

Epidemiological Characteristics of Pain Among Rowers: A Retrospective Questionnaire Study

Huiru Ma^{1,*}, Ziwen Mu^{1,*}, Hanyan Yan¹, Tingxv Zhang¹, Haoxiang Wang¹, Zhiqiang Han¹, Kazuhiro Imai², Xiao Zhou^{1,2}, Hongtao Zeng¹

¹School of Physical Education, Huazhong University of Science and Technology, Wuhan, Hubei, People's Republic of China; ²Department of Life Sciences, Graduate School of Arts and Sciences, The University of Tokyo, Tokyo, Japan

*These authors contributed equally to this work

Correspondence: Xiao Zhou; Hongtao Zeng, School of Physical Education, Huazhong University of Science and Technology, Luoyu Road 1037, Wuhan, Hubei, 430074, People's Republic of China, Tel +86- 027-8755-6274, Email syuu@hust.edu.cn; zenghongtao@hust.edu.cn

Purpose: This study aimed to analyze the distribution, incidence, and high-risk technical phases of pain among rowers aged 12–24 in China.

Methods: In 2024, a retrospective questionnaire survey was performed among 207 rowers. The questionnaire comprised four sections: (1) basic information; (2) rowing-related injury sites over the past year; (3) rowing-related pain sites over the past year; and (4) body locations of pain during rowing strokes in the past year and the specific technical phase when pain occurred. Pain was defined as any painful physical discomfort occurring while maintaining athletic capability. Rowing-related pain rate was standardized to rates per 1000 training sessions and per 1000 training hours, calculated using the Poisson distribution based on sex.

Results: The overall pain rate was 24.2%, with 118 reported pain instances. The most common site was the lower back (16.1%), followed by the thigh and shoulder joint. The pain rate per 1000 training sessions was 1.94 (95% CI: 1.59–2.29), and per 1000 training hours was 0.41 (95% CI: 0.34–0.49). Both lower back and knee pain were significantly associated with the risk of shoulder pain. During rowing, approximately half of the athletes reported lower back pain, predominantly occurring during the drive phase.

Conclusion: Approximately one-quarter of Chinese rowers experienced pain during training, with low back pain being the most commonly reported. Both lower back and knee pain are significantly associated with shoulder pain risk; and pain during rowing most frequently occurs in the drive phase. This study provides a theoretical basis for enhancing early injury prevention, optimizing athletic performance, and guiding.

Keywords: epidemiology, motor phases, rowing players, pain

Introduction

Sports injuries are common among adolescents who engage in long-term sports training. With the increasing competitiveness in elite sports, young athletes are subjected to high-intensity training at an early age, significantly raising their risk of overuse injuries and sports burnout.¹ Studies indicate that injury risk escalates with age and competitive level,² and many severe injuries in elite athletes often stem from cumulative microtraumas sustained during adolescence period.³

Rowing is a highly demanding endurance sport that requires exceptional physiological and psychological capabilities. Research has shown that rowers possess the most outstanding aerobic capacity among endurance athletes, frequently pushing human physiological and psychological limits.⁴ As a cyclic sport, the rowing stroke comprises four phases: catch phase, drive phase, finish phase, and recovery phase.⁵ The unique mechanical transmission patterns and repetitive flexion-extension actions in rowing can cause cumulative microtrauma to specific fascial layers with nerve supply, thereby increasing athletes' risk of pain and injury.^{6,7} Studies show that 33.4–38.2% of elite rowers experience at least one sports injury during their careers,^{8,9} with the lower back and knees being the most affected areas.^{8–11} Statistics indicate an injury rate of 1.75–2.25 cases per 1000 training sessions among elite rowers,^{8–10,12} while the injury rate per 1000 hours of training exposure is 3.67 cases.¹²

Currently, rowing athletes (including para-rowers) commonly face issues with pain and injuries. Research indicates that some elite rowers have even been forced to withdraw from competitions due to injuries, with postoperative recovery periods lasting up to eight months.^{13,14} We note that in sports such as badminton and baseball, pain has been established as an early biomarker of tissue micro-damage. By advancing injury prevention strategies to focus on pain management, athlete injury risk can be further reduced. Although the epidemiological characteristics of rowing injuries are now well-defined, current research predominantly focuses on post-injury interventions, with insufficient attention given to pre-injury pain warning signals.^{15,16}

To ensure athletes' long-term pain-free and injury-free participation in training, the development of scientific prevention plans remains essential. Prior to formulating prevention strategies, comprehensive epidemiological data collection across different age groups is imperative. However, research on pain in rowers is limited, and there is a lack of epidemiological studies on pain among Chinese rowers. Therefore, this study focuses on Chinese rowing athletes, investigating their pain distribution patterns, incidence, and the technical phases most frequently associated with pain occurrence, while also analyzing pain differences between male and female athletes. The research aims to enhance athletic performance, effectively extend athletes' professional careers, and provide theoretical support for scientific training methodologies.

Materials and Methods

In 2024, a retrospective study was performed aimed at investigating the prevalence of physical pain among rowing athletes nationwide. The study employed a random convenience sampling method. With the support and consent of coaches from various provinces and cities, and on the basis of voluntary participation from the athletes themselves, questionnaires were distributed using online surveys and Email to athletes from provincial rowing teams (eg, Hebei, Hunan, Sichuan) and municipal rowing training centers (eg, Shijiazhuang, Yueyang, Zhuzhou, Leshan). The research protocol was reviewed and approved by the Institutional Ethics Board of Tongji Medical College, Huazhong University of Science and Technology, China (Notification Number [2023] IEC (S172)). The study strictly adhered to the ethical guidelines of the Declaration of Helsinki. All adult participants signed informed consent forms, while minors provided consent through their guardians. Rowing athletes inclusion criteria were as follows: 1) ≥ 1 year of rowing training; 2) participation in at least one district-level or higher competition; 3) complete questionnaire data without logical inconsistencies. Questionnaires with anomalies or missing values were excluded.

The questionnaire was adapted from past studies^{10,11} and comprised of four sections: The first section collected basic parameters, including sex, age, weight, height, years of rowing training experience, training hours per day, and training days per week. The second section investigated rowing-related injury sites over the past 12 months: chest, shoulder, elbow, wrist, upper arm, forearm, lower back, thigh, knee, calf, ankle, foot, and other sites. The third section investigated rowing-related pain sites over the past 12 months (pain at the anatomical site identical to the injury). The fourth section examined pain sites during rowing strokes over the past 12 months: shoulder, wrist, lower back, knee, ankle, and other areas, along with the technical phases associated with pain occurrence (catch phase, drive phase, finish phase, recovery phase). Please see [Appendix 1](#) for the detailed content of the questionnaire.

Definitions

In this study, we adopted the International Olympic Committee's criteria for defining sports injury/pain to maintain consistency and enable comparisons with data from other studies.¹⁷ Pain was defined as any painful physical discomfort (localized soreness or pain, with or without referred pain) under the premise of retained athletic ability, meeting the following criteria: 1) ability to continue the current rowing training session or competition; 2) no time loss, allowing immediate participation in the next rowing training or competition; 3) no need for medical care during or after rowing training or competition.¹⁸ Sports injury was defined as physical discomfort during training or competition meeting any of the following three criteria: 1) unable to complete the current training or competition; 2) unable to participate in subsequent training or competition; 3) injury requiring medical care, regardless of time loss.¹⁷ Pain episodes coinciding with injuries at the same anatomical site were excluded. Each instance of pain experienced by an athlete is considered a statistically independent event, with the incidence of pain calculated based on the total number of pain events rather than the number of athletes, while excluding simultaneous pain episodes associated with injuries to the same anatomical site.

Statistical Analysis

The normality of baseline parameters was examined by the Shapiro–Wilk test. Height followed a normal distribution, whereas age, weight, body mass index (BMI), years of rowing training experience, training hours per day, training days per week, training hours per week, and annual training hours did not. Participants were divided into male and female groups. Independent samples t-test and non-parametric tests were employed to statistically analyze baseline parameters between groups (male group, female group). Pain rates per 1000 training sessions and per 1000 training hours were calculated using the Poisson distribution, along with 95% confidence intervals (CI). A training hour was defined as one hour of training participation, and a training session was defined as one day of training participation. The time spent on the warm-up and cool-down practices was not considered as training time. Pain rates during rowing training were computed as follows:

$$\text{pain rate per 1000 training sessions} = \left\{ \frac{\sum (\text{total number of pain})}{\sum [(\text{training days per participant per week} \times \text{weeks per participant one year})]} \right\} \times 1000;$$

$$\text{pain rate per 1000h} = \left\{ \frac{\sum (\text{total number of pain})}{\sum [(\text{training hours per participant per day} \times \text{training days per participant per week} \times \text{weeks per participant one year})]} \right\} \times 1000.$$

The denominators for pain rate calculations represented the total training time or sessions across all participants. If the 95% CIs did not overlap, the pain rates per 1000 training hours and sessions were considered significantly different between groups.

In this study, logistic regression analysis was employed, and three models were constructed: the crude model, Model 1, and Model 2, to gradually exclude potential confounding factors. For covariate selection, the variance inflation factor (VIF) was used to determine variable inclusion and exclusion, aiming to identify possible multicollinearity among variables. If the VIF value of a variable reached or exceeded 10, multicollinearity was considered to exist, and only one of the collinear variables was retained in the model. In statistical analyses, a *p*-value <0.05 was deemed statistically significant. The statistical analysis in this study was performed by an author (H.M).

Results

A total of 228 rowing athletes were recruited for this study, and 207 were finally included after screening. All the participants were grouped by sex, with 134 players in the male group and 73 players in the female group (Table 1). Significant differences were observed between the male and female groups in age (*p* = 0.025), height (*p* < 0.001), weight (*p* < 0.001), and BMI (*p* < 0.001) (Table 1).

Table 1 Basic Parameters of Rowing Athletes by Sex and Age

Variable	Male (n=134)	Female (n=73)	Total (n=207)
Age (yrs)	17.1 ± 2.6	16.3 ± 2.6*	16.8 ± 2.7
Height (cm)	186.3 ± 7.7	173.3 ± 7.2***	181.7 ± 9.7
Weight (kg)	81.4 ± 18.8	64.9 ± 9.7***	75.6 ± 18.0
BMI (kg/m ²)	23.3 ± 4.7	21.5 ± 2.2***	22.7 ± 4.1
Training years of experience	3.2 ± 2.2	2.8 ± 2.0	3.0 ± 2.1
Training hours daily	4.7 ± 2.3	4.5 ± 1.9	4.6 ± 2.2
Training days weekly	6.1 ± 1.1	6.2 ± 1.0	6.1 ± 1.1
Training hours weekly	28.8 ± 15.1	28.4 ± 13.2	28.6 ± 14.4
Training sessions a year	291.0 ± 52.4	298.2 ± 46.6	293.6 ± 50.5
Training hours a year	1380.1 ± 723.3	1363.5 ± 635.4	1374.2 ± 692.1
Total training sessions a year	39000	21768	60768
Total training hours a year	184932	99532.8	284464.8

Notes: BMI: body mass index, calculated by height and weight. **p*-value < 0.05, ****p*-value < 0.001, between the male group and the female group.

Among all participants, the overall pain incidence was 24.2%, with 50 participants reporting 118 rowing-related pain cases. Most participants experienced multi-site pain. The pain incidence was 28.4% in males, with 38 male participants reporting 82 rowing-related pain cases; in females, the rate was 16.4%, with 12 female participants reporting 36 rowing-related pain cases.

Regarding anatomical sites, the highest pain incidence occurred in the lower back (19 cases; 16.1%), followed by the thigh (15 cases; 12.7%) and shoulder (14 cases; 11.9%). Among male participants, the most common pain sites were the lower back (14 cases; 17.1%), knee (12 cases; 14.6%), and thigh (10 cases; 12.2%). Female participants exhibited the shoulder, wrist, lower back, thigh, and calf each reporting 5 pain cases, all accounting for 13.9% (Table 2).

Figure 1A and B show the overall rowing-related pain rates per 1000 training sessions and per 1000 training hours stratified by sex. The pain rate per 1000 training sessions was 1.94 (95% CI: 1.59–2.29), and the pain rate per 1000 training hours was 0.41 (95% CI: 0.34–0.49). Among male rowers, the pain rate per 1000 training sessions was 2.10 (95% CI: 1.65–2.56), and per 1000 training hours was 0.44 (95% CI: 0.35–0.54). For female rowers, the pain rate per 1000 training sessions was 1.65 (95% CI: 1.11–2.19), and per 1000 training hours was 0.36 (95% CI: 0.24–0.48) (Figure 1).

Through collinearity diagnostics, it was found that 5 variables in Model 1 presented collinearity. After removing the variable with the highest VIF, body weight (VIF = 202.48), the VIF values of the remaining 4 variables were all less than 5. In Model 2, 8 variables exhibited collinearity. After removing the variable with the highest VIF, weekly training duration (VIF = 41.94), the VIF values of the remaining 7 variables were all less than 5. Therefore, the variables in Model 1 were gender, age, height, and BMI, while the variables in Model 2 were gender, age, height, BMI, years of training, duration per training session, and frequency of training per week.

The results revealed that both lower back and knee pain were significantly associated with shoulder pain risk. In the crude analysis, participants with lower back pain had a 7.10-fold higher risk of shoulder pain (95% CI: 2.10–24.09, $p=0.002$) compared to those without lower back pain, while participants with knee pain had an 8.18-fold higher risk (95% CI: 2.14–31.19, $p=0.002$). In Model 1, these associations remained stable or strengthened, with the OR for lower back pain increasing to 7.90 (95% CI: 2.26–27.63, $p=0.001$) and the OR for knee pain rising to 9.86 (95% CI: 2.35–41.41, $p=0.002$). In Model 2, the impact of knee pain on shoulder pain became particularly pronounced, with the OR sharply increasing to 13.74 (95% CI: 2.84–66.50, $p=0.001$), while the OR for lower back pain remained elevated at 8.55 (95% CI: 2.18–33.45, $p=0.002$). No correlation was observed between lower back pain and knee pain (Table 3).

Among all participants, the overall pain incidence during water-based training was 30.9%, with 64 participants reporting 89 rowing-related pain cases. Most participants experienced multi-site pain. The pain incidence was 27.6% in males, with 37 male participants reporting 44 water-based training-related pain cases; in females, the rate was 37.0%, with 27 female participants reporting 45 water-based training-related pain cases (Figure 2).

Regarding anatomical sites, the highest pain incidence during water-based rowing training occurred in the lower back (43 cases; 48.3%), followed by the knee (17 cases; 19.1%) and shoulder (16 cases; 18.0%). Among male participants, the

Table 2 Pain Distribution by Anatomical Site

Site	Male (n = 134)	Female (n = 73)	Total (n = 207)
Chest	5 (6.1%)	0 (0.0%)	5 (4.2%)
Shoulder	9 (11.0%)	5 (13.9%)	14 (11.9%)
Elbow	4 (4.9%)	0 (0.0%)	4 (3.4%)
Wrist	4 (4.9%)	5 (13.9%)	9 (7.6%)
Upper arm	7 (8.5%)	4 (11.1%)	11 (9.3%)
Forearm	4 (4.9%)	3 (8.3%)	7 (5.9%)
Lower back	14 (17.1%)	5 (13.9%)	19 (16.1%)
Thigh	10 (12.2%)	5 (13.9%)	15 (12.7%)
Knee	12 (14.6%)	1 (2.8%)	13 (11.0%)
Calf	3 (3.7%)	5 (13.9%)	8 (6.8%)
Ankle	4 (4.9%)	1 (2.8%)	5 (4.2%)
Foot	2 (2.4%)	1 (2.8%)	3 (2.5%)
Other	4 (4.9%)	1 (2.8%)	5 (4.2%)
Total	82 (100.0%)	36 (100.0%)	118 (100.0%)

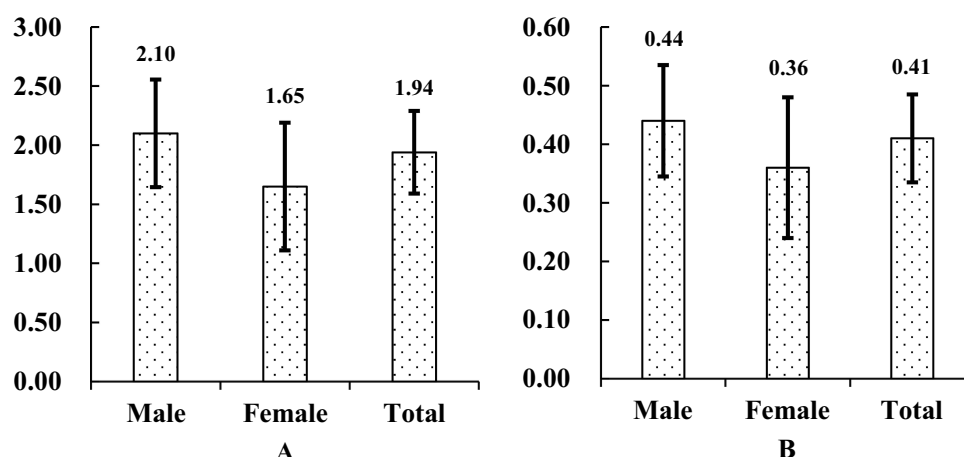


Figure 1 (A) Incidence of pain per 1000 training sessions in rowing athletes. (B) Incidence of pain per 1000 training hours in rowing athletes (The error bars represent 95% CI).

most common pain sites were the lower back (27 cases; 61.4%), knee (7 cases; 15.9%), and shoulder (6 cases; 13.6%); among female participants, the most common pain sites were the lower back (16 cases; 35.6%), knee (10 cases; 22.2%), and shoulder (10 cases; 22.2%) (Table 4).

Table 5 displays the technical phases of rowing strokes linked to pain during water-based training, stratified by sex. The drive phase accounted for the highest proportion of pain reports 69.7% overall (males:65.9%, females:73.3%), while other phases (Catch phase, Finish phase and Recovery phase) showed significantly lower proportions (Table 5).

Discussion

To the best of our knowledge, this study may be the first epidemiological investigation of pain characteristics among rowers. Some unique and vital findings were found: one-quarter of participants experienced at least one rowing-related pain. The highest incidence occurred in the lower back, followed by the thigh and shoulder. Both lower back and knee pain were significantly associated with shoulder pain. Further analysis of sport-specific training contexts showed that during water-based training, the overall pain incidence reached 30.9%, with the lower back being the most frequent site (48.3%), followed by the knee (19.1%) and shoulder (18.0%). Pain predominantly occurred during the drive phase (69.7%).

This study analyzed the epidemiological features of rowing-related pain. Given the scarcity of pain-focused epidemiological research in this field, we compared our findings with existing data on rowing injuries. Regarding anatomical sites, prior injury studies reported lower back injury incidences of 31.8–32.3% and knee injury incidences of 14.2%–18.8%.^{8,9,11} Among male rowers, lower back injuries (31.8–34.7%) were most common, followed by knee (12.6–19.6%) and arm/wrist injuries (15.2%).^{8,9,19} Female rowers most frequently experienced lower back injuries 29.9%–33.3%, followed by shoulder 25.9% and knee injuries 16.9%–17.6%.^{8,9,19} Our study identified the lower back as the most common pain site (16.1%), followed by the thigh (12.7%) and shoulder (11.9%). In males, the predominant pain sites were the lower back (17.1%), knee (14.6%), and

Table 3 Logistic Regression Analysis of the Low Back and Knee in Relation to Shoulder Joint Pain

	Crude			Model 1			Model 2		
	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Lower back	7.10	2.10–24.09	0.002	7.90	2.26–27.63	0.001	8.55	2.18–33.45	0.002
Knee	8.18	2.14–31.19	0.002	9.86	2.35–41.41	0.002	13.74	2.84–66.50	0.001

Notes: Crude was the unadjusted model; Model 1 adjusted for sex (categorical variable), age (continuous variable), height (continuous variable), and BMI (continuous variable); Model 2 includes the factors from Model 1 plus the following variables: years of rowing training (continuous variable), daily training hours (continuous variable), and weekly training days (continuous variable).

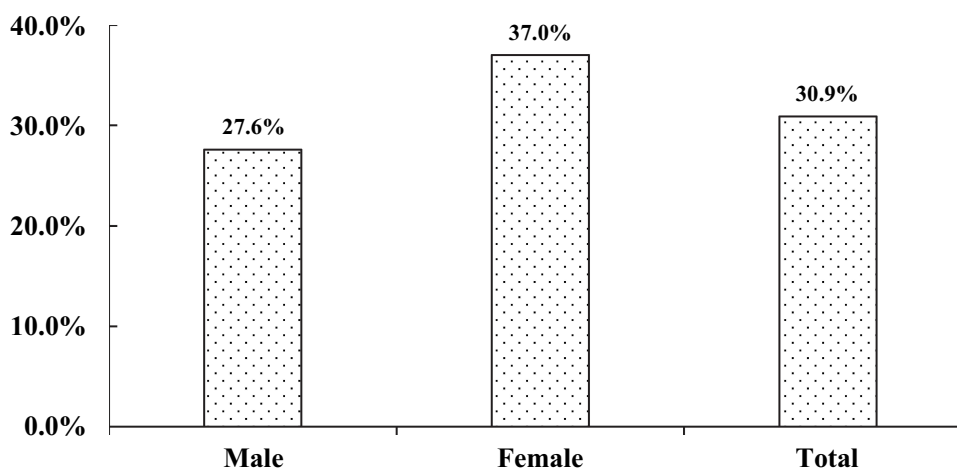


Figure 2 Pain incidence during water-based rowing training.

thigh (12.2%); females exhibited balanced distribution across the lower back, shoulder, thigh, wrist, and calf (5 cases each, 13.9%). This consistency with prior injury sites suggests that untreated pain may lead to injuries.

An epidemiological study of pain among baseball players aged 7–12 reported shoulder pain in 15.9% and elbow pain in 29.2%.²⁰ A cross-sectional study of basketball players aged 6–15 found lower back pain in 12.9%, shoulder pain in 4.6%, and elbow pain in 2.7%.²¹ Among overhead athletes (6–15 years), shoulder pain was common in baseball (10.7%), knee pain in softball (14.3%) and handball (28.6%), respectively back pain in tennis (11.8%), foot pain in badminton (17.9%), and knee pain in volleyball (12.1%).²² Increasingly, sports are recognizing pain as an early biomarker of tissue microtrauma, advocating proactive prevention to reduce injury risk.

Table 4 Pain Anatomical Sites During Water-Based Rowing Training

Site	Male (n = 134)	Female (n = 73)	Total (n = 207)
Shoulder	6 (13.6%)	10 (22.2%)	16 (18.0%)
Elbow	1 (2.3%)	1 (2.2%)	2 (2.2%)
Wrist	1 (2.3%)	4 (8.9%)	5 (5.6%)
Lower back	27 (61.4%)	16 (35.6%)	43 (48.3%)
Hip/Gluteal	1 (2.3%)	1 (2.2%)	2 (2.2%)
Knee	7 (15.9%)	10 (22.2%)	17 (19.1%)
Ankle	0 (0.0%)	3 (6.7%)	3 (3.4%)
Other	1 (2.3%)	0 (0.0%)	1 (1.1%)
Total	44 (100.0%)	45 (100.0%)	89 (100.0%)

Table 5 Technical Phases Associated with Pain During Water-Based Rowing Training

Technical Phases	Male (n = 134)	Female (n = 73)	Total (n = 207)
Catch phase	2 (4.5%)	4 (8.9%)	6 (6.7%)
Drive phase	29 (65.9%)	33 (73.3%)	62 (69.7%)
Finish phase	7 (15.9%)	6 (13.3%)	13 (14.6%)
Recovery phase	6 (13.6%)	2 (4.4%)	8 (9.0%)
Total	44 (100.0%)	45 (100.0%)	89 (100.0%)

Regarding pain incidence, a retrospective study of badminton players (7–12 years) reported a pain rate of 60.9%, with an overall rate of 3.06 per 1000 training hours (95% CI: 2.81–3.32).¹⁵ Our study found a rowing pain incidence of 24.2%, with 0.41 cases per 1000 training hours (95% CI: 0.34–0.49).

The rowing stroke is a cyclic action comprising the catch, drive, finish, and recovery phases. Catch phase, the blade enters vertically, hips maximally flexed, legs compressed, arms extended, with co-activation of lower limb, core, and upper limb muscles. The drive phase engages the back, shoulders, and arms as cantilevers to transfer force from the legs through the lower back and arms to the blade. Finish phase, legs fully extend, trunk slightly reclines, elbows flex, hands lower the blade parallel to the water. Recovery phase, arms extending to guide trunk lean; as hands pass knees, feet flex and legs return to the catch phase.^{5,6} Rowing biomechanics relies on maximal power output from trunk extensors and efficient kinetic chain coordination from the lower limbs to the core and finally the upper limbs to maximize propulsion.²³ Thus, repetitive technical execution likely contributes to multi-site pain. The observed association between lower back/knee pain and shoulder pain risk aligns with the kinetic chain mechanism: joints (knee, lower back, shoulder) as force-transfer nodes may develop compensatory movement patterns when impaired, increasing adjacent joint injury risk. Notably, 69.7% of rowing-related pain occurred during the drive phase.

To ensure rowers can participate in training without pain or injury, implementing scientific preventive measures is crucial. Research demonstrates that neuromuscular training, by comprehensively improving strength, balance, and agility, can effectively reduce the incidence of knee injuries and ankle sprains, decreasing lower limb injury risk by 35% and knee injury risk by 26%.^{24–27} The shoulder injury prevention program developed by Oslo Sports Trauma Research Center, through improving joint mobility, strengthening rotator cuff muscles, and enhancing scapular stability, can reduce shoulder injury incidence by 28%.²⁸ Furthermore, core stability training, by strengthening core muscles and improving neuromuscular control and lumbar stability, not only significantly alleviates chronic nonspecific low back pain but also reduces lumbar injury risk.²⁹ Implementation should be supervised by professional coaches with particular emphasis on proper technique and pain-free principles.

Limitation

This study has the following limitations: first, the retrospective design relies on participants' subjective recall of pain history, which may introduce memory bias and compromise data objectivity; second, gender imbalance in the sample (females: 35.3%) may affect the reliability of sex-difference analyses; finally, the cross-sectional analysis focused on athletes' pain lacks dynamic observation, thus precluding causal inference between pain and injury. Future study should adopt prospective study designs, longitudinally tracking detailed athlete data (training loads, pain sites, injury locations) through training logs, wearable devices, and team physician diagnoses, with focused investigation on the pain-injury relationship to validate whether rowing-related pain serves as an early predictor of sports injuries.

Conclusion

Among Chinese rowers aged 12–24, lower back pain was the most prevalent, followed by thigh and shoulder pain. Both lower back and knee pain were significantly associated with shoulder pain. During rowing water-based training, more than one-third of athletes reported pain, with nearly half of these cases being lower back pain, which primarily occurred during the drive phase of the stroke. These findings elucidate the high-risk anatomical areas in rowing and the significant correlations between pain sites, identify the key technical phases during which pain occurs, and provide a theoretical basis for enhancing early injury prevention, improving athletic performance, and guiding scientific training.

Data Sharing Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author, Xiao Zhou, PhD (Email: syuu@hust.edu.cn), upon reasonable request.

Ethics Approval and Consent to Participate

Ethical approval for this study was obtained from Tongji Medical College, Huazhong University of Science and Technology, China (Notification Number [2023] IEC (S172)).

Acknowledgments

We are deeply grateful to the rowing athletes from Hebei Province, Liaoning Province, Jilin Province, Sichuan Province, and Hunan Province for their collaboration with us in data collection.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

“Huazhong University of Science and Technology Double First-Class Funds for Humanities and Social Sciences (Project Number: 2025WKQN011)”, “Hubei Provincial Natural Science Foundation of China (Project Number: 2025AFD614)”, and “Huazhong University of Science and Technology Double First-Class Funds for Humanities and Social Sciences (Project Numbers: 2026WKQN034)” are acknowledged for the partial financial support provided.

Disclosure

The authors have declared that there are no conflicts of interest in this work.

References

- DiFiori JP, Benjamin HJ, Brenner J, et al. Overuse injuries and burnout in youth sports: a position statement from the American medical society for sports medicine. *Clin J Sport Med.* 2014;24(1):3–20. doi:10.1097/JSM.0000000000000060
- Zacchilli MA, Owens BD. Epidemiology of shoulder dislocations presenting to emergency departments in the United States. *J Bone Joint Surg Am.* 2010;92(3):542–549. doi:10.2106/JBJS.1.00450
- Andrews JR, Fleisig GS. Preventing throwing injuries. *J Orthop Sports Phys Ther.* 1998;27(3):187–188. doi:10.2519/jospt.1998.27.3.187
- Volianitis S, Secher NH. Rowing, the ultimate challenge to the human body - implications for physiological variables. *Clin Physiol Funct Imaging.* 2009;29(4):241–244. doi:10.1111/j.1475-097X.2009.00867.x
- Arumugam S, Ayyadurai P, Perumal S, et al. Rowing injuries in elite athletes: a review of incidence with risk factors and the role of biomechanics in its management. *Indian J Orthop.* 2020;54(3):246–255. doi:10.1007/s43465-020-00044-3
- Hosea TM, Hannafin JA. Rowing injuries. *Sports Health.* 2012;4(3):236–245. doi:10.1177/1941738112442484
- Fede C, Petrelli L, Pirri C, et al. Innervation of human superficial fascia. *Front Neuroanat.* 2022;16:981426. doi:10.3389/fnana.2022.981426
- Smoljanović T, Bohaček I, Hannafin J, et al. Sport injuries in international masters rowers: a cross-sectional study. *Croat Med J.* 2018;59(5):258–266. doi:10.3325/cmj.2018.59.258
- Ma H, Zhou X, Imai K, et al. Epidemiological characteristics of injuries among rowing athletes based on gender and age: a retrospective study. *Appl Sci.* 2025;15(9):5048. doi:10.3390/app15095048
- Smoljanovic T, Bojanic I, Hannafin JA, et al. Traumatic and overuse injuries among international elite junior rowers. *Am J Sports Med.* 2009;37(6):1193–1199. doi:10.1177/0363546508331205
- Wilson F, Gissane C, Gormley J, et al. A 12-month prospective cohort study of injury in international rowers. *Br J Sports Med.* 2010;44(3):207–214. doi:10.1136/bjsm.2008.048561
- Smoljanovic T, Bohacek I, Hannafin JA, et al. Acute and chronic injuries among senior international rowers: a cross-sectional study. *Int Orthop.* 2015;39(8):1623–1630. doi:10.1007/s00264-014-2665-7
- Zuckerman SL, Kerolus MG, Buchanan IA, et al. Lumbar discectomies in elite rowers: presentation, operative treatment, and return to play. *Phys Sportsmed.* 2022;50(5):414–418. doi:10.1080/00913847.2021.1948309
- Puce L, Biz C, Trompetto C, et al. A scoping review with bibliometric analysis of para-rowing: state of the art and future directions. *Healthcare.* 2023;11(6):849. doi:10.3390/healthcare11060849
- Zhou X, Imai K, Chen Z, et al. The characteristics of badminton-related pain in pre-adolescent and adolescent badminton players. *Children.* 2023;10(9):1501. doi:10.3390/children10091501
- Nebel AR, Fava AW, Bordelon NM, et al. Comparison of peak shoulder distraction forces between pain and pain-free youth baseball pitchers. *Orthop J Sports Med.* 2023;11(6):23259671231177320. doi:10.1177/23259671231177320
- Hainline B, Derman W, Vernec A, et al. International Olympic Committee consensus statement on pain management in elite athletes [published correction appears in Br J Sports Med. 2018 52(3):209. doi: 10.1136/bjsports-2017-097884corr1.]. *Br J Sports Med.* 2017;51(17):1245–1258. doi:10.1136/bjsports-2017-097884
- Bahr R. No injuries, but plenty of pain? On the methodology for recording overuse symptoms in sports. *Br J Sports Med.* 2009;43(13):966–972. doi:10.1136/bjsm.2009.066936
- Bernardes F, Mendes-Castro A, Ramos J, et al. Musculoskeletal Injuries in Competitive Rowers. *Acta Med Port.* 2015;28(4):427–434. doi:10.20344/amp.6364
- Matsuura T, Suzue N, Iwame T, et al. Epidemiology of shoulder and elbow pain in youth baseball players. *Phys Sportsmed.* 2016;44(2):97–100. doi:10.1080/00913847.2016.1149422

21. Hagiwara Y, Yabe Y, Sekiguchi T, et al. Upper extremity pain is associated with lower back pain among young basketball players: a cross-sectional study. *Tohoku J Exp Med.* **2020**;250(2):79–85. doi:10.1620/tjem.250.79
22. Sekiguchi T, Hagiwara Y, Momma H, et al. Coexistence of trunk or lower extremity pain with elbow and/or shoulder pain among young overhead athletes: a cross-sectional study. *Tohoku J Exp Med.* **2017**;243(3):173–178. doi:10.1620/tjem.243.173
23. Ledergerber R, Jacobs MW, Roth R, et al. Contribution of different strength determinants on distinct phases of Olympic rowing performance in adolescent athletes. *Eur J Sport Sci.* **2023**;23(12):2311–2320. doi:10.1080/17461391.2023.2230937
24. Hübscher M, Zech A, Pfeifer K, et al. Neuromuscular training for sports injury prevention: a systematic review. *Med Sci Sports Exerc.* **2010**;42(3):413–421. doi:10.1249/MSS.0b013e3181b88d37
25. Emery CA, Roy TO, Whittaker JL, et al. Neuromuscular training injury prevention strategies in youth sport: a systematic review and meta-analysis. *Br J Sports Med.* **2015**;49(13):865–870. doi:10.1136/bjsports-2015-094639
26. Owøye OBA, Palacios-Derflinger LM, Emery CA. Prevention of ankle sprain injuries in youth soccer and basketball: effectiveness of a neuromuscular training program and examining risk factors. *Clin J Sport Med.* **2018**;28(4):325–331. doi:10.1097/JSM.0000000000000462
27. Emery CA, Pasanen K. Current trends in sport injury prevention. *Best Pract Res Clin Rheumatol.* **2019**;33(1):3–15. doi:10.1016/j.berh.2019.02.009
28. Andersson SH, Bahr R, Clarsen B, et al. Preventing overuse shoulder injuries among throwing athletes: a cluster-randomised controlled trial in 660 elite handball players. *Br J Sports Med.* **2017**;51(14):1073–1080. doi:10.1136/bjsports-2016-096226
29. Xu S, Wang R, Ma S, et al. Interventional effect of core stability training on pain and muscle function of youth with chronic non-specific lower back pain: a randomized controlled trial. *Heliyon.* **2024**;10(12):e32818. doi:10.1016/j.heliyon.2024.e32818

Journal of Pain Research

Publish your work in this journal

The Journal of Pain Research is an international, peer reviewed, open access, online journal that welcomes laboratory and clinical findings in the fields of pain research and the prevention and management of pain. Original research, reviews, symposium reports, hypothesis formation and commentaries are all considered for publication. The manuscript management system is completely online and includes a very quick and fair peer-review system, which is all easy to use. Visit <http://www.dovepress.com/testimonials.php> to read real quotes from published authors.

Submit your manuscript here: <https://www.dovepress.com/journal-of-pain-research-journal>

Dovepress
Taylor & Francis Group