

What are the Main Risk Factors for Running-Related Injuries?

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Abstract

Background Despite several studies that have been conducted on running injuries, the risk factors for running-related injuries are still not clear in the literature.

Objective The aim of this study was to systematically review prospective cohort studies that investigated the risk factors for running injuries in general.

Data Sources We conducted electronic searches without restriction of language on EMBASE (1980 to Dec 2012), PUBMED (1946 to Dec 2012), CINAHL (1988 to Dec 2012) SPORTDiscus (1977 to Dec 2012), Latin American and Caribbean Centre on Health Sciences Information (1985 to Dec 2012) and Scientific Electronic Library

Online (1998 to Dec 2012) databases, using subject headings, synonyms, relevant terms and variant spellings for each database.

Study Selection Only prospective cohort studies investigating the risk factors for running-related musculoskeletal injuries were included in this review. Two independent reviewers screened each article and, if they did not reach a consensus, a third reviewer decided whether or not the article should be included.

Study Appraisal and Synthesis Methods Year of publication, type of runners, sample size, definition of running-related musculoskeletal injury, baseline characteristics, reported risk factors and the statistical measurement of risk or protection association were extracted from the articles. A scale adapted by the authors evaluated the risk of bias of the articles.

Results A total of 11 articles were considered eligible in this systematic review. A total of 4,671 pooled participants were analysed and 60 different predictive factors were investigated. The main risk factor reported was previous injury (last 12 months), reported in 5 of the 8 studies that investigated previous injuries as a risk factor. Only one article met the criteria for random selection of the sample and only six articles included a follow-up of 6 months or more. There was no association between gender and running injuries in most of the studies.

Limitations It is possible that eligible articles for this review were published in journals that were not indexed in any of the searched databases. We found a great heterogeneity of statistical methods between studies, which prevented us from performing a meta-analysis.

Conclusions The main risk factor identified in this review was previous injury in the last 12 months, although many risk factors had been investigated in the literature.

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Relatively few prospective studies were identified in this review, reducing the overall ability to detect risk factors. This highlights the need for more, well designed prospective studies in order to fully appreciate the risk factors associated with running.

1 Introduction

Running is one of the most popular physical activities around the world, and, due to the health benefits, low cost and ease of implementation, the number of runners has grown significantly over the past decade [1–3]. However, injuries in runners are common [4, 5]. Depending on the population of runners studied and the definition of running-related musculoskeletal injuries (RRMI) used [4, 6, 7], incidence rates range between 18.2 and 92.4 %, and prevalence rates range between 6.8 to 59 injuries per 1,000 hours of running [4, 8–11]. Running injuries have multifactorial aetiology and are commonly related to overuse (repetitive microtrauma that overloads musculoskeletal structures). In addition, they can be classified as gradual onset injuries caused by repeated microtrauma without a single and identifiable event [11, 12]. Generally, the factors associated with running injuries are attributed to personal characteristics of the runners (anatomical or biomechanical factors) and training errors such as training volume, weekly distance and running experience [2, 5, 9, 13].

Some studies have reviewed the literature on the associated factors for running injuries [4–7, 14]. However, some of these reviews are not systematic or included studies with retrospective or cross-sectional designs, which are not the appropriate designs for investigating risk factors [15]. Additionally, runners experience over 20 different injuries and the most common injuries vary among studies [16]. Therefore, when assessing risk factors of all running injuries, including studies of specific injuries may introduce bias by placing too much emphasis on that injury or a specific risk factor, and may overlook other important risk factors. We note that only a systematic review of prospective cohort studies focused on all injuries caused by running is capable of overcoming these limitations [15, 17, 18]. Despite several studies that have been conducted on running injuries, the risk factors for running-related injuries are still not clear in the literature. Therefore, this study aims to systematically review only prospective cohort studies that investigated the risk factors for running injuries in general.

2 Methods

2.1 Information Sources

We conducted electronic searches on Embase (1981 to Dec 2012), PubMed (1946 to Dec 2012), CINAHL (1988 to Dec 2012) SPORTDiscusTM (1977 to Dec 2012), Latin American and Caribbean Centre on Health Sciences Information (LILACS) [1985 to Dec 2012] and Scientific Electronic Library Online (SCIELO) [1998 to Dec 2012] databases, without restriction for languages and date of publication. We used subject headings, synonyms, relevant terms and variant spellings for the searches on each database. The full electronic search for EMBASE database is presented in Appendix S1 of the electronic supplementary material (ESM).

2.2 Study Selection

We only included prospective cohort studies that investigated risk factors for running-related injuries, since prospective cohort studies are the preferred design to provide direct and accurate estimates of incidence and risk [15]. We excluded articles that (i) studied risk factors for a specific injury (e.g., medial tibial stress syndrome); (ii) aimed to analyse risk factors and/or injuries of other sports that include running (e.g., triathlons); (iii) analysed only injured runners or did not describe if all runners were injury-free at baseline; (iv) reported on experimental and controlled studies on the effectiveness of an intervention or prevention programme. We chose to exclude articles that focused on specific injuries because some injuries could be under- or over-represented in this review and our results would be biased toward risk factors for that specific injury regardless of the true injury distribution in the population of injured runners. The screening of eligible studies was performed in two steps. First, screening the title and abstract, where we excluded articles if they did not mention runners or running. Second, the full text of the selected articles were analysed according to our inclusion and exclusion criteria. Each step was performed by two independent reviewers (BTS and TPY), and if they did not reach a consensus, a third reviewer (ADL) helped decide whether the article should be included.

2.3 Data Collection

The following data were extracted from these articles selected for the review: first author's name, year of publication, type of runners (e.g., marathon runners or recreational runners), sample size, definition of RRMI,

baseline characteristics, reported risk or protection factors, and the statistical measurement of risk or protection factors associated with RRMI. The results were expressed with the statistical measure used by the author (HR: hazard ratio; OR: odds ratio; RR: relative risk; RIR: relative injury rate; and CI: confidence intervals). Predictive factors to running-related injuries were classified as risk or protection. A risk factor was considered when HR, OR, RR or RIR was greater than 1.0, and a protective factor was considered when HR, OR, RR or RIR was lower than 1.0. Two independent reviewers extracted the data (BTS and LCHJ) and disagreements were resolved by discussion between the two review authors; if no agreement could be reached, arbitration was performed by a third reviewer (ADL).

2.4 Risk of Bias Assessment

The instrument used for assessing risk of bias of the included articles was adapted from the Newcastle Ottawa Scale (NOS) for cohort studies [19]. The NOS is a quality assessment tool for cohort and case-control studies, in which a star rating system is used to indicate the quality of a study, with a maximum of nine stars [20]. The instrument was modified for the purpose of this review and the population of runners, with three criteria added to the original scale. The criteria adopted to assess risk of bias were: (i) description of runners or type of runners; (ii) definition of RRMI; (iii) representativeness of the exposed cohort; (iv) selection of the non-exposed cohort; (v) ascertainment of exposure; (vi) demonstration that outcome of interest

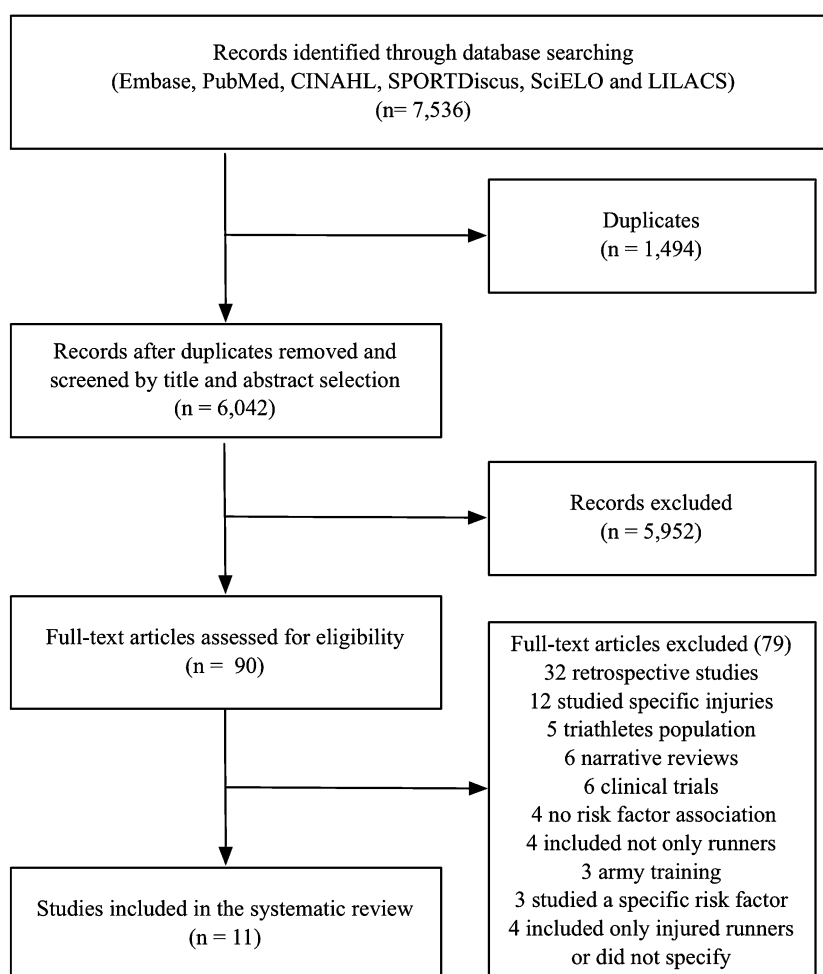
Table 1 Description of the 11 criteria designed to assess risk of bias in the studies^a

Criterion	Description of criteria
1. Description of runners or type of runners	There are several types of runners (recreational, elite, ultra marathoners, marathoners, etc.). Without the description regarding to the type of runners it is impossible to conclude which population the incidence rates refer to. Studies that reported a description of the runners or informed the type of runners receive a star for this criterion. Studies conducted in running races (which may determine the type of runners; e.g., marathon race) and which describe the race characteristics receive a star for this criterion as well. Studies that did not describe the characteristics or the type of runners, and studies conducted in running races that did not describe the characteristics of the race did not receive a star for this criterion
2. Definition of running-related musculoskeletal injury	Studies that aimed to investigate running injuries should present a definition of a running-related musculoskeletal injury informing what was considered as an injury in the study. Studies that present a definition of running-related musculoskeletal injury received a star for this criterion
3. Representativeness of the exposed cohort	(a) Truly representative of the average runners in the community*; (b) somewhat representative of the average runners in the community*; (c) selected group of users; (d) no description of the derivation of the cohort
4. Selection of the non-exposed cohort	(a) Drawn from the same community as the exposed cohort*; (b) drawn from a different source; (c) no description of the derivation of the non-exposed cohort
5. Ascertainment of exposure	(a) Secure record*; (b) structured interview*; (c) written self report; (d) no description
6. Demonstration that outcome of interest was not present at start of study	(a) Yes*; (b) no. Studies that described that all runners included were injury-free at baseline received a star for this criterion
7. Comparability of cohorts on the basis of the design or analysis	(a) Study controls for the most important factor (stated in the background of the study*); (b) study controls for any additional factor*. For this criterion, studies could be awarded with two stars
8. Assessment of outcome	(a) Independent blind assessment*; (b) record linkage*; (c) self-report; (d) no description
9. Was follow-up long enough for outcomes to occur?	(a) Yes*; (b) no. Studies that carried out a follow-up period of at least 12 weeks received a star for this criterion
10. Adequacy of follow-up of cohorts	(a) Complete follow-up of all subjects accounted for*; (b) subjects lost to follow-up unlikely to introduce bias (up to 20 % loss) or description provided of those lost*; (c) follow-up rate <80% and no description of those lost; (d) no statement. A loss to follow-up greater than 20 % may increase the risk of bias in prospective studies [21]
11. Statistic measurement for risk association	Prospective studies should inform a statistical measure to determine risk association (e.g., hazard ratio, odds ratio, relative risk) and the confidence interval. Studies that gave a statistical measure of risk received a star for this criterion

^a The articles could be awarded a maximum of one star for each item, except for item 7, which could be awarded two stars. A total of 12 stars could be given for the articles

* Articles with this alternative received a star for this criterion

Fig. 1 Flow diagram of selection and inclusion process in the systematic review



was not present at start of study; (vii) comparability of cohorts on the basis of the design or analysis; (viii) assessment of outcome; (ix) whether follow-up was long enough for outcomes to occur; (x) adequacy of follow-up of cohorts; (xi) statistical measurement of the association of risk factors (e.g., HR, OR, RR). The articles could be awarded a maximum of one star for each item, except for item 7, which could be awarded two stars. Thus, a total of 12 stars could be given to the articles. The description of each criterion is presented in Table 1.

3 Results

A total of 7,536 studies were found. Among them, 1,494 were duplicates that appeared in at least two databases. Screening the titles, abstracts and full text, if appropriate, we found 11 prospective cohort studies that met the inclusion criteria. Figure 1 shows a flow diagram of the complete process of article inclusion.

From the 11 articles included in this review, a total of 4,671 participants were pooled and 60 different risk factors

were investigated. The main intrinsic risk factor reported by the studies was previous injury in the last 12 months (Table 2), reported as a risk factor in five [22–27] of eight studies that investigated this factor. Higher quadriceps angle of the knee (Q angle) was associated with running injuries in two [24, 28] of the three studies that analysed this factor. Two [23, 27] of the five studies that investigated weekly distance as a risk factor identified that training for more than 64 km a week was a risk factor for lower extremity injuries. Five studies investigated the relationship between weekly running frequency and running injuries, and two of these studies [27, 29] reported a significant association with running injuries. One study [27] reported that running three to seven times a week was a risk factor for running injuries in men and running seven times a week was a risk factor for women. Another study [29] reported that running once a week was a risk factor for women. Gender was not associated with running injuries in most of the studies.

Due to the importance of the ‘previous injury’ factor found in this study, we presented all data of the articles that investigated previous injuries in a separate table (Table 3).

Table 2 Risk factors related to running-related injury observed in at least two articles

Risk factor	Articles that identified risk factor (<i>n</i>)	Articles that investigated risk factor (<i>n</i>)
Previous injuries	5	8
Q angle	2	3
Weekly distance	2	5
Weekly frequency	2	5

Eight studies investigated previous injury as a risk factor and five of these found a positive association (62 %), two articles found the association in men and three articles found the association for both sexes. Due to the different statistical measures used by the studies, we contacted the authors for the raw study data. However, most authors did not provide the raw data, which prevented us from performing a meta-analysis or a more comprehensive inter-study comparison. We extracted data from multivariable analysis, since univariate or raw data were not available in most of the articles included. The full list with the 60 factors investigated by the studies is presented in Table S1 (see ESM). The characteristics of the 11 articles included in this review are described in Table 4.

Regarding the assessment of risk of bias, the criteria most frequently awarded a star were definition of RRMI (11/11), selection of the non-exposed cohort (11/11), demonstration that outcome of interest was not present at start of study (11/11) and follow-up long enough for outcomes to occur (11/11). On the other hand, the criteria with fewer stars awarded to the articles were ascertainment of exposure (4/11) and assessment of outcome (3/11). The

average stars awarded to the included articles was 9 of a total of 12 stars, with a maximum of 11 and a minimum of 5 (Table 5).

4 Discussion

Eleven articles met the inclusion criteria and were included in this systematic review. A total of 4,671 pooled participants was analysed and 60 different risk factors were investigated. However, whilst many risk factors have been investigated, just ten of these were investigated in at least five articles. The main risk factor found was previous injuries, usually in the past 12 months, reported in 62 % of the articles that investigated this factor. Weekly distance, weekly frequency and higher Q angle were associated as risk factors by two studies. This is the first systematic review with only prospective cohort studies that studied risk factors for running-related injuries. Other reviews focusing on the factors associated with running injuries have also found an association with previous injury and weekly distance.

The association between previous injury and the development of a new injury or a similar injury of greater magnitude has been reported as a risk factor for sports in general [34]. In addition, some authors suggested that the association between previous injuries and new injuries was due to an incomplete recovery from the earlier injury [26, 29]. Most studies (6/8) defined the period for previous injuries to be in the last 12 months. Running injuries are commonly related to overuse, which is an overload of the musculoskeletal system [11]. An overuse injury can be defined as one caused by repeated microtrauma without a single, identifiable event responsible for the injury [12]. Therefore, increased training loads can exacerbate the

Table 3 Studies that found previous injuries as a risk factor for running-related injuries

Study	Previous injury period (months)	Risk factor for men		Risk factor for women		Risk factor for both sexes	
		Statistic	95 % CI	Statistic	95 % CI	Statistic	95 % CI
Pileggi et al. [30]	NR	$p > 0.05$	NR	$p > 0.05$	NR		
Buist et al. [22]	3–12	HR 2.7	1.3–5.3 ^a	NR	NR		
	>12	HR 2.1	1.0–4.3 ^a	NR	NR		
Lun et al. [31]	12	NR	NR	NR	NR		
Fields et al. [32]	NR	$p > 0.05$	NR	$p > 0.05$	NR		
Macera et al. [23]	12	OR 2.7	2.6–2.7 ^a	OR 1.9	0.7–4.9		
Walter et al. [27]	12	RR 1.69	1.3–2.2 ^a	RR 2.3	1.3–4.1 ^a		
Rauh et al. [24] ^b	NR					RR 1.8	1.0–3.1 ^a
Wen et al. [26]	12					RIR 2.0	1.2–3.2 ^a

CI confidence interval, HR hazard ratio, OR odds ratio, RR relative risk, RIR relative injury rate, NR not reported

^a Statistically significant

^b This article found the risk factor only for more than four previous injuries

Table 4 Description of studies included, statistic measures and 95 % confidence interval of multivariate analysis^a

Study	Follow-up period	Population	Country of origin	Risk factors for men	Risk factors for women	Risk factors for both sexes
Bredeweg et al. [33]	9 weeks	210 novice runners	The Netherlands	NA	NA	NA
Pileggi et al. [30]	12 months	18 amateur runners	Brazil	NA	NA	Lower left knee extension ($p < 0.05$) Lower left plantar flexion ($p < 0.05$) Lower resting cardiac frequency ($p < 0.05$) Less lower extremities flexibility ($p < 0.05$)
Buist et al. [22]	13 weeks	532 novice runners	The Netherlands	Higher BMI (HR 1.14/CI 1.05–1.25) Previous injury 3 to 12 months prior (HR 2.7/CI 1.32–5.30) Previous injury >12 months prior (HR 2.14/CI 1.05–4.35) Previous sports activities without axial load (HR 2.05/CI 1.03–4.11)	Navicular drop (HR 0.87/CI 0.77–0.98)	NA
Rauh et al. [28]	One season	393 cross-country runners	USA	Q angle 15 to <20 (RR 1.5/CI 1.1–2.3) Q angle right-left difference ≥ 4 (RR 1.8/CI 1.1–2.9)	Q angle ≥ 20 (RR 1.6/CI 1.1–2.5) Q angle right-left difference ≥ 4 (RR 1.8/CI 1.3–2.7)	Q angle ≥ 20 (RR 1.7/CI 1.2–2.4) Q angle right-left difference ≥ 4 (RR 1.8/CI 1.4–2.5)
Rauh et al. [24]	11 weeks	421 cross-country runners	USA	NA	NA	Q angle ≥ 15 and <20 (RR 1.4/CI 1.1–1.9) Q angle >20 (RR 2.0/CI 1.4–2.8) Q angle ≥ 20 (RR 1.8/CI 1.3–2.4) Previous running injuries ≥ 4 (RR 1.8/CI 1.0–3.1) Pace adjusted—Q angle ≥ 20 (HR 2.43/CI 1.63–3.63) Pace adjusted—summer injury (HR 1.62/CI 1.02–2.56) Surface adjusted—Q angle ≥ 20 (HR 2.42/CI 1.62–3.63) Surface adjusted—summer injury (HR 1.60/CI 1.01–2.55) Terrain adjusted—Q angle ≥ 20 (HR 2.45/CI 1.64–3.65) Terrain adjusted—summer injury (HR 1.64/CI 1.04–2.61)
Lun et al. [31]	6 months	87 recreational runners	Canada	NA	NA	NA

Table 4 continued

Study	Follow-up period	Population	Country of origin	Risk factors for men	Risk factors for women	Risk factors for both sexes
Taunton et al. [29]	13 weeks	844 recreational runners	Canada	BMI >26 kg/m ² (RR 0.40/CI 0.21–0.78) Running shoe age 4–6 months (RR 0.35/CI 0.15–0.83)	Age >50 years (RR 1.91/CI 1.10–3.32) Age <31 years (RR 0.57/CI 0.34–0.96) Frequency 1 day/week (RR 3.64/CI 1.08–12.29) Running shoe age 4–6 months (RR 1.73/CI 1.00–2.98) Running shoe age 1–3 months (RR 0.61/CI 0.37–0.98)	NA
Wen et al. [26]	32 months	255 runners of a marathon training programme	USA	NA	NA	Exposure hours: low leg-length difference (RIR 1.96/CI 1.07–3.58) Exposure hours: hours/week increased (RIR 0.57/CI 0.45–0.73) Exposure hours: high arch index (RIR 0/CI 0–0.36) Exposure miles: hours/week increased (RIR 0.57/CI 0.42–0.78) Exposure miles: low age (RIR 0.38/CI 0.15–0.97) Exposure weeks: high experience (RIR 1.88/CI 1.15–3.05) Exposure weeks: previous injuries (RIR 2.01/CI 1.26–3.21) Type A behaviour high scores (<i>p</i> < 0.05)
Fields et al. [32]	1 year	40 runners of a running club	USA	NA	NA	NA
Macara et al. [23]	12 months	583 recreational runners	USA	LEX injury 12 months (OR 2.7/CI 2.6–2.7) Running experience 0–2 years (OR 2.2/CI 1.5–3.3) Weekly distance >64 km (OR 2.9/CI 1.1–7.5)	Concrete surface (OR 5.6/CI 1.1–29.3)	NA

Table 4 continued

Study	Follow-up period	Population	Country of origin	Risk factors for men	Risk factors for women	Risk factors for both sexes
Walter et al. [27]	12 months	1,288 runners enrolled in 2 community race events	Canada	Type of runner—competitive (RR 1.73/CI 1.21–2.49) Previous injury past 12 months (RR 1.69/CI 1.27–2.25) Height—average 1.70–1.79 cm (RR 2.04/CI 1.15–3.46) Height—tallest \geq 1.80 cm (RR 2.30/CI 1.29–3.90) 3 days running per week (RR 2.93/CI 1.27–6.20) 4 days running per week (RR 2.49/CI 1.08–5.26) 5 days running per week (RR 3.13/CI 1.38–6.46) 6 days running per week (RR 3.66/CI 1.62–7.50) 7 days running per week (RR 5.92/CI 2.49–12.75) Running year round (RR 1.64/CI 1.12–2.35) Longest run each week >8 km (RR 2.49/CI 1.64–3.71) Weekly distance \geq 64 km (RR 2.22/CI 1.30–3.68) Use of stretching—sometimes (RR 1.56/CI 1.10–2.21)	Injuries in previous year (RR 2.35/CI 1.33–4.07) 7 days running per week (RR 5.50/CI 1.44–17.39) Running year round (RR 2.00/CI 1.01–3.75) Weekly distance \geq 64 km (RR 3.42/CI 1.42–7.85)	NA

BMI body mass index, CI confidence interval, HR hazard ratio, LEX lower extremity, NA no association, OR odds ratio, RR relative risk, RIR relative injury rate

^a We extracted only data from multivariate analyses for the articles, because some articles did not report the univariate analysis or used a different statistical analysis

Table 5 Risk of bias assessment of the studies

Study	Criteria for assessing risk of bias ^a										
	1	2	3	4	5	6	7	8	9	10	11
Bredeweg et al. [33]	*	*	*	*	*	*	**			*	*
Pileggi et al. [30]	*	*		*	b	*		*	*	*	
Buist et al. [22]	*	*	*	*		*	**		*	*	*
Rauh et al. [28]	*	*	*	*	*	*	*	*	*	*	*
Rauh et al. [24]	*	*	*	*	b	*	**	*	*		*
Lun et al. [31]	*	*	*	*	*	*			*	*	
Taunton et al. [29]	*	*	*	*		*	**		*		*
Wen et al. [26]	*	*		*	*	*	**		*		*
Fields et al. [32]		*		*		*			*	*	
Macera et al. [23]	*	*	*	*		*	**		*	*	*
Walter et al. [27]	*	*	*	*		*	**		*	*	*

^a Criteria for assessing risk of bias: (1) description of runners or type of runners; (2) definition of running-related musculoskeletal injuries; (3) representativeness of the exposed cohort; (4) selection of the non-exposed cohort; (5) ascertainment of exposure; (6) demonstration that outcome of interest was not present at start of study; (7) comparability of cohorts on the basis of the design or analysis; (8) assessment of outcome; (9) was follow-up long enough for outcomes to occur; (10) adequacy of follow-up of cohorts; (11) statistical measurement of the association of risk factors

^b Some of the exposures were classified as 'secure record' and others as 'self-reported'

*Star(s) awarded for each criterion

symptoms of a previous overuse injury, which can be mistaken as a new injury. Importantly, runners can adopt different biomechanical patterns when injured, probably in an attempt to execute a strategy of motor protection of the injured structure during running. This change of pattern can lead to overloading of musculoskeletal structures that were intact before the injury, causing a new injury.

Only one biomechanical (alignment) risk factor was found in more than one study. Higher Q-angle factor was significantly associated with running-related injury. Theoretically, a greater Q angle is related to the increase of the lateral pull on the patella against the lateral femoral condyle, which contributes to patellar subluxation and other patellofemoral disorders [28]. A recent systematic review [35] of the factors associated with patellofemoral pain syndrome demonstrated that a large Q angle could be associated with the development of patellofemoral syndrome, despite the great difference found among several methods of measuring the Q angle that made it difficult to compare studies. Furthermore, there is no consensus on what can be considered a normal Q angle [35, 36]. This high heterogeneity of studies demonstrates the importance

of standardizing the methods of measuring and interpreting the Q angle [35, 36].

This review found in two studies [23, 27] that weekly distance was a risk factor for running injuries; runners who train a distance of more than 64 km per week might be more likely to sustain a running injury. Runners who usually train longer distances each week can overload their musculoskeletal structures beyond their body's regeneration abilities, resulting in a musculoskeletal injury. Two studies [27, 29] also reported an association between weekly frequency and running injuries. One study [27] reported that a frequency of three to seven times per week for men and seven times a week for women was associated with risk of injury. In another study [29], a frequency of once a week was found as a risk factor for only women. The association between training characteristics and running injuries seems to be complex. A systematic review of training errors and running injuries could not identify which training variables are related to running injuries, since methodological limitations hindered comparison between studies [14].

The magnitudes of risk found for all risk factors were between 1.4 and 5.9. For the main risk factor, previous injury, the magnitude of risk varied from 1.7 to 2.7 among the studies, which represents the same scale of risk for most studies that investigated previous injuries. In the assessment of risk of bias, most of the articles awarded at least nine stars (75 %) of a total of 12, representing a relatively low risk of bias. Only one article awarded four stars, representing less than half of the total stars; however, no study achieved the maximum number of stars (12). The criteria met least by the articles were ascertainment of exposure (4/12) and assessment of outcomes (3/12), representing a large source of bias in the studies included. The criteria in which most articles were awarded a star were definition of RRMI (12/12), which is directly related to the rates of injury, and consequently to the predictive factors reported [7, 37]; selection of the non-exposed cohort (12/12); demonstration that outcome of interest was not present at start of study (12/12), which is related to our inclusion criteria; and follow-up long enough for outcomes to occur (11/12), in this case we chose to use 12 weeks because we understand that is a minimum period for an overuse injury occur.

Even though the electronic search was conducted in the main databases related to the sports-injuries field, it is possible that eligible articles have been published in journals not indexed in any of the searched databases. We found a great heterogeneity of statistical methods between studies, which prevented us from performing a meta-analysis. All authors were contacted regarding the raw data of the studies, but unfortunately most authors did not provide these data. We extracted data from multivariable analysis,

since univariate analysis was not available in most of the articles included. These inconsistencies among studies complicate inter-study comparisons and prevent us from confirming the relationship between all risk factors and running injuries. In addition, relatively few prospective studies were identified in this review, reducing the overall ability to detect risk factors.

Despite the great amount of speculation and conflicting results regarding running-related injuries, our findings clarify the risk factors presented in the literature. Our findings demonstrate that previous injury is an important risk factor for running-related injuries. We suggest that more attention is necessary for this factor. Researchers and health professionals must understand the nature and clinical status of the previous injuries reported by runners. This may provide insight into treatment plans for a subsequent injury. Future prospective studies controlling for multiple variables should consider the risk factors presented in this systematic review when investigating running injuries.

5 Conclusion

The main risk factor identified in this review was previous injury in the last 12 months, although many risk factors had been investigated in the literature. Relatively few prospective studies were identified in this review, reducing the overall ability to detect risk factors. This highlights the need for more, well designed prospective studies in order to fully appreciate the risk factors associated with running.

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References

- Pazin J. Corredores de rua: características demográficas, treinamento e prevalência de lesões. *Revista Brasileira de Cineantropometria & Desempenho Humano*. 2008;10:6–11.
- Fredericson M, Misra AK. Epidemiology and aetiology of marathon running injuries. *Sports Med*. 2007;37:437–9.
- Paluska SA. An overview of hip injuries in running. *Sports Med*. 2005;35:991–1014.
- van Gent RN, Siem D, van Middelkoop M et al. Incidence and determinants of lower extremity running injuries in long distance runners: a systematic review. *Br J Sports Med*. 2007;41:469–80; discussion 80.
- Fields KB, Sykes JC, Walker KM, et al. Prevention of running injuries. *Curr Sports Med Rep*. 2010;9:176–82.
- Hoeberigs JH. Factors related to the incidence of running injuries. A review. *Sports Med*. 1992;13:408–22.
- Wen DY. Risk factors for overuse injuries in runners. *Curr Sports Med Rep*. 2007;6:307–13.
- Hreljac A, Marshall RN, Hume PA. Evaluation of lower extremity overuse injury potential in runners. *Med Sci Sports Exerc*. 2000;32:1635–41.
- Hreljac A. Impact and overuse injuries in runners. *Med Sci Sports Exerc*. 2004;36:845–9.
- Kretsch A, Grogan R, Duras P, et al. Melbourne marathon study. *Med J Aust*. 1980;1984(141):809–14.
- Hreljac A. Etiology, prevention, and early intervention of overuse injuries in runners: a biomechanical perspective. *Phys Med Rehabil Clin N Am*. 2005;16:651–67, vi.
- Bahr R. No injuries, but plenty of pain? On the methodology for recording overuse symptoms in sports. *Br J Sports Med*. 2009;43:966–72.
- Chang WL, Shih YF, Chen WY. Running injuries and associated factors in participants of ING Taipei Marathon. *Phys Ther Sport*. 2012;13:170–4.
- Nielsen RO, Buist I, Sorensen H, et al. Training errors and running related injuries: a systematic review. *Int J Sports Phys Ther*. 2012;7:58–75.
- Bahr R, Holme I. Risk factors for sports injuries—a methodological approach. *Br J Sports Med*. 2003;37:384–92.
- Lopes AD, Hespanhol Junior LC, Yeung SS, et al. What are the main running-related musculoskeletal injuries? a systematic review. *Sports Med*. 2012;42:891–905.
- Herbert R, Jamtvedt G, Mead J, et al. Practical evidence-based physiotherapy. 1st ed. London: Elsevier; 2005.
- Verhagen E, van Mechelen W. Sports injury research. 1st ed. Oxford: Oxford University Press; 2010.
- Wells G, Shea B, O'Connell D et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. [cited 2013 September 24]. http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp.
- Hartling L, Milne A, Hamm MP, et al. Testing the Newcastle Ottawa Scale showed low reliability between individual reviewers. *J Clin Epidemiol*. 2013;66:982–93.
- Fewtrell MS, Kennedy K, Singhal A, et al. How much loss to follow-up is acceptable in long-term randomised trials and prospective studies? *Arch Dis Child*. 2008;93:458–61.
- Buist I, Bredeweg SW, Lemmink KA, et al. Predictors of running-related injuries in novice runners enrolled in a systematic training program: a prospective cohort study. *Am J Sports Med*. 2009;38:273–80.
- Macara CA, Pate RR, Powell KE, et al. Predicting lower-extremity injuries among habitual runners. *Arch Intern Med*. 1989;149:2565–8.
- Rauh MJ, Koepsell TD, Rivara FP, et al. Epidemiology of musculoskeletal injuries among high school cross-country runners. *Am J Epidemiol*. 2006;163:151–9.
- Van Middelkoop M, Kolkman J, Van Ochten J, et al. Risk factors for lower extremity injuries among male marathon runners. *Scand J Med Sci Sports*. 2008;18:691–7.
- Wen DY, Puffer JC, Schmalzried TP. Injuries in runners: a prospective study of alignment. *Clin J Sport Med*. 1998;8:187–94.
- Walter SD, Hart LE, McIntosh JM, et al. The Ontario cohort study of running-related injuries. *Arch Intern Med*. 1989;149:2561–4.
- Rauh MJ, Koepsell TD, Rivara FP, et al. Quadriceps angle and risk of injury among high school cross-country runners. *J Orthop Sports Phys Ther*. 2007;37:725–33.
- Taunton JE, Ryan MB, Clement DB, et al. A prospective study of running injuries: the Vancouver Sun Run “In Training” clinics. *Br J Sports Med*. 2003;37:239–44.

30. Pileggi P, Gualano B, Souza M, et al. Incidência e fatores de risco de lesões osteomioarticulares em corredores: um estudo de coorte prospectivo. *Revista Brasileira de Educação Física e Esporte*. 2010;24:453–62.
31. Lun V, Meeuwisse WH, Stergiou P, et al. Relation between running injury and static lower limb alignment in recreational runners. *Br J Sports Med*. 2004;38:576–80.
32. Fields KB, Delaney M, Hinkle JS. A prospective study of type A behavior and running injuries. *J Fam Pract*. 1990;30:425–9.
33. Bredeweg SW, Kluitenberg B, Bessem B, et al. Differences in kinetic variables between injured and noninjured novice runners: a prospective cohort study. *J Sci Med Sport*. 2012;16:205–10.
34. Fuller CW, Bahr R, Dick RW, et al. A framework for recording recurrences, reinjuries, and exacerbations in injury surveillance. *Clin J Sport Med*. 2007;17:197–200.
35. Lankhorst NE, Bierma-Zeinstra SM, van Middelkoop M. Factors associated with patellofemoral pain syndrome: a systematic review. *Br J Sports Med*. 2013;47:193–206.
36. Livingston LA. The quadriceps angle: a review of the literature. *J Orthop Sports Phys Ther*. 1998;28:105–9.
37. van Mechelen W. Running injuries. A review of the epidemiological literature. *Sports Med*. 1992;14:320–35.