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SYSTEMATIC REVIEW

# TRAINING ERRORS AND RUNNING RELATED INJURIES: A SYSTEMATIC REVIEW

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## ABSTRACT

***Purpose:*** The purpose of this systematic review was to examine the link between training characteristics (volume, duration, frequency, and intensity) and running related injuries.

***Methods:*** A systematic search was performed in PubMed, Web of Science, Embase, and SportDiscus. Studies were included if they examined novice, recreational, or elite runners between the ages of 18 and 65. Exposure variables were training characteristics defined as volume, distance or mileage, time or duration, frequency, intensity, speed or pace, or similar terms. The outcome of interest was Running Related Injuries (RRI) in general or specific RRI in the lower extremity or lower back. Methodological quality was evaluated using quality assessment tools of 11 to 16 items.

***Results:*** After examining 4561 titles and abstracts, 63 articles were identified as potentially relevant. Finally, nine retrospective cohort studies, 13 prospective cohort studies, six case-control studies, and three randomized controlled trials were included. The mean quality score was 44.1%. Conflicting results were reported on the relationships between volume, duration, intensity, and frequency and RRI.

***Conclusion:*** It was not possible to identify which training errors were related to running related injuries. Still, well supported data on which training errors relate to or cause running related injuries is highly important for determining proper prevention strategies. If methodological limitations in measuring training variables can be resolved, more work can be conducted to define training and the interactions between different training variables, create several hypotheses, test the hypotheses in a large scale prospective study, and explore cause and effect relationships in randomized controlled trials.

***Level of evidence:*** 2a

***Key words:*** Duration, frequency, injuries, intensity, running, training, volume

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## INTRODUCTION

Weight loss and smoking cessation have been associated with running,[1] and it has been stated that running has positive effects on health and fitness.[2] However, Running Related Injuries (RRI) of the lower extremities are commonly a negative side effect. Depending on injury definition and length of follow up period, the injury incidence among runners varies between 11–85%[1,3-15] or 2.5 to 38 injuries per 1000 hours of running.[9,16-18] Several risk factors contributing to injuries have been reported[18-21] and general consensus exists with regard to training characteristics and previous running injuries being associated with the development of RRI. Training characteristics are of particular importance, since the training regimen is under the control of the runners (and coaches) and can be modified in contrast to previous injuries which cannot be modified.[22,23] Furthermore, anecdotal evidence suggests that training errors (i.e. excessive distance, sudden change of training routines, etc.) are the cause of 60–70% of all running injuries.[16,24,25] In a review of the etiology and prevention of and intervention for overuse injuries in runners, Hreljac[20] concluded that the causes of all overuse running injuries could be classified as training errors, and thus, all overuse running injuries should be preventable. In order to summarize and present the information that examines the evidence about training errors and RRI, a systematic review may be a starting point to identify which training errors have been reported to be associated with injury development. To date, the authors have found no published systematic review that aims to present an overview of the literature, investigating the relation between volume, duration, intensity, and frequency of running, herein defined as training characteristics, and the development of RRI. Therefore, the purpose of this systematic review was to investigate the association between training characteristics and running related injuries.

## METHOD

### Search strategy and inclusion criteria

The Cochrane database was searched, revealing no systematic reviews about training characteristics and RRI. A search of the Pubmed, Web of Science, Embase, and Sportdiscus databases was conducted October 11th 2011 to identify studies that met the inclusion criteria using the search strategy presented in Appendix 1. The search was limited to studies of humans, published in English, and included only original articles.

Prospective cohort studies, cross-sectional studies, case-control studies, and randomized controlled trials were included in the current systematic review if a relationship between training characteristics and RRI was investigated. Studies with novice, recreational, and elite runners between the ages of 18 to 65 were included. Articles were excluded if participants were sprinters or middle distance runners, or were predominantly exposed to types of sporting activity other than running such as triathlons, and military training programs. Articles on cadavers, computer modeling/simulation studies were excluded.

The exposure variables of interest were training characteristics including volume, distance, mileage, time, duration, frequency, intensity, speed, and pace. Different methods for analyzing or reporting these characteristics were accepted. For instance, volume could be measured as kilometers or miles per day, per week, per month or as the gradual increase in mileage per week over a given period of time. The outcome of interest was RRI in general or specific RRI of the lower extremity or spine. Muscle cramps, corns, blisters, and calluses were not included as RRI.

### Data collection and analysis

Each study identified as a result of the electronic search was initially evaluated independently by two authors (RON and IB) by screening the title and abstract. Articles without an abstract were excluded. All articles of interest were retrieved and evaluated for eligibility. Articles were excluded if no information was provided on injuries during follow up, in case of overview articles, or articles about degenerative diseases only.

### Methodological quality assessment

The methodological quality of the cross sectional studies, case-control studies, and prospective cohort studies was assessed by means of a methodological quality assessment list developed and used by van der Worp et al,[26] which was based on a list developed by van der Windt et al.[27] The list was adapted slightly to make it specific for training and RRI. The assessment contains items on information and validity and/or precision in five categories: study objective, study population, outcome measurements, assessment of the outcome, and analysis and data presentation. Separate quality assessment lists were constructed for cross-sectional studies, case-control studies, and prospective cohort studies. The items of the quality assessment list are presented in Table 1. Each item was evaluated as either positive (+) or negative (-) by two reviewers independently. In cases where it was unclear whether a study did or did not meet an item, or if no clear information regarding the item was stated, the item was scored as negative (-). Results of the quality assessment made by the two reviewers were compared, and any disagreement concerning an item was resolved in a consensus meeting. The total quality of each study was calculated by counting the number of items being positive (+) from item 3 to 16 divided by the total number of items for the study type (11 for case-control studies, 9 for prospective cohort studies, and 8 for cross sectional studies).

The methodological quality of the randomized controlled trials included was rated using the PEDro rating scale which is based on the Delphi list developed by Verhagen and colleagues.[28] The total methodological quality score was found by evaluating the internal validity and statistical reporting using an 11 criteria list. The total quality of each randomized controlled trial was calculated by counting the number of items being positive (+) from item 2 to 11 divided by 10. Previously, the PEDro scale has demonstrated an inter-rater agreement of $[k] = 0.73–0.82$.[29]

## Results

After examining 4561 titles and abstracts, 62 articles were identified as potentially relevant. After reference checking, one additional study was identified.[30] The full texts of all 63 articles were retrieved and were subsequently evaluated by both RON and IB. Review of the complete texts excluded 32 articles. Of the excluded articles, four were overview articles,[31-34] four included persons less than 18 years of age,[35-38] three included persons with degenerative diseases only,[39-41] eight articles did not describe the relationship between training characteristics and RRI,[42-47] three had no control group,[48-50] two were modeling articles,[51,52] seven had a faulty injury definition or none at all,[53-59] and one was a design article.[60] Finally, 30 articles were included in the review.

## Risk of bias in included studies

The quality of included studies is presented in Table 2. The overall methodological quality of the included prospective studies, case-control studies, and cross sectional studies was 44.1% ranging from 9 to 89%. The most problematic areas were 1) the main purpose of many of the studies was different than the relation between training and RRI, 2) description of the demographic characteristics (gender, age, body mass index) of the participants was lacking, and 3) lack of adjustment for the effect of multiple training variables. The overall quality of the three randomized controlled trials was 43%.

## Description of studies and injury definition

The year of publication for the included studies ranged from 1977 to 2008. The studies represented populations in USA, Canada, New Zealand, The Netherlands, Denmark, Switzerland, Germany, and Sweden. The total sample size of included participants was 24,066, ranging from 28 to 4,335 subjects in each study. Of the 30 included studies, nine were retrospective cohort studies, 12 were prospective cohort studies, six were case-control studies, and three randomized controlled trials. The study characteristics of the selected studies were described to obtain insight into the homogeneity of the study populations (Table 3). The types of participants (novice, recreational, and elite), and the injury definition used varied considerably between the studies. For instance, Lysholm et al[16] used "all injuries that markedly hampered training or competition for at least 1 week were noted" while Valliant[61] used "injury was defined as physiological damage or bodily pain which interfered with one´s ability to run". The mean age of all participants in the 30 studies varied from 19.5 years to 44 years with an average of 35.4 years. Mean body mass index was 22, ranging from 20.97 to 25.86. Four studies included only males while two included only females. For the remaining studies, an average of 67.6% of the participants included were males. Table 3 presents summary data from each study regarding the type of runner, demographic characteristics, and injury definition as quoted verbatim from the article.

## Description of training characteristics

In 22 studies, the training characteristics were assessed retrospectively by a questionnaire. The recall period varied from two weeks to 10 years. In eight studies,

**Table 1.** *Summary of quality scoring criteria for cross-sectional studies, case control studies, and prospective cohort studies.*

| Category | | Study type |
|---|---|---|
| *Study objective* | | |
| 1 | Positive, if the study had a clearly defined objective and the main purpose was to investigate the relation between training characteristics and RRI | CS / CC / PC |
| *Study population* | | |
| 2 | Positive, if the main features of the study population are described (sampling frame and demographic characteristics) | CS / CC / PC |
| 3 | Positive, if cases and controls are drawn from the same population and a clear definition of cases and controls is given and if subjects with RRI in the past 3 months are excluded. | CC |
| 4 | Positive, if the participation rate is at least 80% or if the participation rate is 60-80% and the non-response is not selective (data shown). | CS / CC / PC |
| 5 | Positive, if the participation rate at main moment of follow-up is at least 80% or if the non-response is not selective (datashown). | PC |
| *Outcome measurements* | | |
| 6 | Positive, if data on history of RRI is collected and included in the statistical analysis. | CS / CC / PC |
| 7 | Positive, if the outcome is measured in an identical manner among cases and controls. | CC |
| 8 | Positive, if the outcome assessment is blinded with respect to RRI status | CS / CC |
| 9 | Positive, if the outcome is assessed at a time before the occurrence of RRI. | CC |
| *Assessment of the outcome* | | |
| 10 | Positive, if the time period on which the assessment of RRI was based was at least 1 year. | PC |
| 11 | Method for assessing injury status: physical examination blinded to exposure status (+); self-reported: specific questions relating to symptoms/disease/use of manikin (+), single question (-). | CS / CC / PC |
| 12 | Positive, if incident cases were included (prospective enrollment). | CC |
| *Analysis and data presentation* | | |
| 13 | Positive, if the measures of association estimated were presented (OR / RR), including CI and numbers in the analysis. | CS / CC / PC |
| 14 | Positive, if the analysis is controlled for confounding or effect modification: individual factors (BMI, previous injuries etc.). | CS / CC / PC |
| 15 | Positive, if the analysis is controlled for confounding or effect modification: Training related factors. | CS / CC / PC |
| 16 | Positive, if the number of cases in the final multivariate model was at least 10 times the number of independent variables in the analysis. | CS / CC / PC |

CS = cross-sectional studies. CC = case-control studies. PC = prospective cohort studies. RRI = Running Related Injuries.

**Table 2.** *Summary of quality scoring for all included studies. Scores given for the items of the quality assessment list for prospective cohort studies, cross sectional studies, and case-control studies and the PEDro scale for randomized controlled trials.*

| Reference | Study type | (1) | (2) | (3) | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Total | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Satterthwaite 1999 | PC | - | - | | + | + | + | | | | - | + | | + | + | + | + | 8 / 9 | 89% |
| Macera 1989 | PC | - | + | | + | + | + | | | | + | - | | + | + | + | + | 8 / 9 | 89% |
| Walter 1989 | PC | - | - | | - | + | + | | | | + | + | | + | + | + | + | 8 / 9 | 89% |
| Hootman 2002 | PC | - | - | | - | + | + | | | | + | - | | + | + | + | + | 7 / 9 | 78% |
| Middelkoop 2008 | PC | - | + | | - | + | + | | | | - | + | | + | + | + | + | 7 / 9 | 78% |
| Wen 1998 | PC | - | + | | - | + | + | | | | - | + | | + | + | + | + | 7 / 9 | 78% |
| Kelsey 2007 | PC | - | + | | - | + | + | | | | + | + | | + | + | + | - | 7 / 9 | 78% |
| Colbert 2000 | CC | + | - | + | - | | + | + | - | - | | + | + | + | + | + | + | 8 / 11 | 73% |
| Taunton 2003 | PC | - | - | | + | - | + | | | | - | + | | + | + | + | + | 6 / 9 | 67% |
| McKean 2006 | CS | - | - | | - | | + | | - | | | + | | + | + | - | + | 5 / 8 | 63% |
| Reinking 2007 | PC | + | - | | + | + | + | | | | - | + | | + | - | - | - | 5 / 9 | 56% |
| Wen 1997 | CS | - | + | | - | | + | | - | | | - | | - | + | + | + | 4 / 8 | 50% |
| Knobloch 2008 | CS | + | + | | + | | + | | - | | | + | | + | - | - | - | 4 / 8 | 50% |
| Fields 1990 | PC | - | - | | + | + | + | | | | + | - | | - | - | - | - | 4 / 9 | 44% |
| Jacobs 1986 | CS | - | - | | - | | - | | - | | | + | | - | - | - | - | 1 / 8 | 38% |
| Valliant 1981 | CS | + | - | | - | | - | | - | | | - | | - | + | + | - | 2 / 8 | 25% |
| Marti 1988b Women only | CS | + | - | | + | | - | | - | | | + | | - | - | - | - | 2 / 8 | 25% |
| Marti et al 1988a | CS | - | - | | + | | - | | - | | | + | | - | - | - | - | 2 / 8 | 25% |
| McCrory 1999 | CC | + | + | - | - | | - | + | - | - | | - | - | + | - | - | - | 2 / 11 | 18% |
| Messier 1995 | CC | + | - | - | - | | - | + | - | - | | - | - | + | - | - | - | 2 / 11 | 18% |
| Duffey 2000 | CC | + | - | - | - | | - | + | - | - | | - | - | + | - | - | - | 2 / 11 | 18% |
| Messier 1991 | CC | + | - | - | - | | - | + | - | - | | - | - | + | - | - | - | 2 / 11 | 18% |
| Koplan 1995 | CS | - | - | | - | | - | | - | | | + | | - | - | - | - | 1 / 8 | 13% |
| Koplan 1982 | CS | - | - | | - | | - | | - | | | + | | - | - | - | - | 1 / 8 | 13% |
| Lysholm 1987 | PC | + | - | | - | - | - | | | | + | - | | - | - | - | - | 1 / 9 | 11% |
| Bovens 1989 | PC | - | + | | - | - | - | | | | + | - | | - | - | - | - | 1 / 9 | 11% |
| Pollock 1977 | PC | + | - | | - | - | + | | | | - | - | | - | - | - | - | 1 / 9 | 11% |
| Messier 1988 | CC | + | - | - | - | | - | + | - | - | | - | - | - | - | - | - | 1 / 11 | 9% |
| | | | | | | | | | | | | | | | | | | | |
| | **Pedro criteria** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | | | | | | **Total** | **%** |
| Buist 2008 | RCT | + | + | + | + | - | - | - | + | + | + | + | | | | | | 7 / 10 | 70% |
| vanMechelen 1993 | RCT | + | + | - | - | - | - | - | - | + | + | + | | | | | | 3 / 10 | 30% |
| Jakobsen 1994 | RCT | - | - | - | + | - | - | - | - | + | + | - | | | | | | 3 / 10 | 30% |

PC=Prospective study, CC=Case-control study, CS=Cross sectional study, RCT=Randomized controlled trial.

daily running diaries[9,16,17,30,62-64] or an internet based log[15] were used. In five studies, training interventions were used.[5,9,15,17,30] Odds Ratio (OR), Hazard Ratio (HR), and Relative Risk (RR) were the most common measures of association. The unit of measurement in this review is miles. However, some articles used kilometers. In these cases, kilometers were converted into miles using 0.62137 as conversion factor. Different definitions were used in the reviewed studies for training volume, duration, intensity, and frequency.

*Volume*

In 28 articles out of 30 articles, the link between training volume and RRI was investigated. The most commonly used approach to define exposure was to measure the average weekly miles[4,13,14,16,22,61-63,65-69] or kilometers[10,11,17,70] of running over a period of time. In other studies, weekly distance per weekly frequency[7] or total running distance[64,71] were used as the measure of exposure.

*Duration*

In three articles, average hours[9,17,69] or minutes[15] spent running per week were used as the exposure variable. In another study, the weekly progressive increase in duration during a graded training program was used,[15] while two other studies used minutes per day[3,30] as their measure of exposure.

*Intensity*

In 16 articles, training intensity was described.[1,4,9,11,13,14,17,22,63-70] In a majority of these, average pace of

**Table 3.** *Descriptions of included studies characteristics. Injury definitions are quoted verbatim unless stated otherwise.*

| Author, year | Running type | Included / Analyzed | Description of population | Injury definition |
|---|---|---|---|---|
| Bovens 1989 | Healthy untrained volunteers with the goal of running a marathon within 1½ years | 115 / 73 = 63.5 % | M / F: 58 / 15<br>Age: 35 ± 8 (M), 33 ± 6.4 (F)<br>BMI: 22.67 (M) 20.97 (F). | "Any physical complaint developed in relation with running activities and causing restriction in running distance, speed, duration, or frequency, was considered to be an injury." |
| Buist 2008 | Healthy novice runners | 603 / 486 = 80.6 % | M / F: 180 / 306<br>Age: 39.8 ± 10.1<br>BMI: 24.9 ± 3.5 | "An RRI was defined as any musculoskeletal complaint of the lower extremity or back causing a restriction of running for at least one week." |
| Colbert 2000 | | 5327 / 3923 = 73.6 % | Cases<br>M / F: 698/ 169<br>Age: N / A<br>BMI: N / A<br><br>Controls<br>M / F: 2358 / 698<br>Age: N /A<br>BMI: N / A | "Injury related to physical activity during the 12 months immediately preceding the survey that necessitated a physician visit." |
| Duffey 2000 | Same as Messier 1995 | | Controls<br>M / F: 53 / 17<br>Age 35 ± 1<br>BMI: 22.9 ± 0.3<br><br>Cases /AKP<br>M / F: 68 / 31<br>Age: 36 ± 1<br>BMI: 23.3 ± 0.3 | Same as Messier 1995 + "The diagnosis of anterior knee pain was based on clinical examination…" |
| Fields 1990 | Participants had to train an average of 3 days and run at least 10 miles per week | 51 / 40 = 78.4 % | M / F: 31 / 9.<br>Age: N / A<br>BMI: N / A | "An injury was defined as any musculoskeletal problem occurring during running that interrupted training for 1 or more days." |
| Hootman 2002 | Persons who had been running at least 1 year from 1981 to 1985. | 11972 / 3090 = 25.8 % | M / F: 2.481 / 609.<br>Age: N / A<br>BMI: N / A | "First reported lower extremity injury requiring consultation with an physician that occurred after the start of an RWJ program and during the 5 year recall period." or "lower extremity injury requiring consultation with an physician during the 12-months recall period" |
| Jacobs 1986 | Runners participating in "National Championship" USA 1985 | 550 / 451 = 0.82 % | M / F: 355/ 96<br>Age 33.9 (M) 32.4 (F)<br>BMI: N / A | "A runner was considered to have been injured… if the pain caused a restriction in running distance or speed, or prevented any running at all." |
| Jakobsen 1994 | Recreational long distance runners (marathon) | | Controls:<br>M / F: 18 / 2<br>Age: 43.1<br>BMI: 22.9<br><br>Intervention:<br>M / F: 19 / 2<br>Age: 40.6<br>BMI: 22.5 | "An injury was defined as any injury of the musculoskeletal system that was sustained during running and prevented training or competition" |
| Kelsey 2007 | Female cross-country runners running at least 40 miles per week during peak training times. | 150 / 127 = 84.6 % | Female only<br>Age: 22 ± 2.6<br>BMI: 21.2 ± 1.9 | "Participants were asked to record the occurrence of a possible stress fracture on a monthly calendar and also to report their occurrence to us immediately. The fracture had to be confirmed by x-ray, bone scan, or magnetic resonance imaging to be counted in this study." |
| Knobloch 2008 | Elite | 291 / 291 = 100% | M / F: 248 / 41<br>Age: 42 ± 9<br>BMI: 23 ± 2.2 | "Any physical complaint sustained by a runner that result from a running competition or training, irrespective of the need for medical attention or time lost from running activities" |
| Koplan 1982 | Participants in 10 km. road race. | 2500 / 1423 = 56.9 % | M / F: 730 / 693<br>Age: 33.4 (M) 29.9 (F)<br>BMI: N / A | "An injury was defined as a musculoskeletal ailment attributed to running that caused the runner to reduce the weekly mileage, take medicine, or visit a health professional." |

**Table 3. (Continued)** *Descriptions of included studies characteristics. Injury definitions are quoted verbatim unless stated otherwise.*

| | | | | |
|---|---|---|---|---|
| Koplan 1995 | Recreational | 742 / 535 = 72.1 % | M / F: 321 / 214<br>Age: N / A<br>BMI: 24.6 (M) 21.5 (F) | "A musculoskeletal ailment that caused respondents to reduce or cease exercise or interfered with their work or school activities" |
| Lysholm 1987 | Long distance runners. | | Male only<br>Age 34.5 ± 7.4<br>BMI: N / A | "All injuries that markedly hampered training or competition for at least 1 week were noted" |
| Macera 1989 | Habitual runners | 1576 / 583 = 37 % | M / F: 485 / 98<br>Age: 41.6 ± 9.5 (M) 36.1 ± 8.2 (F)<br>BMI: 23.0 ± 2.2 (M) 25.8 ± 2.4 (F) | "Self reported "muscle, joint or bone problem/injury" of the lower extremities (foot, ankle, achillestendon, calf, shin, knee, thigh, or hip) that the participant attributed to running. The problem had to be severe enough to cause a reduction in weekly distance, a visit to a health professional, or the use of medication." |
| Marti 1988a | Participants in 10 mile road race. | | Male only.<br>Age: 35.0 ± 10.0<br>BMI: 22.51 ± 1.98 | "Grade I injuries involved maintenance of full training activity in spite of symptoms; grade II, a reduction of training activity, and grade III, full training interruption defined as "involuntary complete interruption of running of at least two weeks´ duration." |
| Marti 1988b | Female runners participating in 10 mile road race. | 622 / 428 = 68.8 % | Female only<br>Age: N / A<br>BMI: N / A | Same as Marti 1988a |
| McCrory 1999 | Same as Messier 1995 | | Controls<br>M / F: N / A<br>Age 34.5 ± 1.2<br>BMI 23.<br><br>Achilles tendinitis group M/F: N /A<br>Age: 38.4 ± 1.8<br>BMI: 23.45 | "Achilles tendinitis was defined as inflammation and irritation of the achilles tendon 2-6 cm above its insertion into the calcaneus." |
| McKean 2006 | Participants in a running relay race | 6823 / 2886 = 42.3 % | M / F: N / A<br>Age: N / A<br>BMI: N / A | "An event that affected the athlete's ability to train or race over the previous 1 year period" |
| Mechelen 1993 | Runners with at least 10 km / week all year around | 421 / 326 = 77.4 % | Male only<br>Age: N / A<br>BMI: N / A | "A running injury was defined as any injury that occurred as a result of running and caused one or more of the following: 1) the subject had to stop running; 2) the subject could not run on the next occasion; 3) the subject could not go to work the next day; 4) the subject needed medical attention; 5) the subject suffered from pain or stiffness during 10 subsequent days while running." |
| Messier 1995 | Recreational and competitive runners who had been running a minimum of 10 miles / week for at least a year | | Controls:<br>M / F: 53 / 17<br>Age 35.0 ± 1.2<br>BMI 23.8<br><br>ITBFS group:<br>M / F: 33 / 23<br>Age: 33.9 ± 1.2<br>BMI: 22.8 | "An injury exists when an entity causes symptoms resulting in 1) missed workouts, 2) a decrease in running mileage, and/or 3) a visit with a medical specialist." |
| Messier 1991 | Same as Messier 1995. | | Controls<br>M / F: 12 / 4<br>Age: N / A<br>BMI: N / A<br><br>Cases<br>M / F: 14 / 6<br>Age: N / A<br>BMI: N / A | "Patellofemoral pain was defined as tenderness along the medial or lateral joint capsule, pain or compression of the patella against the underlying femur, and tenderness along the medial facet of the patella" |
| Messier 1988 | Same as Messier 1995 | | Controls:<br>M / F: N / A<br>Age: N / A<br>BMI: N / A<br><br>Cases<br>M / F: N / A<br>Age: N / A<br>BMI: N / A | "IT band friction syndrome was defined as inflammation of the iliotibial band as it passes over the lateral femoral condyle and / or inflammation at the insertion on Gerdy´s tubercle. Shin splints was defined as pain along the medial distal two thirds of the tibia which is usually caused by tendinitis and periosteal irritation of the tibialis posterior muscle and tendon, the flexor muscles and tendons, and/or other soft tissue attached to the posteromedial border of the tibia. Plantar fasciitis was defined as inflammation of the fascia and soft connective tissue at the site of the plantar fascia attachment on the inferior aspect of the calcaneal tuberosity." |

**Table 3. (Continued)** *Descriptions of included studies characteristics. Injury definitions are quoted verbatim unless stated otherwise.*

| | | | | |
|---|---|---|---|---|
| Middelkoop 2008 | Marathoners | 1500 / 694 = 46.3 % | Male only<br>Age: 44 ± 9.6<br>BMI: 23.5 ± 2.1 | "Self-reported injury on muscles, joints, tendons and/or bones of the lower extremities (hip, groin, thigh, knee, lower leg, ankle, foot, and toe) that the participant attributed to running. The problem had to be severe enough to cause a reduction in the distance, speed, duration or frequency of running." |
| Pollock 1977 | Sedentary prison inmates | 122 / 157 = 77.7 % | M / F: N / A<br>Age: N / A<br>BMI: N / A | A training related incident that prevented a subject from jogging for at least one week |
| Reinking 2007 | Collegiate cross-country athletes. | 124 / 67 = 54 % | M / F: 44 / 44<br>Age: 19.5<br>BMI: N / A | Self-reported ERLP based on the athletes received additional explanation regarding the definition of leg pain. (Corrected by the Authors). |
| Satterthwaite 1999 | Marathoners | 1357 / 875 = 64.5 % | M / F: N / A<br>Age: N / A<br>BMI: N / A | Stiffness or pain in the hip, front thigh, hamstrings, knee or calf (Corrected by the Authors) |
| Taunton 2003 | Novice and intermediate runners. | 1020 / 844 = 82.7 % | M / F: 205 /635<br>Age: N / A<br>BMI: N / A | "Grade 1 injury (pain only after exercise) or greater" Authors remark: The grading system is different from Marti 1988a. |
| Valliant 1981 | Participants in a 5-, 8- or 10-mile race. | 80 / 41 = 51.3 % | M / F: N / A<br>Age: N / A<br>BMI: N / A | "Injury was defined as physiological damage or bodily pain which interfered with one´s ability to run." |
| Walter 1989 | Runners participating in 3.5 – 14 mile running events. | 2524 / 1288 = 51 % | M / F: 985 / 303<br>Age: N / A<br>BMI: N / A | "Injuries are defined as severe enough to reduce the number of miles run, take medicine, or see a health professional" |
| Wen 1997 | Runners preparing for marathon | 304 / 355 = 85.6 % | M / F: 133 / 171<br>Age: 41.1 ± 10.6<br>BMI: 25.76 (M) 23.7 (F) | "Subject answered yes to having had injury or pain to that anatomic part; and answered yes to having had to stop training, or to have to slow pace, stop intervals, or otherwise to have had to modify training, and the onset of the injury was gradual (vs. immediate), or his or her diagnosis was one that is generally considered an overuse injury." |
| Wen 1998 | Runners preparing for marathon. | 355 / 255 = 71.8 % | M / F: 102 / 153<br>Age 41.3 ± 10.8<br>BMI: 25.86 (M) 24.22 (F) | Same as Wen 1997 |

M/F= Male and female, BMI= Body mass index, N/A= Not available.

workout was used to express intensity during training, measured as minutes per mile (min/mile) or minutes per kilometer (min/km).[13,22,63,65-70,72] Other studies used kilometers per hour,[17,64] 16 km running time,[14] or percentage of maximal attainable heart rate.[9]

*Frequency*

The number of weekly training sessions was reported in a variety of ways as number of training sessions,[71] times,[9] frequency,[22,73] days,[5,11,13,30,64] runs,[74] or workouts[4] per week. Most often the data were analyzed by dividing the weekly amount of days running into different categories. The comparisons vary widely across studies, however. The reference groups were defined as either 1, 1-2, 1-3, 1-4, or 1-5 days per week, and were compared to either one or several exposure groups varying between 3, 4, 5, 6, 7, 4-5, 5-7, 6-7 days per week. In one article, a regression model was used to investigate the risk of RRI as the weekly frequency increased during training prior to a marathon.[6]

## Relationship between training characteristics and RRI

*Volume*

Hootman et al[4] found an increased risk of injury among males (HR = 1.66 [1.43, 1.94]) and females (HR = 2.08 [1.45, 2.98]) running more than 20 miles per week. Lysholm et al[16] found a significant correlation (r = 0.59) in long-distance/marathon runners between the distance covered in a given month and the number of injury days during the following month. Walter et al[11] found no significant difference in relative risk between the reference group who ran less than 10 miles per week and the groups who ran distances between 10 and 39 miles per week. However, the relative risk of injury was significantly higher among males (2.22 [1.30-3.68]) and females (3.42 [1.42-7.85]) running ≥40 miles per week. This was supported by Macera et al[22] who found a significantly increased odds ratio for sustaining injury among males running ≥40 miles per week over a period of 3 months (2.9 [1.1-7.5]). In the same study,

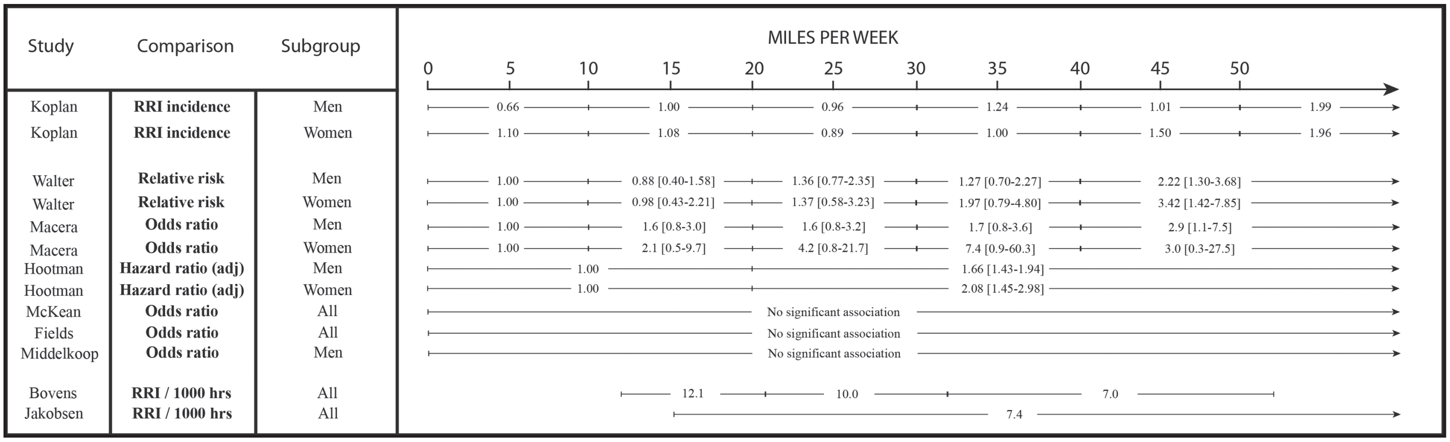


**Figure 1.** *Relationship between miles per week and Running Related Injury (RRI) reported as mean [95% confidence interval] for different comparisons. Results from the articles by Bovens and Jakobsen are calculated based on figures in the articles. RRI = Running Related Injury. Adj = adjusted. Hrs = Hours.*

no association was found between weekly mileages and risk of injury among women.[22] Although a majority of studies reported a relationship between weekly mileage and RRI, no significant association between miles per week and likelihood of injury was found in two prospective studies and one retrospective study.[7,62,74]

In retrospective studies, several authors compared total volume per week between injured and non-injured subjects. Koplan et al[12] investigated the proportion of injuries over a 10 year period in different mileage strata. The proportion of women reporting injury was highest in those who ran 40-49 miles per week. For men, the proportion was highest among those who ran 30-39 miles per week. Those running more or less miles per week had a smaller proportion of injuries. Marti et al[14] found that runners who sustained injuries during the study period ran greater weekly mileage when compared to non-injured runners (26.3 km [3.2-83.8] versus 22.0 km [2.1-78.6], p 0.01). In a one-way analysis, Valliant[61] also indicated that injured runners ran significantly more miles per week than non-injured runners (47.5 $\pm$ 20.5 miles versus 29.6 $\pm$ 16.7 miles, $p < 0.01$). This is supported by Jacobs et al[13] and Koplan et al[1] who found mileage run per week to be highly associated with injury.

In two studies, the RRI per 1000 hours of running in groups running different mileages per week were investigated.[9,17] The number of injuries per 1000 hours of running appeared to decrease with increasing weekly mileage (Figure 1).

Walter et al[11] investigated the relationship between longest run per week and risk of injury. The relative risk of sustaining an injury when the longest run each week is >5 miles, is 2.49 [1.64-3.71] among males and 1.78 [0.99-3.13] among females compared with a reference group having their longest run below 5 miles. Van Middelkoop et al[7] measured weekly distance per weekly frequency. Running an average of 6.8–9.3 miles per training session was not associated with increased or decreased risk of sustaining an injury compared to average runs above or below 6.8–9.3 miles.

Several authors have investigated the relationship between training volume and specific running injuries. Reinking et al[10] investigated subjects sustaining exercise related lower leg pain and found no significant difference in injuries between individuals training more or less than 40 miles per week. Satterthwaite et al[6] found an increased odds ratio for hamstring (1.07 [1.02, 1.13]) and knee (1.13 [1.04, 1.23]) injuries by a weekly increase in mileage of 6 miles. Wen et al[69] found a significant difference in weekly mileage between subjects sustaining hip (18.7 miles per week) or hamstring injuries (22.4 miles per week) compared to controls (13.3 and 13.4 miles per week). Kelsey et al[8] found miles run per week in the past year to be non-predictive of stress fractures. Wen et al[69] found weekly mileage and hours per week protective against overall injuries, knee injuries, and foot injuries. In case-control studies, no difference in weekly mileage was found between controls and persons with plantar fasciitis,[65] shin splints,[65] achilles tendinitis,[70] or anterior knee pain,[68] while patients with patellofemoral

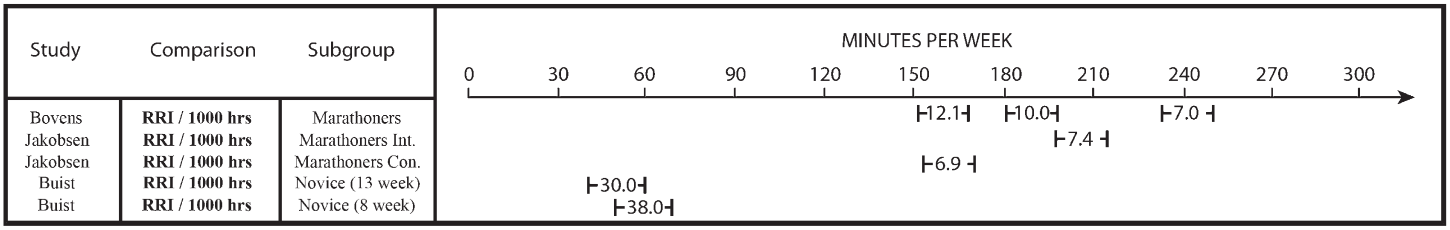


**Figure 2.** *Relation between minutes per week and number of Running Related Injury (RRI) per 1000 hours of running. Results from the articles by Bovens and Jakobsen are calculated based on figures in the articles. Int = intervention. Con = controls. RRI = Running Related Injury. Hrs = Hours.*

pain ran significantly less than healthy controls.[66] For iliotibial band friction syndrome, Messier and colleagues found conflicting results in two different studies. In one study, injured participants ran significantly less than healthy controls, and in the other study no significant difference in weekly mileage between injured and healthy participants was reported.[65,67]

*Duration*

Pollock et al[30] found an increasing injury incidence among novice runners who ran in 15, 30, and 45 minute duration groups of 22%, 24%, and 54%, respectively. Jakobsen et al[17] reported 7.4 and 6.9 RRI per 1000 hours of running among marathon runners who ran 204 [95% CI: 198-210] and 162 [95% CI: 156-168] minutes per week on average over a one year period. Over a time period of 18 months, Bovens et al[9] reported 12.1, 10.0, and 7.0 injuries per 1000 hours of running among marathon runners who ran 162, 192, and 240 minutes per week. Buist et al[15] found an average of 33 [95% CI: 27-40] RRI per 1000 hours of running in two groups of novice runners. One group was instructed to run an average of 52 minutes per week over a 13 week period (30 RRI/1000 hours), while the other group were instructed to run an average of 59 minutes per week over a 8 week period (38 RRI/1000 hours). Figure 2 shows the RRI/1000 hours of running in groups running different minutes per week.

Buist et al[15] investigated the relationship between weekly progression in running duration and likelihood of injury. There was no significant difference in the incidence of RRI in a group of runners with a 13 week training program with a mean duration increase of 10% per week compared to the incidence of RRI in a group of runners training an 8 week training program with a mean duration increase of 24% per week. However, although not significant, the mean survival time of runners in the 13 week training group was 212 minutes, compared to 167 minutes in runners of the 8 week training group.

*Intensity*

In fourteen studies, the relationship between training intensity and development of RRI was investigated.[1,4,11,13,14,17,63-70] Jacobs et al[13] found a pace above 8 min/mile to increase the risk of injury as compared with a pace below 8 min/mile ($p < 0.05$). Hootman et al[4] found a reduced odds ratio (0.51 [0.35, 0.74]) for sustaining an injury among males who ran at above a 15 min/mile pace compared to those who ran at a faster pace ($p = 0.0004$). A similar significant difference was found for female subjects ($p \leq 0.05$). However, lack of adjustment for other predictor variables such as weekly mileage weakened this association. This is supported by Marti et al,[14] who found that running speed calculated from 10 mile race time was positively related to injury incidence in univariate analysis, but adjustment for mileage clearly weakened this association. In eight studies, no significant relationship between average training pace and likelihood of injury were found.[1,11,17,63-66,68] Wen et al[63,69] reported that no association was found between running pace and injury. However, it was reported that interval training increased the risk of shin injury ($p < 0.05$).[63] In a case-control study, Messier et al[67] found runners with iliotibial band friction syndrome to run on average 3 seconds/mile faster than the control group during non-competition training ($p = 0.05$). McCrory et al[70] found training pace to be a significant ($p \leq 0.05$) discriminator between persons with achilles tendinitis when they examined pace in minutes per kilometer, where the pace of those injured was $4.64 \pm 0.08$ as compared to controls which was $4.87 \pm 0.07$.

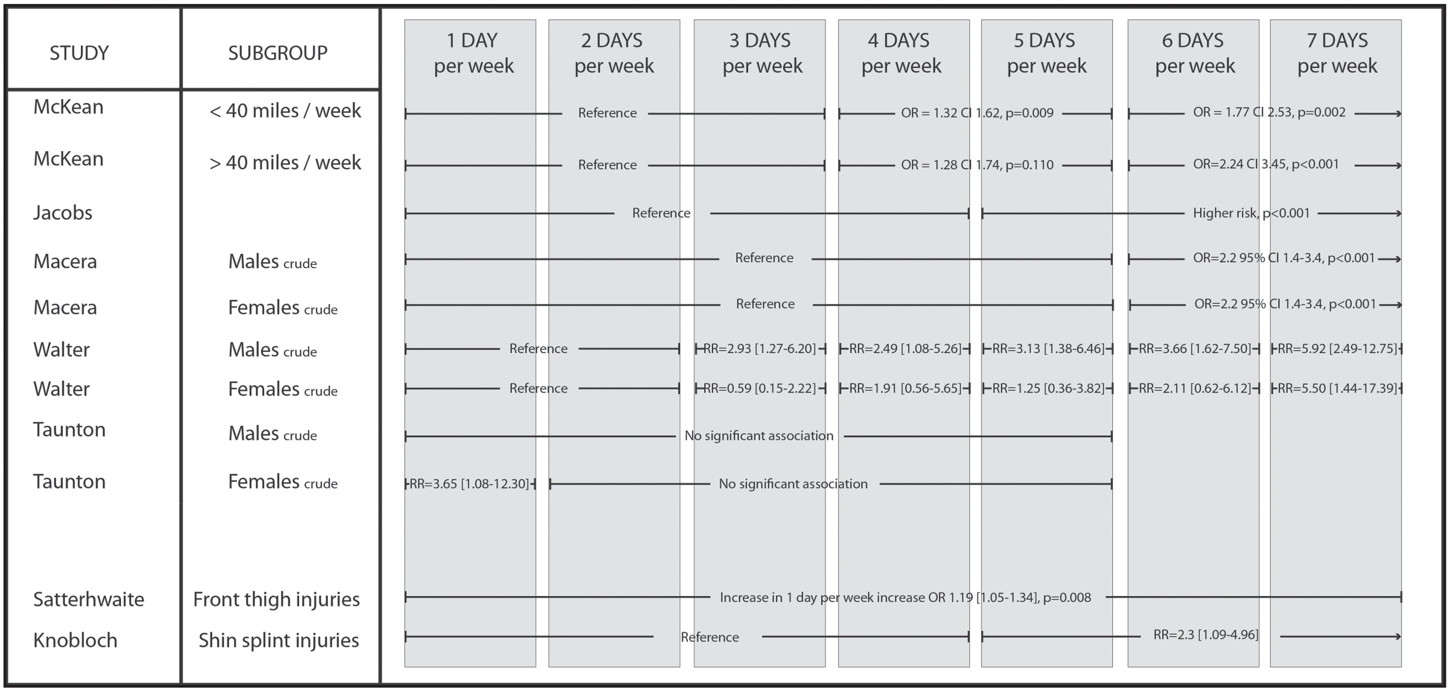


**Figure 3.** *Relationship between running frequency (days per week) and Running Related Injury (RRI). OR = odds ratio; RR = relative risk; CI = Confidence Interval.*

*Frequency*

In eight articles, the relationship between training frequency and development of RRI was investigated.[5,6,11,13,22,30,64,71,74] Results are presented in Figure 3. In six articles, RRIs in general were investigated;[5,11,13,22,74] one investigated front thigh injuries,[6] and one shin splint.[71] In several studies, an increased risk, relative risk, or odds ratio for sustaining an RRI was reported when the weekly running frequency increased.[11,13,22,30,69,71,74] Persons running 6-7 times per week had the highest risk. On the contrary, Taunton et al[5] found an increased risk of injury among females running one time per week. Males also showed a similar trend, although it was not statistically significant ($p = 0.064$). Satterthwaite et al[6] found the odds ratio for sustaining an anterior thigh injury increased by 1.19 [1.05-1.34] per one day increment in running frequency. No significant association was found for hamstring, hip, knee, or calf injuries. Knobloch et al[71] reported an increased risk of shin splints among individuals running more than five days per week.

## DISCUSSION

The purpose of this study was to investigate the relationship between training characteristics and running related injuries using a systematic review of the literature. Training characteristics were categorized into four groups: volume, duration, intensity, and frequency. The majority of the included prospective studies had a higher methodological quality when compared with the case-control studies and cross sectional studies.

### Volume and duration

Previously, several authors[19,75] proposed that a high weekly mileage is associated with an increased risk of sustaining RRI. This is generally supported by the findings from the current systematic review. However, Fields et al[62] questions the reliability of mileage as an injury predictor, since they found injured runners averaging essentially the same mileage as healthy runners. According to Jakobsen et al,[17] it is therefore correct to use the incidence (injury per time) for comparison purposes because the risk of injury must be related to the time spent engaged in running. When injuries are related to exposure time, expressed as 1000 hours of exercise, Bovens et al,[9] found that the number of injuries decreased when weekly mileage during an 18 month period increased from 15 miles per week to 37 miles per week. The assumption that injury incidence is decreased when running greater distances is supported in other studies which investigated injury incidence among runners training different mileages per week. In the study by Bovens et al,[9] the mileage increase was accompanied by maturation as a runner, which possibly can explain the reduced risk of injury as weekly mileage increase; experienced runners may know the injury threshold better than novice runners. If this is the case, maturation as a runner would have to be considered an uncontrolled, confounding factor. The incidence is reported from 2.5 to 7.4 injuries per 1000 hours of exercise among marathon runners,[16,17] while injury incidence per 1000 hours of running among novice runners who trained 30 to 90 minutes per week is 33.[15] Based on these findings, a hypothetical example of the number of RRI over a 26 week period can be calculated for novice and marathon runners. If novice runners run for 30 minutes 3 times per week over 26 weeks they will run 39 hours in total. Taking into account the risk of injury of 33 per 1000 hours of running reported by Buist et al[15] the novice runner will sustain 1.29 injuries when running 39 hours. Similarly, marathon runners with the risk of 7.4 RRI per 1000 hours of running reported by Jakobsen et al[17] can expect 1.15 injuries if they run 156 hours (2 hours 3 times per week) over the same period of time. In this hypothetical example, the absolute numbers of injuries would be higher among novice runners. This is consistent with the findings by Walter et al[11] who stated that the risk of injury per mile of training declines with total mileage, so the small absolute increment in risk associated with increasing mileage may be acceptable to many athletes. All in all, these findings suggest that the relative injury threshold becomes higher in runners with higher weekly mileage.

In overview articles, authors[35,76] have suggested a maximal increase of weekly volume of no more than 10% per week, the so called "10% rule", in order to reduce the risk of injury. This suggests that runners who increase the weekly volume by less than 10% have reduced risk of RRI when compared with runners whose weekly increase is above 10%. In a randomized controlled trial by Buist et al,[15] the 10% rule was tested in novice runners. No significant difference in injury rates were found between runners following a graded training program with an increase in weekly duration of 10.5% compared to runners with an increase in weekly duration of 23.7%. However, it must be noted that both groups had a progression rate above 10%. If runners with a progression rate below 10% per week were compared with runners who increase their weekly volume for instance 40–60%, a statistically significant difference in injury rates may be shown. However, it may be unethical to conduct a randomized controlled trail with the intervention group having an increase in weekly mileage above 40%. In the study by Taunton et al,[5] all runners had to participate in one weekly training session. The length of this weekly training session was increased every week. An increased risk of injury was found among females who only participated in one training session compared to runners who ran more training sessions per week. Although not significant, a similar trend was found for males. Taunton et al[5] suggest that it stands to reason that a person who does not build an adequate training base during the other weekly training sessions will be more likely to be injured when they participate in a program that steadily increases in volume. However, information on progression rates were not reported in the study by Taunton et al,[5] and because of this it is not possible to relate the results to the 10% rule.

In conclusion, there is some evidence suggesting weekly mileages to be associated with injury. However, the relative injury threshold becomes greater in runners with higher weekly mileage. Clearly, more studies must be conducted to investigate the link between weekly increase in running volume and development of RRI, taking into account the influence of intensity, duration, and frequency.

**Intensity**

The literature showed conflicting results with regard to training intensity and development of injuries. Thus, the way of assessing and reporting training pace may be the reason for inconsistent results. In all included studies, training intensity was measured subjectively by assessing the self-reported running pace. This may be a major problem, since self-reporting may be affected by recall bias. Furthermore, the participants only reported the average pace. The variation in training pace within and between sessions is therefore not accounted for. Thus, the variation in training intensity is likely unknown and may or may not play a role in the relationship between training intensity and risk of RRI. One possible solution is to measure the training intensity objectively or quasi-objectively in each training session. To date, no studies were found that described a quasi-objective measure such as perceived exertion or other objective measures of training in relationship to injury. Again, more studies have to be conducted to ascertain if there is a relationship between training intensity and development of injury.

**Frequency**

A "U-shaped" pattern between frequency and development of RRI may exist: Taunton et al[5] found an increased risk of injury among female runners training one time per week. While McKean et al,[74] Jacobs et al,[13] Macera et al,[22] and Walter et al,[11] reported an increased risk among runners training 6-7 times per week compared with those training 2-5 times per week. Based on this, one might conclude that the ideal frequency is 2-5 running sessions per week. However, in the studies by Macera et al[22] and Walter et al[11] no additional risk was found after controlling for running volume. Therefore, Brill and Macera[23] suggested that cumulative distance is a better indicator of injury risk than the lack of rest between runs. Thus, based on all the studies included in this review it must be concluded that it is not possible to determine the specific role of running frequency with regard to injury.

**Running experience**

The experience of the runners included in the different studies may bias the results, since the included studies include a wide variety of types of runners. Jakobsen et al[17] and Marti et al[14] reported that experience was an important factor for injury risk, because high running experience diminished the risk of injury. In the study by Buist et al[15] novice runners reported the highest number of RRIs per 1000 hours of running. This was supported by Macera et al[22] who reported new runners to be at greater risk for injury than more experienced runners. Perhaps habitual and experienced runners know their own injury threshold better as compared to novice runners and are therefore less likely to sustain RRI. This may seem to lead to the conclusion that novice runners have greater risk of injury. However, novice runners may be more likely to report injuries compared to experienced runners who, in many cases, have sustained several injuries previously and therefore do not consider some conditions or pain severe enough to classify them as injuries.

**Definitions of Running Related Injury**

In the study by Mechelen et al[64] no attempt was made to compare the injury patterns between studies because of the differences in definitions and research methods, as well as research outcome. A similar problem exists in the current systematic review. In Table 3 the different injury definitions used in the 30 studies included was presented. There is a large variation in injury definition and it must be questioned if the different definitions of RRI in the studies included in this review are comparable. In their review, Ryan et al[77] stated that a standardized definition of running injury would benefit the understanding of injury prevalence, and can ultimately assist in injury prevention. Additionally, Satterthwaite et al[6] and Reinking et al[10] question the validity and reliability of measuring injury by self-reporting, as this method of describing RRI may be affected by subject recall bias.

**Measurement of training characteristics**

The methods used to collect information on exposure data are very similar. In all studies included in this review, questionnaires, surveys, or self-report diaries were used to collect information on training exposure. In this regard, several authors have concluded that the training exposure may have been estimated or reported incorrectly[71] again due to recall bias.[4,7] Therefore, the methods used in all studies to measure training exposure by subjective measurements (questionnaires, surveys, diaries) should be taken into careful consideration. Methods that utilize technology such as Global Positioning Systems (GPS) and actual distance recording may provide more valid and reliable information on training volume, frequency, and intensity.[78]

**Analysis of training characteristics**

Analysis of training characteristics is complex, since one or more training variable may interact with other training variables. In most papers included in the current review, only the crude association between a single training variable and the risk of injury was investigated, without accounting for the confounding or modifying effect of other training variables. Volume and duration are two partially independent variables. Running intensity is dependent on volume and duration, since intensity is volume divided by duration. Since volume, duration, and intensity all affect one another it may be relevant to measure and analyze all three variables. Since it seems likely that the relationship between the exposure variable and RRI may depend on the level of other training variables, future studies should allow for such comparisons. Furthermore, the frequency should be included in the analysis[74] even though it is not directly linked with volume, duration, or intensity. This approach is supported by Buist et al[15] who stated that the increase of running duration, intensity, and frequency should be taken into careful consideration. Hootman et al[4] investigated the relationship between an exposure variable and the risk of RRI while adjusting for other training related variables. However, it was not mentioned which training variables were adjusted for. Walter et al[11] used a better approach by described the training variables which were adjusted for. An increased risk of injury was found among those performing interval training. However, the association was considered unimportant once the result was adjusted for the effect of total training volume. Another example was in the study Marti et al.[14] In this study, running speed was positively related to injury in univariate analysis, but again adjustment for mileage clearly weakened this association. The approaches used by Walter et al and Marti et al are clear examples of authors trying to take into account the interactions between several training variables. It must be emphasized that the analysis of training characteristics should use, to some extent, the same assumption: that training variables are related and affect each other. Based on this, the current approaches used to analyze exposure data in order to investigate the relationship between training characteristics and RRI in a majority of the reviewed articles must be taken into careful consideration when the results are interpreted. In future studies the interaction between running volume, duration, intensity, and frequency must be considered.

Data may also have to be analyzed differently than it has been previously, especially if training variables are measured by GPS or other objective methods. Since data from GPS measurements are extensive they could be analyzed in a variety of ways. For example variability between training sessions or variations within sessions could be analyzed in addition to sudden increases in one or more training variables. Based on their measurements Wen et al[69] stated, that the possibility to examine for sudden increases in training variables was limited. This may be a key point, since it has been suggested that a sudden increase in running duration or intensity can overwhelm the ability for adaptive change, tissue repair, and result in injury.[79] The lack of ability to objectively measure such increases defined as "sudden" may affect the possibility to investigate the relationship between training exposure and RRI, since Jacobs et al[13] reported that one third of those injured described they had changed their training just prior to their injuries. Although it is not possible to examine this statement based on articles included in this review, an interesting focus for future research would be to investigate if the sudden increase in one or more training variables, as suggested by many,[24,75,79-81] is more strongly related to injury than the absolute volume which is currently suggested to be the main contributor to injury.[18-20,82] It must be emphasized that there is a strong need for future studies regarding RRI with the primary purpose of investigating the link between training characteristics and the development of RRI.

## CONCLUSION

Based on the studies reviewed it was not possible to identify which training errors are related to running related injuries. Running experience and injury threshold seem to play a role in the relationship between training characteristics and development of injuries, while volume, duration, intensity, and frequency seem to have a complex interaction with each other which is not accounted for in the majority of the included studies. All training variables should be measured and accounted for when studies on the relationship between training characteristics and injuries are examined in future studies. If methodological limitations can be solved by objectively measuring the training characteristics more studies can be conducted to carefully define training variables and their interactions, and then plan a large scale prospective study or randomized controlled trial to determine whether cause and effect relationships exist.

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## APPENDIX 1: SEARCH TERMS

("Running"[Mesh] OR (foot race)) AND ("Exercise"[Mesh] OR exposure OR "Physical Therapy Modalities"[Mesh] OR "Clinical Protocols"[Mesh] OR (regim*) OR program OR programme OR "Healthy People Programs"[Mesh] OR marathon OR marathon OR training OR (training characteristics) OR (running patterns) OR volume OR intensity OR frequency OR speed OR pace OR distance OR mileage) AND (injur* OR syndrome* OR tendin* OR fractur* OR ("pain"[Mesh]) OR fasciitis OR bursitis OR splint* OR tear* OR sprain* OR strain* OR entrapment* OR ostei* OR osteopor* OR osteoa* OR rupture* OR arthros* OR arthri* OR lipoma OR sciatica OR lumbago OR laceration* OR split* OR tenosynovitis OR blister* OR cramp* OR corn OR callus* OR edema* OR sesamoiditis OR ganglion* OR hernia* OR muscle soreness OR delayed onset muscle soreness OR hemorrh* OR ischi* OR neuroma* OR abrasion OR wart* OR mold* OR dislocation* OR damage OR trauma OR displacement OR periostitis) NOT ("addresses"[Publication Type] OR "bibliography"[Publication Type] OR "biography"[Publication Type] OR "case reports"[Publication Type] OR "clinical conference"[Publication Type] OR "comment"[Publication Type] OR "congresses"[Publication Type] OR "dictionary"[Publication Type] OR "directory"[Publication Type] OR "editorial"[Publication Type] OR "festschrift"[Publication Type] OR "government publications"[Publication Type] OR "interview"[Publication Type] OR "lectures"[Publication Type] OR "legal cases"[Publication Type] OR "legislation"[Publication Type] OR "letter"[Publication Type] OR "news"[Publication Type] OR "newspaper article"[Publication Type] OR "retracted publication"[Publication Type] OR "retraction of publication"[Publication Type] OR "review"[Publication Type] OR "scientific integrity review"[Publication Type] OR "technical report"[Publication Type] OR "twin study"[Publication Type] OR "validation studies"[Publication Type] OR pregnancy OR rugby OR soccer OR football OR rheumatoid)