

RESEARCH ARTICLE



Towards the strategies of return to sport after lateral ankle Sprain: a systematic review

Return to Sport of Lateral Ankle Sprain

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ABSTRACT

Background: Returning to sport (RTS) from lateral ankle sprain (LAS) is multifaceted and interdisciplinary. This systematic review aimed to investigate the factors involved in RTS and further establish a standard paradigm of RTS to treat and rehabilitate the LAS.

Methods: Four electronic databases, including PubMed (MEDLINE), Web of Science, Science Direct, and Scopus, were searched until March 1, 2024. The literature was identified, screened, evaluated, managed and data was extracted by developing inclusion criteria based on the PICO model for systematic reviews. The quality of the studies was assessed using the Downs and Black checklist and the measurement parameters were summarised.

Results: This systematic review included 20 papers with a mean quality score of $75.36 \pm 10.40\%$. Participant's information, research content, purpose, methods, and interventions were extracted and summarized. The included articles were divided into four categories for further discussion, including (1) rehabilitation measures for LAS, (2) criteria for RTS of LAS, (3) performance assessment after RTS of LAS, and (4) the relationship between criteria and time of RTS for LAS.

Conclusion: RTS for LAS is a continuous process, which is influenced by complex factors, such as the injury extent, injury causation, treatment protocols, and recovery criteria. The standard paradigms of RTS rehabilitation for LAS is still lacking in the literature. Current study identified the procedure and timeline of RTS for LAS. Findings may provide theoretical basis, clinical implications, and decision-making guidance for the RTS of LAS patients.

ARTICLE HISTORY

Received 15 October 2024
Accepted 30 October 2025

KEYWORDS

Ankle Sprain; clinical treatment; Foot and ankle; return to play; sport rehabilitation

1. Background

Lateral ankle sprain (LAS) is one of the most frequently occurring musculoskeletal injuries in general and athletic populations engaged in recreational and competitive sports [1–8]. The precise etiology of LAS is complex [9] and often presents as a mechanical laxity and proprioception deficit [5]. Clinically, lateral ankle sprains are categorized into grade I injury as mild, grade II injury as moderate, and grade III injury as severe [1,5]. Although LAS is typically believed to be a one-off injury, the evidence from hospital emergency department records shows that up to 74% of patients with LAS continue to have persistent symptoms [10,11]. Studies reported that LAS patients have the most significant risk of re-injury in all lower-extremity musculoskeletal injuries [12]. In specific sports populations, the re-injured population could be as high as 70% [13], and nearly 40% of LAS patients would experience chronic ankle instability

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 Supplemental data for this article can be accessed online at <https://doi.org/10.1080/07853890.2025.2586334>.

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within a year of the initial injury due to the re-injury [13,14]. The high rate of re-injury might be brought on by either premature return to sport (RTS) or inadequate rehabilitation [15,16].

RTS is considered safe for an injured athlete to return to training or competition [17]. This also results from the anticipated evaluation, medical intervention, and rehabilitation procedure [17,18] RTS should be viewed as a continuous process rather than finished in a single step. Thus, each stage is seen as a tiny step toward the RTS [19]. Arden et al. [20,21] defined the RTS continuum as the three process parts of “return to performance”, “return to sport”, and “return to participation” [19,22]. These three processes are influenced by the injury grade, rehabilitation strategies, pre and post RTS foot function tests, the amount of time spent in RTS, psychosocial elements of RTS, emotional values, and self-perceptions [21,23–25]. All these factors could be combined to assess whether the injured athlete satisfied the criteria for RTS and gauged the performance level after RTS.

Even though the criteria for RTS in patients with LAS have not been clarified in the current literature, the components of RTS decision-making (i.e. pain, ankle perception, including proprioception, ankle injuries, muscle activation, sensorimotor control systems, and motor testing) were previously described in narrative reviews, with consensus among clinical experts [10,26,27]. Furthermore, it has been shown that the decision-making factors for RTS in patients with LAS consider using quantitative methods, which is a crucial criterion for RTS [21,28]. Similarly, these quantitative parameters should be incorporated into self-reporting and assessing ability after RTS decision-making in patients with LAS [29]. The evidence-based clinical guidelines [16,25,27] recently included exercise-based rehabilitation programs for various treatment options for LAS patients [30]. In addition, some studies have shown that kinesio taping may facilitate RTS by improving muscle contraction [31], although this is not without debate [32]. This treatment can help LAS to have a good supporting effect during exercise performance, but it may also have a negative impact on the active stability of the lateral muscles [33]. In addition, there are many other therapies, such as (acupuncture [34], laser [35], manual [36], etc.), which can help LAS to RTS [37]. However, the clinical experience typically dictates how best to treat patients with LAS and when sports activities may be resumed [38,39]. In such cases, the time of RTS is used to measure and quantify the rehabilitation success [18,40]. However, the isolated assessment methods may be counterproductive, as evidenced by the significant recurrent rate of LAS injuries. Therefore, it's essential to build a methodical decision-making process for patients with LAS regarding RTS, considering various factors.

The process of RTS from LAS is multifactorial, and there has yet to be a published systematic review that evaluates this complex process over time. Therefore, this systematic review aims to investigate the process factors of RTS for LAS, including the timing of RTS for LAS, the rehabilitation program, the outcome indicators, and the assessment of the performance recovery after decision-making, to provide further guidance and clinical implications for LAS patients to develop RTS program.

2. Methods

2.1. Protocol registration

The PRISMA 2020 Guidelines Reporting Items checklist [41] was strictly followed to conduct the current systematic review, with protocol in compliance with the Preferred Reporting Items for Systematic Evaluations (PRISMA) statement. The study protocol was registered on the International Register of Prospective Systematic Evaluations (PROSPERO) (registration number: CRD42024522798).

2.2. Search strategy

Four online electronic literature databases, including Web of Science, MEDLINE (via PubMed), Scopus, and ScienceDirect, were searched up to March 1, 2024. Two researchers (H.J. and Y.W.) developed the search strategy, filtered by term-level search, to identify possible studies. Two sets of terms combined with the Boolean indicator “AND” were used, including Lateral Ankle Sprain (e.g. “Lateral Ankle Coper”, “Lateral Ankle Injury”) and Return To Sport (e.g. “Return To Play”). The terms used were either MESH or non-MESH terms, and the Boolean indicator separated the words in each term, “OR”. This technique was restricted to the use of the English language. All screened documents were imported into reference management

software (Endnote®version X9, Thomson Reuters, Philadelphia, PA, USA), and duplicate references were removed. A third researcher (Q.M.) would be referred to discuss solutions if any discrepancies were found during the search.

2.3. Eligibility criteria

This study covered prospective studies, surveys, and randomized controlled trials (RCT) published in peer-reviewed scientific articles written in English before March 1, 2024. Firstly, the titles and abstracts were screened by two researchers (H.J. and Y.W.) using a glossary of terms. Then, the full text was reviewed using the following inclusion and exclusion criteria: the third researcher (Q.M.) was referred to decide the eligibility of the final study if an agreement could not be reached during the screening process. Finally, we conducted a manual search after completing the full-text search to find any studies that had been overlooked the first time.

2.3.1. Inclusion criteria

These articles were included in this review if, (1) the subjects are human and were not restricted by sex or race; (2) RTS is the article's primary outcome; (3) the article should report the biomechanical parameters covering the lower extremity kinematics, kinetics, muscle activity, joint range of motion, functional assessment, or dynamic postural control; (4) the articles should concentrate solely on LAS; (5) studies that obtained a score of quality assessment at least 50% were included in this review [42].

2.3.2. Exclusion criteria

The following criteria were followed to exclude articles, (1) conferences, dissertations, reviews, abstracts, and meta-analyses; (2) study subjects were non-human; (3) LAS requires ligament reconstruction surgery; (4) the results of the article were not relevant to RTS; (5) studies that obtained a score of quality assessment less than 50% were excluded in this review [42].

2.3.3. Outcome of RTS

The result indicators in the article should be pertinent to RTS. We concluded that due to the multifactorial nature of the RTS process, the following outcome indicators should be used to screen articles, the evaluation of LAS, the duration from the time of the sprain until RTS, rehabilitation measures, decision-making indicators (pre- and post-functional tests, pre- and post-pain tests, self-perceptions, mood determinations, and quantitative parameters) and post-decision-making tests (ratings of athleticism and observations of athletic performance).

2.4. Quality assessment and risk of bias assessment

The quality and risk of bias of the included articles were assessed using an improved quality indicator checklist [28,43,44]. Fourteen (1, 2, 3, 5, 6, 7, 10, 11, 12, 16, 18, 20, 21, 22) out of the 27 items on the list were used in the previous review study on chronic ankle instability and LAS [42,45,46]. This prior research could assign multiple quality labels according to quality scores. Consequently, 14 items from the list were adopted in this study to examine the confounding bias, reporting, external validity, and internal validity of all the papers. Half of the 14 item types in the list were assessments of data descriptions. According to the purpose of this study, studies with a score of > 50% were included in this review; otherwise, they were excluded. Two researchers (H.J. and Y.W.) independently scored each article in this review, yielding a maximum quality score of 15.

2.5. Data extraction and manager

Two researchers (H.J. and Y.W.) independently employed standardized and pre-programmed data modules for extraction tables. For each article that met the requirements of this review, modules were selected and data removed according to the study: (1) authors, (2) publication year, (3) country, (4) sample size (gender and age), (5) duration (time from intervention initiation), (6) frequency of interventions (number and

intervals), (7) level of LAS, (8) treatment (measures of rehabilitation interventions), (9) outcome variables (10) main result, (12) evaluator, (13) research type, (14) criteria for RTS, (15) RTS time, and (16) RTS tests.

2.6. Statistical analyses

Due to the large number of direct variables and lack of indirect comparative variables in the randomized controlled trials (RCT) and prospective studies included in this study, the present work failed to satisfy the meta-analysis standards. Therefore, the resultant data was presented in the Tables of this study.

3. Result

3.1. Search results

In the beginning, 1081 records were found. After removing all duplicates, 690 records were retained. Three hundred eighteen records were included based on title and abstract screening for a full-text review of inclusion and exclusion criteria. A total of 18 articles satisfied the inclusion criteria. After another manual search for studies missed during the initial search, two articles fulfilled the inclusion criteria. In the end, all 20 articles achieved more than 50% scores of quality. The flow chart for this systematic review is shown in [Figure 1](#).

3.2. Quality assessment results

The mean quality score of the 20 articles included in this study was 11.3 ± 1.56 , and the modified quality index checklist was $75.36\% \pm 10.40\%$, ranging from 55.3%–88.7%, and all >50%. Of the scores recorded, 11 articles scored >70%, and 19 articles scored > 60%. The Modified Quality Index checklist papers had the most methodological constraints regarding external validity ((8), (9)) and internal validity ((13), (14)). [Table 1](#) presents the quality assessment of each included study.

3.3. Characteristics of the included studies

This review divided the 20 studies into four categories based on the topic and content of the included studies, which were the rehabilitation measures for patients with LAS to RTS ([Table 2](#)), the criteria for RTS in LAS patients ([Table 3](#)), the performance assessment after RTS in LAS patients ([Table 4](#)), and the relationship between test assessment and time of RTS in LAS patients ([Table 5](#)). Each table provided a comprehensive summary of all the variables related to the RTS procedure. The 20 studies included three questionnaires [15,47,48], 11 randomized controlled trials [5,6,26,34,49–55], 7 prospective studies [36,56–60], and 1 prospective study that qualified as a randomized controlled trial [61].

3.4. Process factors of RTS in patients with LAS

All 20 studies included in this systematic review described criteria for RTS in patients with LAS and analyzed process factors from LAS to post-RTS.

3.4.1. Rehabilitation measures for patients with LAS to RTS

Rehabilitation measures for patients with LAS to RTS were summarized in the 12 [9,49,51,54,57,60,62–68] included studies. Eight [49,51,54,57,64–66] of these studies were on rehabilitation measures for grade 1, 2 LAS sprains, two [49,62] were on rehabilitation measures for grade 2 LAS sprains, and two [60,68] were on rehabilitation measures for grade 1,2,3 LAS sprains. Included were eleven [49,51,54,57,60,62–66,68] with a set control group and one [69] with an intervention group only. Most of the interventions for LAS were delivered within the 48-hour post-trauma acute period; only one [62] was given within three weeks of trauma, and one [51] did not mention the time of intervention initiation. For the rehabilitation measures in treating 941 patients with LAS, the mean age was 27 years (age was not mentioned in two

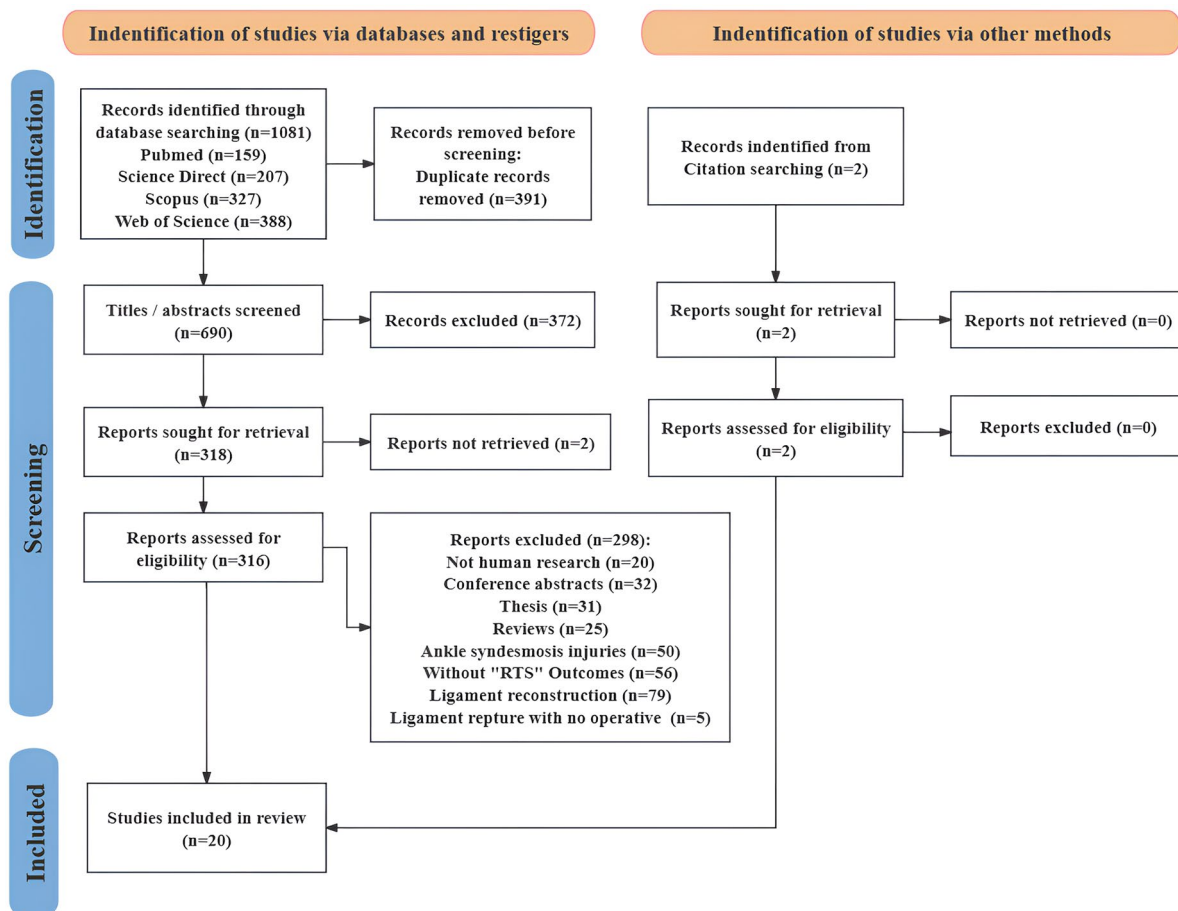


Figure 1. Illustration of flowchart during literature identification, screening, and inclusion in this systematic review.

[51,66] studies). In the studies where the gender ratio was mentioned, women accounted for about 44% and men for about 56%, according to [Table 2](#).

3.4.2. Classification of outcome indicators

The outcome indicators of the included rehabilitation treatments were classified according to the PAASS guidelines [70] as: (1) pain severity: [numerical rating scale (NRS) for pain, visual analog scale (VAS), pain after/during 20m walk]; (2) ankle impairments: [isometric strength, range of motion, total ankle mobility, lateral differences in total mobility]; (3) athlete perception: [Brunel mood scale BRUMS, psychological preparation for return to sport (Psychological Preparation for RTS Scale I-PRRS)]; (4) sensorimotor control: [assessment of static balance (BESS), dynamic balance (SEBT), sense of joint repositioning, measures of postural control, self-report (Walking Disability Scale)]; (5) sport/functional performance: [gait running and jumping analysis]; (6) other (not part of the PAASS classification): adherence to rehabilitation [Rehabilitation Adherence Scale (RAdMAT)], foot and ankle function tests [Karlson Ankle Function Scale (KAFS), Foot and Ankle Ability Test (FAAM)], Impairment [Foot and Ankle Disability Index (FADI), overall assessment of ankle impairment (5-point categorical scale)], patient satisfaction with treatment (10-point flat scale), time to return to pain-free and disability-free exercise, number of recurrent ankle sprains, the effectiveness of assigned treatment, Cumberland Ankle Instability Tool (CAIT), activities of daily living (ADL), and numeric pain rating scale (ALT).

3.4.3. Classification of intervention treatments

3.4.3.1. Electrotherapy. Electrotherapy could release high amplitude/density currents based on electrode positioning [54,66]. Acute [66] or chronic [62] injuries were treated by selectively stimulating A, δ , and c nerve fibers. Since the electrode positions and the current frequency were different, the effectiveness

Table 1. Quality assessment of included studies.

Studies	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭	Total	Percentage
Aguilaniu et al. 2021[95]	1	1	0	2	1	1	1	0	0	1	1	1	0	0	10	66.70%
Aguilaniu et al. 2023 [30]	1	1	0	2	1	1	1	0	0	1	1	1	0	0	10	66.70%
Ammendolia et al. 2023 [77]	1	1	1	2	1	1	1	0	0	1	1	1	1	1	13	86.70%
Arvinen-Barrow et al. 2019 [71]	1	1	1	2	1	1	0	0	0	1	1	1	0	1	11	73.30%
Cross et al. 2002 [81]	1	1	1	2	1	1	1	0	0	1	1	1	1	1	13	86.70%
Mailuhu et al. 2015 [56]	1	1	1	2	1	1	1	0	0	0	1	1	0	0	10	66.70%
McCann et al. 2018 [60]	1	1	1	2	1	1	1	0	0	1	1	1	1	1	13	86.70%
Mendel et al. 2010 [35]	1	1	1	2	1	1	1	0	0	1	1	1	1	1	13	86.70%
Noda et al. 2023 [96]	1	1	1	2	1	1	1	0	0	0	1	1	0	0	10	66.70%
O'Connor et al. 2011 [75]	1	1	1	2	1	1	1	0	0	0	1	1	0	0	10	66.70%
Petrella et al. 2015 [73]	1	1	1	2	1	1	0	0	0	1	1	1	1	1	12	80%
Petrella et al. 2007 [97]	1	1	1	2	1	1	0	0	0	1	1	1	1	1	12	80%
Picot et al. 2023 [79]	1	1	1	2	1	1	1	0	0	1	1	1	1	1	13	86.70%
Punt et al. 2015 [74]	1	1	1	2	1	1	1	0	0	0	1	1	0	0	10	66.70%
Razzano et al. 2018 [65]	1	1	1	2	1	1	1	0	0	0	1	1	0	0	10	66.70%
Tennler et al. 2023 [61]	1	1	1	2	1	1	1	0	0	1	1	1	1	1	13	86.70%
Toyoshima et al. 2021 [78]	1	1	1	2	1	1	1	0	0	0	1	1	0	0	10	66.70%
Wells et al. 2019 [76]	1	1	1	2	1	1	0	0	0	1	1	1	1	1	12	80%
Yokoei et al. 2021 [80]	1	1	0	2	1	1	1	0	0	0	0	1	0	0	8	53.30%
Lam et al. 2023 [53]	1	1	1	2	1	1	1	0	0	1	1	1	1	1	13	86.70%
Criterion fulfilled in% of studies	100%	100%	85%	100%	100%	100%	80%	0%	0%	65%	95%	100%	50%	50%		

Abbreviations: ① Is the study's hypothesis/aim/objective clearly described? ② Are the primary outcomes to be measured clearly described in the Introduction or Methods section? ③ Are the characteristics of the patients included in the study clearly described? ④ Are the distributions of principal confounders in each group of subjects to be compared clearly described? ⑤ Are the main findings of the study clearly described? ⑥ Does the study provide estimates of the random variability in the data for the primary outcomes? ⑦ Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the primary outcomes except where the probability value is less than 0.001? ⑧ Were the subjects asked to participate in the study representative of the entire population from which they were recruited? ⑨ Were those subjects prepared to participate as representatives of the entire population from which they were recruited? ⑩ If any of the study's results were based on "data dredging," was this made clear? ⑪ Were the statistical tests used to assess the primary outcomes appropriate? Were the main outcome measures used accurate (valid and reliable)? ⑫ Were the patients in different intervention groups (trials and cohort studies), or were the cases and controls (case-control studies) recruited from the same population? ⑬ Were the patients in different intervention groups (trials and cohort studies), or were the cases and controls (case-control studies) recruited from the same population? ⑭ Were the patients in different intervention groups (trials and cohort studies), or were the cases and controls (case-control studies) recruited from the same population?

and principles of treatment vary. Mendel et al. [35] used high-voltage pulsed present, based on inhibiting edema, to treat patients with grade 1 and 2 LAS within 48h of the injury. It was found that HVPC did not influence the healing process for moderate (grade 2) ankle sprains and prolonged recovery from grade 1 LAS by approximately one day.

This method had no clinical significance for recovery after LAS and was only used as an adjunctive treatment. Also, using electrotherapy in patients with grade 1 and 2 LAS within 48h, Razzano et al. [66] found that the use of noninvasive interactive nerve stimulation, an electrotherapy that works by targeting areas of the skin with low impedance, improved the short-term prognosis of athletes with grade I or II LAS and may accelerate the return to physical activity by half the time.

3.4.3.2. Balanced intervention approach. Injured athletes were provided with a sense of autonomy by creating variability in rehabilitation to increase their perceived control [63]. Arvinen-Barrow et al. [71] used active video gaming (AVG) as a balancing intervention for individuals suffering from grade 2 LAS. This approach provided more flexibility for both static and dynamic postural control exercises and responded to the perceived readiness for RTS and the emotional state of patients with LAS ($M \pm SD = 26.75 \pm 19.03$).

3.4.3.3. Joint injection. Pharmacological injections that would change the intra-articular matrix and fill in skin gaps could reduce pain and stiffness [72]. Petrella et al. [73] and Petersen et al. [64] used hyaluronic acid to treat patients with grade 1 and 2 LAS. HA is a naturally occurring biological substance that is a significant component of the ultrastructure of ligaments, cartilage, and synovium. In the short and long term, this method demonstrated outstanding outcomes in treating LAS [49] and allowed the patients to RTS 6 days earlier.

3.4.3.4. Functional movement approach. Patients treated with functional movement therapy return faster

Table 2. Rehabilitation measures for patients with LAS to RTS.

Author	Country	Subject Description	Duration	Time Of Test	Level Of Injury	Treatment 1	Treatment 2	Treatment 3	Outcome Variables	Main Results
Ammendolia et al. 2023 [77]	Italy	25 soccer players (age = 22.8±12.62; treatment 1: treatment 2=13:12)	Within two weeks of trauma	T0=baseline, End of treatment, T2=1 month after treatment, T3=2 months after treatment.	1, 2 LAS	Cryo-ultrasound therapy combined with conventional physical therapy	Sham cryo-ultrasound therapy combined with traditional physical therapy	--	NRS, FADI	Significant between-groups differences were reported in terms of pain relief (NRS: 4.08±1.29 vs. 5.87±1.19; $p=0.003$) and physical function (FADI: 50.9±10.3 vs. 38.3±11.5; $p=0.021$)
Arvinen-Barrow et al. 2019 [71]	America	Two soccer players (2 females)	Within 36 h of trauma	T0=baseline, T1=2 weeks.	1, 2 LAS	Using AVG to complete balance exercises	TRAD	--	balance (Balance Error Scoring System, Star Excursion Balance Test), rehabilitation adherence (Rehabilitation Adherence Measure for Athletic Training), foot and ankle function (Foot and Ankle Ability Measure), perceptions of pain (Visual Analog Scale for Pain), perceived readiness to return to sport (Injury Psychological Readiness to RTS Scale), and mood (Brunel Mood Scale)	AVG and TRAD were equally effective in restoring the patient's balance to functional levels
Mailuhu et al. 2015 [56]	Netherlands	169 patients (aged = 14–65)	Within three weeks of trauma	T0=baseline, T1=once a month for one year after baseline.	2 LAS	Receive a standardized eight-week neuromuscular training program guided by an App.	TRAD	--	The total number of ankle sprains reported during one year of follow-up	The treatment program has proven to be effective for athletes, and it also can reduce the number of re-sprains in patients
Mendel et al. 2010 [35]	America	50 patients (18 females, 32 males, aged = 17–33)	Within 25 h of trauma	T=use nearly continuously for the first 72 h after lateral ankle sprains	1, 2 LAS	Received active sub-sensory cathodal HVPC	Received placebo stimulation	--	Time lost to injury measured from time of injury until declared fit to play	HVPC had no clinically meaningful effect on the rate of recovery after ankle sprains in athletes
O'Connor et al. 2011 [75]	Ireland	54 patients (18 females, 36 males, aged = 16–60)	Within 24 h of trauma	T0=10 days, T1=1 month	1, 2, 3 LAS	Elastoplast bandage	Double tubigrip bandage	no support	KAFS	Compared to double tubigrip and no support, Elastoplast bandaging improved average ankle function at both periods.
Petrella et al. 2015 [73]	Canada	158 patients (79 females, 79 males, aged = 16–33)	Within 48 h of trauma	T0=baseline, T1=4 days, T2=8 days, T3=30 days, T4=90 days, T5=712 days	1, 2 LAS	HA+RICE	PL+RICE	--	VAS (0–10 cm), pain when bearing weight and walking 20 meters, patient satisfaction with therapy, duration to return to pain-free and handicap-free sport, recurrent ankle sprains, total days missed from participating in primary sports, and adverse events	When compared to PL, periarthral HA therapy for acute ankle sprains was far more effective in the short and long-terms
Petrella et al. 2007 [97]	Canada	158 patients (79 females, 79 males, aged = 16–33)	Within 48 h of trauma	T0=baseline, T1=4 days, T2=8 days, T3=30 days, T4=90 days	1, 2 LAS	HA+RICE	PL+RICE	--	VAS (0–10 cm), pain when bearing weight and walking 20 meters, patient satisfaction with therapy, duration to return to pain-free and handicap-free sport, recurrent ankle sprains, total days missed from participating in primary sports, and adverse events	When compared to PL, periarthral HA therapy for acute ankle sprains was far more effective in the short and long-terms

(Continued)

Table 2. Continued.

Author	Country	Subject Description	Duration	Time Of Test	Level Of Injury	Treatment 1	Treatment 2	Treatment 3	Outcome Variables	Main Results
Punt et al. 2015 [74]	Switzerland	90 patients (39 females, 51 males)	–	T0=baseline, T1=6 weeks	1,2 LAS	Nintendo Wii Fit™	TRAD	no exercise therapy	Foot and Ankle Ability Measure, pain during rest and walking, delay before return to sport, patient satisfaction, and effectiveness of the allocated treatment.	Wii Fit™ could be used as an exercise therapy to treat ankle sprain patients.
Razzano et al. 2018 [65]	Italy	61 patients (average age = 23)	Within 48 h of trauma	T0=baseline, T1=5 days, T2=10 days, T3=30 days	1,2 LAS	NIN	sham device	--	Functional impairment (IWS), VAS, Daily Intake of Etoricoxib dosage	NIN can improve short-term outcomes in athletes with acute grade I or II ankle sprain
Tennler et al. 2023 [61]	Germany	82 patients (age = 14–41)	Within 48 h of trauma	T0=baseline, T1=2 weeks, T2=8 weeks, T3=6 months, T4=12 months	1,2 LAS	SMART	NORM	--	CAIT, FAAM, isokinetic and isometric strength diagnostics, joint repositioning sense, range of motion, measurements of postural control, gait, run analysis, and jump analysis	SMART could be used as an exercise therapy to treat ankle sprain patients
Toyoshima et al. 2021 [78]	Japan	82 patients (56 males, 26 females, age = 17.4 ± 4.0 years)	Within 25 ± 28 h of trauma	T0=baseline, T1=2 weeks	LAS	A short-leg cast + isometric exercises + EMS	a short-leg cast	--	Side-to-side ankle ROM, the time to RTP	During immobilization, isometric exercise with EMS boosted the total ankle range of motion and decreased the amount of time required to reach RTS
Bradley Wells et al. 2015 [76]	America	Ten patients (average age = 26.7)	2.3 days from injury	T0=baseline, T1=4 weeks, T2=8 weeks, T3=12 weeks	2 LAS	Wear a lace-up ankle brace + RICE	–	--	Self-reported function (FAAM, ADL, NPRS, ALT, YBT), ankle ROM, and pain	This method protects the injured ligament, maintains and restores normal ankle motion

Abbreviations: NRS=numeric rating scale, FADL=foot, and ankle disability index, TRAD=traditional exercises (RICE included rest, ice, compression, and elevation), HVPC=high-voltage pulsed current, KAFTS=consists of eight items to measure ankle joint function, PL=placebo injection, HA=hyaluronic acid injection, VAS=visual analog scale, AEs=adverse events, NIN=noninvasive interactive neurostimulation, CAIT=cumbarl and ankle instability tool (CAIT), FAAM=the foot and ankle ability measurement, SMART (S=sensory stimulation, M=mobilization, A=activation and re-integration, T=transfer to function and performance), NORMT=standard therapy, EMS=electrical muscle stimulation, ADL=activity of daily living, NPRS=numeric pain rating scale, ALT=Y-balance test, RTS=return to sport.

to sport or work [64]. This approach not only consistently reduces swelling but also improves mobility [64]. Mailuhu et al. [56] developed a standardized 8-week neuromuscular training program using APP for patients with grade 2 LAS. It has been demonstrated that this program affects well for athletes and may be a useful immediate treatment option for acute LAS in general. Similarly, Punt et al. [74] and Tennler et al. [61] designed a 6-week training intervention program, and both results recognized that exercise therapy can improve ankle function in patients with LAS by 8–9 points.

3.4.3.5. Ligament fixation Protection method. O'Connor et al. [75] and Wells et al. [76] used ligament immobilization protection for patients with lateral ankle sprains. This is a conservative therapy approach, which is the main objective of ligament preservation [51]. They protect the injured ligament from excessive tension by immobilization in a bandage or cast for 4–12 weeks to achieve moderate healing. For complete recovery, almost a year is needed [57,60,65].

3.4.3.6. Combination of approaches. Athletes, particularly in contact sports (such as basketball and football), may often suffer multiple ankle injuries with typical joint instability, thus requiring a safe and rapid approach to help sports rehabilitation [62]. Therefore, various methods were successfully merged to shorten the period and RTS. Ammendolia et al. [77] used a combined process of ultrasound therapy and cold therapy in patients with grade 1 and 2 LAS, which was effective in relieving the pain intensity and speeding up the time of RTS. However, it was difficult to identify the role of cold therapy and ultrasound therapy separately. In contrast, Toyoshima et al. [78] employed a combined Electrical Muscle Stimulation method using isometric exercise during immobilization, which not only increased total ankle mobility and shortened the time to reach RTS but also optimized single-factor rehabilitation measures by being able to separately identify the roles and benefits of ligament immobilization and protection.

3.4.4. Criteria for RTS in patients with LAS

Criteria for RTS in LAS patients were listed in four of the included studies [1,30,38,70]. Three of these investigations specifically interviewed 347 doctors, 20 athletes, and 103 physical therapists using questionnaires, with 99 doctors with over 15 years of clinical experience [30,38,70]. One prospective diagnostic investigation created and verified a novel clinical composite score ("Ankle-Go" included SLS, mSEBT, SHT, and F8T) that provided a new approach for RTS but lacked crucial elements for performance recovery [1]. Picot et al. [79] statistically classified and defined new decision criteria, including swelling, mechanical ankle instability, strength, range of motion, ability to engage in functional tasks, functional ankle instability perception, and pain perception. However, another study reported that ankle muscle strength was a significant factor to consider when evaluating the ability to perform RTS after suffering LAS [38]. Yokoe et al. [80] also developed a questionnaire consisting of 12 questions based on the recommendations in the current Clinical Practice Guidelines (CPGs) published by the Dutch Orthopaedic Society, reporting that most general orthopedic surgeons would not use the current CPGs recommendations to treat LAS. Therefore, there are no objective RTS decision criteria for LAS patients, as presented in Table 3.

3.4.5. Performance assessment after RTS in LAS patients

The 2 included studies enumerated residual impairments after RTS for LAS and included 687 LAS patients with 54.4% male. McCann et al. [60] assessed self-reported physical function, pain, edema, dorsiflexion ROM, ligamentous laxity, and dynamic postural control in LAS patients within 48 h of RTS, reporting that LAS individuals had persistent deficits and activity restrictions linked to dorsiflexion range of motion, ankle laxity, and dynamic postural control. Similarly, Lam et al. [53] assessed patients following RTS and reported that a large number of the patients experienced impairments in pain (65.1%), function (86.2%), or disability (35.6%). Structural or functional impairments and activity limitations following LAS were not corrected upon RTS. Therefore, deficits present after RTS may persist and endure over time (Table 4).

3.4.6. The relationship between test assessment and time of RTS in LAS patients

The four included studies summarized the variables predicting the RTS time from LAS. A total of 979 LAS patients participated in the experiments, with approximately 52% males. Cross et al. [81] discovered that activity level and self-reported functional indicators were significant predictors of RTS time. On the other

Table 3. Criteria for RTS in patients with LAS.

Author	Country	Subject Description	Evaluator	Duration	Research Type	Criteria For RTS
Aguilaniu et al. 2021 [95]	Belgium	109 respondents (from Belgium, France, and Switzerland);	Included physicians with and without Sports Medicine education, varied levels of experience, and athletes	–	Survey report	Pain, swelling, ankle range of motion, ankle muscle strength, functional ankle instability (perceived instability), proprioception (deep sensitivity), ability to engage in practical tasks (balance, jumping, running, cutting movements, ..), mechanical ankle instability (pathological laxity), and other criteria.
Aguilaniu et al. 2023 [30]	Belgium	212 respondents	Included 109 physicians and 103 physiotherapists	–	Survey report	Ankle muscle strength
Picot et al. 2023 [79]	France	64 patients (including 36 women and 28 men, 33.7 ± 13.2 years old) who had suffered a first or recurrent ankle sprain	It included one surgeon and one physiotherapist	After LAS 2 months and four months	Prospective diagnostic study	The ankle-GO test consists of functional tests (including SLS on a firm surface, mSEBT, SHT, and F8T) and self-reported questionnaires (including FAAMadl and FAAMsport).
Yokoe et al. 2021 [80]	Japan	129 respondents	It included forty-eight private clinics (48 doctors) and 28 hospitals (81 doctors), and 99 respondents had experience as an orthopedic surgeon >15 years.	–	Survey report	Pain, the absence of instability, the time after LAS, no limitation of ankle ROM, and the lack of swelling

Abbreviations: RTS = return to sports.

hand, Noda et al. [82] concluded that the LAS severity grade could predict the time to resume sports. Similarly, another theory was proposed by Toyoshima et al. [78] suggesting that ankle joint mobility was a predictor of RTS time. Gender was also included as a predictor of RTS time by Lam et al. [53] While no valid criteria for RTS after LAS were concluded, and return to sport was primarily a time-based decision [53,67,83]. Time played a key role in the decision-making choice of RTS, which was also the most practical and easily measured parameter, thus used as an assessment criterion and a process baseline to describe RTS for LAS. Therefore, exploring other potential factors contributing to the RTS time for LAS is critical during clinical settings and sports rehabilitation, as presented in Table 5.

4. Discussion

4.1. Rehabilitation measures for LAS patients to RTS

This systematic review aimed to create a continuum of rehabilitation processes by exploring the strategies associated with RTS after LAS. A further aim was to report the complete process from LAS for returning to sport/work/post-training. For most LAS cases, early treatment may help speed up recovery from LAS but still requires a long-term prognosis [84]. All rehabilitation measures were the primary strategy during the acute phase of LAS in the included articles, which rarely required surgical treatment [59], thus excluding the grade III injuries (treated with surgery) from this review. Several articles in the rehabilitation therapy statistics failed to include a sufficient number of individuals for each injury level, thus lacking information on the number of patients with three levels of LAS. Following previously reported guidelines [85], it is necessary to gather demographic data (age, height, weight, injury severity classification, sports history, and previous LAS) before the rehabilitation treatment. The reason for the lack of demographics for grade-specific LAS was due to the difficulty in determining whether a ligament was

Table 4. Evaluation of patients with LAS after RTS.

Author	Country	Subject Description	Duration	Level Of Injury	Outcome Variables	Secondary Outcomes	Main Results
McCann et al. 2018 [60]	America	50 patients (15 Females, 35 Males; 17.6 ± 3.6 years; 178.3 ± 11.5 cm; 85.3 ± 27.0 kg)	Within 48 h of RTS	At least one day of activity time loss	Self-reported physical function, pain, edema, dorsiflexion ROM, ligamentous laxity, dynamic postural control	DRTS	Athletes demonstrated increased ankle ligamentous laxity, reduced self-reported function, dorsiflexion range of motion, and dynamic postural control at RTS.
Lam et al. 2023 [53]	America	637 patients (males = 53.2%)	medically cleared to return to sport within 60 days.	Each patient had LAS that restricted from sport at the time of injury	Scores for health status (Global Rating of Change), pain (Numeric Pain Rating Scale), function (Global Rating of Function), and disability (Global Rating of Disability).	DRTS	Many noted deficits related to pain (65.1%), function (86.2%), or disability (35.8%) at RTS.

Abbreviations: LAS=lateral ankle sprain; return to sports; the days to RTS (represented the total number of days from injury onset until the participant returned to unrestricted sporting activity).

ruptured in the first few days after an injury and that pain, swelling, and muscle tightness make it difficult to judge the grade of the injury, which was consistent with the view of Witjes et al. [86]. Determination of the injury grade, then take the correct actions to promote a speedy recovery. Future studies are recommended to employ additional techniques for evaluating LAS grade before the execution of rehabilitation treatment for RTS.

Outcome indicators assessed the effectiveness of rehabilitation measures and preparation for RTS [85]. As previously suggested [69,87,88], a total of 16 elements were included in the PAASS framework to evaluate ankle injuries, pain severity, sensorimotor control, athlete perception/readiness, and motor/functional performance to help RTS decisions. However, the findings revealed that more indicators than those listed in the framework guidelines should be considered, which include adherence to rehabilitation, tests of foot and ankle function, patient satisfaction with treatment, time to return to pain-free and disability-free movement, number of recurrent ankle sprains, the effectiveness of allocated treatment, activities of daily living and motor subscales. As a result, we discovered that increasing numbers of studies treated the RTS for LAS not just as a decision but as a composite of multiple factors.

No clinically consented guidelines for LAS were reported in the literature, and rehabilitation treatment strategies were limited [57]. Non-surgical therapy could produce good to excellent outcomes for LAS during the acute phase of injury. Additionally, transdermal therapies, laser therapies, energy transfer capacitive and resistive therapies, and other forms of electrotherapy are also available [58,59], which are considered conservative treatment methods. Ankle sprains were acute and often self-limiting conditions, and longer follow-ups may make recovery difficult to attribute to interventions alone. Thus, integrated rehabilitation approaches shall be considered [70]. The rehabilitation programs included in the review were mostly based on PRICE [89] (Protection, Rest, Ice, Compression, and Elevation) principles. Most of the intervention techniques of the rehabilitation measures in Table 2 were innovative treatments. The outcome and decision-making indicators should be considered to define criteria, incorporate demanding factors into rehabilitation programs, and use fused methods to achieve rapid rehabilitation.

Currently, there is no consensus on the best clinical treatment for LAS [48]. Several methods and interventions were included in this systematic review, and the definition of “TRAD” in the table is not only traditional treatment but also relative to the therapy before the intervention. Therefore, no indirect comparative variables formed a closed-loop network loop. As a result, a META mesh diagram could not be used for the module on rehabilitation measures for LAS to derive the optimal clinical treatments. Future studies shall focus on rehabilitation in the acute phase of LAS to identify the most appropriate

Table 5. The relationship between test assessment and time of RTS in patients with LAS.

Author	Country	Subject Description	Level Of Injured	Time			Test			Outcome Variables	Main Results
				After Sprain	After RCT	After sprain	Completed functional testing specific to sports	After RCT	After RCT		
Cross et al. 2002 [81]	America	20 college athletes (7 males, 13 females; mean age = 19.2 ± 1.1 years)	Immediate acute phase after the LAS	Within 24 h, acute LAS	The final data was collected on the day following the subject's total return to competition.	Three self-reported measures (global function question, SF36PF, visual analog pain scale) and four clinical measures (AROM, ankle dorsiflexion strength, ankle plantar flexion strength, ambulation status)				DAYS	A statistically significant relationship between DAYS and the global function question ($r = 0.22$), the SF36PF ($r = 0.28$), and the patient's ambulation status ($r = 0.27$)
Noda et al. 2023 [96]	Japan	240 athletes (149 males, 91 females, age = 15.3 ± 2.5 years)	Immediate acute phase after the LAS	Within three days after acute LAS	Returned to previous sports level	SLL test	Performed competition-specific movements, deep squats, and single-legged side			DAYS, time to jog	The SLL test was found to affect the time to fly and RTS significantly
Toyoshima et al. 2021 [78]	Japan	82 patients (56 males, 26 females, age = 17.4 ± 4.0 years)	Immediate acute phase after the LAS	After diagnosis and the day before the short-leg cast	Able to participate in all sports activities	--	Measurement of ankle ROM			DAYS	The side-to-side difference in total ankle ROM significantly correlated with time to RTS.
Lam et al. 2023 [53]	America	637 patients (males 53.2%)	Immediate acute phase after the LAS	After diagnosis	RTP within 60 days	Health status (Global Rating of Change), pain (Numeric Pain Rating Scale), function (Global Rating of Function), and disability (Global Rating of Disability).	Summarize scores for health status (Global Rating of Change), pain (Numeric Pain Rating Scale), function (Global Rating of Function), and disability (Global Rating of Function), and disability (Global Rating of Function).			DAYS	The differences between sexes affect the time to RTS

Abbreviations: SF36PF = Short Form-36 Physical Function scale; AROM = active range of motion; DAYS = The days to return to sport; SLL test = the patients were classified into the following four levels through by a series of tests; RTS = return to sports; LAS = lateral ankle sprain

approach early on after quantitative comparisons. Specifically, two directions deserve consideration; firstly, the time of RTS should be one of the criteria, and the number of LAS recurrences should be the secondary outcome indicator. Shorter RTS time from injury and fewer recurrences after RTS shall be employed to define the rehabilitation protocol. A blank control group may be set up in the experimental design of future studies to investigate the potential indirect variables.

4.2. Criteria for RTS in LAS patients

There are no validated criteria for RTS following the treatment of LAS [40]. To help and guide RTS in LAS patients, the International Ankle Consortium categorized the outcome of RTS decisions for LAS into patients returning to pre-injury or higher levels and those not, i.e. RTS or lower levels of the sport. However, it is difficult to evaluate the actual game, sport, or tangible pre-injury performance, thus being vital to accurate measures for decision-making [61].

Given the consensus and partially concordant results, decisions about RTS for LAS should be based on the assessment of movement ability, static balance, patient-reported outcomes, range of motion, and strength [67]. Appropriately timed and safe RTS for injured athletes results from a rehabilitative approach [50]. This is consistent with the findings and reaffirms that RTS with LAS is a multi-factorial and continuous process. In addition to the assessment methods listed in the module on outcome indicators for rehabilitation measures, most physicians defined the absence of pain, instability, time since LAS, unrestricted ankle ROM, and absence of swelling as the reference criteria to determine the pre-RTS decisions [90]. In the assessment of pre-RTS decision-making, physicians rarely used quantitative measures with the patients [91]. Although numerous available assessments for pre-RTS decision-making, clinicians still employed the absence of pain as the most commonly used diagnostic criterion based on experience, which may also be the reason why premature RTS in LAS patients may lead to multiple recurrences. Therefore, only a combination of quantitative and qualitative assessment methods could assist physicians in making RTS decisions [38]. It is recommended that future studies incorporate instrument measurement into the evaluation procedure in the assessment method to determine whether quantitative methods reach the qualitative aspect of RTS decision-making.

4.3. Evaluation of patients with LAS after RTS

Patients with LAS showed recurrent injuries after RTS [47,52], and the residual injuries after RTS were responsible for the recurrences. The dorsiflexion ROM and postural control after RTS were similar to those of CAI patients [47]. However, those outcomes leading to recurrent LAS and chronic ankle instability remained unclear due to multiple recurrences [92]. The deficient outcomes listed in the results may not represent all deficient outcomes in RTS, and how these outcomes would affect the long-term effects deserves further investigation. Therefore, follow-up studies are recommended to address the residual structural and functional impairments and activity limitations and explore whether the deficits are prospective predictors of recurrent injury and CAI.

According to the findings in the current literature, the appraisal of pain, rate of recovery, and readiness for RTS may be influenced by several factors, including the severity of the injury, injury history, playing status, playing time history, and duration of the season [40], which could affect the overall mood (psychological readiness) and expectations of RTS. However, the decision to RTS could be made while balancing full recovery with the risk of adverse outcomes [93], or considering the risk of recurrent injury, persistent injury, or chronic disease when considering RTS after LAS [55,94]. Therefore, further work in future clinical research may focus on methodologies for evaluation and rehabilitation to guide comprehensive treatment and assist the decision-making of RTS.

4.4. Summary

This systematic review describes the entire process from LAS to post-RTS, and the discussion highlights the variables of each stage. According to RTS guidelines [94], we divided the RTS process into three components: return to “participation”, return to “performance”, and return to “exercise”. Using the time

from injury to RTS as a baseline for comparison, the process of “return to participation” should include the recording of essential patient information, rating of injury level, treatment of rehabilitation measures, and standardized assessment (not medically, physiologically, or psychological “readiness”). The process of “RTS” should include RTS with minor deficits that fail to return to previous levels, and “Return to performance” refers to the process of reaching the desired level of satisfaction or prior level of performance without the risk of chronic illness or recurrences. The time frame is determined by the extent of tissue injury and healing, a process influenced by complex multiple variables. Although no standardized recovery criteria were reported in the literature, a new definition of the RTS process was proposed in this study.

4.5. Limitation

The process of LAS to RTS is a long-term and complex process. This complexity has led to a substantial volume of research, yet the content is relatively fragmented. Therefore, there are limited studies that meet the screening criteria of this study. This scarcity might introduce inaccuracies in the results, as a small sample size of relevant studies may not comprehensively represent the full spectrum of the LAS to RTS process. Moreover, due to the paucity of studies, observational research designs were incorporated into this review. Observational studies are highly susceptible to confounding factors. These factors can distort the relationship between variables of interest, such as the factors influencing the transition from LAS to RTS. As a result, the data extracted from these observational studies may not be comprehensive, which potentially led to misinterpretations of the true nature of the LAS to RTS process. Further limitations in this review article shall be noted considering the multiple factors in the RTS process, which may be direct evidence and expected criteria. Currently, no consensus on evaluation and metrics measurement for LAS patients, RTS decisions, or post-RTS deficits were reported.

Therefore, following a comprehensive literature search, this review article provided a thorough discussion and summary of the rehabilitation approaches and timeline for the process of LAS to post-RTS and summarized a standardized procedural paradigm for the rehabilitation care of RTS with different LAS degrees. However, the physiological environment and individual motor capacities may lead to uncertainties for the RTS time and strategy. Thus, no unified paradigm standard, especially for a process entirely of uncertainties, could be found and summarized from the current literature. However, an “all-suit” model shall be focused. The current study established dynamic paradigms and identified the point of balance with retained mobility and RTS. Therefore, in future studies, the rehabilitation treatment measures, decision-making, and defects of the RTS of the LAS from the experimental, clinical, and theoretical fields shall be investigated *via* the dynamic paradigm system of RTS with the inclusion of new variables and linear relations.

5. Conclusion

In the current literature, no studies have identified the application of a standard paradigm for rehabilitation care for RTS of LAS. Therefore, we summarized and discussed the time for LAS to RTS, the rehabilitation plan, outcome indicators, and the assessment of return to performance after decision-making. Based on the time from LAS to RTS, we divided into three processes, recovery participation, recovery performance, and RTS. However, there were no standardized outcome metrics for each process. Therefore, future studies should explore RTS following LAS in relation to various facets and areas of rehabilitation treatment measures, decisions, and shortcomings.

Authors' contributions

CRedit: **Hanhui Jiang**: Conceptualization, Data curation, Methodology, Writing – original draft; **Qichang Mei**: Conceptualization, Methodology, Project administration, Supervision, Writing – review & editing; **Yuan Wang**: Conceptualization, Formal analysis, Writing – original draft; **Xiaoyi Yang**: Conceptualization, Methodology, Writing – original draft; **Bernard XW Liew**: Methodology, Writing – review & editing; **Justin Fernandez**: Supervision, Writing – review & editing; **Yaodong Gu**: Conceptualization, Writing – original draft, Writing – review & editing.

Disclosure statement

No potential conflict of interest was reported by the author(s)

Funding

This study was supported by the National Natural Science Foundation of China (12202216), Ningbo Natural Science Foundation (2023J128), and the "Mechanics+" Interdisciplinary Top Innovative Youth Fund Project of Ningbo University (GC2024006), and K.W. Wong Magna Fund in Ningbo University.

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Data availability statement

Will be available upon request from the corresponding author.

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