Identifying Evidence-Practice Gaps for Shoulder Injury Risk Factors in Competitive Swimmers: Uniting Literature and Expert Opinion

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ABSTRACT

Objectives – To identify evidence-practice gaps regarding shoulder injury risk factors in competitive swimmers.

Methods – We gathered insights from 27 swimming experts including elite swimmers, coaches, high-performance staff, and applied researchers using Concept Mapping. Participants brainstormed, sorted, and rated (from 1 [least] – 10 [most] important and modifiable) their ideas of shoulder injury risk factors in competitive swimmers. Proposed risk factors rated above the grand mean for importance (6.2 ±0.4) or modifiability (6.5 ±0.5) ratings were considered highly important/modifiable. Expert opinions were then juxtaposed with systematic review findings to identify overlaps or convergences.

Results – Brainstorming generated 126 proposed shoulder injury risk factors for competitive swimmers, subsequently refined to 61 unique proposed risk factors through removing duplicates and combining similar responses. The 61 risk factors were then sorted into seven distinct clusters by participants. Experts perceived 36/61 proposed risk factors as highly important, of which six were supported by literature, six showed no association with injury, two had conflicting evidence, and the remaining 22 have not yet been investigated, suggesting an evidence-practice gap. Three proposed risk factors "inconsistent training load", "poor stroke technique", and "low posterior shoulder strength-endurance" exhibited high perceived importance, high perceived modifiability, and supporting evidence.

Conclusion – An evidence-practice gap was identified for 28 proposed risk factors perceived as highly important by swimming experts despite either i) no relevant empirical research (n=22), or ii) no association with injury (n=6) from synthesised evidence. Greater collaboration between researchers and practitioners is needed to effectively address shoulder injury risk factors in competitive swimmers.

SUMMARY BOXES

What is already known on this topic?

- Shoulder injuries are prevalent in competitive swimmers with a limited understanding of aetiology and risk factors, raising the potential for ineffective or inappropriate prevention protocols.
- With a paucity of high-quality research, practitioners are required to rely on their personal experience, which has not yet been captured in the literature.

What this study adds

- An evidence-practice gap was identified in the misalignment of practitioner priorities and systematic investigation. Experts identified 22 highly important proposed risk factors that have not yet been investigated through empirical research.
- Practitioners perceived six proposed risk factors related to maximal strength, range of motion, or training volume as highly important despite systematically reviewed evidence indicating they are not associated with shoulder injury.
- Three proposed risk factors with high perceived importance and modifiability (inconsistent training load, poor stroke technique, and low posterior shoulder strength-endurance) had supporting evidence.

How this study might affect research and practice

- Researchers should consider investigating the risk factors with the highest practical importance, specifically the 22 highly important, un-investigated proposed risk factors.
- Swimming practitioners should consider monitoring low posterior shoulder strength-endurance, poor stroke technique, and inconsistent/acute increases in training load as modifiable risk factors towards injury prevention.

INTRODUCTION

Competitive swimming presents a significant risk for shoulder injury. Trinidad, et al. [1] reported that between 2010-2020, up to 76% of all swimming injuries involve the shoulder. Further, up to 96% of American college swimmers experience shoulder pain throughout a competitive season[2]. Due to this high prevalence, American high school swimmers consider shoulder pain a normal part of the sport (87% consider mild pain and 43% consider moderate pain normal)[3].

While comparative data is lacking, shoulder injury rates do not appear to be declining[1]. This could be the result of several factors including technique and training evolution, lack of appropriate or adherence to prevention protocols, and potentially misunderstood injury risk factors. Understanding the nuanced associations between proposed risk factors and injury could support practitioners to implement effective preventative strategies. We recently conducted a systematic review on shoulder injury risk factors in competitive swimmers, none of the 80 variables exhibited a strong association with shoulder injury[4]. Two variables presented moderate supporting evidence, while seven displayed moderate evidence opposing an association with shoulder injury. The remaining variables showed inconclusive results: eight presented conflicting data, 19 with limited support, and 39 with limited opposing evidence. Table 1 defines each strength of evidence category.

The paucity of conclusive evidence likely necessitates practitioners to rely on personal/professional experience and anecdotal evidence when addressing injury risk. Previous reports suggest 52% (n=23) of elite swimming strength coaches use their anecdotal experience as their primary information source[5]. Within this context, there is a clear need to explore the gap between practitioner perspectives and systematic evidence. Here we defined the evidence-practice gap as a bi-directional relationship encompassing instances where practitioner's beliefs misalign with the established literature/evidence and where research focus is misaligning with practitioner priorities.

The purpose of this investigation was to identify evidence-practice gaps by: (i) gathering expert opinions of shoulder injury risk factors in competitive swimmers, then (ii) comparing these expert opinions to synthesised evidence resulting from our recent open access systematic review[4].

METHODS

To gather expert opinion regarding shoulder injury risk factors in competitive swimmers, we employed concept mapping which is a mixed-method approach that facilitates the gathering, sorting, and rating of opinions provided by domain specific experts[6]. This valid and reliable method[7] has been used to explore expert beliefs regarding sports injury risk factors and prevention strategies[8-10]. Our concept mapping prompt and related rating questions were developed by researchers and approved by industry partners. The Griffith University Human Research Ethics Committee approved this study (2022/594).

Participants

Participants were expert swimming practitioners, including current elite swimmers and coaches, high performance support staff, and applied researchers. Any individual capable of obtaining and sustaining a role working/completing with senior national squad members (from any country) was deemed an expert given the competitive nature of such positions. Potential participants were recruited with the assistance of professional bodies (Swimming Australia and the Queensland Academy of Sport [QAS]), through advertisements on social media, and via direct emails to participants asking them to engage with the online data collection platform. Recruitment primarily targeted Australian swimming networks; potential participants were encouraged to disseminate the online survey link with their international professional network, regardless of location. Participant eligibility was cross-checked with their self-reported demographic information including age, sex, years in competitive swimming (including non-elite), role(s) in elite swimming, and relevant qualifications on the groupwisdom™ platform to ensure the inclusion criteria was met. Participants provided implied consent when they clicked on the "I agree" icon on the opening page of the online data collection platform.

Procedures

Consenting participants were instructed to complete the brainstorming phase via the online platform (Figure 1). Participants were prompted with the question *"based on your experience, what* *specific risk factors do you believe are contributing to shoulder injury in swimmers?"* and invited to contribute as many statements as they wished while the data collection platform was open (September to October). Brainstorming continued until researchers were satisfied, through daily inspection of new responses by multiple researchers, that incoming responses were exclusively duplicates of previous responses. Researchers cleaned the de-identified raw statements by removing irrelevant or incomprehensible statements, splitting compound statements, eliminating redundancies, and consolidating similar statements to best convey the underlying concept. This standard concept mapping process[6] was conducted through group conversations with all research team members present to ensure consensus and coherence in capturing the underlying concept. This process was repeated until a manageable number (i.e., that minimized the sorting and rating time burden for participants) of proposed risk factors that represented the breath of ideas generated by participants, were available to progress into the subsequent two steps[6].

All brainstorming phase participants received a second link to complete the sorting and rating. Additionally, the QAS and Swimming Australia aided with a second email invitation to prospective participants in their elite swimming programs who did not accept the initial invitation. For the sorting phase, participants were instructed to click-and-drag each proposed risk factor on to an online 'sorting table'. They were asked to group similar risk factors together based on their content, without considering factors such as difficulty, importance, or feasibility. Participants were asked to aim to create approximately 5-20 groups and assign each group a descriptive name that represented its contents. Responses were excluded from analysis if sorting was based on anything except content (i.e., importance or modifiability). In the rating phase, participants rated importance and modifiability of each of the 61 unique proposed risk factors, on a scale from 1 (least) to 10 (most). Participants were prompted with "*how important do you think it is for this risk factor to be addressed in a shoulder injury prevention program for swimmers?"* and "*how confident are you that this risk factor can be modified in a shoulder injury program for swimmers?"*. Participants could self-select which activity sorting, rating importance, or rating modifiability to complete first.

INSERT FIGURE 1

Expert Opinion Data Analysis and Visualisation

Following collection, the data were visually inspected to ensure participants complied with sorting and rating procedure instructions. This involved ensuring participants responded with variable ratings (i.e., not indicate "5" for all ratings), and that there were approximately 5-20 sorted groups based on content (not a value). Groupwisdom™ software was used for multidimensional scaling and hierarchical cluster analysis. The number of clusters represented in the final cluster-map was guided by researchers as per Kane and Trochim [6]. During this standard step, researcher redrawing of cluster boundaries to locate statements to adjacent clusters was undertaken to improve the conceptual fit. A "Go-Zone" figure (Figure 2) was used to visualise the relationship between mean importance and modifiability ratings of each proposed risk factor. A stress index was calculated to provide an indication of the agreement between the grouping data and the two-dimensional point map. A meta-analysis of concept mapping studies found an average value of 0.285 ±0.04[6]. Lower values indicates a better fit between the participants sorting data and two-dimensional map, and represent a more simply structured and generally agreed upon conceptual phenomena[6].

Evidence-Practice Gap Analysis

The evidence-practice gap analysis aimed to identify alignment or divergence between participant's perceptions and current evidence (and vice-versa). The synthesised evidence was derived from our recently published systematic review of shoulder pain and injury risk factors in competitive swimmers[4]. The systematic review synthesised the evidence for 80 unique variables that had been previously investigated for an association with shoulder pain or injury in published original research. Individual studies were ranked on methodological quality using a modified Newcastle Ottawa Scale[11]. Next, all studies investigating the same variable were synthesised and the risk factor was categorised into either strong, moderate, limited, or conflicting evidence supporting/opposing an association with shoulder pain/injury. The criteria for each category was adopted from Asker, et al. [12] and can be found in Table 1.

Further detail regarding the systematic review's methods can be found in the open access article[4]. Critically, this review was not publicly available at the time of data collection for the current study.

Table 1

Synthesised evidence criteria categories (adopted from McKenzie, et al. [4])

Strong evidence
Evidence provided by two or more high- quality studies and by generally consistent findings across these studies (≥75% of the studies reported consistent findings).
Moderate evidence
Evidence provided by one high- quality study and/or multiple studies of acceptable quality and by generally consistent findings (≥75% of the studies reported consistent findings).
Limited evidence
Evidence provided by one study of acceptable quality and/or one or more studies of borderline quality.
Conflicting evidence
Inconsistent findings in multiple studies (<75% of the studies reported consistent findings).

Each proposed risk factor from the current study was cross-referenced with synthesised evidence by two researchers independently (AM and RD). Individual concept mapping statements could be paired with multiple investigated variables if, for example, a more generic statement (trunk strength and strength-endurance) aligned with multiple specific measures (e.g., trunk extension strength, ball-bridge test, and trunk flexion strength). Overlaps or divergences between statements and review findings were recorded, providing insight into the alignment and potential disconnection between current practice and existing scientific evidence. We calculated the grand mean rating for importance (6.2 ±0.4) and modifiability (6.5 ±0.5) for all risk factors combined and used these scores as thresholds to dichotomise proposed risk factors into either "high" (i.e., above the grand mean) or "low" (i.e., below the grand mean) perceived importance/modifiability for the purpose of discussion. The grand mean scores are represented in figure 3 and are commonly used to differentiate between quadrants in other concept mapping studies.

Equity, Diversity, and Inclusion

Our team combines interdisciplinary expertise in exercise physiology, sports science, physiotherapy, and sport and social science, to solve a significant real-world problem that affects both males and females equally. The team consists of females and males, early career clinicians, practitioners, junior and senior researchers ensuring professional development through mentoring and collaboration with senior team members. Equitable recruitment was enabled through strategic collaborations with Swimming Australia and the Queensland Academy of Sport, we ensured that all professional staff, regardless of race, ethnicity, or culture, were invited and had an equal opportunity to participate without bias. Potential participants were not included or excluded based on sex; rather, all practitioners were invited equally.

RESULTS

Participants

Sixteen participants contributed brainstorming data before saturation was reached. Twenty-three participants completed the sorting phase, 23 completed modifiability ratings, and 25 completed the importance ratings. Overall, 27 participants completed at least one activity in the sorting and rating phases.

The sample was comprised of 21 male and 6 female participants (age = 40.8 ±9.3yrs, years in competitive swimming = 15.6 ±13.0yrs) and included participants from a variety of disciplines: 13 physiotherapists, 6 strength and conditioning coaches, 6 swimming researchers, 2 current elite swimmers, 2 elite swimming coaches, 1 nutritionist, and 1 physician. Some participants held multiple roles. Four participants resided outside Australia during participation (Brazil, England, and Belgium).

Brainstorming

Participants contributed 126 risk factors during brainstorming. This was reduced to 61 unique statements for participants to consider in all subsequent sorting and rating activities following data cleaning and redundancy checking.

Statement Sorting & Cluster Maps

Two participants' sorting data were removed due to non-compliance (grouping risk factors based on their perceived importance, rather than content). Researchers agreed a seven-cluster map best capsulated the proposed risk factors based on content and the average number of clusters created by participants (7.87 ±2.88 clusters/participant). These clusters, ordered from most-to-least important, were: injury history (8.72 ±1.57), land training (6.27 ±1.54), pool training (6.25 ±1.43), strength (6.25 ±1.28), biopsychosocial (6.24 ±0.99), motor control (6.04 ±0.86), and range of motion (5.92 ±0.81) (all data available in Figure 2 and Table 2).

The 0.18 stress value indicates a good fit between the two-dimensional map and participants' original sorting data[6]. This value also signifies a greater level of consensus between participants in the current study compared to other sports injury-related concept mapping investigations[8-10].

INSERT FIGURE 2

Table 2 All proposed shoulder injury risk factors in competitive swimmers with their perceived importance and modifiability.

ID	Risk factor	Importance		Modifiability		Go-Zone Quadrant
		mean	SD	mean	SD	
CLUSTER – Injury History		***8.72***	***1.57***	***2.55***	***2.65***	
61	previous shoulder injury/pain	8.72	1.57	2.55	2.65	2
CLUSTER – Land Training		***6.27***	***1.54***	***7.62***	***1.01***	
55	inappropriate strength training (including loads and exercise selection)	8.20	1.38	8.09	1.86	1
38	insufficient tendon loading	7.16	2.10	7.96	1.46	1
59	inconsistent/lack of shoulder prehab	7.08	2.41	8.17	1.99	1
56	lack of dry-land training	6.92	2.14	8.48	1.31	1
58	inappropriate application of prehab exercises (e.g., dry-land prehab)	6.28	1.99	8.13	1.79	1
54	inappropriate shoulder-specific cross-training	6.17	1.79	7.39	2.15	3
57	lack of shoulder specific hypertrophy	5.24	2.49	7.45	2.06	3
53	DOMS following resistance training	3.12	1.81	5.30	2.64	4
CLUSTER – Pool Training		***6.26***	***1.43***	***6.06***	***1.45***	
43	inconsistent training load	8.84	0.75	7.43	2.48	1
40	acute increases in swim training load	8.40	1.47	6.78	2.83	1
31	poor stroke technique	7.84	1.84	6.52	2.52	1
41	excessive high intensity swimming training	7.20	2.75	6.83	2.71	1
44	progressing too fast from junior to senior squads	6.80	2.31	5.48	3.07	2
32	new technique alterations	6.48	1.94	6.04	2.62	2
42	high absolute training load	6.24	2.39	6.64	2.66	1
48	high km/week	6.04	2.39	5.95	3.06	4
46	inadequate swimming-specific warm-up	5.80	2.20	7.86	1.91	3
45	low generalised aerobic level	5.36	2.34	7.04	2.50	3
47	young swimming training age	5.08	2.75	3.70	2.99	4
34	use of hand paddles	4.68	2.53	6.74	3.03	3
33	unilateral breathing during freestyle	4.64	2.16	5.30	3.04	4
35	stroke specialty	4.24	2.07	2.52	2.25	4
CLUSTER – Strength		***6.25***	***1.28***	***7.57***	***0.51***	
5	generalised rotator cuff strength-endurance	8.04	1.54	8.19	1.83	1
3	poor strength-endurance overhead	7.64	1.80	8.17	1.11	1
14	subscapularis weakness in the catch position	7.60	1.78	7.32	1.96	1
11	posterior shoulder strength-endurance	7.48	1.76	8.39	1.03	1
13	low scapulo-thoracic strength	7.00	1.76	7.41	1.89	1
1	internal and external rotation strength imbalance	6.72	2.28	7.73	1.91	1
4	maximal external rotation strength	6.60	2.57	7.95	1.81	1
6	maximal internal rotation strength	6.52	2.31	7.57	1.83	1

7	low long lever shoulder extension strength while overhead	6.24	2.35	7.78	1.44	1
15	trunk strength and strength-endurance	6.20	1.55	7.43	1.67	3
12	low scapula retraction strength	6.12	2.60	7.74	1.86	3
8	low maximal number of pull ups	4.56	2.42	7.52	1.78	3
9	maximal neck extension strength	4.48	2.26	6.74	2.82	3
10	neck extension strength-endurance	4.40	2.24	6.78	2.47	3
2	lower limb strength and strength-endurance	4.20	2.16	6.83	2.50	3
CLUSTER – Biopsychosocial		***6.24***	***0.99***	***6.27***	***0.95***	
52	inadequate recovery	7.48	1.78	7.35	2.55	1
51	poor sleep (quality and quantity)	7.24	2.47	6.30	2.36	2
60	lack of education indicating an acceptable level of pain to train through	6.28	2.61	7.22	2.43	1
49	Inadequate fuelling (nutrition) surrounding training	6.24	2.49	6.55	2.79	1
50	low energy availability (nutrition)	6.24	2.60	6.43	2.76	2
37	rapid increase in body mass	5.72	2.26	5.35	2.48	4
36	excessive adipose tissue	4.48	2.35	4.73	2.73	4
CLUSTER – Motor Control		***6.04***	***0.86***	***6.11***	***0.76***	
17	poor shoulder motor control overhead	6.96	1.93	7.09	1.78	1
16	poor activation patterns of the rotator cuff	6.56	2.29	6.35	2.39	2
18	low scapulo-thoracic stability	6.44	2.24	6.41	2.22	2
39	poor length-tension relationships of the shoulder (i.e., poor posture)	5.16	2.48	5.17	2.37	4
19	scapular dyskinesia	5.08	2.66	5.52	2.47	4
CLUSTER – Range of Motion (ROM)		***5.92***	***0.81***	***5.58***	***1.19***	
23	limited internal rotation ROM	6.84	1.97	6.39	2.33	2
24	limited internal rotation ROM while overhead	6.75	2.15	6.50	2.26	2
27	limited total rotational ROM (internal + external range)	6.72	2.17	6.36	1.84	2
25	limited thoracic extension ROM	6.60	1.50	5.45	1.97	2
26	limited thoracic rotation ROM	6.44	1.66	6.36	2.17	2
22	limited external rotation ROM	6.24	2.20	6.09	2.22	2
28	shoulder hypermobility	5.36	2.56	2.65	1.85	4
21	limited abduction ROM	5.20	2.10	6.09	2.07	4
30	shortened pec minor length at rest	5.16	1.99	5.65	2.21	4
29	limited cervical ROM	5.08	2.06	5.83	2.37	4
20	excessive external rotation ROM	4.72	2.28	4.04	2.38	4
	grand mean (all statements)	**6.22**		**6.52**		

Statement Rating

Figure 3 and Table 2 detail the mean perceived importance and modifiability ratings of each individual statement. Figure 3 (Go-zone) contains quadrants, quadrant 1 and 3 contain risk factors above the grand mean for modifiability, whereas quadrants 1 and 2 contain risk factors above the grand mean for importance. Quadrant 1 contains the most modifiable and most important risk factors and quadrant 4 contains the least important and least modifiable proposed risk factors.

Importance

"Inconsistent training load" (ID43) was perceived as the most important proposed risk factor to be addressed in a shoulder injury prevention program for swimmers, also exhibiting the lowest standard deviation (8.84 ±0.75). Conversely, "DOMS following resistance training" (ID53, 3.12 ±1.81) was perceived as the least important. The greatest standard deviation in importance ratings between participants appeared in both "Excessive high intensity swimming training" (ID41, 7.20 ±2.75) and "young swimming training age" (ID47, 5.08 ±2.75).

Modifiability

Confidence in the modifiability of proposed risk factors was greatest in "lack of dry-land training" (ID56, 8.48 ±1.31) and lowest for "specialty stroke" (ID35, 2.52 ±2.25) and "injury history" (ID61, 2.55 ±2.65). There was lowest standard deviation in participants' modifiability ratings for "posterior shoulder strength-endurance" (ID11, 8.39 ±1.03) and lowest agreement for "progressing too fast from junior to senior squads" (ID44, 5.48 ±3.07).

INSERT FIGURE 3

Evidence-Practice Gap

Eight of the 61 proposed shoulder injury risk factors were supported in the findings of our systematic review[4] (1 = moderate evidence, and 7 = limited evidence), 12 had evidence showing no association with shoulder injury (4 = moderate, 7 = limited, 1 = combination of conflicting, limited, and moderate), seven had conflicting evidence, and 34 statements had not been investigated. Figure 4 displays each proposed risk factor that also appeared in our systematic review, along with the corresponding synthesised level of evidence and the relating article(s) investigating each variable.

INSERT FIGURE 4

DISCUSSION

Our study introduced a novel method of gathering expert opinion on shoulder injury risk factors in competitive swimmers and comparing these practitioner beliefs to current evidence. Key findings indicate that of the 36 proposed risk factors rated as highly important, six showed supporting evidence, six had evidence opposing an association with injury, two had conflicting evidence, and the remaining 22 are yet to be investigated (see figure 4). There is an evident evidence-practice gap in shoulder injury risk factors for competitive swimmers.

Where practice and evidence align

Eight proposed risk factors aligned with evidence supporting an association with shoulder injury (see Figure 4), six of these were perceived as highly important to address in prevention programs. The current low level of evidence in shoulder injury risk factors prevents strong practice guidelines being inferred. However, practitioners should consider addressing risk factors that are perceived as highly important, highly modifiable, and supported by the best available evidence.

Posterior shoulder strength-endurance (ID11) was perceived as highly important, highly modifiable, and has been investigated in swimmers using "the posterior shoulder strength-endurance test"[2 13]. Further, lower strength-endurance during both external rotation and abduction have each been individually associated with injury[14] and together contribute to the posterior shoulder strength-endurance test movement. When assessed in 201 junior competitive swimmers, every 1-repetition increase in posterior shoulder strength-endurance test score was associated with by a 5% in the odds of developing pain[13]. Using a modified version in 30 division-III college swimmers, test scores increased throughout the season, with researchers postulating this increase could have provided protection against injury[2]. The hypothetical protective mechanism, or lack thereof, has recently been discussed by Drigny and Gauthier [15] and McKenzie, et al. [16].

Poor stroke technique (ID31) was perceived as highly important and modifiable with supporting evidence. Although the proposed risk factor refers to poor stroke technique generally, a more medial hand entry position has been associated with shoulder injury[13]. Further, an investigation of the prevalence of biomechanical errors in freestyle technique in 62 shoulders (on 31 swimmers with 11.3 ±1.41 years of competitive swimming experience) found that the most prevalent stroke errors were a dropped elbow during the pull-through phase (61%) and recovery phase (52%) which was postulated to increase the risk of impingement syndromes[17]. While participants suggested that poor stroke technique causes injury, this does not mean that "optimal" stroke technique removes injury risk. Conceptually, mechanically sound stroke technique will increase the tolerable training load, however, training load was also perceived as a highly important injury risk factor.

Inconsistent training load (ID43) and acute increases in swimming training load (ID40) both exhibited high perceived importance and supporting evidence. Swimming training demands over 16,000 strokes each week[18], equating to millions over a career. The cumulative load on the shoulder is likely the main cause of the overuse tendinopathies typically seen in the swimmer's shoulder[19]. The evidence supports the use of acute: chronic workload ratio as an injury predictor, with a 1-unit increase in this ratio leading to 4.3 times greater odds of injury[13]. However, swimming-specific practice guidelines for effective training load monitoring are limited[20 21], with some researchers refuting the use of this ratio due to inherent statistical artefact[22 23]. In swimming, there is a complex interaction of total number of strokes, stroke intensity, and fatigue which are not yet being well understood or quantified. Nevertheless, 38% (n=31) of swimming practitioners perceived their training load monitoring strategies as "very" or "extremely effective" at preventing injury, and 92% reported using session rating of perceived exertion (sRPE) as a monitoring tool[24]. While literature is emerging[25 26], sRPE has not yet been used when investigating shoulder injury risk indicating another evidence-practice gap in swimming's training load monitoring strategies[4 21 24].

Poor activation patterns of the rotator cuff (ID16) also exhibited high perceived importance and moderate supporting evidence. Evidence suggests that swimmers with a painful shoulder will recruit shoulder musculature differently to un-injured swimmers[27-29]. However, due to study designs, we are unable to ascertain if the differences in activity have occurred prior to or following the injury.

The final risk factor with high perceived importance and supporting evidence was injury history (ID61). Although non-modifiable, previous injury has been shown to increase future risk by up to 11.3

times[30]. Therefore, we recommend practitioners consider injury history when formulating targeted injury prevention strategies and highlight the need for primary prevention.

Six proposed risk factors in our study exhibited low perceived importance and evidence reporting a lack of association with shoulder injury. These are low scapular retraction strength (ID12), limited abduction ROM (ID21), scapular dyskinesis (ID19), excessive external rotation ROM (ID20), unilateral breathing side (ID33), and stroke specialty (ID35). Excluding low scapular retraction strength (ID12), all these factors were perceived to have low modifiability. Given these findings, we recommend practitioners carefully consider whether continued monitoring efforts for these proposed risk factors align with their overall injury prevention strategies.

The evidence-practice gap – Where experts and evidence disagree.

An evidence-practice gap is apparent in the bottom tier of Figure 4, where highly important proposed risk factors have evidence opposing an association with shoulder injury. The evidence-practice gap is clear for low scapula-thoracic strength (ID13), limited internal rotation ROM (ID23), maximal external rotation strength (ID4), maximal internal rotation strength (ID6), high absolute training load (ID42), and limited external rotation range of motion (ID22). Due to the limited-to-moderate quality evidence for the investigated risk factors, the current evidence is insufficient to refute the opinions of the expert practitioners involved in our study. To establish greater certainty for all variables, regardless of current direction of association, additional prospective research is imperative.

An evidence-practice gap is also evident by the lack of proposed risk factors with high perceived importance that have not been investigated in the literature. Twenty-two (61%) highly important proposed risk factors have not been investigated in the literature, indicating a misalignment of practitioner and researcher priorities. Some of which are unable to be assessed using our current technologies and understanding (e.g., ID's 38 and 60), whereas others are relatively easy for researchers to assess and simply highlight the need for variables to be assessed in a more swimming-specific position (ID's 3, 7, 14, and 17).

Greater collaboration is needed between swimming associations, coaches, athletes, practitioners, and researchers to bridge the evidence-practice gap. Our study suggests future research is needed to (re)evaluate perceptively important risk factors, facilitating authentic practice-driven research. Prioritizing research involving risk factors that experts perceive as being the most important is essential. In the context of developing injury prevention strategies, this prioritization could be further refined to focus on proposed risk factors that are perceived to be highly importance and modifiability regardless of the current level of evidence, i.e., risk factors in quadrant 1 (Q1) of Figure 3. This approach is transferable across sports, urging sports medicine researchers in other disciplines to adopt similar methodology for impactful research. Additionally, translating research findings to professionals using innovative strategies becomes pivotal, as the traditional model of dissemination through journal publications appears to be ineffective in swimming, as evidence by the evidence-practice gap.

Limitations

Reflecting on the concept mapping process, we suggest researchers initially contribute all previously investigated risk factors into the brainstorming phase while also allowing experts to contribute their ideas. This addition will ensure all previously investigated, and identified, risk factors will be considered by participants.

Turning to the study findings, it is important to recognise that expert opinion is fundamentally low-level evidence[31]. Therefore, practice guidelines should not be created solely based on these results. However, this study can inform clinical decision making and future research directions. Secondly, the experts involved were primarily male Australian-based physiotherapists and strength coaches which may have limited the diversity of opinions. Future research should aim to include a more balanced representation of genders to ensure a wider range of insights. Additionally, conducting studies with swimming organisations that have access to different resources could further diversify the outcomes and strengthen the overall conclusions. Unfortunately, this study was under-powered to investigate differences between professions/disciplines. Further, there may have been inter-subject variability in how each statement was perceived, for example the high standard deviation for the relative importance rating of “poor activation patterns of the rotator cuff” (ID 16) could have been due to different interpretations of the statement. Finally, this study exclusively evaluated injury risk factors, so any suggestion to reduce monitoring of a specific measure is made for the purpose of injury prevention, not performance.

CONCLUSION

Our investigation highlighted three key risk factors – low posterior shoulder strength-endurance, poor stroke technique, and inconsistent/acute increases in training load that exhibited high perceived importance, high perceived modifiability, and supporting evidence. Therefore, we recommend swimming practitioners prioritize the monitoring and addressing of these risk factors within their injury prevention strategies.

Furthermore, our study underscores the value of combining expert opinion with current evidence, particularly in situations where prevalent practical issues are investigated using low methodological quality. Researchers are encouraged to (re)evaluate the risk factors presented in quadrant 1 (Q1) of Figure 3 using high-quality prospective studies. This innovative approach offers a more comprehensive evidence-based understanding of the potential impact these factors have on injury prevention in competitive swimming.

FIGURE & TABLE CAPTIONS

Figure 1. Schematic diagram and timeline of concept mapping procedures.

Table 1. *Synthesised evidence criteria categories (adopted from McKenzie, et al. [4])*

Figure 2. Seven-cluster map of variables perceived to be shoulder injury risk factors in competitive swimmers.

Note: the grey dashed lines indicate the original cluster solution before researchers re-drew cluster boundaries based on the reassignment of some statements.

Table 2. All proposed shoulder injury risk factors in competitive swimmers with their perceived importance and modifiability.

Figure 3. Go-Zone graph indicating the mean perceived importance (X-axis) and modifiability (Y-axis) for each proposed shoulder injury risk factor.

Note: Colours indicates cluster as per Figure 2.

Figure 4. Swimming's evidence-practice gap regarding shoulder injury risk factors.

Note: The bar graph (left side) illustrates the perceived risk factors identified through concept mapping. The dots (right side) and text, with references, are the risk factors previously investigated and synthesised in our systematic review [4]. Hypothetically, a risk factor with 10/10 importance (bar graph) and strong supporting evidence (dots), would indicate 100% agreement between practice and evidence. The (N = __) indicates the total number of swimmers included in the studies investigating the listed risk factor. Pec. = pectoralis, IR = internal rotation, ROM = range of motion, ER = external rotation, sEMG = surface electromyography.

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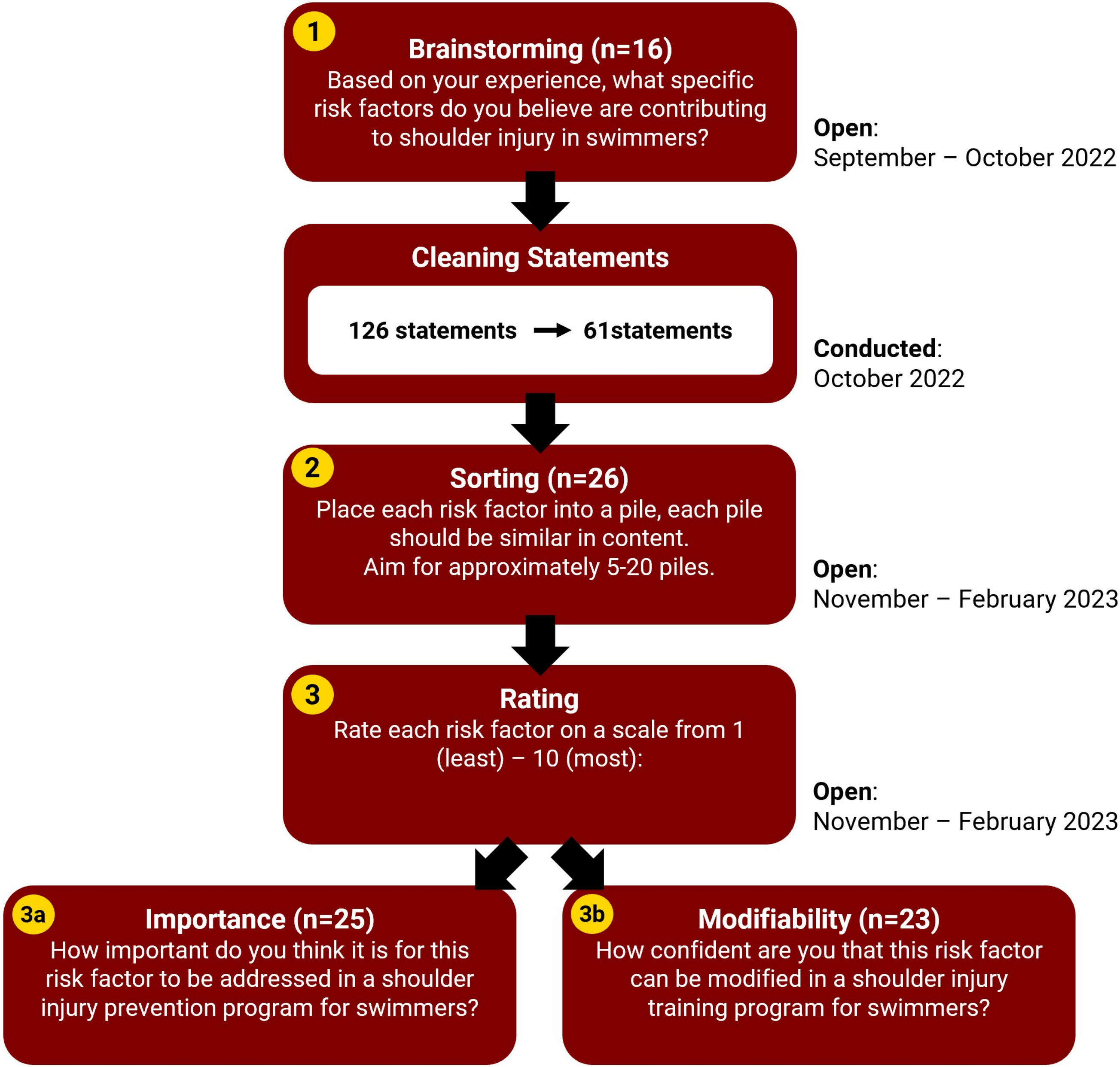
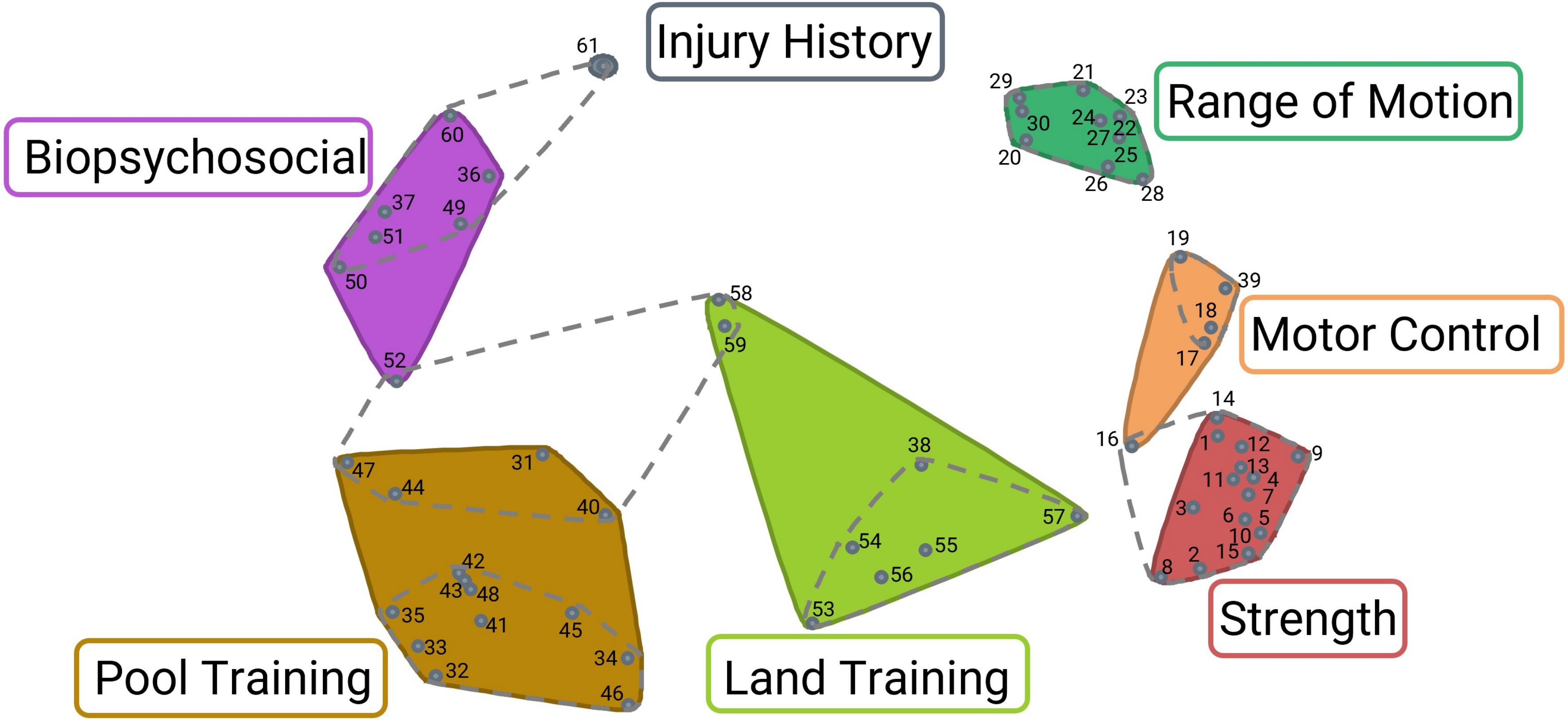
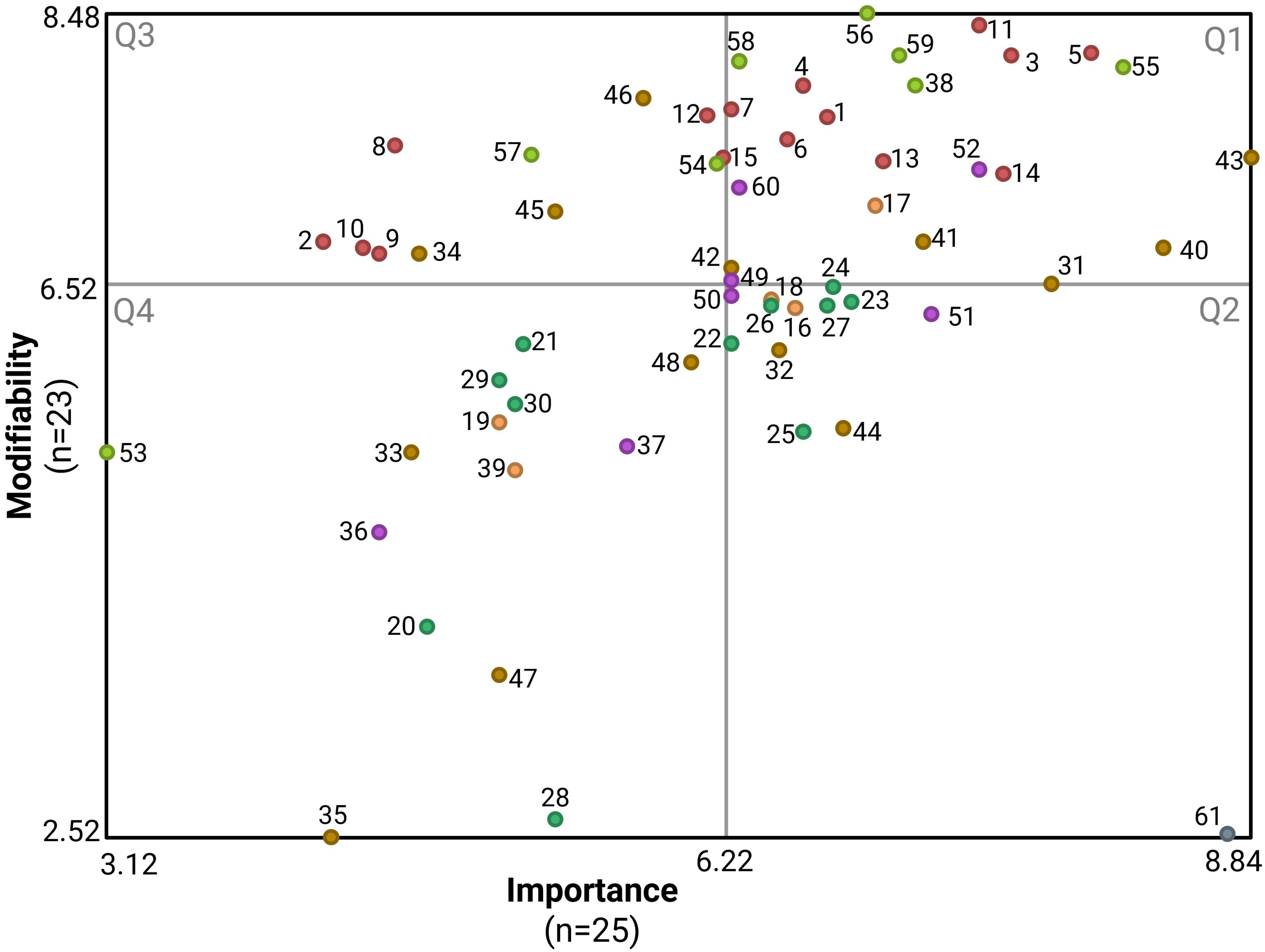
Ethical approval information: Griffith University Human Research Ethics Committee approved this study (2022/594).

Data sharing statement: All data is presented in manuscript figures excluding original brainstormed ideas. These can be made available upon request.

Patient involvement: No patient involvement.


1
Brainstorming (n=16)
Based on your experience, what specific risk factors do you believe are contributing to shoulder injury in swimmers?
Open:
September – October 2022
Cleaning Statements
126 statements → 61statements
Conducted:
October 2022
2
Sorting (n=26)
Place each risk factor into a pile, each pile should be similar in content.
Aim for approximately 5-20 piles.
Open:
November – February 2023
3
Rating
Rate each risk factor on a scale from 1 (least) – 10 (most):
Open:
November – February 2023
3a
Importance (n=25)
How important do you think it is for this risk factor to be addressed in a shoulder injury prevention program for swimmers?
3b
Modifiability (n=23)
How confident are you that this risk factor can be modified in a shoulder injury training program for swimmers?


Injury History
Range of Motion
Biopsychosocial
Motor Control
Strength
Pool Training
Land Training


8.48
6.52
2.52
3.12
6.22
8.84
Q1
Q2
Q3
Q4
Modifiability
(n=23)
Importance
(n=25)
1
2
3
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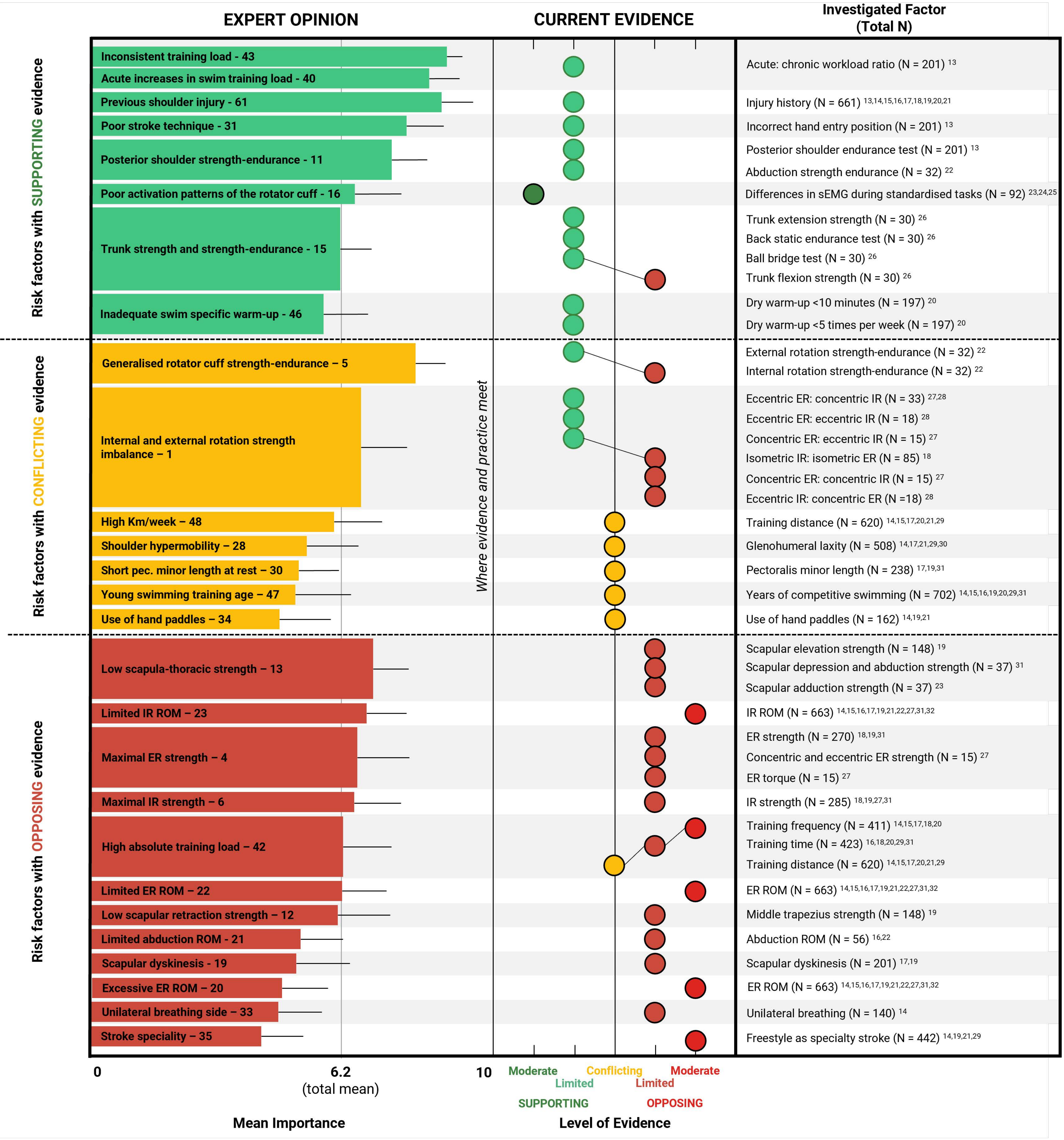

EXPERT OPINION
CURRENT EVIDENCE
Investigated Factor (Total N)
Risk factors with SUPPORTING evidence
Inconsistent training load - 43
Acute increases in swim training load - 40
Acute: chronic workload ratio (N = 201) 13
Previous shoulder injury - 61
Injury history (N = 661) 13,14,15,16,17,18,19,20,21
Poor stroke technique - 31
Incorrect hand entry position (N = 201) 13
Posterior shoulder strength-endurance - 11
Posterior shoulder endurance test (N = 201) 13
Abduction strength endurance (N = 32) 22
Poor activation patterns of the rotator cuff - 16
Differences in sEMG during standardised tasks (N = 92) 23,24,25
Trunk strength and strength-endurance - 15
Trunk extension strength (N = 30) 26
Back static endurance test (N = 30) 26
Ball bridge test (N = 30) 26
Trunk flexion strength (N = 30) 26
Inadequate swim specific warm-up - 46
Dry warm-up <10 minutes (N = 197) 20
Dry warm-up <5 times per week (N = 197) 20
Risk factors with CONFLICTING evidence
Generalised rotator cuff strength-endurance – 5
External rotation strength-endurance (N = 32) 22
Internal rotation strength-endurance (N = 32) 22
Internal and external rotation strength imbalance – 1
Eccentric ER: concentric IR (N = 33) 27,28
Eccentric ER: eccentric IR (N = 18) 28
Concentric ER: eccentric IR (N = 15) 27
Isometric IR: isometric ER (N = 85) 18
Concentric ER: concentric IR (N = 15) 27
Eccentric IR: concentric ER (N =18) 28
High Km/week – 48
Training distance (N = 620) 14,15,17,20,21,29
Shoulder hypermobility – 28
Glenohumeral laxity (N = 508) 14,17,21,29,30
Short pec. minor length at rest – 30
Pectoralis minor length (N = 238) 17,19,31
Young swimming training age – 47
Years of competitive swimming (N = 702) 14,15,16,19,20,29,31
Use of hand paddles – 34
Use of hand paddles (N = 162) 14,19,21
Where evidence and practice meet
Risk factors with OPPOSING evidence
Low scapula-thoracic strength – 13
Scapular elevation strength (N = 148) 19
Scapular depression and abduction strength (N = 37) 31
Scapular adduction strength (N = 37) 23
Limited IR ROM – 23
IR ROM (N = 663) 14,15,16,17,19,21,22,27,31,32
Maximal ER strength – 4
ER strength (N = 270) 18,19,31
Concentric and eccentric ER strength (N = 15) 27
ER torque (N = 15) 27
Maximal IR strength – 6
IR strength (N = 285) 18,19,27,31
High absolute training load – 42
Training frequency (N = 411) 14,15,17,18,20
Training time (N = 423) 16,18,20,29,31
Training distance (N = 620) 14,15,17,20,21,29
Limited ER ROM – 22
ER ROM (N = 663) 14,15,16,17,19,21,22,27,31,32
Low scapular retraction strength – 12
Middle trapezius strength (N = 148) 19
Limited abduction ROM - 21
Abduction ROM (N = 56) 16,22
Scapular dyskinesis - 19
Scapular dyskinesis (N = 201) 17,19
Excessive ER ROM – 20
ER ROM (N = 663) 14,15,16,17,19,21,22,27,31,32
Unilateral breathing side – 33
Unilateral breathing (N = 140) 14
Stroke speciality – 35
Freestyle as specialty stroke (N = 442) 14,19,21,29
0
6.2
(total mean)
10
Moderate
Limited
Conflicting
Limited
Moderate
SUPPORTING
OPPOSING
Mean Importance
Level of Evidence