

REVIEW OPEN ACCESS

An Investigation Into the Measurement of Injury Severity in Running-Related Injury Research: A Scoping Review

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ABSTRACT

Understanding injury severity is essential to inform injury prevention practice. The aims of this scoping review were to investigate how running-related injury (RRI) severity is measured, compare how it differs across studies, and examine whether it influences study outcomes (i.e., injury rates and risk factor identification). This scoping review was prospectively registered with Open Science Framework. A systematic electronic search was conducted using PubMed, Scopus, SPORTDiscuss, MEDLINE, and Web of Science databases. Included studies were published in English between January 1980 and December 2023, investigated RRIs in adult running populations, and included a measure of injury severity. Results were extracted and collated. Sixty-six studies were included. Two predominant primary criteria are used to define injury severity: the extent of the effect on running and/or the extent of the physical description. When secondary definition criteria are considered, 13 variations of injury severity measurement are used. Two approaches are used to grade injury severity: a categorization approach or a continuous numerical scale. Overall, the measurement of RRI severity is relatively inconsistent across studies. Less than half of studies report incidence rates per level of injury severity, while none report specific risk factors across levels, making it difficult to determine if the approach to measuring injury severity influences these study outcomes. This lack of information is possibly contributing to inconsistent rates of RRIs reported, and the lack of clarity on risk factors.

1 | Introduction

The consequences of running-related injuries (RRIs) are far reaching [1], and can cause negative physical [2], psychological [3], and social outcomes [4]; disruptions and time-loss from training [5]; and significant financial cost (from time lost from work and the cost of medical treatments) [2]. With high rates of RRIs [6], the development of effective injury prevention strategies is essential.

There are two primary steps in the process of preventing injuries: firstly, to establish the magnitude of the injury problem (e.g., incidence and prevalence rates), and secondly, to identify their risk factors [7, 8]. Most RRI studies to date appear to capture injury dichotomously (i.e., considering someone as either injured or uninjured) [9, 10], despite there clearly being varying levels of injury severity [11, 12]. It is important to capture the severity of injury because it provides meaningful

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insight into the full extent and burden of injuries, helping to determine the appropriate allocation of resources for injury management [13–18]. Furthermore, capturing injury severity over time is crucial for the assessment of the effectiveness of injury prevention or rehabilitation interventions [13, 19, 20]. When investigating risk factors, injury severity is also a key aspect for directing the focus of injury prevention research [21], as different severities of injury may have different underlying risk factors. In addition, a lower severity injury to one structure may itself be a risk factor for a more severe injury to another structure, due to a reduced capacity to control movement and/or due to compensatory protective changes in running technique [22, 23]. A failure to appropriately consider injury severity may in part explain the lack of foundational epidemiological evidence with inconsistencies in both the rates of injury reported across studies [24, 25] and their associated risk factors [23, 26–28]. While some RRI research seems to consider injury severity [9, 11, 12], various approaches to its measurement appear to be employed [29, 30], which may affect study outcomes and impede between-study comparisons (and meta-analyses).

Despite its importance, only one systematic review examining the descriptors used to define RRIs has included RRI severity in their report, but only examined it as a tertiary aim [9]. Therefore, the present study has two aims. Primarily, to investigate how the severity of general RRIs is measured, by (i) describing the injury severity scales used (in terms of the criteria for defining injury severity and its grading) and (ii) comparing to what extent these scales differ. A secondary aim is to examine if the way in which injury severity is measured influences study outcomes, in terms of (i) the rate of injury reported and (ii) the risk factors identified.

2 | Materials and Methods

2.1 | Protocol and Registration

It was deemed appropriate to conduct a scoping review to map the existing evidence on the topic of injury severity in the RRI literature [31–34]. The Joanna Briggs Institute Evidence Synthesis and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis scoping review (PRISMA-ScR) guidelines were followed [33] as these reflect best practice [34] (Appendix S1). This scoping review was registered with Open Science Framework (<https://doi.org/10.17605/OSF.IO/NGJQV>).

2.2 | Information Sources

The search for information sources was limited to fully published research articles from academic journals involving human subjects and published in English between January 1980 and December 2023. Review articles, study protocols, conference proceedings, opinion pieces, commentaries, or case studies were excluded. The search terms were combined using Boolean phrases (Appendix S2). The bibliographies of included articles were also searched for possible sources.

2.3 | Search Strategy

Five authors (AL, KM, EW, AB, and SOC) determined the patient, concept, and context of interest, along with a comprehensive search strategy detailing the search terms, search limits, possible sources of information, and inclusion and exclusion criteria (Appendices S2 and S3). A systematic search was undertaken by one author (AL) on December 1, 2023. Databases PubMed, Scopus, SPORTDiscuss, MEDLINE, and Web of Science were searched, according to the search strategy, for studies that included a measure of injury severity for general RRIs.

2.4 | Selection of Studies

Articles were considered for inclusion in two phases. Firstly, article titles and abstracts were screened by two authors independently (AL and AB), using the predetermined selection criteria. The full texts of those which met the inclusion criteria were independently reviewed by two authors (AL and AB). If the full text could not be obtained, the respective authors were contacted with a request to provide the full text. If the details of the employed injury severity scale were not provided or were unclear, respective authors were contacted for clarification. Any disagreements regarding inclusion were mediated through discussion, or by a third reviewer if necessary (KM).

2.5 | Data Extraction and Analysis

Data extraction was planned a priori with a data extraction form developed to aid the process and summarize relevant information. This form was tested in a pilot phase in which two authors (AL and AB) independently reviewed and extracted a percentage of the included studies. To assess consistency and the effectiveness of the data extraction form, authors compared their data extraction. The data extraction form was updated iteratively to ensure it could comprehensively capture the diversity of injury severity scales. The full data extraction process was then independently performed by two authors (AL and AB). Extracted data included: authors' names, publication year, study design, study length, study aim/purpose, sample size, sex, age, type of runner, measure of injury severity used (definition criteria used, grading approach employed, citation if provided), definition of injury (if provided), and study outcomes (e.g., incidence rate). Table 1 details the phraseology that will be used in order to report and discuss injury severity.

A content analysis was conducted to determine the definition criteria used to measure injury severity [35]. Visual representations of each injury severity scale were developed, with each level of injury plotted on a horizontal scale (Appendices S4–S6). If a study defined the least severe level of injury as “no injury” (or other equivalent phraseology), this level was included in the visual representation, but not considered a level of injury. An amalgamated comparison scale of injury severity was developed by the authors for each primary criterion (e.g., effect on running) by comparing all individual injury severity scales associated with that primary criterion (Appendices S4–S6). Where no length of time was specified for a level of injury (e.g., a level

defined solely as an “inability to run”), the minimum possible length was assumed (i.e., at least 1 day).

A rate of injury was considered an “incidence” rate if it was reported as the number of new injuries that were sustained during

a specific period of time, whereas they were considered a “prevalence” rate if the rate reflected the proportion of people who were injured at a single point in time [36].

3 | Results

3.1 | Overview of Findings

The electronic search identified 7618 studies. After duplicates were removed ($n = 1288$), 6330 titles and abstracts were screened. In total, 180 full texts were assessed for eligibility, of which 114 were excluded. Primary reasons for exclusion were injury severity was not measured and wrong outcome measure (i.e., RRIs were not investigated) (Figure 1; Appendices S2 and S3). Reviewing bibliographies identified no further articles, resulting in a total of 66 studies being included for analysis (Figure 1).

3.2 | Article Information

Publication years ranged from 1986 to 2024, with 2021 being the year with most publications (21%, $n = 14$) (Figure 2) (*Note:* One study has a publication date of January 2024, despite being identified in the December 2023 search). The majority of studies were prospective (64%, $n = 42$), followed by cross-sectional (27%, $n = 18$), and retrospective (9%, $n = 6$). Of the prospective studies, the majority were <6 months in duration (69%, $n = 29$). Primarily, studies were conducted to examine injury epidemiology (e.g., rates of injury) (82%, $n = 54$) and risk factors (52%, $n = 34$).

3.3 | Population Information

A total of 37 395 participants were included across studies, with 55% identifying as male and 45% as female (Figure 2). The average age of participants was 37.6 ± 11.1 years. The majority of studies examined recreational runners (30%, $n = 20$), marathon/half-marathon runners (24%, $n = 16$), or trail runners (18%, $n = 12$) (Figure 2).

3.4 | Measurement of General RRI Severity

In line with the primary aim of this review, the methods used to measure injury severity have been grouped into the description of the injury severity scales (Sections 3.4.1 and 3.4.2) and comparing the extent to which these scales differ (Section 3.5) (Appendix S7).

TABLE 1 | Phraseology used to report and discuss general RRI severity.

Phraseology	Explanation
Injury severity scale	The measurement scale used in each individual study, being made up of the <i>definition criteria</i> and a <i>grading approach</i>
Definition criteria	How injury severity was defined (e.g., “effect on running”)
Grading approach	How each scale progresses from least to most severe level of injury
Level of injury	Each individual point on an injury severity scale (e.g., “mild injury”)
Comparison scale	An amalgamated scale of injury severity developed by the present authors to represent the scope of injury severity captured by each definition criterion (described below)

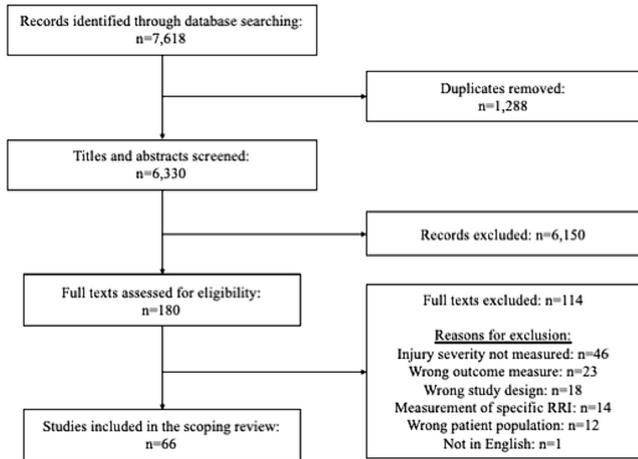


FIGURE 1 | Preferred Reporting Items for Systematic Reviews and Meta-Analysis scoping review (PRISMA-ScR) flow diagram.

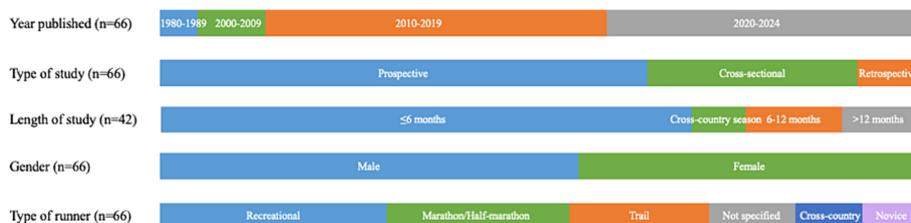


FIGURE 2 | Article and population information. *Note:* The year published, 2020–2024, spans 5 years, while the other periods span 10 years.

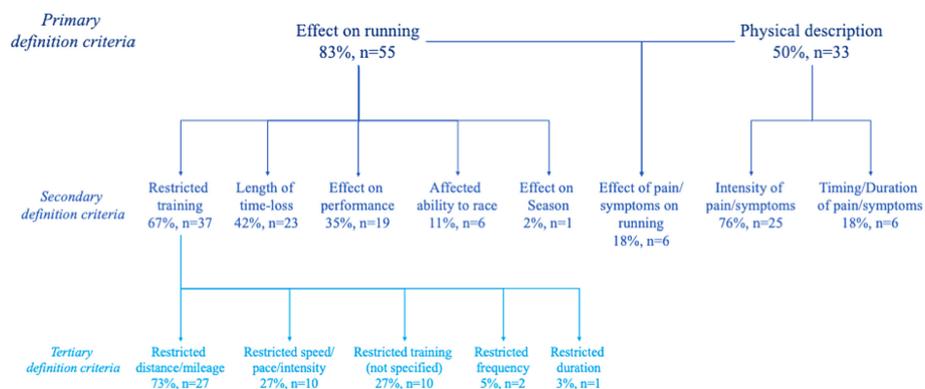


FIGURE 3 | Flowchart of primary, secondary, and tertiary definition criteria.



FIGURE 4 | Combination of the primary and secondary definition criteria of injury severity. *Note:* Multicolored segments relate to primary or secondary definition criteria used in combination with one another (e.g., effect of running AND physical description, represented by the blue and green segments). All primary and secondary definition criteria were used in an AND combination. Secondary definition criteria are organized based on descending frequency of use, relative to the primary definition criterion.

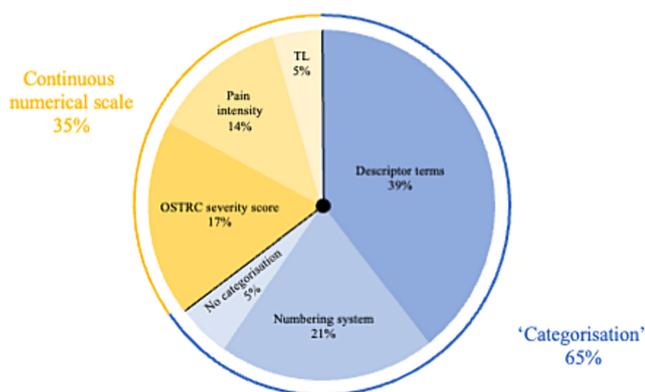


FIGURE 5 | Grading approaches of injury severity used. *Note:* OSTRC, Oslo Sports Trauma Research Centre; TL, length of time-loss. Percentages are in relation to the total number of included studies [$n = 66$].

3.4.1 | Description of the Criteria for Defining Injury Severity

Injury severity was defined using primary, secondary, and tertiary definition criteria (Figures 3 and 4, Appendix S8). There were two primary definition criteria identified: “effect on running” and “physical description” (Figure 3), used in three combinations—(i) “effect on running” in isolation, (ii) “effect on running and physical description,” and (iii) “physical description” in isolation (Figure 4). Within the “effect on running” criterion alone, there were six secondary definition criteria, with “restricted training” being the most common (67%) (Figure 3, Appendix S8). Five tertiary definition criteria

were identified within “restricted training” alone, with “restricted distance/mileage” being the most common (73%) (Figure 3, Appendix S8). Three secondary definition criteria within “physical description” were identified, with “intensity of pain/symptoms” being the most common (76%) (Figure 3, Appendix S8). Considering all secondary definition criteria combinations, 13 different injury severity scales were used across studies (Figure 4).

3.4.2 | Description of the Grading of Injury Severity

Two approaches to the grading of injury severity were identified: a categorization scale or a continuous numerical scale (Figure 5, Appendix S7). Between two and six levels of injury were used in the categorization approaches (Appendix S9). Descriptor terms (e.g., mild, moderate, and severe), a numbering system (e.g., Grade I, Grade II, and Grade III), or no system (i.e., only including an explanation of each level) was used to categorize these levels (Figure 5). Five studies measured injury severity on a continuous numerical scale but subsequently translated it into a categorical scale for their analysis and reporting, and therefore, these studies were included in the categorization grading approach.

For those that used a continuous numerical scale, a minimum and maximum level was defined, however no further description of the intermediate levels was provided. The majority of these studies used either the Oslo Sports Trauma Research Centre (OSTRC) severity score from 0 to 100, a pain intensity scale, or the length of time-loss in days (Figure 5).

The OSTRC severity score was the most commonly cited tool, used in 24% ($n=16$) of studies. Of these, the OSTRC health version questionnaire (OSTRC-H) was used in 69% ($n=11$) and the OSTRC overuse injury questionnaire (OSTRC-O) was used in 31% ($n=5$). The majority were classified as continuous numerical scales (69%, $n=11$), using the OSTRC 0–100 severity score. The remaining 31% ($n=5$) applied a categorization in addition to using the continuous OSTRC severity score. In the majority of these latter studies (80%, $n=4$), injuries were predominately categorized as “no problem” (severity score = 0), a “problem” (severity score > 0), or a “substantial problem” (if Questions 2 and 3 scored $\geq 13/25$) [2, 37–39]. Just one study [40] applied a different categorization in which injuries were classified as mild, moderate, or severe.

3.5 | Comparison of the Extent to Which Injury Severity Scales Differ

Following examination of the description of injury severity scales, a comparison across scales took place to examine the extent to which they differ. Individual scales were first grouped based on the primary definition criteria, and then compared with one another according to their secondary definition criteria and grading approach to report on the scope of injury severity captured, and assess the consistency of RRI severity measurement. An amalgamated comparison scale for the primary definition criteria of “effect on running” (Figure 6) and “effect on running AND physical description” (Figure 7) was developed. It was not possible to develop a comparison scale for “physical description” in isolation as different secondary criteria were used.

3.5.1 | Effect on Running

The comparison scale identified two broad aspects of injury severity in studies using “effect on running” in isolation (50%, $n=33$): restricted training, and time-loss, with time-loss representing the majority of this scale (Figure 6). Twelve levels, which are not equidistant from one another, were identified, with the most frequently used level being a stoppage of running for 1 day (48%, $n=16$). Ten studies (30%) used a scale that captured the entirety of this comparison scale.

Scales could be grouped further with consideration of the secondary definition criteria (Appendix S7) with “length of time-loss” in isolation ($n=13$) and “restricted training AND length

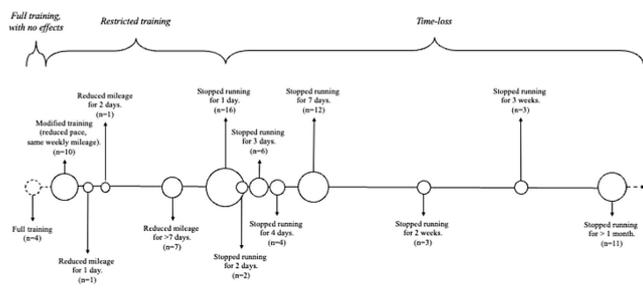


FIGURE 6 | Comparison scale of injury severity for the “effect on running” primary definition criterion ($n=33$). Note: Each circle represents a level of injury. The size of the circles indicates the number of studies that used the relevant category of injury.

of time-loss” ($n=9$) the most frequently used combinations (Figure 4, Appendix S5).

In relation to “length of time-loss” in isolation ($n=13$), the injury severity scales seem to be similar to one another, typically using 1 day of time-loss as the least severe level of injury, and either at least 21 days (3 weeks) or 28 days (4 weeks) as the most severe (Appendix S5). Additionally, most studies (62%, $n=8$) recognized a length of time-loss for 7 days as a level of injury. Three studies did not provide any categorization alongside the length of time-loss [41–43] (i.e., they did not define mild/moderate/severe injuries), three studies recognized two levels [44–46], while seven studies recognized between four and five levels of injury [47–53]. Typically, “slight” injuries resulted in 1–3 days of time-loss, “minor” injuries resulted in 4–7 days of time-loss, “moderate” injuries resulted in 8–28 days of time-loss, and “severe” injuries resulted in more than 28 days of time-loss.

With regard to “restricted training AND length of time-loss” ($n=9$), restricted training was defined as reduced pace, reduced mileage, or both (Appendix S5). Three of the nine studies appear to use the same scale entirely, for the least and most severe levels of injury, the number of levels defined, and the definition of these levels [54–56]. The remaining six studies do not align however, with no commonality across the least or most severe levels, the number of levels, or the definition of these levels [29, 57–61].

3.5.2 | Effect on Running AND Physical Description

The comparison scale identified three broad aspects of injury severity in studies using an “effect on running AND physical description” (33%, $n=22$): full training with pain, restricted training with pain, and time-loss (Figure 7). Ten levels, which are not equidistant from one another, were identified, with the most frequently used levels being a stoppage of running for at least 1 day (100%, $n=22$) and pain during running with restrictions (86%, $n=19$). Some scales specified restrictions in training as distance, speed, or duration. However, this was not consistent across studies, and so a general training restriction was defined in the comparison scale. Four studies (18%) appear to have used a scale that captured the entirety of this comparison scale [62–65].

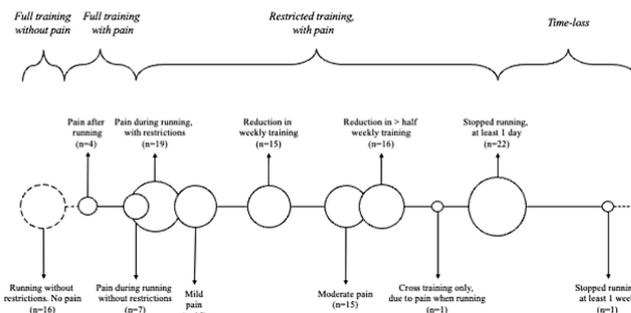


FIGURE 7 | Comparison scale of injury severity for the “effect on running AND physical description” primary definition criterion ($n=22$). Note: Each circle represents a level of injury. The size of the circles indicates the number of studies that used the relevant category of injury.

TABLE 2 | Incidence rate and frequency of injuries suffered across different levels of injury severity.

Study	Least to most severe levels of injury					
	Least severe level					Most severe level
(a) Incidence rate reported across different levels of injury severity ($n = 9$)						
Marti et al. (1988) [58]	62%	63%	44%			
Marti (1988) [57]	29%	26%	14%			
Kerr et al. (2016) [44]	60%	11%				
Kluitenberg et al. (2016) [64]	58%	29%	23%	26%	10%	8%
Matos et al. (2020) [51]	66%	26%	8%			
Torsedahl et al. (2020) [66]	49%	9%				
Toresdahl et al. (2022) [67]	49%	10%				
Toresdahl et al. (2022) [68]	12%	2%				
Stenerson et al. (2023) [40]	37%	33%				
(b) Frequency of injuries suffered across different levels of injury severity ($n = 18$)						
Lun (2004) [29]	NR	NR	NR	NR	NR	24%
Parker et al. (2011) [55]	44%	56%				
Theisen et al. (2014) [47]	28%	20%	22%	30%		
Malisoux et al. (2015) [48]	44%	20%	21%	16%		
Malisoux et al. (2016) [49]	SS: 27% MCS: 21%	SS: 7% MCS: 24%	SS: 41% MCS: 36%	SS: 25% MCS: 18%		
Messier et al. (2018) [59]	48%	52%				
Begizew, Grace, and van Heerden (2019) [50]	23%	15%	33%	29%		
Hayes, Boulos, and Cruz (2019) [69]	75%	25%				
Franke et al. (2019) [40]	50%	50%				
Malisoux et al. (2020) [46]	SfS: 54% HS: 69%	SfS: 46% HS: 31%				
Moreno et al. (2020) [52]	21%	26%	53%			
Gajardo-Burgos et al. (2021) [70]	19%	27%	34%	14%	7%	
Gonzalez-Lazaro, Arribas-Cubero, and Rodriguez-Marroyo (2021) [71]	75%	25%				
Gutiérrez-Hellín et al. (2021) [53]	14%	51%	35%			
Thorpe, Blockman, and Burgess (2021) [72]	33%	67%				
Viljoen et al. (2021) [65]	23%	26%	33%	18%		
Warne et al. (2021) [56]	6%	19%	20%	30%	25%	
Zapata-Rodrigo et al. (2023) [73]	69%	20%	8%	3%		

Abbreviations: HS, hard shoe; MCS, motion control shoe; NR, not reported; SfS, soft shoe; SS, standard shoe.

Considering the secondary definition criteria (Appendix S8), these scales could be grouped further, with one dominant approach identified: “intensity of pain AND restricted training AND effect on performance” ($n = 15$) (Appendix S6). All studies that used this approach used the OSTRC-H or -O tools.

These studies used this standardized tool in the same manner: the least severe level of injury was determined consistently by using the OSTRC severity score of 0–100, the number of levels was consistent (either four or five levels, represented by the scoring system of 0, 8, 17, 25 or 0, 6, 13, 19, 25, depending

on the relevant question), and the description of these levels was consistent (e.g., reduced training volume to a minor, moderate, or severe extent), although there were slight differences between the health (OSTRC-H) and overuse injury (OSTRC-O) versions.

3.5.3 | Physical Description

It was not possible to develop a comparison scale for studies using “physical description” in isolation ($n = 11$) because the secondary criteria differed across studies, and the levels of injury were often not accompanied with a comparable description (Appendix S4). However, eight studies (73%) using “intensity of pain/symptoms” in isolation as a secondary criterion used a numerical rating scale from 0 to 10 to rate the intensity of pain (with lower scores correlating with less severe pain). This approach appears to facilitate consistency in measuring intensity of pain.

3.6 | Influence of Injury Severity Measurement on Study Outcomes

In line with the secondary aim, six study outcomes were identified, with rates of injury (i.e., investigation into the incidence and/or prevalence of RRIs) (82%, $n = 54$) and risk factor investigation (53%, $n = 35$) being the most common. Other outcomes included investigating consequences of injury (11%, $n = 7$), RRI prevention (9%, $n = 6$), and research methodologies (5%, $n = 3$).

3.6.1 | Rates of Injury

Incidence rates were reported in 89% ($n = 48$) of the 54 relevant studies, with an overall average rate of $43.0\% \pm 20.5\%$ (range: 0.6%–86.0%). Prevalence was reported in 28% ($n = 15$), with an overall average rate of $37.4\% \pm 26.2\%$ (range: 0.0%–90.0%). Less than half (48%, $n = 26$) reported an incidence rate for each specific level (Table 2a; *Note*: only incidence rates were examined due to low numbers of studies reporting prevalence). With different definitions of severity employed across studies, it was not possible to obtain an accurate average incidence rate per level of severity. However, a trend can be observed with levels of lower severity typically being associated with a higher incidence rate (Table 2a). While not providing an incidence rate for each level of severity, some studies reported the frequency of injuries at each level, out of the total number of injuries. However, there seems to be no obvious trend as some studies reported that injuries of a lower severity were more frequent, while others reported the opposite (Table 2b).

The anatomical locations (65%, $n = 35$) and types (33%, $n = 18$) of injuries sustained were reported in some studies. However, few report information on the severity of injuries per location [30, 38, 58, 74–76] or type [58] of injuries (Appendix S10).

3.6.2 | Risk Factor Investigation

Of the 35 studies examining risk factors, 80 potential risk factors were investigated and grouped into six categories:

training-related, socio-demographic, health-related, sport history, biomechanical, and psychosocial (Appendix S11). No studies reported risk factors for specific levels of injury, and in consequence, no studies compared different risk factors for specific levels of injury severity. This makes it challenging to examine whether the measurement of injury severity directly influences the risk factors identified. Therefore, the primary definition criteria were compared across the studies that identified the most frequently identified statistically significant risk factors: previous injury (37%, $n = 13$), running inexperience (20%, $n = 7$), and high weekly mileage (17%, $n = 6$) (Table 3).

Studies which defined injury severity by an “effect on running” in isolation identified previous injury and running inexperience as significant risk factors most frequently, when compared to studies that used other primary definition criteria (Table 3). No clear pattern was evident for high weekly mileage.

4 | Discussion

The aims of this scoping review were twofold. Primarily, to investigate how the severity of general RRIs is measured, by (i) describing the injury severity scales used (in terms of the criteria used to define injury severity and its grading) and (ii) comparing to what extent these scales differ. A secondary aim was to examine if the way in which injury severity is measured influences study outcomes in terms of (i) the rate of injury reported and (ii) the risk factors identified.

Overall, there is inconsistency in how injury severity is measured due to the inter-related factors of different criteria being used to define injury severity (with 13 variations identified), and different approaches taken to grading injury severity (with two approaches identified, and between two and six categorical levels used) (discussed below). The reason for this inconsistency may be related to the challenge imposed by the insidious nature of RRI development, which typically lacks a definite “point” of injury onset [77]. Approaches more suitable for determining the severity of acute injuries (e.g., length of time-loss), where the “point” of injury onset is more explicit, appear to be utilized by some in RRI research. A more consistent and appropriate method of measuring RRI severity is needed.

4.1 | Measurement of General RRI Severity

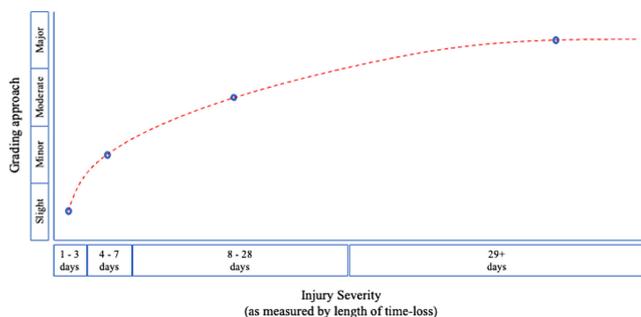
Four factors delineate general RRI severity measurement: the definition criteria, the lowest level of injury severity defined, the number of levels (if applicable), and the distribution of these levels (if applicable). The former two factors relate to how injury severity is defined, while the latter two refer to how it is graded.

Regarding the definition of injury severity, the criteria capture a broad scope of injury (Figures 6 and 7), based on the least severe level defined. However, many studies fail to capture lower severity injuries. This appears to be due to the slow, progressive nature associated with RRIs, and the associated difficulty in

TABLE 3 | The influence of the primary definition criteria on the identification of significant risk factors for RRIs.

Risk factor	Investigated (<i>n</i>)	Identified as significant (<i>n</i>)	Identified percentage
Previous injury			
Effect on running	11	10	91
Effect on running AND physical description	9	2	22
Physical description	4	1	25
Running inexperience			
Effect on running	9	6	67
Effect on running AND physical description	5	1	20
Physical description	4	0	0
High weekly mileage			
Effect on running	13	2	15
Effect on running AND physical description	10	3	30
Physical description	2	1	50

Note: *n*, number of studies; %, the proportion of studies that identified a risk factor as significant among those that investigated the risk factor.

**FIGURE 8** | Nonlinear relationship between the grading approach and the injury severity (as measured by length of time-loss).

determining when ‘injury’ occurs [77]. It seems that many studies use traditional approaches (i.e., length of time-loss) which are more suitable in acute injury research when identifying the point of “injury” onset is more explicit [78]. The complexity of RRI severity is enhanced further with some athletes not considering themselves “injured,” even when experiencing pain and restricted training [11, 12], and many considering pain as “good” (see Tarr and Thomas [79] for an in-depth description of this in dancers). Failing to capture the entire scope of injury severity may be influencing the wide range of injury rates reported [64] (Table 2) and the lack of consideration for potential risk factors [22] (Table 3), contributing to the unclear and limited foundational epidemiological evidence stunting the progression of injury prevention research.

With regard to the grading of injury severity, the inconsistent use of numerous levels of injury severity makes comparisons across studies challenging. This challenge is not exclusive to chronic injuries; it is also evident in the analysis of acute injury severity as seen by the Munich Consensus Statement using four grades to classify muscle injuries [80], while the British Athletics Muscle Injury Classification uses 10 grades [81]. Consideration should also be given to the finding that many

levels of injury severity are not distributed equally within their respective scales. For example, injuries based on the length of time-loss were often categorized as slight (1–3 days), minor (4–7 days), moderate (8–28 days), and major (more than 29 days). This is mirrored in the discussion of the updated OSTRC statement [82]. The OSTRC severity score was previously suggested as a continuous measure (0–100) [19, 83]. More recently it was discussed that this tool does not represent equidistance between possible outcomes, and therefore, it should be considered an ordinal measure. This latter finding may be problematic for some statistical analyses, which require uniformity in outcome scores (e.g., chi-squared tests) [84, 85]. It is worth noting that no study within the current review appears to explicitly justify the use of a non-equidistant approach to injury severity grading. This may reflect a presumed nonlinear relationship between grading and injury severity (Figure 8). It could be argued that a continuous approach to grading injury severity is advantageous for exploring the relationship between RRI severity and injury rates or risk factors (e.g., for some statistical analyses). The validity and implications of this approach requires further investigation.

The predominant approach of defining general RRI severity by an “effect on running” and/or “physical description” is comparable to both the consensus definition of a RRI [86] and to runners’ own descriptions of injury [11, 12, 87]. It is also similar to methods used in sport in general, with the OSTRC tools determining injury severity by the extent of (i) difficulties participating in training/competition, (ii) training modifications required, (iii) reductions in performance, and (iv) symptoms/pain [19, 83]. In contrast to this predominant approach in RRIs, many consensus statements for other sports (such as athletics [88], aquatic sports [89], and tennis [90]), define injury severity solely by the length of time-lost from activity. By using additional criteria, the approach taken in RRI research seems to be advantageous (for overuse injuries) over these consensus statement recommendations, as two

consequences of injury are captured, and the lower levels of injury severity are recognized.

It is interesting to note that none of the reviewed studies included the need for medical attention to measure injury severity. This is in contrast to this criterion often being used for defining a RRI dichotomously (i.e., considering someone as either injured or uninjured) [9], and it being a commonly used criterion for measuring the severity of general sport injuries [7]. This criterion may *not* be the most appropriate for defining RRI severity as runners often do not seek medical advice when injured (especially for lower severity injuries) [11, 12], and there is wide variety in individuals' access to and use of medical services [91]. Therefore, using medical attention for defining injury severity may not be appropriate, although capturing detail on the utilization of medical attention (e.g., duration, type, and expertise required) can provide insight into the full burden of injury [18]. Similarly, while possibly not necessary for *defining* injury severity, capturing and reporting the psychosocial effects of injury may enhance our understanding of the true burden of injuries with varying severities [15, 18]. These additional insights may also be useful in monitoring injury prevention and rehabilitation strategies [7, 8].

4.2 | Influence of Injury Severity Measurement on Study Outcomes

While it is well understood that the definition of injury can affect the outcomes of research [64, 78], little is known specifically about how the approach to measuring RRI severity affects study outcomes; this review is the first to examine the topic. Two primary study outcomes were identified: rates of injury (with incidence being the predominant figure reported) and potential risk factors.

4.2.1 | Influence of Injury Severity Measurement on Rates of Injury

No studies directly compared whether different approaches to injury severity measurement, either in terms of its definition or its grading, influenced the rate of injury reported. Therefore, to examine this, we have taken the somewhat methodologically weaker approach of comparing across studies. Surprisingly, definition criteria do not appear to affect the average incidence rate reported. There does, however, appear to be a trend with regard to the grading approach, with lower severity injuries associated with a higher incidence rate, and conversely, higher severity injuries having a lower incidence rate (Table 2). This is not surprising given the progressive nature of RRIs in which they develop insidiously (i.e., starting as low severity injuries), with opportunities for appropriate management intervention strategies that can decrease the likelihood of progression to higher severity injuries (as opposed to acute injuries which can immediately present as a higher severity injury) [12]. This finding also reflects runners' lived experience of lower severity injuries being highly frequent [12]. However, less than half of the studies in this review reported a specific incidence rate for each level of injury severity measured. Even fewer studies reported data on the locations

and types of injury sustained per level of severity. Without information on rates (and locations and types) of injuries per severity level, it is more challenging to accurately determine the magnitude of the injury problem [7, 8], inhibiting the development of targeted, effective injury prevention programs.

4.2.2 | Influence of Injury Severity Measurement on Risk Factors for Injury

Despite 35 studies capturing severities of injury when exploring risk factors, none report risk factors for specific levels of injury. This makes it challenging to determine whether the approach to measuring injury severity influences the ability to identify risk factors. The primary definition criterion of "effect on running" appears most effective at identifying risk factors based on whether a statistically significant effect was identified (Table 3). This observation is limited due to the possibility of confounding factors affecting the identification of significant risk factors (e.g., study design, population sample, and definition of injury) [92]. The importance of considering the effect of injury severity on risk factor identification can be explained by the following example. A runner sustains a lower severity injury to their knee; however, they continue to run (despite experiencing symptoms and training modifications). Simultaneously, this lower severity injury causes a (subconscious) change in the runner's technique in an attempt to off-load the injury at the knee. The runner subsequently goes on to develop a higher severity injury at their hip, forcing them to stop running. If researchers or clinicians are unaware of the lower severity injury at the knee, they may fail to recognize its potential impact as a risk factor for the development of the (higher severity) injury at the hip. Future research clearly needs to capture, report, and directly compare differences in risk factors across levels of injury severity in a single cohort, and how lower severity injuries relate to higher severity injuries.

5 | Recommendations and Practical Implications

There is a complex interaction of multiple factors to consider when choosing a measure of injury severity, including, but not limited to (i) ensuring the aims of the study can be addressed, (ii) attempting to be consistent with other researchers' practices to facilitate comparison of findings, and (iii) ensuring the full scope of injury severity is captured (especially the least severe levels). With this being the first review to investigate how injury severity is measured, and examine possible influences on study outcomes, RRI research seems to have overlooked the crucial role severity of injury plays in understanding the true burden of injury [18]. It appears that, in line with recommendations [1], studies have chosen measures of injury severity to allow their aims to be addressed. However, this has subsequently resulted in inconsistency and an inability to compare findings across studies.

While it may not be practical nor applicable for each study to analyze data pertaining to varying levels of injury severity (e.g., if a sample size estimation was performed to address a specific question), there needs to be a concerted approach

from researchers to better understand RRIs. We make two recommendations. Firstly, where consistent with study aims (and an appropriate sample size permits), researchers should capture injury severity using a consistent, continuous measure, acquiring information on the intensities and types of pain, the extent of training restriction (e.g., volume, duration, frequency, and intensity), and the length of time-loss; supported by the OSTRC [19, 83]. Specific injury severity measures (e.g., length of time-loss categories) can then be applied post hoc to address individual study aims. Initially, it is unlikely that there will be enough participants in a single study to provide conclusive findings. Therefore, our second recommendation is for the formation of an expert group to guide the establishment of a single repository for RRI data, promoting the collection of continuous data. This continuous data repository could facilitate various statistical analyses that require larger data (e.g., machine learning/artificial intelligence and nonlinear approaches) and comparison of findings across studies, ultimately advancing RRI prevention. Examples of disease-based repositories include the European Cystic Fibrosis Society's Patient registry (www.ecfs.eu/ecfspr), National Institute of Diabetes and Digestive and Kidney Diseases Central Repository (www.repository.niddk.nih.gov), and Parkinson's Progression Markers Initiative (www.ppmi-info.org).

In terms of practical implications, clinicians, coaches, and runners clearly need to consider lower severity injuries and their potential role in contributing to higher severity injuries. Clinicians and coaches should also consider that runners may be perceiving low severity injuries in a positive manner, when possibly, they are “true” injuries with consequences that need to be addressed.

6 | Limitations

This review should be considered in light of some limitations. Firstly, only measures of “general” RRI severity were included, with no inclusion of studies which measured the injury severity of specific RRIs (e.g., Achilles tendinopathy). The findings in relation to the effect of injury severity on injury rate reported and/or risk factor identification should be considered in light of this, as findings may differ when considering specific RRIs. Future studies should explore this. Secondly, with the segregation of studies into various groups of definition criteria, grading approaches, and outcomes, low numbers of studies were available for some analyses. Finally, for those that used either of the OSTRC tools, the majority were classified as “continuous” because only the 0–100 severity score was used, as referenced in the original papers [19, 83]. Considering recent discussion on the OSTRC tools' more appropriate consideration as an ordinal measure [82], it is possible that these studies could be considered “categorical.”

7 | Conclusion

Injury severity is a key aspect of effective injury surveillance research [13]. However, many studies have not captured or reported on the severity of general RRIs [9], thereby reducing our understanding of the true burden of RRIs. The current review describes, compares, and examines the influence of the different approaches to measuring injury severity; identifying

a broad array used. Primary and secondary criteria are used to define all scales of injury severity, with a categorization approach to grading prevailing. With a failure to recognize lower severity injuries, the majority of studies do not capture the entire scope of injury severity. While there is some consistency among studies which use specific approaches (e.g. length of time-loss), the wide variety of approaches result in overall inconsistency in RRI severity measurement. The approach to measuring RRI severity may affect study outcomes, with a noticeable trend in low severity injuries being associated with a higher incidence rate, and an “effect on training” approach to defining injury severity seemingly the most effective at identifying significant risk factors. The current review highlights that less than half of included studies report rates of injury for specific levels of severity, and none report data on risk factors for specific levels. This deficiency is possibly contributing to the inconsistent findings for rates of injury [24, 25], and a lack of clarity on risk factors for injury [23, 26, 28], thus hampering attempts to prevent injuries. By capturing consistent, continuous data on injury severity, and founding an expert group to guide the establishment of a repository for RRI data, significant advancements in understanding and preventing RRIs are possible.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

All data supporting the findings of this review are available within the paper, its supplementary material and in an online data repository, available at: <https://doi.org/10.17605/OSF.IO/YJ87C>.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.