Interventional Therapies for Subacromial Impingement Syndrome: A Systematic Review and Fragility Analysis of Randomized Controlled Trials

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INTRODUCTION: Subacromial impingement syndrome (SAIS) is a leading cause of shoulder pain, responsible for a significant proportion of all shoulder-related physician visits. Despite the continued burden of SAIS and increasing utilization of interventions such as arthroscopic decompression, corticosteroid injections, and acupuncture, randomized controlled trials (RCTs) evaluating these therapies have produced conflicting results. Some studies suggest measurable benefit, while others fail to demonstrate clinical significance. A central issue is the sole reliance on p-values as indicators of efficacy, which, though conventionally accepted, are limited by their arbitrary thresholds and sensitivity to sample size, event distribution, and attrition rates. Fragility metrics such as the fragility index (FI), reverse fragility index (rFI), and fragility quotient (FQ) offer complementary insights by quantifying the robustness of dichotomous outcome findings. This study aimed to systematically evaluate the statistical fragility of outcomes in RCTs investigating interventional therapies for SAIS.

METHODS: A systematic review adhering to PRISMA guidelines was conducted across PubMed, Embase, and MEDLINE for studies published between January 1, 2000, and July 1, 2024. Eligible studies were English-written RCTs that compared at least two SAIS treatments with at least one interventional therapy and reported dichotomous outcomes. Of 519 results, 38 studies met inclusion criteria, yielding 150 evaluable outcomes. The FI and rFI were calculated via two-tailed Fisher's exact tests at a significance threshold of 0.05. The FQ was calculated as the FI or rFI divided by total sample size, contextualizing robustness relative to cohort size. Outcomes were stratified by statistical significance, intervention type, outcome category, publication year, and patient follow-up rates.

RESULTS:

Among 150 outcomes, the median FI was 4 (IQR 3-6), and the median FQ was 0.061 (IQR 0.026-0.100), meaning that in many cases, reversal of just 4 events could change significance. Of the 31 outcomes reported as statistically significant, the median FI remained 4 (IQR 2-6) with an FQ of 0.066 (IQR 0.033-0.099), indicating limited robustness. The 119 nonsignificant outcomes showed a comparable median rFI of 4 (IQR 3-6) and FQ of 0.060 (IQR 0.025-0.100), suggesting that the absence of significance in many cases was similarly fragile. Importantly, in 39.4% of outcomes, the number of patients lost to follow-up exceeded the FI or rFI, raising further concerns about statistical reliability.

Subgroup analyses revealed little difference in fragility by intervention (surgery, injection, acupuncture) or outcome category (treatment success, failure, adverse events). Injection-based therapies had the most outcomes (n=89), but their FI and FQ distributions were similar to surgical and acupuncture groups. Comparing time periods, outcomes from 2011-2024 demonstrated a higher FQ (0.070) than those from 2000-2010 (0.036), suggesting modest improvement in statistical robustness over time, likely related to improved methodology or larger sample sizes.

DISCUSSION AND CONCLUSION: Findings from RCTs evaluating interventional therapies for SAIS are statistically fragile. Both significant and nonsignificant outcomes can be reversed by minimal event changes, and in over one-third of cases, statistical conclusions may be less stable than the patient attrition rate. The reliance on p-values alone is insufficient to assess true clinical significance. We recommend that future trials include fragility metrics, particularly FI and FQ, in addition to conventional statistical measures to better contextualize results. Improved patient retention, larger sample sizes, and consistent use of fragility reporting could strengthen the interpretability and clinical utility of findings in SAIS research. As the debate over the value of interventions like subacromial decompression continues, fragility analysis provides a much-needed lens to reassess the weight and reliability of the current evidence base.

Figure 1 – Demonstration of statistical significance reversal with fragility index of 1. Data taken from Wang et al, Archive of Physical Medicine and Rehabilitation.

	(+)	(-)		(+)	(-)
Treatment A (Guided injection)	7	23	Treatment A	7	23
Treatment B (Dual-target injection)	1	29	Treatment B	0	30
		p = 0.052			p = 0.011

Table 1 - Fragility indices and quotients for all SAIS Interventional Therapy outcomes with stratification by outcome significance. Abbreviations: RCT - Randomized Controlled Trials, FI - fragility index, rFI - reverse fragility index, FQ=fragility quotient, IQR=interquartile range.

	Number of Outcomes	FI/rFI, Median (IQR)	FQ, Median (IQR)
All RCT Outcomes	150	4 (3-6)	0.061 (0.026-0.100)
Significant Outcomes (P<0.05)	31	4 (2-6)	0.066 (0.033-0.099)
Nonsignificant Outcomes (P≥0.05)	119	4 (3-6)	0.060 (0.025-0.100)
FI < # of Patients Lost to Follow-Up	62	4 (1-6)	0.028 (0.015-0.074)
FI > # of Patients Lost to Follow-Up	88	5 (3-6)	0.077 (0.050-0.111)