled	DK	Rest not described
Sato et al., 2024 [66]	E4. Trial selection pre-specified/objective	DK	A repeat was allowed if the swimmer did not feel maximal
Sato et al., 2024 [66]	E5. Repeated trials handled	DK	Number of trials per condition unclear
Manz et al., 2019 [65]	3. Sample size justified	N	No sample-size justification
Manz et al., 2019 [65]	6. Selection likely representative	N	Convenience recruitment, 19 of 80 excluded for not performing a proficient start
Manz et al., 2019 [65]	9. Measurement valid/reliable	DK	Three 120 Hz cameras, 2D DLT, no reliability data
Manz et al., 2019 [65]	15. Results internally consistent	DK	Text states 14 excluded, count gives 19 (80 − 61)
Manz et al., 2019 [65]	19. Funding/conflicts acceptable	DK	NFHS funding, conflicts of interest not stated
Manz et al., 2019 [65]	E1. Condition order randomised/counterbalanced	N	Ledge always in the second condition (not counterbalanced)
Manz et al., 2019 [65]	E2. Familiarisation	N	No familiarisation with the ledge
Manz et al., 2019 [65]	E3. Rest/fatigue controlled	DK	Rest between starts not described
Ikeda et al., 2017 [63]	3. Sample size justified	N	Not justified, n = 13
Ikeda et al., 2017 [63]	6. Selection likely representative	DK	Selection not described
Ikeda et al., 2017 [63]	9. Measurement valid/reliable	DK	60 Hz cameras above and below water, DLT, reliability not reported
Ikeda et al., 2017 [63]	17. Conclusions justified	DK	Gain attributed to a 'reduced entry area' without direct measurement
Ikeda et al., 2017 [63]	18. Limitations discussed	DK	Unclear
Ikeda et al., 2017 [63]	E1. Condition order randomised/counterbalanced	DK	Order of sets not described
Ikeda et al., 2017 [63]	E2. Familiarisation	N	No familiarisation with the device (stated choice)
Ikeda et al., 2017 [63]	E3. Rest/fatigue controlled	DK	Rest unclear
Ikeda et al., 2017 [63]	E4. Trial selection pre-specified/objective	DK	Not described
Ikeda et al., 2017 [63]	E5. Repeated trials handled	DK	3 trials per condition

Study	AXIS item	Rating	Reason
Szczepan et al., 2026 [73]	3. Sample size justified	DK	A priori calculation (n = 27) performed but not reached (n = 12), acknowledged as a limitation
Szczepan et al., 2026 [73]	6. Selection likely representative	N	Convenience sample from one team
Szczepan et al., 2026 [73]	E4. Trial selection pre-specified/objective	DK	2 starts per technique, unclear whether the best or the mean was used
Szczepan et al., 2026 [73]	E5. Repeated trials handled	DK	2 trials per condition, within-subject reliability not reported
Qiu et al., 2024 [74]	3. Sample size justified	N	Not justified
Qiu et al., 2024 [74]	6. Selection likely representative	N	Volunteers
Qiu et al., 2024 [74]	18. Limitations discussed	N	No limitations section found
Qiu et al., 2024 [74]	E5. Repeated trials handled	N	1 trial per condition, within-subject reliability not reported
Matúš et al., 2024a [51]	3. Sample size justified	N	Not justified, limitation acknowledged
Matúš et al., 2024a [51]	6. Selection likely representative	DK	Selection not described
Matúš et al., 2024a [51]	9. Measurement valid/reliable	DK	SwimPro + Dartfish, validity by reference
Matúš et al., 2024a [51]	15. Results internally consistent	DK	Mean height '186 ± 0.07 cm' (inconsistent units)
Matúš et al., 2024a [51]	17. Conclusions justified	DK	Recommendations based on small differences (0.02–0.08 s)
Matúš et al., 2024a [51]	E4. Trial selection pre-specified/objective	DK	Does not state whether the mean or the best of 3 was used
Matúš et al., 2024a [51]	E5. Repeated trials handled	DK	3 trials per condition
Matúš et al., 2025b [16]	3. Sample size justified	N	Not justified, n = 10 (only described as appropriate for a repeated-measures design)
Matúš et al., 2025b [16]	6. Selection likely representative	DK	Recruitment not described
Matúš et al., 2025b [16]	15. Results internally consistent	DK	Time to the first lower-limb action is described with distance-based wording in the results
Matúš et al., 2025b [16]	E4. Trial selection pre-specified/objective	DK	Two starts per position, not stated whether the mean or the best start was analysed
Matúš et al., 2025b [16]	E5. Repeated trials handled	DK	Handling of the two starts per position not stated
Abo-Touq & Abdel-Fattah, 2020 [46]	3. Sample size justified	N	Not justified, n = 6
Abo-Touq & Abdel-Fattah, 2020 [46]	6. Selection likely representative	N	Purposive selection
Abo-Touq & Abdel-Fattah, 2020 [46]	9. Measurement valid/reliable	DK	One 60 Hz camera above water (Kinovea), underwater phase measured from above the water, reliability not reported

Study	AXIS item	Rating	Reason
Abo-Touq & Abdel-Fattah, 2020 [46]	11. Methods replicable	DK	Protocol described in Arabic, number of trials per swimmer unclear
Abo-Touq & Abdel-Fattah, 2020 [46]	15. Results internally consistent	N	t = 0.493 with p = 0.030 for start time (inconsistent)
Abo-Touq & Abdel-Fattah, 2020 [46]	17. Conclusions justified	DK	Conclusions on technique from 6 swimmers
Abo-Touq & Abdel-Fattah, 2020 [46]	18. Limitations discussed	DK	Unclear
Abo-Touq & Abdel-Fattah, 2020 [46]	19. Funding/conflicts acceptable	DK	Not reported
Abo-Touq & Abdel-Fattah, 2020 [46]	20. Ethics/consent	DK	Not reported
Abo-Touq & Abdel-Fattah, 2020 [46]	E1. Condition order randomised/counterbalanced	DK	Not described
Abo-Touq & Abdel-Fattah, 2020 [46]	E2. Familiarisation	DK	Not described
Abo-Touq & Abdel-Fattah, 2020 [46]	E3. Rest/fatigue controlled	DK	Not described
Abo-Touq & Abdel-Fattah, 2020 [46]	E4. Trial selection pre-specified/objective	DK	Not described
Abo-Touq & Abdel-Fattah, 2020 [46]	E5. Repeated trials handled	N	Independent-samples t test on 12 trials from 6 swimmers per technique
Agopyan et al., 2026 [43]	6. Selection likely representative	DK	Selected by technical level, not random
Agopyan et al., 2026 [43]	9. Measurement valid/reliable	DK	Physical tests with reported reliability, reliability of kinematics not confirmed in the text read
Agopyan et al., 2026 [43]	E4. Trial selection pre-specified/objective	DK	Number of trials per technique not clearly reported
Agopyan et al., 2026 [43]	E5. Repeated trials handled	N	Apparently 1 trial per condition
Iizuka et al., 2016 [67]	2. Appropriate design	DK	Pre–post without control: order/learning effect not controlled
Iizuka et al., 2016 [67]	3. Sample size justified	N	Not justified, n = 9
Iizuka et al., 2016 [67]	6. Selection likely representative	N	Convenience, swimming stroke not considered
Iizuka et al., 2016 [67]	9. Measurement valid/reliable	DK	200 Hz 3D video, reliability by reference

Study	AXIS item	Rating	Reason
Iizuka et al., 2016 [67]	17. Conclusions justified	DK	Improvement attributed to the intervention without control of order
Iizuka et al., 2016 [67]	19. Funding/conflicts acceptable	DK	Not reported
Iizuka et al., 2016 [67]	E1. Condition order randomised/counterbalanced	N	Fixed order (pre→post)
Iizuka et al., 2016 [67]	E3. Rest/fatigue controlled	DK	Post-test start immediately after the exercises
Iizuka et al., 2016 [67]	E5. Repeated trials handled	N	Single trial per condition, reliability not reported
Matúš et al., 2021b [50]	3. Sample size justified	N	No sample-size justification
Matúš et al., 2021b [50]	6. Selection likely representative	N	Convenience sample
Matúš et al., 2021b [50]	9. Measurement valid/reliable	DK	SwimPro + Dartfish, validity by reference
Matúš et al., 2021b [50]	17. Conclusions justified	DK	Practical recommendations from passive-glide trials
Matúš et al., 2021b [50]	18. Limitations discussed	DK	Limitations briefly discussed
Matúš et al., 2021b [50]	E4. Trial selection pre-specified/objective	DK	Trial selection not clearly stated
Matúš et al., 2021b [50]	E5. Repeated trials handled	DK	Handling of repeated trials not described
Matúš et al., 2026 [53]	3. Sample size justified	N	No sample-size justification
Matúš et al., 2026 [53]	6. Selection likely representative	N	Convenience sample
Matúš et al., 2026 [53]	9. Measurement valid/reliable	DK	Four-camera SwimPro system, reliability by reference
Matúš et al., 2026 [53]	17. Conclusions justified	DK	Recommends the new block although glide was passive and measured only to 5 m
Matúš et al., 2026 [53]	E2. Familiarisation	DK	Familiarisation with the new block not clearly described
Matúš et al., 2026 [53]	E4. Trial selection pre-specified/objective	DK	Trial selection not clearly stated
Matúš et al., 2026 [53]	E5. Repeated trials handled	DK	Handling of the two trials per condition unclear
de Jesus et al., 2016 [64]	3. Sample size justified	N	No sample-size justification
de Jesus et al., 2016 [64]	6. Selection likely representative	N	Volunteers
de Jesus et al., 2016 [64]	18. Limitations discussed	DK	Limitations to be checked in the published version
de Jesus et al., 2016 [64]	19. Funding/conflicts acceptable	DK	To be checked in the published version
de Jesus et al., 2016 [64]	E4. Trial selection pre-specified/objective	DK	Trial used not stated
de Jesus et al., 2016 [64]	E5. Repeated trials handled	DK	Handling of the three trials not stated
Vantorre et al., 2010b [75]	3. Sample size justified	N	n = 11
Vantorre et al., 2010b [75]	6. Selection likely representative	N	Convenience
Vantorre et al., 2010b [75]	15. Results internally consistent	DK	Unclear whether the 3 trials were treated as independent

Study	AXIS item	Rating	Reason
Vantorre et al., 2010b [75]	18. Limitations discussed	DK	Not found
Vantorre et al., 2010b [75]	19. Funding/conflicts acceptable	DK	Not reported
Vantorre et al., 2010b [75]	E3. Rest/fatigue controlled	DK	Rest not reported
Vantorre et al., 2010b [75]	E5. Repeated trials handled	DK	3 trials
Wądrzyk et al., 2022 [76]	3. Sample size justified	N	Not justified
Wądrzyk et al., 2022 [76]	6. Selection likely representative	N	Convenience
Wądrzyk et al., 2022 [76]	15. Results internally consistent	DK	Groups defined by mean ± SD, number of swimmers per group not reported
Wądrzyk et al., 2022 [76]	E5. Repeated trials handled	DK	3 trials, within-subject reliability not reported
Lin et al., 2025 [77]	3. Sample size justified	N	Not justified, n = 10 per group
Lin et al., 2025 [77]	6. Selection likely representative	N	4 swimmers excluded on time to 5 m (2 slow elite, 2 fast sub-elite): a selection that accentuates the group difference
Lin et al., 2025 [77]	17. Conclusions justified	DK	Coordination interpreted from 60 Hz video with a small n
Lin et al., 2025 [77]	E5. Repeated trials handled	DK	3 trials per swimmer, handling in the analysis unclear
Rejman et al., 2017 [47]	2. Appropriate design	DK	Pre–post without a control group (choice justified by the authors)
Rejman et al., 2017 [47]	3. Sample size justified	N	Not justified, n = 9
Rejman et al., 2017 [47]	6. Selection likely representative	N	Volunteers
Rejman et al., 2017 [47]	9. Measurement valid/reliable	DK	Two 100 Hz cameras, reliability not assessed in this study
Rejman et al., 2017 [47]	10. Statistical significance stated	DK	Statistical test not identified in the text read
Rejman et al., 2017 [47]	11. Methods replicable	DK	Cameras and protocol described, statistical analysis unclear
Rejman et al., 2017 [47]	15. Results internally consistent	DK	Height '179.4 ± 0.10 cm' (inconsistent units)
Rejman et al., 2017 [47]	16. All analyses reported	DK	Unclear
Rejman et al., 2017 [47]	17. Conclusions justified	DK	Changes attributed to plyometrics without control of in-water training
Rejman et al., 2017 [47]	19. Funding/conflicts acceptable	DK	Not reported
Rejman et al., 2017 [47]	E4. Trial selection pre-specified/objective	DK	3 starts, trial analysed unclear
Rejman et al., 2017 [47]	E5. Repeated trials handled	N	df = 26: 3 trials from 9 swimmers treated as independent
Chen et al., 2025a [35], Chen et al., 2023 [36]	2. Appropriate design	DK	Pre–post without control, acceptable for an acute/descriptive effect, weak for causal inference
Chen et al., 2025a [35], Chen et al., 2023 [36]	3. Sample size justified	N	Not justified
Chen et al., 2025a [35], Chen et al., 2023 [36]	5. Appropriate sample frame	DK	Origin of the swimmers poorly described

Study	AXIS item	Rating	Reason
Chen et al., 2025a [35], Chen et al., 2023 [36]	6. Selection likely representative	N	Volunteers
Chen et al., 2025a [35], Chen et al., 2023 [36]	17. Conclusions justified	DK	Differences attributed to technique without control for training or maturation
Chen et al., 2025a [35], Chen et al., 2023 [36]	18. Limitations discussed	N	No limitations section
Chen et al., 2025a [35], Chen et al., 2023 [36]	E5. Repeated trials handled	DK	3 trials, best analysed, reliability not reported
Born et al., 2020 [78]	3. Sample size justified	N	No sample-size calculation
Born et al., 2020 [78]	6. Selection likely representative	DK	Recruited at the centre, alternating allocation by start-velocity ranking (not random)
Born et al., 2020 [78]	17. Conclusions justified	DK	Effects in the U17 subgroup highlighted with marginal p values after no overall effect
Born et al., 2020 [78]	E5. Repeated trials handled	DK	3 trials, reliability cited, not calculated
Chen et al., 2025b [79]	2. Appropriate design	DK	Two active groups without a non-training control
Chen et al., 2025b [79]	3. Sample size justified	N	No a priori sample size, small sample acknowledged (n = 16)
Chen et al., 2025b [79]	6. Selection likely representative	N	Convenience sample from one team
Chen et al., 2025b [79]	9. Measurement valid/reliable	DK	Kinovea with pool markings, reliability of video variables not reported
Chen et al., 2025b [79]	17. Conclusions justified	DK	Concludes that both programmes improve start performance from time effects without a control group
Chen et al., 2025b [79]	E5. Repeated trials handled	DK	Within-subject reliability not reported
Tor et al., 2018 [18]	3. Sample size justified	N	Not justified, case study of three swimmers
Tor et al., 2018 [18]	6. Selection likely representative	DK	Recruited from the AIS programme, selection not described
Tor et al., 2018 [18]	9. Measurement valid/reliable	DK	Reliability cited from earlier work, not assessed in this sample
Tor et al., 2018 [18]	15. Results internally consistent	DK	The pre- and post-test first lower-limb action distances reported for Participant 1 are identical to those of Participant 2
Tor et al., 2018 [18]	19. Funding/conflicts acceptable	DK	Funding and conflicts of interest not reported
Nosiadek et al., 2024 [39], Wądrzyk & Staszkiewicz, 2018a [40]	3. Sample size justified	N	No sample-size justification
Nosiadek et al., 2024 [39], Wądrzyk & Staszkiewicz, 2018a [40]	6. Selection likely representative	N	Convenience sample
Nosiadek et al., 2024 [39], Wądrzyk & Staszkiewicz, 2018a [40]	9. Measurement valid/reliable	DK	Two cameras, SkillSpector, marker placement by one person, reliability not reported

Study	AXIS item	Rating	Reason
Nosiadek et al., 2024 [39], Wądrzyk & Staszkiewicz, 2018a [40]	19. Funding/conflicts acceptable	DK	Funding and conflicts not found
Nosiadek et al., 2024 [39], Wądrzyk & Staszkiewicz, 2018a [40]	E4. Trial selection pre-specified/objective	DK	Trial analysed not clearly stated
Nosiadek et al., 2024 [39], Wądrzyk & Staszkiewicz, 2018a [40]	E5. Repeated trials handled	DK	Handling of the three trials unclear
Vantorre et al., 2010a [80]	3. Sample size justified	N	Not justified
Vantorre et al., 2010a [80]	6. Selection likely representative	N	Volunteers
Vantorre et al., 2010a [80]	9. Measurement valid/reliable	DK	50 Hz cameras, 0.02 s precision, reliability only for velocity (ICC 0.896)
Vantorre et al., 2010a [80]	18. Limitations discussed	DK	Not found
Vantorre et al., 2010a [80]	19. Funding/conflicts acceptable	DK	Not reported
Vantorre et al., 2010a [80]	E3. Rest/fatigue controlled	DK	Rest not reported
Burkett et al., 2010 [41]	6. Selection likely representative	N	Convenience
Burkett et al., 2010 [41]	17. Conclusions justified	DK	Stepwise regression with n = 20 and dummy variables
Burkett et al., 2010 [41]	19. Funding/conflicts acceptable	DK	Not reported
Burkett et al., 2010 [41]	E3. Rest/fatigue controlled	DK	Rest not reported
Cossor & Mason, 2001 [57]	3. Sample size justified	N	Not justified, very small n per event
Cossor & Mason, 2001 [57]	6. Selection likely representative	DK	Only lanes 5–8 (100 m) and 1–4 (50 m) analysed because of camera obstruction
Cossor & Mason, 2001 [57]	9. Measurement valid/reliable	DK	25 Hz cameras (50 fields/s), AIS system, reliability not reported
Cossor & Mason, 2001 [57]	11. Methods replicable	DK	Little detail
Cossor & Mason, 2001 [57]	12. Basic data described	N	No swimmer characteristics
Cossor & Mason, 2001 [57]	16. All analyses reported	N	Only significant correlations reported (selective reporting)
Cossor & Mason, 2001 [57]	18. Limitations discussed	DK	Only states that larger samples would yield more correlations
Cossor & Mason, 2001 [57]	19. Funding/conflicts acceptable	DK	Not reported
Cossor & Mason, 2001 [57]	20. Ethics/consent	N	Not reported (competition data)
Cossor & Mason, 2001 [57]	E4. Trial selection pre-specified/objective	DK	Round (heat/semi-final/final) not stated
Marinho et al., 2021 [55]	3. Sample size justified	DK	Whole event
Marinho et al., 2021 [55]	9. Measurement valid/reliable	DK	50 Hz video, reliability not reported
Marinho et al., 2021 [55]	14. Non-responders described	DK	95/106 participants vs 86/88 analysed – reason for exclusions not given
Marinho et al., 2021 [55]	18. Limitations discussed	DK	Not found

Study	AXIS item	Rating	Reason
Marinho et al., 2021 [55]	E4. Trial selection pre-specified/objective	DK	Round analysed (heats or finals) not stated
Morais et al., 2022 [56]	3. Sample size justified	DK	Whole event
Morais et al., 2022 [56]	12. Basic data described	DK	Only % of record
Morais et al., 2022 [56]	18. Limitations discussed	DK	Not found
Morais et al., 2022 [56]	E4. Trial selection pre-specified/objective	DK	Unclear whether several rounds of the same swimmer were included
Arellano et al., 2022 [59]	3. Sample size justified	DK	Not justified, but all semi-finalists/finalists were included
Arellano et al., 2022 [59]	17. Conclusions justified	DK	Repeated measures of the same swimmer across rounds/events: unclear whether dependence was handled
Arellano et al., 2022 [59]	18. Limitations discussed	DK	Only the limitation of the above-water camera is mentioned
Arellano et al., 2022 [59]	19. Funding/conflicts acceptable	DK	Public funding reported, no conflict-of-interest statement found
Qiu et al., 2021 [33], Qiu et al., 2020 [34]	3. Sample size justified	DK	All swimmers who swam both events
Qiu et al., 2021 [33], Qiu et al., 2020 [34]	12. Basic data described	DK	Race times only
Qiu et al., 2021 [33], Qiu et al., 2020 [34]	18. Limitations discussed	DK	Not found
Qiu et al., 2021 [33], Qiu et al., 2020 [34]	E3. Rest/fatigue controlled	DK	Fatigue between races not controlled
Qiu et al., 2021 [33], Qiu et al., 2020 [34]	E4. Trial selection pre-specified/objective	DK	Individual final or semi-final
Gao et al., 2025 [60]	3. Sample size justified	N	Not justified
Gao et al., 2025 [60]	6. Selection likely representative	DK	Finalists only, number of events/competitions and whether the same swimmer appears more than once not stated
Gao et al., 2025 [60]	9. Measurement valid/reliable	DK	50 Hz video, 2D-DLT with pool markings, single analyst, reliability not tested (acknowledged)
Gao et al., 2025 [60]	12. Basic data described	DK	Sex and level only, no age or anthropometry
Gao et al., 2025 [60]	15. Results internally consistent	DK	'Reaction time, also referred to as block time' – the two concepts are conflated
Gao et al., 2025 [60]	17. Conclusions justified	DK	Cross-sectional correlations interpreted as 'determinants'
Gao et al., 2025 [60]	E4. Trial selection pre-specified/objective	DK	Unclear whether each swimmer contributes one race

Study	AXIS item	Rating	Reason
Grznár et al., 2019 [58]	3. Sample size justified	N	Not justified, n = 8 per event
Grznár et al., 2019 [58]	8. Variables appropriate to aims	DK	Start reaction and time underwater after the start, definition of underwater time not given
Grznár et al., 2019 [58]	9. Measurement valid/reliable	DK	Secondary data from public websites (TritonWear, FINA), measurement method not described
Grznár et al., 2019 [58]	11. Methods replicable	DK	Data sources named, definitions missing
Grznár et al., 2019 [58]	17. Conclusions justified	DK	Training recommendations from correlations with n = 8
Grznár et al., 2019 [58]	18. Limitations discussed	N	No limitations section
Grznár et al., 2019 [58]	19. Funding/conflicts acceptable	DK	Funding and conflicts not reported
Matúš et al., 2024b [61]	3. Sample size justified	DK	Not justified, but the whole population of the event was analysed
Matúš et al., 2024b [61]	9. Measurement valid/reliable	DK	SwimPro 50 Hz + Dartfish, validity/reliability supported only by reference to previous studies, not tested here
Matúš et al., 2024b [61]	12. Basic data described	DK	Only n and entry time per age group, no exact age or anthropometry
Matúš et al., 2024b [61]	17. Conclusions justified	DK	Training recommendations by age group go beyond a cross-sectional design
Matúš et al., 2024b [61]	18. Limitations discussed	N	No limitations section
Matúš et al., 2024b [61]	19. Funding/conflicts acceptable	DK	VEGA funding reported, conflicts of interest not declared
Matúš et al., 2024b [61]	20. Ethics/consent	N	Ethical approval/consent not reported
Matúš et al., 2025a [52]	3. Sample size justified	N	Not justified, limitation acknowledged
Matúš et al., 2025a [52]	6. Selection likely representative	DK	Selection not described, males only
Matúš et al., 2025a [52]	E1. Condition order randomised/counterbalanced	DK	Order of swimmers randomised, not of trials
Born et al., 2024 [17]	3. Sample size justified	N	Not justified, n = 47
Born et al., 2024 [17]	6. Selection likely representative	DK	Selection from the national teams not described
Born et al., 2024 [17]	12. Basic data described	DK	Sex not reported
Born et al., 2024 [17]	15. Results internally consistent	DK	Table 4 reports n = 55 against a study sample of 47, and some reliability values differ between text and table
Born et al., 2024 [17]	E4. Trial selection pre-specified/objective	DK	Trials excluded for poor visibility, selection of the analysed trial not described
Born et al., 2024 [17]	E5. Repeated trials handled	DK	Two starts per swimmer, handling not described

Table S6. Breakout and surfacing variables reported by the included studies.

Study	Variable(s)	Landmark	Reference event	Velocity at breakout	Context
Tor et al., 2015a [27], Tor et al., 2014 [28]	Breakout distance and time of surfacing	Head (first break of the water surface)	Distance from the wall. Underwater phase from water entry to resurfacing	No (mean underwater velocity)	National-team testing
Born et al., 2026 [62]	Breakout time and distance	Top of the head	Time from the starting signal. Distance from the pool wall	No	Instrumented block + motion capture
Burkhardt et al., 2023 [69]	Breakout time and distance	Not stated (same KiSwim system as [62])	Not stated	No	Same testing centre as [62,78]
Born et al., 2020 [78]	Breakout time and distance	Top of the head	Not stated	No	Training study
Marinho et al., 2021 [55]	Water break time and distance	Head (breaking the water surface)	Time from the starting signal, distance from the wall	No (mean underwater speed from hand entry to water break)	Race analysis, 50 Hz video
Morais et al., 2022 [56]	Water-break time and distance, underwater time and distance	Head	Water-break time from the starting signal, distance from the wall, underwater time and distance from hand entry	No (mean underwater speed)	Race analysis
Cossor & Mason, 2001 [57]	Underwater time, distance and mean velocity	Head	Head contact with the water to head resurfacing	No (mean underwater velocity)	Race analysis (Sydney 2000)
Qiu et al., 2021 [33], Qiu et al., 2020 [34]	Emersion distance, underwater distance	Head	Emersion: starting wall to head resurfacing, underwater: head entry to head resurfacing	No (mean emersion velocity only)	Race analysis
Qiu et al., 2024 [74]	Emersion	Head (resurfacing)	Time from the starting signal (individual) or the incoming swimmer's wall touch (relay), distance from the wall	No (mean emersion velocity = emersion distance/time)	Individual vs relay start
Gao et al., 2025 [60]	Water breakout time and distance	Head (breaking the water surface)	Time from the starting signal (includes reaction and flight), distance from the wall	No (mean underwater speed from hand entry to head breakout)	Race analysis, 50 Hz video
Arellano et al., 2022 [59]	Underwater time, distance and speed	Head (out of the water); if not appreciable, hands meeting at	Hand entry	No (mean underwater speed)	Race analysis (2021 European Championships)

Study	Variable(s)	Landmark	Reference event	Velocity at breakout	Context
		the midpoint of the first stroke			
Matúš et al., 2024b [61]	Underwater time and distance	Head (breaking the water surface)	First contact of the hands with the water	No	Race analysis (Orca Cup 2023)
Gonjo & Olstad, 2020 [68]	Underwater time and distance	Head (head breakout, when its vertical displacement changed from downward to upward)	Feet entry	No (mean underwater horizontal head velocity)	Race analysis (50 m butterfly)
Matúš et al., 2025b [16]	Breakout distance and time, underwater time	Head (first breaks the water surface)	Starting wall (distance), not stated (breakout time), water entry (underwater time)	No	Laboratory, three kick-start positions
Born et al., 2024 [17]	Breakout distance	Top of the head (breaking through the water surface)	Pool wall	No	Validity study, Swiss national teams
Tor et al., 2018 [18]	Breakout distance, time spent underwater	Head (breaks the surface of the water for the first time)	Not stated	No (average velocity)	Feedback intervention, three swimmers
Xie et al., 2024 [15]	Breakout time and distance, underwater descent and ascent times	Head (breaks the surface of the water for the first time)	Start wall (distance), starting signal (time)	No	Phase model, ten female swimmers
Abo-Touq & Abdel-Fattah, 2020 [46]	Distance and time to head emergence, underwater distance and time	Head	Starting wall (distance), water entry (underwater distance and time)	No	One camera above water
Cicenia Achurra et al., 2019a [31], Cicenia et al., 2019b [32]	Underwater time to resurfacing	Not stated	Water entry	No	Laboratory
Cicenia Achurra et al., 2020 [72]	Underwater time to resurfacing	Not stated	Water entry	No	Laboratory
Chen et al., 2025b [79]	Underwater speed (entry to breakout)	Any body part	Water entry (fingertip contact) to breakout	No (mean underwater speed)	Training study
Tor et al., 2015b [71]	Breakout time and distance, total underwater time	Not stated	Not stated	No	Three imposed underwater trajectories

Study	Variable(s)	Landmark	Reference event	Velocity at breakout	Context
Vantorre et al., 2010a [80]	Underwater phase duration (glide and lower-limb actions until the head reached the water surface)	Head	Toe immersion	No	Laboratory, grab start
Vantorre et al., 2010b [75]	Underwater phase duration (entry, glide and propulsion until the head reached the water surface)	Head	Hand entry	No	Laboratory, grab start, elite vs trained
Vantorre et al., 2010c [44]	Underwater phase duration (entry, glide and propulsion until the head reached the water surface)	Head	Hand entry	No	Laboratory, track vs grab start
Hermosilla et al., 2022 [45]	Glide distance to first head breakout	Head	Starting wall (includes flight)	No	Passive glide, no lower-limb actions

Note: Studies that considered the end of the underwater phase as the breakout, surfacing, emersion, water break or head emergence. Landmark and reference event are stated as reported by the authors. "Not stated" refers to the lack of definition in the report. Studies reporting underwater time or distance without naming the end event (therefore not counted as measuring breakout): Burkett et al. [41] and the laboratory studies listed in Table 2.

Table S7. Measures of the initiation of the first underwater lower-limb action reported by the included studies.

Study	Measure(s)	Reference event	Onset or completion	Landmark	Context
Tor et al., 2015a [27], Tor et al., 2014 [28]	Time of first lower-limb action; distance of first lower-limb action; time after entry of first lower-limb action	Time of first lower-limb action: not stated. Distance: not stated. Time after entry: water entry	Time of first lower-limb action: completion. Distance: onset. Time after entry: end of the first downward lower-limb action	Centre of the head (distance, time after entry)	National-team testing
Tor et al., 2015b [71]	Time, distance and depth of first lower-limb action	Not stated	Not stated	Not stated	Three imposed underwater trajectories
Born et al., 2026 [62]	Time and distance to the first underwater lower-limb action	Starting signal (time), pool wall (distance)	Not stated	Centre of the head (distance)	National-team testing

Study	Measure(s)	Reference event	Onset or completion	Landmark	Context
Matúš et al., 2025b [16]	Distance of first lower-limb action, time of first lower-limb action, glide time	Starting wall (distance), not stated (time), toe submersion (glide time)	Distance: onset (where the first lower-limb action was initiated). Time: completion. Glide time: onset (start of the downward movement)	Not stated	Laboratory, three kick-start positions
Tor et al., 2018 [18]	Distance of first lower-limb action	Not stated	Onset (commencement of the first underwater lower-limb action)	Centre of the head	Feedback targeting first lower-limb action distance in one swimmer
Chen et al., 2025a [35], Chen et al., 2023 [36]	First lower-limb action distance and time	Starting wall (distance), starting signal (time)	Completion (after the first underwater lower-limb action is completed)	Head (distance)	Lateral-entry training
Gonjo & Olstad, 2020 [68]	Glide time	Feet entry	Onset (beginning of the first downward lower-limb action)	Not applicable (video event)	Race analysis (50 m butterfly)
Lin et al., 2025 [77]	Transition phase duration	Toe entry	Onset (just before the foot initiates the downward lower-limb action)	Foot	Laboratory, elite vs sub-elite
Vantorre et al., 2010a [80], 2010b [75], 2010c [44]	Glide phase duration	Toe immersion	Onset (beginning of the lower-limb propulsion)	Feet	Laboratory, grab and track starts

Note: Measures as defined by the original authors. “Onset” refers to the measure that scores the beginning of the first underwater lower-limb action and “completion” refers to its end. "Not stated" refers to the lack of definition in the report. Imposed underwater trajectories changed the time of the first lower-limb action in Tor et al. [71], and feedback targeted the distance of the first lower-limb action in one swimmer in Tor et al. [18], but no experiment isolated the effect of its timing.