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Endoscopy-Related Musculoskeletal Injuries: A Systematic Review and Meta-Analysis on Prevalence, Risk Factors and Prevention

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ABSTRACT

Background: Endoscopy-related musculoskeletal injuries (ERIs) are a major occupational hazard, impacting career longevity and personal well-being.

Objective: This systematic review and meta-analysis aimed to update and expand on previous findings by assessing prevalence, risk factors and management of ERIs among endoscopists.

Methods: Following PRISMA guidelines, we systematically searched MEDLINE, Web of Science and Scopus for relevant studies published since the last comprehensive review. A manual search of the references of relevant manuscripts was also performed. Outcomes of interest included the prevalence of ERIs, common pain syndromes, risk factors, and preventive or treatment strategies. Studies' quality was assessed using the National Institutes of Health (NIH) Quality Assessment Tool.

Results: Thirty studies were included, incorporating data from 7646 gastrointestinal endoscopists. The pooled career-long prevalence of overall ERI was 62.5% (CI 52.6–71.8, I^2 = 98%), including pain (67.5%; CI 46.4%–85.6%; I^2 = 98%) and numbness (12.4%; 95% CI 6.6%–19.7%; I^2 = 98%) syndromes. Among pain syndromes, the most affected areas were the hand (28.2%; CI 19.2%–38.2%; I^2 = 99%), lower back (27.3%; CI 20.1%–35.2%; I^2 = 97%), thumb (27.1%; CI 18.9%–37.7%; I^2 = 99%) and neck (25.7%; CI 19.3%–32.7%; I^2 = 98%). Higher procedural volume, years in practice and female gender were consistently reported as risk factors for ERIs.

Concerning therapy, 41.8% of endoscopists used medications (CI 31.2%–52.8%; I^2 = 94%), while 28.2% engaged in physical therapy (CI 18.2%–39.5%; I^2 = 96%). Sick leave was reported by 13.8% of endoscopists (CI 7.9%–20.9%; I^2 = 94%). Practice modifications to manage ERIs included adjusting monitor (45.5%, CI 22.2%–69.9%; I^2 = 96%) and table (32.4%, CI 14.5%–53.5%; I^2 = 97%) height, but also reducing the number of cases per endoscopy session (14.6%; CI 10.4%–19.4%; I^2 = 72%).

Conclusion: ERIs are highly prevalent among international gastrointestinal endoscopists, and are linked to procedural volume, years in practice, and gender. Ergonomic training and workplace adaptations are essential to mitigate risks and support career sustainability.
Trial Registration: PROSPERO Registration: CRD42024534349

1 | Introduction

Gastrointestinal (GI) endoscopy is a fundamental activity for modern endoscopists, with most gastroenterologists spending over 40% of their time performing endoscopic procedures [1]. However, despite enormous technological advances that have significantly enhanced diagnostic and therapeutic capabilities, the design of endoscopes has remained largely unchanged since the 1980s, with minimal improvements to the endoscope-human interface [2]. Consequently, endoscopists face a high risk of musculoskeletal injuries, due to repetitive work, prolonged awkward postures and the application of localised high forces [3]. Specific manoeuvres in endoscopy, such as adjusting tip angulation controls, torquing with the right hand, and standing for prolonged periods, contribute to this risk [3]. Endoscopy-related musculoskeletal injuries can lead to serious long-term consequences, from pain and physical restrictions while performing procedures to permanent disability [4]. With endoscopic activity steadily increasing and pressure to expand service capacity [5], ensuring endoscopists' overall well-being is essential to prevent career-shortening overuse injuries.

Understanding this issue is crucial for making endoscopy a sustainable career path. A recent review by Singh et al. assessed the prevalence of endoscopy-related injuries (ERIs). However, since then, several relevant international studies have added significant evidence on this topic. Therefore, we aimed to reassess the prevalence of ERIs in GI endoscopists, better understand the factors contributing to these injuries, and evaluate the treatments and potential practice modifications adopted by endoscopists in response to their ERIs.

2 | Materials and Methods

This systematic review and meta-analysis was designed according to the standards set by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) [6]. The protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) (CRD42024534349).

2.1 | Search Strategy

The authors conducted a systematic search of MEDLINE (via PubMed), Web of Science and Scopus from 1st January 2022 to 1st April 2024, ensuring overlap with the end date of the prior search by Singh et al. (1st September 2022). Additionally, all manuscripts and references from the previous meta-analysis were re-evaluated to identify corrections, updates, and relevant information, aligning them with the aims of this updated meta-analysis. Manual backward citation tracking of all reference lists was performed to ensure that important studies were not missed. The following search terms, incorporating keywords, Medical Subject Headings (MeSH), and Boolean operators, were used: ((Endoscopy) OR (Colonoscopy) OR (ERCP) OR (Esophagogastroscopy) OR (Esophagogastroduodenoscopy)) AND ((Gastroenterologist) OR (Surgeon) OR (Endoscopist) OR (Colonoscopist)) AND ((Ergonomy) OR (Ergonomics) OR (Occupational injury) OR (Cumulative trauma disorder) OR (Musculoskeletal injury) OR (Musculoskeletal disorder) OR (Endoscopy-related injury)). No language restrictions were applied.

2.2 | Eligibility Criteria

Using the PICO model, we searched for records (original studies, conference abstracts) addressing any endoscopy-related musculoskeletal injury and pain or numbness syndromes in GI endoscopists. Studies were excluded as follows: (1) systematic reviews, review articles, case reports, editorials, and letters to the editor; (2) studies enrolling physicians performing non-GI endoscopy; and (3) studies that did not assess or report the outcomes of interest.

2.3 | Study Selection and Data Collection

Rayyan [7], a web-based tool for systematic review management, was used to compile and organise all retrieved records. Duplicate entries from different databases were excluded through combined careful manual verification and automatic detection using Rayyan. Titles and abstracts were then independently screened by two authors (RO and JR) and studies were excluded if they did not meet the eligibility criteria. Afterwards, the full texts of the remaining studies were assessed when available. Disagreements between the two evaluators were resolved by dialogue and consensus or, when necessary, by consultation with a third independent reviewer (MME). Finally, the following data were collected from the selected records: (1) first author's name, year of publication, and country; (2) population performing endoscopy and the specific endoscopic procedures evaluated; (3) type of questionnaires used and its validation status; (4) number of endoscopists included and response rate; (5) sociodemographic and clinical practice data; (6) data on ERIs; (7) data on the treatments for ERIs; (8) data on modifications to practice driven by ERIs. When necessary and feasible, the corresponding authors were contacted to confirm study details.

2.4 | Quality Assessment

Studies' methodological quality was assessed using the National Institute of Health (NIH) quality assessment tool for

Summary

- Summarise the established knowledge on this subject
  - Gastrointestinal endoscopy is a major activity for diagnostic and interventional endoscopists with a continuously rising workload.
  - The basic design of endoscopes has remained largely unchanged since the 1980s.
  - Repetitive work, prolonged awkward postures and the application of high forces place endoscopists at a high risk of musculoskeletal injuries.
  - Endoscopy-related musculoskeletal injuries can lead to serious long-term consequences.
- What are the significant and/or new findings of this study?
  - Career-long prevalence of overall endoscopy-related injuries, namely pain and numbness syndromes, is high in gastrointestinal endoscopists.
  - Higher procedural volume, longer years in practice and female gender are important risk factors for endoscopy-related injuries.
  - Most endoscopists who face endoscopy-related injuries neither seek treatment nor adjust their practice accordingly.
  - Ergonomic and physical training and adaptable endoscopy units are needed to prevent endoscopy-related injuries.

observational cohort and cross-sectional studies [8]. This tool evaluates studies across key domains, including clarity of research objectives, rigour of study design, quality of sampling methods, reliability of outcome measurements, and control of confounding variables. Each study received a quality rating of 'good,' 'fair,' or 'poor' based on its overall adherence to these criteria. Studies rated as 'good' demonstrated robust methodology with minimal risk of bias, those rated as 'fair' showed moderate limitations, and 'poor' studies exhibited significant methodological weaknesses that could impact reliability.

2.5 | Statistical Analysis

The primary outcomes of this meta-analysis were the career-long prevalence of overall ERI, carpal tunnel syndrome, de Quervain's tendinitis, overall and specific pain syndromes, and overall numbness syndromes. ERI was defined as any musculoskeletal pain or disability syndrome imputable to endoscopy practice. Additionally, we evaluated the prevalence of ERI-directed treatments and practice modifications implemented in response to ERI. Data for these outcomes were extracted from each study.

The R software, version 4.1.0 (R Foundation for Statistical Computing, Vienna, Austria) was used to analyse data and generate the funnel and forest plots. Statistical heterogeneity was assessed using Cochran's Q test and the I^2 statistic; an I^2 over 50% corresponded to substantial heterogeneity [9]. A random-effects model was adopted to account for differences observed across studies. A p-value lower than 0.05 was considered statistically significant.

3 | Results

3.1 | Literature Search and Study Selection

The updated electronic database search yielded 2335 results (462 from MEDLINE, 5 from Web of Science and 1868 from Scopus). After removing duplicates (n = 182), 2153 records were screened, of which 2135 were excluded. The remaining 18 studies were then assessed for eligibility, resulting in the exclusion of 9 additional studies. With the addition of 12 studies from the previous systematic review by Singh et al. [10] and 9 studies manually identified through reference list searches, 30 studies were included. The literature search and selection process are illustrated in Figure 1.

3.2 | Characteristics of the Included Studies

The sociodemographic characteristics and clinical practice data of endoscopists across the included studies are summarised in Table 1. Three studies were only available in abstract form [11–13]. Most studies were conducted in the United States of America [1, 12–25], with seven additional studies from Asian countries [11, 26–31], three from European countries [32–34], one from Canada [35], and one from Colombia [36]; a few included international samples [37–39]. Notably, 19 of the 30 studies have been published since 2020 [11, 18–25, 28–34, 36, 38, 39].

Overall, 7646 GI endoscopists were included in the pooled analysis, with study samples ranging from 23 [22] to 1698 [20]. While most studies focused on gastroenterologists, some also included data on colorectal surgeons [28, 36–38] and endoscopy nurses [30, 34, 38, 39]. Five studies specifically included gastroenterology trainees or fellows [16, 17, 19, 22, 25]. Participants' gender and age varied widely, as did the proportion of right-handed endoscopists and glove size, indicating substantial demographic and practice-related heterogeneity across studies.

Most studies employed non-validated pilot questionnaires [12, 14, 17, 19, 20, 22, 24, 25, 27–32, 34, 35], with only four studies using internally validated instruments [13, 15, 33, 36]. Additionally, nine studies [1, 11, 16, 18, 21, 23, 34, 38, 39] adapted questionnaires from prior research, while one study did not report its questionnaire type [37]. Most studies assessed self-reported ERI, except four [21, 29, 33, 36] which used standardised questionnaires to assess pain and disability.

3.3 | Quality of Studies and Risk of Bias

Methodological quality appraisal using the NIH quality assessment tool is summarised in Table S1. Overall, the quality rating was fair for all studies except one rated as good [21] and one as poor [11]. The limitations mainly came from using self-reported questionnaires to collect data and the risk of selection bias, which was increased by the fact that only nine studies had a response rate over 50% [15, 17, 22, 23, 27, 29, 35].

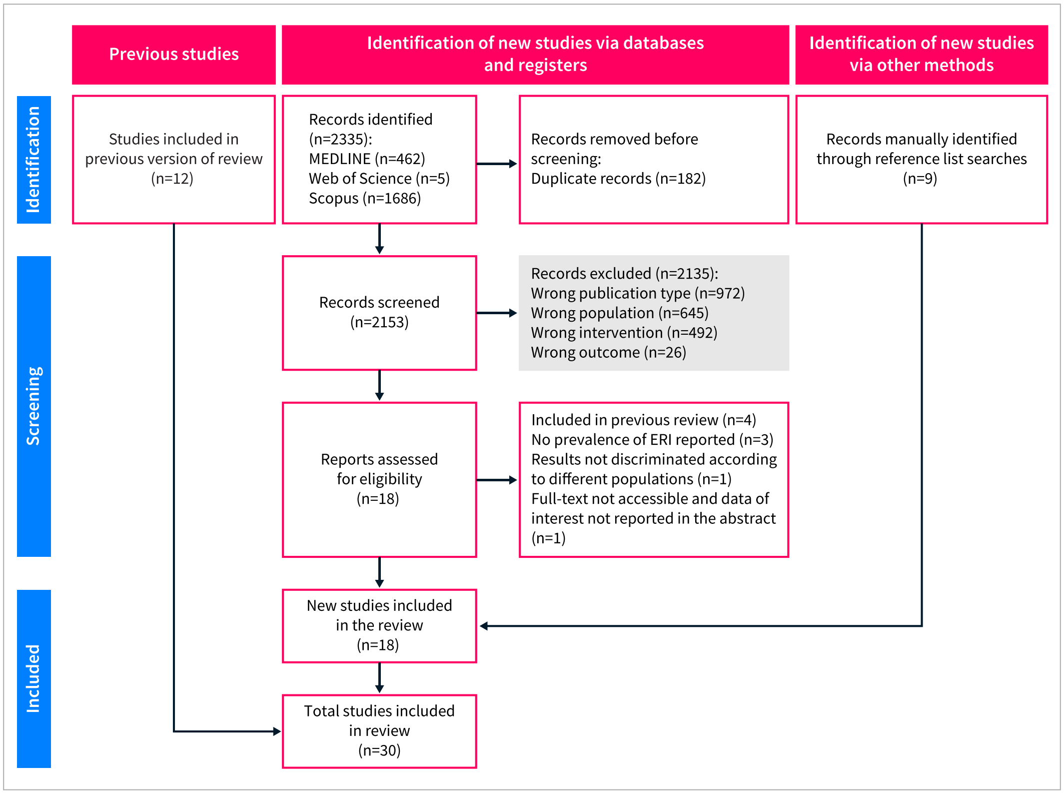

FIGURE 1 | Flow diagram of the study selection and data collection process.

3.4 | Prevalence of Endoscopy-Related Injuries

Descriptive results on the proportion of endoscopists reporting overall ERI [1, 12, 13, 15–17, 19–33, 35–39], overall pain syndromes [18, 20, 21, 26–30, 39], and overall numbness syndromes [1, 14, 19–21, 23, 32, 34, 36] are detailed in Table S2.

The pooled career-long prevalence (PCP) of overall ERI was 62.5% (95% CI 52.6–71.8, $I^2 = 98\%$, $p < 0.01$). The PCP for pain syndromes was 67.5% (95% CI 46.4%–85.6%; $I^2 = 98\%$, $p < 0.01$), while for numbness syndromes it was 12.4% (95% CI 6.6%–19.7%; $I^2 = 98\%$, $p < 0.01$). Carpal tunnel syndrome showed a PCP of 4.5% (95% CI 2.4%–7.3%; $I^2 = 97\%$, $p < 0.01$) and de Quervain's tendinitis of 7.1% (2.2%–14.3%; $I^2 = 97\%$, $p < 0.01$) (Figure 2).

Figure 2 shows considerable heterogeneity across studies, with I^2 values ranging from 97% to 98% for different ERI outcomes, indicating substantial variability in prevalence estimates.

Among specific pain syndromes, the most common were hand (PCP 28.2%, 95% CI 19.2%–38.2%; $I^2 = 99\%$, $p < 0.01$) and thumb (PCP 27.1%, 95% CI 18.9%–37.7%; $I^2 = 99\%$, $p < 0.01$) pain (Figure 3). Notably, left thumb pain (PCP 15.5%, 95% CI 8.4%–24.3%; $I^2 = 97\%$, $p < 0.01$) was more frequent than right thumb's (PCP 8.2%, 95% CI 4.3%–13.1%; $I^2 = 95\%$, $p < 0.01$), while hand pain was more commonly reported on the right (PCP 9.2%, 95% CI 6.0%–13.1%; $I^2 = 84\%$, $p < 0.01$) than the left (PCP 6.8%, 95% CI 3.9%–10.4%; $I^2 = 86\%$, $p < 0.01$) side (Figure S1).

Other frequently reported pain syndromes included lower back (PCP 27.3%, 95% CI 20.1%–35.2%; $I^2 = 97\%$, $p < 0.01$), neck (PCP 25.7%, 95% CI 19.3%–32.7%; $I^2 = 98\%$, $p < 0.01$), shoulder (PCP 21.9%, 95% CI 13.7%–31.4%; $I^2 = 98\%$, $p < 0.01$), and upper back (PCP 15.3%, 95% CI 11.2%–20.4%; $I^2 = 98\%$, $p < 0.01$) pain. Lower body pain syndromes were less prevalent, except for foot pain (PCP 13.4%, 95% CI 5.9%–23.1%; $I^2 = 98\%$, $p < 0.01$) (Figures 3 and 4).

3.5 | Treatments for Endoscopy-Related Injuries

Fourteen studies provided data on treatments used for ERIs [1, 14, 16, 17, 26, 28, 30, 32, 33, 35–39] (Table S3).

The most common treatments were medications, including analgesics and anti-inflammatory drugs (PCP 41.8%, 95% CI 31.2%–52.8%; $I^2 = 94\%$, $p < 0.01$), physical therapy (PCP 28.2%, 95% CI 18.2%–39.5%; $I^2 = 96\%$, $p < 0.01$) and rest (PCP 28.2%, 95% CI 15.5%–42.9%; $I^2 = 94\%$, $p < 0.01$). The PCP of sick leave due to ERIs was 13.8% (95% CI 7.9%–20.9%; $I^2 = 94\%$, $p < 0.01$) (Figure 5).

3.6 | Modifications to Practice Driven by Endoscopy-Related Injuries

Eleven studies reported on practice modifications prompted by ERIs (Table S4) [1, 12, 15, 17, 26, 27, 31–33, 35, 38].

The PCP of overall practice modifications was 43.8% (95% CI 27.8%–60.4%; $I^2 = 97\%$, $p < 0.01$). The most commonly implemented changes included adjusting the monitor (PCP 45.5%, 95% CI 22.2%–69.9%; $I^2 = 96\%$, $p < 0.01$) and table (PCP 32.4%,

TABLE 1 | Characteristics of the included studies.

Author	Country	Population	Procedures evaluated	Questionnaire	Sent	Respondants (response rate, %)	Age (years)	Female, *n* (%)	Time in clinical practice	Time dedicated to endoscopy	Right-handed, *n* (%)	Glove size, *n* (%)	Previous formal ergonomic training, *n* (%)
Buschbacher [14]	USA	Gastroenterologists	—	Non-validated pilot questionnaire	367	265 (72.2)	47.8 ± 8.6 years *Continuous, mean* ± SD	13 (4.9)	—	0–5 h/w: 56 (21.1) 6–10 h/w: 61 (23.0) 11–15 h/w: 61 (23.0) 16–20 h/w: 66 (24.9) 21–25 h/w: 13 (4.9) 26–30 h/w: 5 (1.9) 31–35 h/w: 3 (1.1) 36–40 h/w: 1 (1.1) *Categorical, hours/week, n (%)*	220 (83.0)	—	—
O'Sullivan [35]	Canada	Gastroenterologists	ERCP	Non-validated pilot questionnaire	154	114 (74.0)	—	—	Injured: 14.7 ± 7.0 years Non-injured: 11.6 ± 5.9 years *Continuous, years, mean* ± SD	Injured: 192.8 ± 126.6 Non-injured: 175.8 ± 172.8 *Continuous, cases/year, mean* ± SD	—	—	—
Liberman [37]	International, non-specified	Colorectal surgeons	Lower endoscopy	—	2173	582 (26.8)	48 ± 9.5 years *Continuous, mean* ± SD	62 (10.6)	14.8 ± 8.6 years *Continuous, years, mean* ± SD	2.4 ± 1.9 days/w *Continuous, days/week, mean* ± SD	449 (77.2)	—	—
Keate [12]	USA	Gastroenterologists	—	Non-validated pilot questionnaire	—	237	—	—	—	—	—	—	—
Byun [26]	South Korea	Gastroenterologists	—	Non-validated pilot questionnaire	—	55	39 years (28–47 years) *Continuous, median (range)*	18 (32.7)	39 m (1–228 m) *Continuous, median (range)*	19.5 ± 7.7 h/w *Continuous, hours/week, mean* ± SD	—	—	—
Hansel [15]	USA	Gastroenterologists	Upper and lower endoscopy, ERCP, EUS	Pilot questionnaire, internally validated	115	72 (62.6)	25–35 years: 4 (5.6) 36–45 years: 34 (47.9) 46–55 years: 26 (36.6) 56–65 years: 7 (9.9) *Categorical, n (%)*	12 (16.9)	< 5 years: 5 (7.0) 6–10 years: 17 (23.9) 11–15 years: 19 (26.8) 16–20 years: 14 (19.7) > 21 years: 16 (22.5) Missing: 1 (1.4) *Categorical, years, n (%)*	< 5 h/w: 17 (23.7%) 6–10 h/w: 20 (28.0%) 11–15 h/w: 12 (16.9%) 16–20 h/w: 11 (15.5%) > 20 h/w: 13 (18.3%) *Categorical, hours/week*	62 (87.3)	M: 23 (31.9) L: 27 (37.5)	—
Kuwabara [27]	Japan	Gastroenterologists	Upper and lower endoscopy, ERCP, EUS	Non-validated pilot questionnaire	275	190 (69.1)	41.4 ± 6.7 years *Continuous, mean* ± SD	26 (13.7)	16.2 ± 8.1 year *Continuous, mean* ± SD*1*	11.9 ± 8.7 h/w *Continous, hours/weeK, mean* ± SD	179 (94.2)	—	
Ridtid [1]	USA	Gastroenterologists	Upper and lower endoscopy, ERCP, EUS, enteroscopy	Adapted from a previously developed questionnaire[a]	5329	684 (12.8)	50.8 ± 11.0 years *Continuous, mean* ± SD	81 (11.8)	0–15 years: 293 (42.8) 16–30 years: 250 (36.6) > 30 years: 141 (20.6) *Categorical, years, n (%)*	0–15 h/w: 245 (35.8%) 16–30 h/w: 374 (54.7%) > 30 h/w: 65 (9.5%) *Categorical, hours/week*	612 (89.5)	—	—
Edelman [13]	USA	Gastroenterologists	—	Pilot questionnaire, internally validated	10,590	790 (7.5)	47 years (28–82 years) *Continuous, median (range)*	286 (36.2)	—	—	—	—	36 (4.5)

(Continues)

TABLE 1 | (Continued)

Author	Country	Population	Procedures evaluated	Questionnaire	Sent	Respondants (response rate, %)	Age (years)	Female, *n* (%)	Time in clinical practice	Time dedicated to endoscopy	Right-handed, *n* (%)	Glove size, *n* (%)	Previous formal ergonomic training, *n* (%)
Austin [16]	USA	Gastroenterology trainees or fellows	Upper and lower endoscopy	Adapted from a previously developed questionnaire[b]	1509	165 (10.9)	28–30 years: 38 (23.0) 31–35 years: 110 (67.0) 36–40 years: 11 (7.0) 41–44 years: 4 (2.0) Missing: 1 (1.0) *Categorical, n (%)*	58 (35.0)	1 year: 55 (33.0) 2 years: 50 (30.0) 3 years: 54 (33.0) 4 years: 6 (4.0) *Categorical, years, n (%)*	—	149 (90.0)	—	—
Villa [17]	USA	Gastroenterology trainees or fellows	Upper and lower endoscopy, ERCP	Non-validated pilot questionnaire	217	156 (71.9)	25–30 years: 24 (16.0) 31–35 years: 99 (63.5) 36–40 years: 31 (19.9) > 40 years: 2 (1.3) *Categorical, n (%)*	55 (35.3)	1 year: 51 (32.7) 2 years: 50 (32.1) 3 years: 53 (34.0) > 3 years: 2 (1.3) *Categorical, years, n (%)*	—	—	—	56 (35.9)
Morais [32]	Portugal	Gastroenterologists	Upper and lower endoscopy, enteroscopy, EUS, ERCP, PEG	Non-validated pilot questionnaire	705	171 (24.3)	36 years (26–78 years) *Continuous, median (range)*	94 (55.0)	9 years (0.5–45 years) *Continuous, years, median (range)*	25 h/w (3–52) *Continuous, hours/week, (median (range))*	157 (91.8)	S: 54 (31.6) M: 70 (46.2) L: 34 (19.9) XL: 4 (2.3)	—
Al-Rifaie [38]	International: UK (231, 72.4%), other European countries (48, 15.0%), Asia and Australia (15, 4.7%), North and South America (14, 4.4%), Africa (11, 3.4%)	Gastroenterologists (216, 67.7%), nurse endoscopists (80, 25.1%), surgeons (23, 7.2%)	Lower endoscopy	Adapted from previously developed questionnaire[b], internally validated	1825	319 (17.5)	20–30 years: 3 (0.9) 31–40 years: 63 (19.7) 41–50 years: 135 (42.3) 51–60 years: 88 (27.6) 60 years: 30 (9.4) *Categorical, n (%)*	102 (32.0)	0-5 years: 58 (18.2) 6–10 years: 63 (19.7) > 10 years: 198 (62.1) *Categorical, years, n (%)*	< 6 h/w: 46 (14.4%) > 6 h/w: 273 (85.6%) *Categorical, hours/week*	—	—	—
Campbell III [18]	USA	Gastroenterologists	ERCP	Adapted from a previously developed questionnaire[c]	3276	203 (6.2)	—	8 (3.9)	0-5 years: 18 (8.9) 6–10 years: 42 (20.7) 11–15 years: 27 (13.3) 16–20 years: 20 (9.9) > 20 years: 94 (46.3) Missing: 2 (1.0) *Categorical, years, n (%)*	—	—	S: 8 (3.9) M: 70 (34.5) L: 98 (48.3) XL: 24 (11.8) Missing: 3 (1.5)	50 (24.5)
Kamani [28]	Pakistan	Gastroenterologists, colorectal surgeons	Upper and lower endoscopy, ERCP, EUS	Non-validated pilot questionnaire	—	61	44.0 ± 7.8 years *Continous, mean ± SD*	3 (4.9)	≤ 20 years: 58 (95.1) > 20 years: 3 (4.9) *Categorical, years,*	≤ 5 h/w: 53 (86.7) > 5 h/w: 8 (13.3)	56 (95.1)	6.5: 1 (1.6) 7.0: 14 (23.0)	—

(Continues)

TABLE 1 | (Continued)

Author	Country	Population	Procedures evaluated	Questionnaire	Sent	Respondants (response rate, %)	Age (years)	Female, *n* (%)	Time in clinical practice	Time dedicated to endoscopy	Right-handed, *n* (%)	Glove size, *n* (%)	Previous formal ergonomic training, *n* (%)
									n (%)			7.5: 32 (52.5) 8.0: 13 (21.3) 8.5: 1 (1.6)	
Matsuzaki [29]	Japan	Gastroenterologists	Upper and lower endoscopy, enteroscopy, ERCP, EUS	Non-validated pilot questionnaire	213	110 (51.6)	≤ 29 years: 1 (0.9) 30–39 years: 61 (55.5) 40–49 years: 21 (19.1) 50–59 years: 23 (20.9) ≥ 60 years: 4 (3.6) *Categorical, n (%)*	12 (10.9)	≤ 3 years: 6 (5.5) 4-6 years: 18 (16.4) 7-9 years: 20 (18.2) 10–15 years: 27 (24.5) ≥ 16 years: 38 (34.5) Missing: 1 (0.9) *Categorical, years, n (%)*	—	105 (95.5)	—	—
Pawa [20]	USA	Gastroenterologists	Upper and lower endoscopy, enteroscopy, ERCP, EUS	Non-validated pilot questionnaire	6119	1698 (27.7)	51.9 ± 12.3 years *Continuous, mean* ± SD	583 (34.3)	21.1 ± 12.0 *Continuous, mean* ± SD	Upper endoscopy 0/w: 3 (0.2) 1–10/w: 699 (41.2) 11–20/w: 827 (48.7) 21–30/w: 124 (7.3) 31–40/w: 19 (1.1) 41–50/w: 9 (0.5) 51–60/w: 17 (1.0) Lower endoscopy 0/w: 9 (0.5) 1–10/w: 233 (13.7) 11–20/w: 676 (39.8) 21–30/w: 512 (30.2) 31–40/w: 189 (11.1) 41–50/w: 53 (3.1) 51–60/w: 26 (1.5) ERCP 0/w: 746 (43.9) 1–10/w: 879 (51.8) 11–20/w: 59 (3.5) 21–30/w: 10 (0.6) 31–40/w: 1 (0.1) 41–50/w: 2 (0.1) 51–60/w: 1 (0.1) EUS 0/w: 1021 (60.1) 1–10/w: 607 (35.7) 11–20/w: 58 (3.4) 21–30/w: 11 (0.6) 31–40/w: 1 (0.1) 41–50/w: 0 (0.0) 51–60/w: 0 (0.0) Enteroscopy 0/w: 1024 (60.3) 1–10/w: 666 (39.2)	—	—	654 (38.5)

(Continues)

TABLE 1 | (Continued)

Author	Country	Population	Procedures evaluated	Questionnaire	Sent	Respondants (response rate, %)	Age (years)	Female, *n* (%)	Time in clinical practice	Time dedicated to endoscopy	Right-handed, *n* (%)	Glove size, *n* (%)	Previous formal ergonomic training, *n* (%)
										11–20/w: 4 (0.2) 21–30/w: 0 (0.0) 31–40/w: 0 (0.0) 41–50/w: 0 (0.0) 51–60/w: 4 (0.2) *Categorical, cases/ week, n (%)*			
Bessone [39]	International: USA (9, 4.4%), 11 European countries (117, 57.4%); 7 Asian countries (64, 31.4%), 2 Oceaniac countries (13, 6.4%), missing 1 (0.5%)	Gastroenterologists (182, 89.2%), nurses (22, 10.8%)	Upper and lower endoscopy, ERCP	Adapted from previously developed questionnaire[d], internally validated	—	204	< 25 years: 0 (0.0) 25–34 years: 19 (9.3) 35–44 years: 69 (33.8) 45–54 years: 75 (36.8) 55–64 years: 36 (17.6) > 65 years: 42 (21.5) *Categorical, n (%)*	44 (21.6)	< 2 years: 10 (4.9) 2-5 years: 19 (9.3) 6–15 years: 72 (35.3) 16–25 years: 67 (32.8) 26–35 years: 26 (12.7) > 35 years: 10 (4.9) *Categorical, years, n (%)*	≤ 5 h/w: 18 (8.8) 6–10 h/w: 33 (16.2) 11–15 h/w: 41 (20.1) 16–20 h/w: 41 (20.1) 21–25 h/w: 21 (20.1) > 25 h/w: 50 (24.5) *Categorical, hours/ week, n (%)*	188 (92.2)	5.5: 2 (1.0) 6.0: 8 (3.9) 6.5: 42 (20.6) 7.0: 36 (17.6) 7.5: 64 (31.4) 8.0: 37 (18.1) 8.5: 8 (3.9) 9.0: 7 (3.4)	36 (17.6)
Miller [21]	USA	Gastroenterologists	Upper and lower endoscopy, enteroscopy, EUS, ERCP	Adapted from previously developed questionnaire[e,f]	179	64 (35.8)	44 ± 10.8 years *Continuous, mean* ± SD	18 (28.1)	18.9 ± 10.8 years *Continuous years, mean* ± SD	185.5 ± 117.7 cases/ year *Continuous, cases/ year (mean* ± SD)	51 (79.7)	S/M: 28 (43.8)	—
Pawa [19]	USA	Gastroenterology trainees or fellows	Upper and lower endoscopy, ERCP, EUS, enteroscopy	Non-validated pilot questionnaire	1220	168 (13.8)	32.27 ± 2.77 years *Continuous, mean* ± SD	83 (49.4)	2.09 ± 0.86 years *Continuous, years, mean* ± SD	Upper endoscopy 1–10/w: 66 (39.3) 11–20/w: 87 (51.8) > 21/w: 15 (8.9) Lower endoscopy 0/w: 0 (0.0) 1–10/w: 66 (39.3) 11–20/w: 82 (48.8) > 20/w: 19 (11.3) ERCP 0/w: 83 (49.4) 1–10/w: 79 (47.0) 11–20/w: 4 (2.4) > 20/w: 1 (0.6) EUS 0/w: 99 (58.9) 1–10/w: 66 (39.3) 11–20/w: 3 (1.8) > 20/w: 0 (0.0) Enteroscopy 0/w: 106 (63.1) 1–10/w: 62 (36.9) 11–20/w: 0 (0.0) > 20/w: 0 (0.0) *Categorical, cases/ week, n (%)*	—	—	143 (85.1)

(Continues)

TABLE 1 | (Continued)

Author	Country	Population	Procedures evaluated	Questionnaire	Sent	Respondants (response rate, %)	Age (years)	Female, *n* (%)	Time in clinical practice	Time dedicated to endoscopy	Right-handed, *n* (%)	Glove size, *n* (%)	Previous formal ergonomic training, *n* (%)
Shah [30]	Pakistan	Gastroenterologists: 13 (23.2%), trainees or fellows: 9 (16.1%), endoscopy nurse: 15 (26.8%), endoscopy technician: 19 (33.9%)	—	Non-validated pilot questionnaire	—	56	35.1 year (18–62 years) *Continuous, mean (range)*	17 (30.4)	≤ 5 years: 27 (48.9) > 5 years: 29 (51) *Categorical, years, n (%)*	63.85/w *Continuous, cases/ week (mean)*	49 (87.5)	—	—
Sturm [33]	Germany	Gastroenterologists	Upper and lower endoscopy, enteroscopy, EUS, ERCP, POEM	Pilot questionnaire, internally validated	—	151	49.4 ± 10.4 years *Continuous, mean* ± SD	37 (24.5)	21.0 ± 10.1 year *Continuous, years, mean* ± SD	6.2 ± 2.1 h/d *Continuous, hours/ day (mean* ± SD)	128 (84.8)	S: 22 (14.6) M: 36 (23.8) L: 66 (43.7) XL: 21 (13.9) Missing: 6 (4.0)	—
Sun [11]	China	Gastroenterologists	—	Adapted from previously developed questionnaire	—	200	—	—	—	—	—	—	—
Weilguny-Schöfl [34]	Austria	Gastroenterologists:19 (19.4%), endoscopy nurse: 66 (67.3%)	Upper and lower endoscopy	Adapted from previously validated questionnaire, and non-validated pilot questionnaire	—	98	46.8 ± 9.9 years *Continuous, mean* ± SD	76 (77.6)	—	Endoscopy 0–4/w: 4 (4.71) 5–10: 7 (8.24) 11–20: 11 (12.94) > 20: 63 (74.12) ERCP 0–2/w: 56 (65.88) 3–5/w: 12 (14.12) 6–10: 10 (11.76%) > 10: 7 (8.24) *Categorical, cases/ week, n (%)*	—	—	—
Blanco-Avelleneda [36]	Colombia	Gastrointestinal surgeon: 31 (23.7%), general surgeon: 6 (4.6%), proctologist: 14 (10.7%), Gastroenterologist 80 (61.1%)	Upper and lower endoscopy, ERCP, EUS-FNA, enteroscopy, third-space endoscopy	Pilot questionnaire, internally validated	450	203 (45.1)	20–30 years: 1 (0.76) 31–40 years: 31 (23.6) 41–50 years: 32 (24.2) 51–60 years: 44 (33.6) > 60 years: 23 (17.5) *Categorical, only referring to 131 respondents with ERI, n (%)*	27 (20.6) *Only referring to 131 respondents with ERI, n (%)*	< 3 years: 17 (13) 3 < 4 years: 7 (5.3) 4–10 years: 21 (16) 10–20 years: 32 (24.4) > 20 years: 54 (41.2) *Categorical, years, only referring to 131 respondents with ERI, n (%)*	< 24 h/week: 35 (26.7) 24–48 h/w: 57 (43.5) 49–60 h/: 17 (13) > 60 h/w: 14 (10.7) *Categorical, hours/ week, only referring to 131 respondents with ERI, n (%)*	122 (93.1) *Only referring to 131 respondents with ERI*	S: 24 (18.5) M: 62 (47.7) L: 44 (33.8)	8 (6.2) *Only referring to 131 respondents with ERI*
Gala [22]	USA	Gastroenterology trainees or fellows	—	Non-validated pilot questionnaire	37	23 (62.2)	33 ± 4.7 years *Continuous, mean* ± SD	9 (41.0)	1 year: 5 (21.7) 2 years: 5 (21.7) 3 years: 6 (26.1) 4 years: 7 (30.4) *Categorical, years, n (%)*	—	21 (91.0)	—	9 (39.1)

(Continues)

TABLE 1 | (Continued)

Author	Country	Population	Procedures evaluated	Questionnaire	Sent	Respondants (response rate, %)	Age (years)	Female, *n* (%)	Time in clinical practice	Time dedicated to endoscopy	Right-handed, *n* (%)	Glove size, *n* (%)	Previous formal ergonomic training, *n* (%)
Nam [31]	South Korea	Gastroenterologists	—	Non-validated pilot questionnaire	128	118 (92.2)	30–39 years: 41 (59.4) 40–49 years: 23 (33.3) ≥ 50 years: 5 (6.3) *Categorical*, *n (%)*	49 (41.5)	Males: 61.7 ± 72.3 m Females: 107.9 ± 112.2 m *Continuous*, *months*, *mean* ± SD	—	—	—	—
Ruan [23]	USA	Paediatric gastroenterologists and gastroenterology trainees or fellows	Upper and lower endoscopy	Adapted from previously developed questionnaire[g]	233	146 (62.7)	—	77 (54.6)	0-4 years: 50 (34.2) 5–9 years: 33 (22.6) 10–14 years: 21 (14.4) 15–19 years: 14 (9.6) 20–24 years: 9 (6.2) > 25 years: 19 (13.0) *Categorical*, *years*, *n (%)*	0–5 h/w: 82 (56.2) 6–10 h/w: 42 (28.8) 11–15 h/w: 15 (10.3) 16–20 h/w: 4 (2.7) > 20 h/w: 3 (2.1) *Categorical*, *hours/week*, *n (%)*	129 (92.8)	—	28 (19.2)
Bhatt [24]	USA	Gastroenterologists	—	Non-validated pilot questionnaire	814	107 (13.1)	< 40 years: 45 (42.1) 40–60 years: 45 (42.1) > 60 years: 17 (15.8) *Categorical*, *n (%)*	41 (38.3)	< 5 years: 31 (29) 5–10 years: 32 (30) > 10 years: 44 (41.4) *Categorical*, *years*, *n (%)*	< 20/w: 38 (35.5) 20–40/w: 49 (45.8) > 40/w: 20 (18.7) *Categorical*, *cases/week*, *n (%)*	—	XS: 1 (0.9) S: 21 (19.6) M: 45 (42.1) L: 30 (28) XL: 10 (9.4)	—
Suhail [25]	USA	Gastroenterology trainees or fellows	—	Non-validated pilot questionnaire	704	236 (33.5)	< 30 years: 18 (7.6) 30–34 years: 183 (77.5) 35–40 years: 34 (14.4) > 40 years: 1 (0.4) *Categorical*, *n (%)*	113 (47.9)	1 year: 79 (33.6) 2 years: 77 (32.8) 3 years: 65 (27.7) ≥ 4 years: 14 (6.0) *Categorical*, *years*, *n (%)*	< 10 h/w: 56 (23.8) 10–20 h/w: 110 (46.8) 21–30 h/w: 49 (20.9) 31–40 h/w: 13 (5.5) > 40 h/w: 7 (3.0) *Categorical*, *hours/week*, *n (%)*	—	Females: 5.0: 2 (1.8) 5.5: 7 (6.2) 6.0: 29 (25.7) 6.5: 55 (48.7) 7.0: 15 (13.3) 7.5: 2 (1.8) 8.0: 0 (0.0) 8.5: 0 (0.0) Missing: 3 (2.7) Males: 5.0: 0 (0.0)	99 (41.9)

(Continues)

TABLE 1 | (Continued)

Author	Country	Population	Procedures evaluated	Questionnaire	Sent	Respondants (response rate, %)	Age (years)	Female, *n* (%)	Time in clinical practice	Time dedicated to endoscopy	Right-handed, *n* (%)	Glove size, *n* (%)	Previous formal ergonomic training, *n* (%)
												5.5: 0 (0.0) 6.0: 0 (0.0) 6.5: 5 (4.1) 7.0: 36 (29.3) 7.5: 60 (48.9) 8.0: 16 (13.1) 8.5: 3 (2.4) Missing: 3 (2.4)	

Note: The italic texts clarify if that variable is continuous or categorical.

Abbreviations: d, days; ESD, Endoscopic submucosal dissection; ERCP, Endoscopic retrograde cholangiopancreatography; FTR, full-thickness resection; h, hours; PEG, Percutaneous endoscopic gastrostomy; POEM, Peroral endoscopic miotomy; UK, United Kingdom; USA, United States of America; SD, standard deviation; w, week; y, years.

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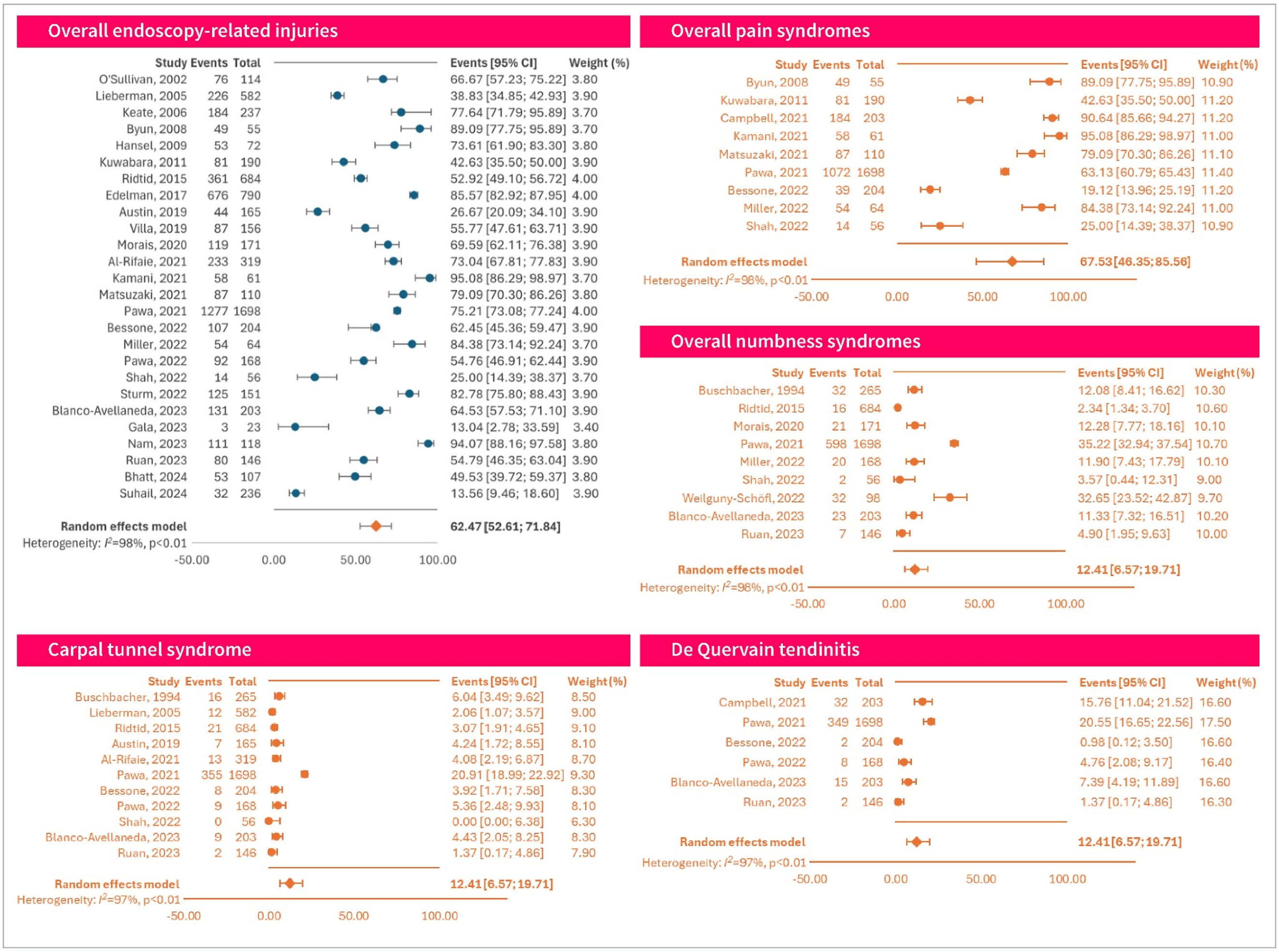

FIGURE 2 | Main endoscopy-related injuries.

95% CI 14.5%–53.5%; $I^2 = 97\%$, $p < 0.01$) heights, and performing stretches between endoscopies or at the end of sessions (PCP 30.0%, 95% CI 14.2%–48.5%; $I^2 = 97\%$, $p < 0.01$). Importantly, a considerable number of endoscopists reported reducing their procedural volume (PCP 14.6%, 95% CI 10.4%–19.4%; $I^2 = 72\%$, $p < 0.01$) (Figure 6).

3.7 | Factors Associated With Endoscopy-Related Injury

Higher procedure volume [1, 13, 14, 18, 20, 31, 36, 37, 39], more years of endoscopy practice [1, 19, 20, 32, 36] and female gender [16, 23, 32, 39] were consistently reported as risk factors for ERIs. Other factors associated with ERI included longer procedure times [29, 31], older age [13, 27], prior injury [13], and increased body weight [13].

Different ERI patterns were observed based on anthropometric factors. Specifically, taller [39] and male [20] endoscopists reported a higher incidence of lower body ERIs, whereas female endoscopists experienced more upper body injuries and a greater overall cumulative ERI burden [20]. Additionally, female endoscopists more frequently reported that endoscopic equipment was not ergonomically adapted to their needs [25, 40], noted a tendency to use the right hand to turn the small wheel [24], and preferred using a paediatric colonoscope for smaller patients during colonoscopy [24].

4 | Discussion

The current study is the most comprehensive systematic review and meta-analysis of endoscopy-related musculoskeletal injuries. The meta-analysis conducted confirmed the high career-long prevalence of ERIs, including overall pain and numbness syndromes in GI endoscopists, and the critical need for targeted treatments and modifications to practice. Notably, substantial statistical heterogeneity was observed across the meta-analysis, evidenced by I^2 values exceeding 95% for most outcomes. While a random-effects model was used to account for between-study variability, this likely reflects differences in study populations, ERI definitions, and ergonomic practices.

The physical demands of endoscopic procedures are a key factor in the high prevalence of ERIs. Pain syndromes affecting the hand and thumb, particularly the right hand and left thumb, are closely linked to fundamental yet physically stressful manoeuvres in endoscopy. These include torquing the endoscope and manipulating the tip angulation controls, which are repetitive

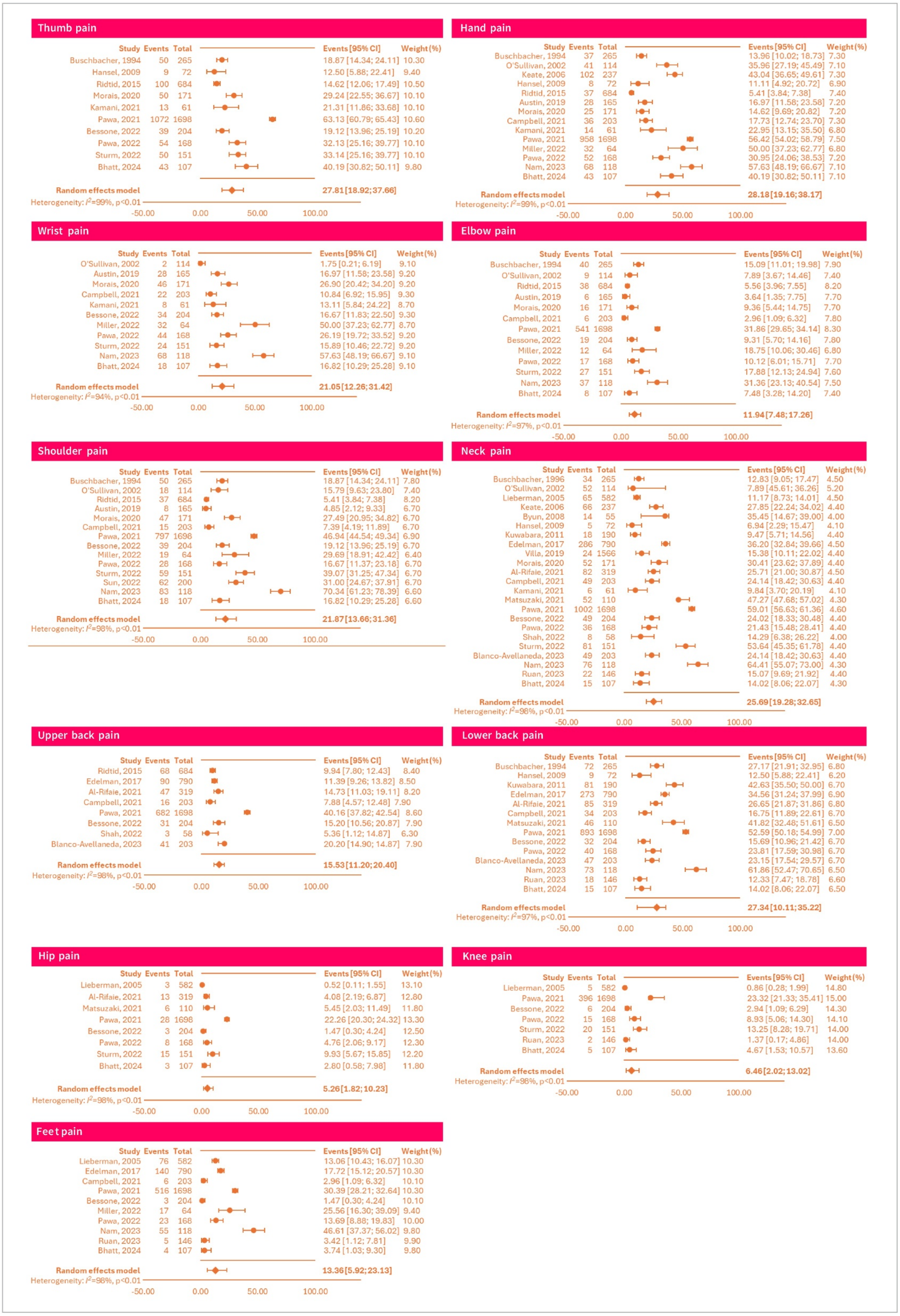

FIGURE 3 | Specific pain syndromes.

and force-intensive tasks [14, 38]. Other frequently reported pain syndromes, such as those involving the lower back and neck, can stem from prolonged periods of standing and awkward postures during procedures [35]. These ergonomic challenges are inherent to even the routine physical actions integral to GI endoscopy, contributing to the high prevalence of musculoskeletal issues among endoscopists.

In contrast, despite the high prevalence of ERIs, the proportion of endoscopists reporting the use of any form of treatment for

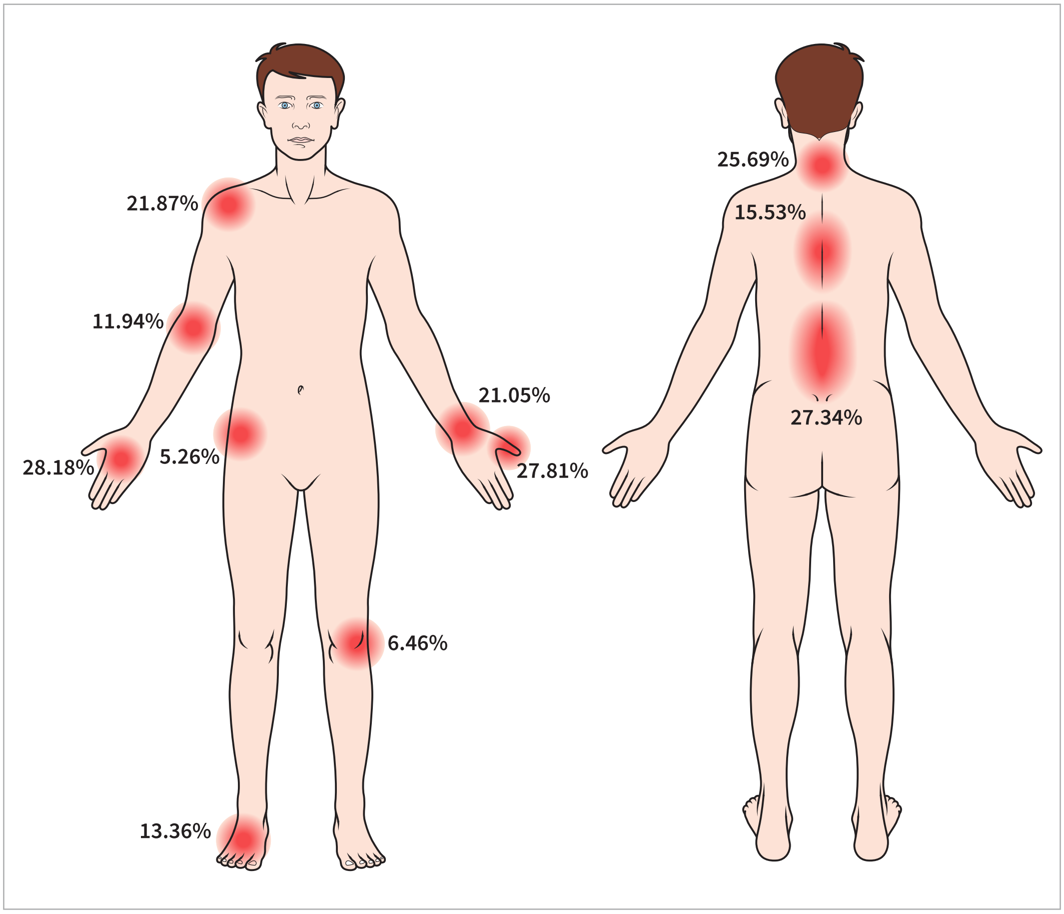

FIGURE 4 | Pooled career-long prevalence of specific pain syndromes in gastrointestinal endoscopists by localisation.

their ERIs was notably low, even for simple interventions such as oral medications. However, this disparity may not reflect a low need for treatment. Instead, it may result from the unique barriers physicians often encounter, such as a medical culture that implicitly suggests physicians should not experience illness or disability [41, 42], potentially compelling endoscopists to work despite their injuries.

Moreover, only a small proportion of endoscopists reported implementing modifications to their practice. Some of these modifications are conducted individually, and the low prevalence of such practices may suggest limited knowledge about ergonomics in GI endoscopy. Although the American Society for Gastrointestinal Endoscopy has recently published guidelines emphasising the role of ergonomics in preventing ERIs [4], and the European Society for Gastrointestinal Endoscopy has identified ergonomics as an essential skill for basic GI endoscopy [43], most training programs still do not include formal ergonomic education. While most studies did not report data on previous ergonomic training, those that did consistently indicated that fewer than half of the respondents had received training.

Furthermore, it is crucial to address the risks trainees face, as many injuries occur early during training [17, 32], with a notable prevalence of transient pain following endoscopy sessions, even among this group [25]. While this may partially reflect the intrinsic learning curve of endoscopy, as less experience correlates with increased ergonomic strain [44], it underscores a critical opportunity to intervene early in training. As the complex yet repetitive movements in endoscopy [45] are often influenced by muscle memory developed during early training [45], incorporating ergonomics into training programs is crucial to fostering good ergonomic habits from the outset of an endoscopist's career. In fact, theoretical and physical therapy and simulation-based curricula have been well-received by trainees [22] and have potentially reduced the risk of ERI [46]. By optimising posture and movements during this period, future injuries could potentially be prevented.

Likewise, higher procedure volumes and longer endoscopy careers are well-established risk factors for ERIs. Many strategies have been proposed to mitigate the risks of ERIs. While some involve more complex interventions, such as motion tracking systems [47] or the use of alternative scopes [48], simpler measures including intraprocedural stretching, microbreaks, and corrective exercises are easily implementable and have demonstrated efficacy in reducing pain in other fields, such as otorhinolaryngologists [49] and surgical residents [50]. These straightforward strategies may provide a practical and effective starting point for reducing ergonomic risks in endoscopy. In fact, knowledge about the high prevalence and consequences of work-related musculoskeletal injuries in other fields, such as surgery and interventional cardiology, is also growing [51], which should highlight the relevance of these injuries and their prevention.

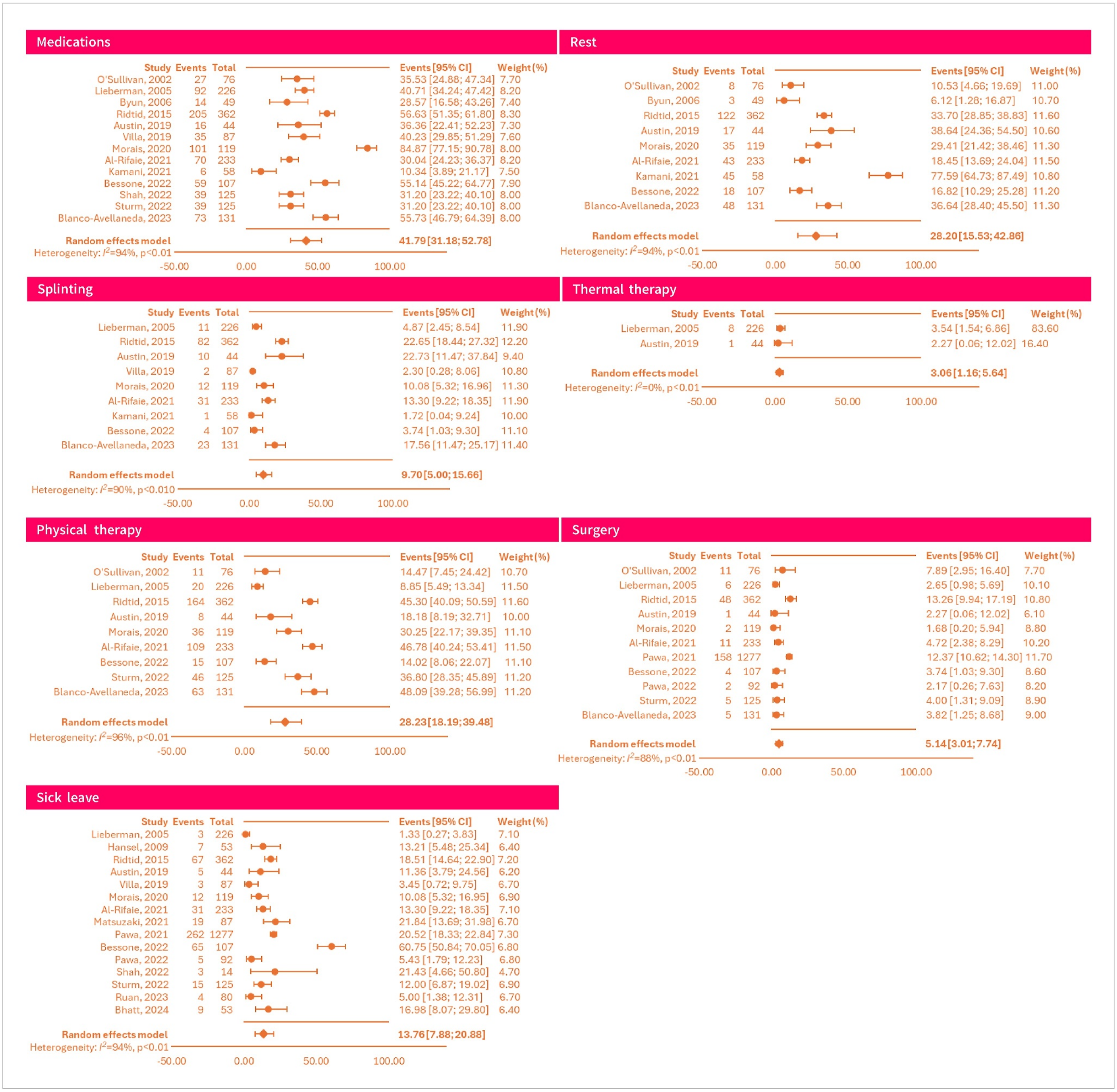

FIGURE 5 | Treatments employed for endoscopy-related injuries.

However, addressing ERIs requires a system-level approach beyond individual practices. Administrative changes, such as procedure scheduling, caseload adjustments, regular endoscope maintenance, and optimising the ergonomic aspects of the endoscopy suite, are crucial [2, 52]. For instance, the low proportion of endoscopists adjusting table and monitor heights [1, 27, 32, 33, 38, 39] may be due to inflexible or poorly designed endoscopy suites rather than a lack of ergonomic knowledge. While optimal workplace design has been advocated for to improve ergonomics [53], the actual implementation of these measures in routine practice remains unclear, and spatial constraints in procedure rooms have been cited as contributing factors to poor posture during procedures [38]. Furthermore, the unique movement patterns that individual endoscopists develop to navigate difficult procedures [54] further complicate the design of universally optimal workspaces.

Another critical factor increasingly recognised as a risk factor for ERIs is gender. Although earlier studies did not identify this association, it may stem from the historically lower representation of women in these studies [16]. Female endoscopists face specific challenges, including smaller hand size, which is associated with greater ergonomic strain [44], as well as suboptimal grip strength, reduced force-generating mass [19], and ergonomically inappropriate instruments [2, 40]. As the representation of women in GI endoscopy grows [53], the prevalence of ERIs is likely to rise if no meaningful changes are made to address these disparities. Unconscious gender bias in the design of work environments and instruments, often not adapted to female physicians or those with smaller hands, has been reported in other procedural fields [55, 56], emphasising the need to align healthcare environments with the demographics of the workforce. By proactively addressing these disparities, the field

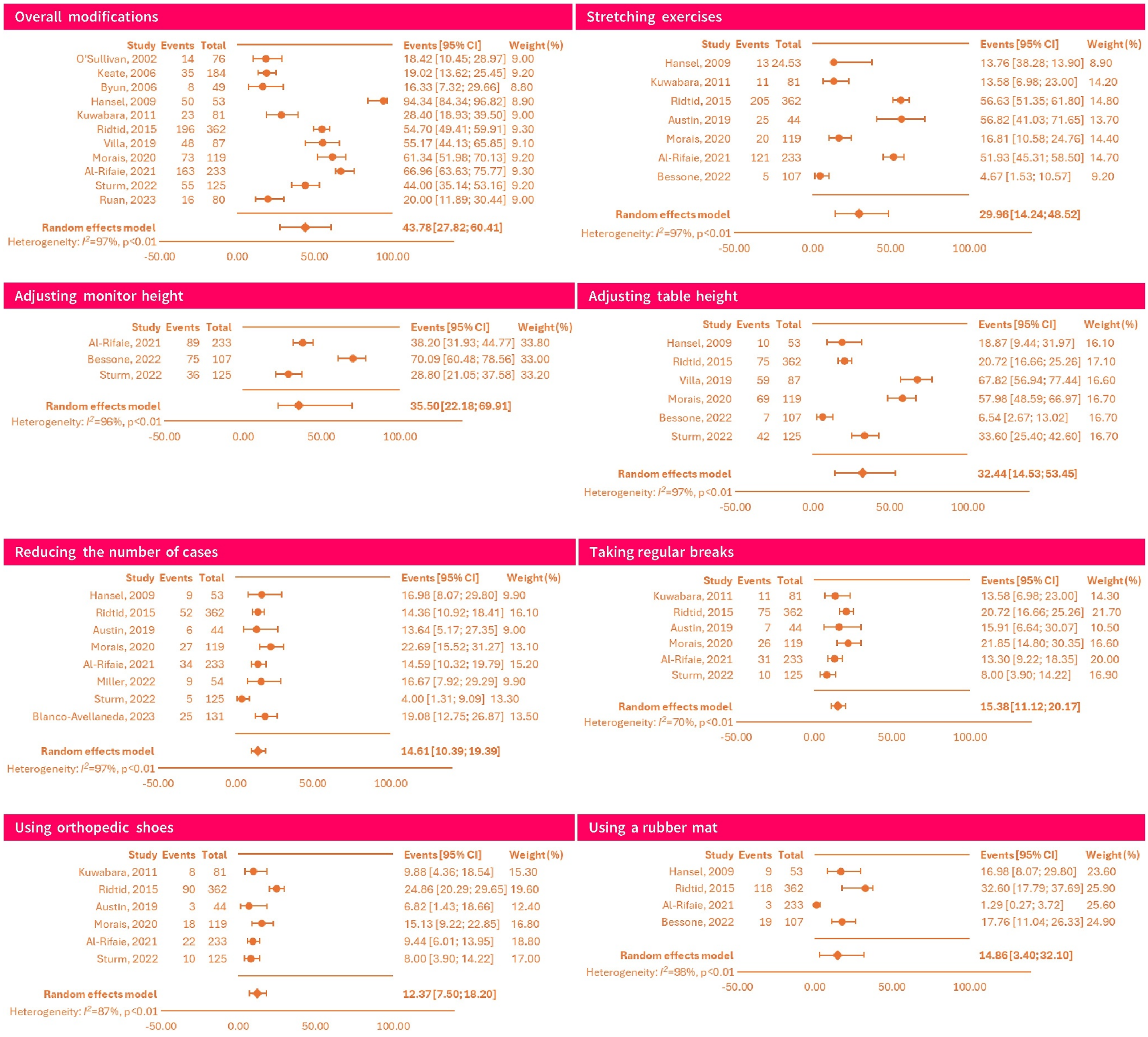

FIGURE 6 | Modifications to practice driven by endoscopy-related injuries.

can prevent an escalation in injury prevalence and create a more inclusive working environment.

Finally, the impact of ERIs extends far beyond the endoscopy suite, affecting both personal and professional aspects of endoscopists' lives. While ERIs have been linked to longer procedural times and limitations in fulfilling normal work duties [21], their consequences also permeate daily activities and overall work satisfaction. For instance, endoscopists frequently report reducing leisure activities due to ERIs [33] and experiencing pain during non-work-related activities [14, 16, 19, 32]. These findings are particularly concerning, as they indirectly suggest a cumulative burden that might ultimately lead not only to premature career termination due to disability but also to increased dissatisfaction with work [21]. Such dissatisfaction, when compounded by the physical toll of ERIs on daily life, can contribute significantly to physician burnout [57], ultimately risking the loss of a highly specialised and essential workforce.

This study has several limitations, primarily indicating the inherent constraints of the included studies. As most studies were cross-sectional, the temporal relationships between risk factors and outcomes cannot be definitively established. The reliance on self-reported data introduces the potential for recall bias, as participants may not accurately recall past injuries or their severity. Furthermore, the participants may be biased to attribute their injuries to endoscopy, though other risk factors and activities might have contributed to the overuse injuries, which were not assessed in most included studies. Additionally, selection bias is a significant concern, as individuals affected by ERIs are more likely to participate in surveys, potentially inflating prevalence estimates. Moreover, as some studies were conducted in the same country over a similar period, response duplication is possible, with the same endoscopist answering more than one survey. The methodological quality of the included studies also varied. Most studies utilised non-validated or pilot questionnaires, which may limit the reliability and reproducibility of the findings. Although a subset of studies employed validated tools, this inconsistency in data collection methods likely contributed to the observed heterogeneity across studies. Furthermore, fewer than half of the studies reported response rates exceeding 50%, compounding concerns about nonresponse bias. Another limitation lies in the demographic and practice-related heterogeneity among the study populations, as well as differences in definitions and assessment of ERIs. Variability in sample sizes, regional ergonomic standards, procedural volumes, and years of practice creates challenges in generalising findings to the broader population of endoscopists. Moreover, the underrepresentation of trainees and female endoscopists in certain studies may limit insights into the unique risk factors and injury patterns affecting these subgroups. Finally, the longer procedural times, specific equipment such as lead gowns, and technical difficulties associated with ERCP and interventional endoscopy may create additional ergonomic challenges. However, the low representation of these endoscopists in the studies precluded a sub-analysis of these groups. Special care in implementing ergonomic strategies in their practice is particularly important.

Despite these limitations, several strengths of this systematic review and meta-analysis should be highlighted. First, this review builds on a prior review by Singh et al. by including a broader dataset and updating the literature through 2024, capturing the latest trends and emerging evidence. Second, the large pooled sample size of 7646 endoscopists enhances the statistical power of the analyses and allows for more robust estimates of ERI prevalence and associated factors. The inclusion of diverse geographic regions, encompassing studies from North America, Europe, Asia, and South America, provides insights into global patterns of ERIs and highlights regional variations in ergonomic practices and risk factors. Third, this review offers a detailed exploration of not only the prevalence of ERIs but also the treatments employed, practice modifications implemented, and factors associated with injury risk.

In conclusion, GI endoscopists face a significantly high prevalence of ERIs, a burden expected to rise with the increasing representation of women in the field and the cumulative effects of procedural volume and years of practice. These findings underscore the urgency of implementing realistic and effective strategies to prevent ERIs, ensuring that GI endoscopy remains a sustainable and fulfilling practice. This study highlights critical gaps in current training programs and workplace practices, particularly the lack of formal ergonomic education and insufficient workplace adaptations. By addressing modifiable risk factors and developing targeted intervention strategies, the field can not only mitigate the physical toll on endoscopists but also enhance their long-term well-being, paving the way for future research and practical initiatives to sustain a highly specialised workforce.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supporting Information

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