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EFFECTS OF STRENGTH TRAINING ON INJURY PREVENTION IN RECREATIONAL RUNNERS: A SYSTEMATIC REVIEW AND META-ANALYSIS

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ABSTRACT: Background: Recreational running is one of the most practiced physical activities and provides several health benefits. However, it is associated with a high incidence of musculoskeletal injuries, particularly among novice runners. Strength training has been proposed as a preventive strategy, but its effectiveness in reducing injuries in this population remains uncertain. **Objective:** To examine the effects of strength training on the prevention of musculoskeletal injuries in recreational runners through a systematic review and meta-analysis. **Methods:** This review was prospectively registered in PROSPERO (CRD42025636048) and conducted according to PRISMA guidelines. Randomized controlled trials comparing strength training with placebo, stretching, or no intervention were included. Searches were performed in PubMed, Cochrane Central, Web of Science, PEDro, CINAHL, and LILACS. Analyses were conducted in R using the *metainc* function, and the GRADE approach was applied to assess the certainty of evidence. **Results:** Six randomized controlled trials involving 1,443 participants were included. The pooled analysis showed no significant difference in overall injury incidence between groups (IRR = 0.74; 95% CI: 0.54–1.03; p = 0.071), with substantial heterogeneity (I^2 = 75.7%). Subgroup and meta-regression analyses found no significant effects of age, sex, or BMI. Evidence certainty ranged from moderate to low due to heterogeneity and imprecision. **Conclusion:** Current evidence does not support a significant protective effect of strength training on injury prevention in recreational runners. Future research should include individualized load prescription and comprehensive baseline assessments to better identify subgroups likely to benefit from strength-based interventions.

Introduction

Recreational running is currently one of the most popular and accessible forms of physical activity in the world, attracting millions of participants due to its simplicity, low cost, and strong association with improvements in physical and mental health. According to a recent systematic review, running has doubled globally in the last decade, driven primarily by its proven benefits for cardiovascular, metabolic, and psychological health. [1]

The positive effects include a reduced risk of cardiovascular disease, improved glucose metabolism, weight control, bone strengthening, and neuropsychological benefits such as relief from anxiety, depression, and stress. [2, 3]

However, these benefits contrast with a high prevalence of musculoskeletal injuries among recreational runners. Studies show that up to 33% of amateur runners report some running-related injury during follow-up periods of just a few months. [4] The anatomical regions most frequently affected include the knee, ankle, leg, and hip, with lesions predominantly affecting soft tissues such as tendons and muscles. [1, 5]

Even among amateur runners, the impact of these injuries is significant: many interrupt their sporting activity for weeks or months, face persistent pain and functional impairment, which can lead to a decrease in quality of life and increased costs for public health systems. Recurrent injuries are also associated with factors such as a previous history of injury and a high body mass index. [6]

Recurrent or inadequately treated musculoskeletal injuries can lead to chronic pain, significant functional loss, and limitations in both sports and daily occupational activities. Even in amateur runners, this type of injury often leads to temporary interruption and, in many cases, permanent abandonment of running. [7]

Given this reality, preventive strategies have been widely discussed in the scientific literature, including: controlling training load, choosing appropriate footwear, interventions in running technique, and, above all, strength training. The latter has gained prominence due to its robust biomechanical basis, strengthening muscle structures, increasing joint stability, promoting neuromuscular control, and delaying fatigue—factors closely linked to reducing the risk of injury. [8]

Despite these fundamentals, the clinical results of strength training as a preventive strategy are still heterogeneous. A recent study with trained runners showed that, although the combination of strength and endurance training significantly improved running economy and VO_2max, the effects on biomechanical variables such as gait kinematics were limited. [7]

Additionally, the use of biomechanical models integrated with large-scale data analysis has been proposed as an alternative to refine prevention strategies, personalizing interventions according to individual risk profiles. [9] However, the lack of consensus in the literature regarding the isolated effectiveness of strength training in recreational runners calls for caution and reinforces the need for more robust clinical trials.

Considering the high incidence of musculoskeletal injuries among recreational runners and the deleterious impacts on health, functionality, and physical performance, understanding the role of strength training as a preventive strategy is a clinical and scientific priority. Although observational studies and clinical trials suggest that muscle strengthening can reduce the risk of overuse injuries, previous systematic reviews present inconsistent results. For example, Machado et al. reported positive effects of strength training on performance in long-distance runners, but did not directly address injury prevention outcomes. [10] The review by Prieto-González et al. (2024) highlights that different strength modalities (maximum, explosive, and combined) distinctly impact performance variables, but their effects on injury indicators remain inconclusive. [11]

Similarly, other reviews have reported inconsistent results due to the heterogeneity of the populations, the variation in the types of intervention, and the lack of focus on resistance training as an isolated strategy. These limitations make it difficult to translate the evidence into clear clinical or practical guidelines, especially for the growing population of recreational runners.

Additionally, these reviews have explored few important moderators that could explain the heterogeneity of the results, such as age, sex, body mass index (BMI), and specific characteristics of strength training protocols. This methodological limitation restricts the applicability of the findings to clinical practice and the development of evidence-based guidelines. Thus, the present systematic review with meta-analysis aims primarily to evaluate the effectiveness of strength training in preventing injuries in recreational runners, and secondarily to explore variables that may moderate its effects, contributing to more personalized and effective interventions in the context of recreational running.

Materials and Methods

Study Design and Registration

This systematic review with meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[12] The study protocol was prospectively registered in the PROSPERO database under registration number CRD42025636048 on January 27, 2025.

Population

The included studies focused on recreational runners, defined as individuals who regularly run without professional or elite competitive goals. Focusing on this population allows for the identification of strategies applicable to a broad and diverse group of individuals who run for leisure, health, or well-being, a population that is still underrepresented in the scientific literature.

Eligibility Criteria

Study design: Only randomized controlled trials (RCTs) that compared the effectiveness of any strength training intervention in recreational runners aged 18 years or older were included. Studies that did not report injury-related outcomes were excluded.

Type of Intervention

Studies that compared strength training interventions (e.g., resistance training, functional training, weight training, or exercise programs) with placebo, no intervention, or other types of training in recreational runners were considered eligible.

Outcomes

Studies should include at least one group involving a strength training protocol and report outcomes related to the incidence or prevention of injuries. Studies focused on elite athletes, sedentary populations, or mixed interventions not relevant to the review's objective were excluded. Studies involving participants with medical conditions that prevented running or strength training, as well as those that exclusively addressed performance without reporting injury outcomes, were also excluded.

Search Strategy

A comprehensive search was conducted between January 28 and 29, 2025, in the following electronic databases: PubMed, Cochrane Central, Web of Science, BVS, PEDro, CINAHL, and LILACS. Clinical trial registries, such as ClinicalTrials.gov, were also consulted to identify ongoing or recently completed studies. When relevant records were found, two attempts were made to contact the authors; in the absence of a response, the study was excluded. The search strategy included terms such as: recreational runners, amateur runners, non-elite runners, joggers, casual runners, strength training, resistance training, weight training, exercise programs, injury prevention, musculoskeletal injuries prevention, running-related injuries, overuse injuries prevention, running economy, among others. Boolean operators (AND, OR, NOT) were used to adapt the searches to each database. No filters were applied regarding date, language, sex, age, or publication status, in order to maximize sensitivity. The complete search strategy is available as supplementary material attached to the document.

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Study Selection

All retrieved citations were screened by two independent reviewers, P.M. and P.V., initially by titles and abstracts, and subsequently by full reading. A third reviewer resolved any discrepancies. A pilot screening round was conducted to assess consistency among reviewers, consisting of a 10% sample of the total articles found undergoing the review process. The degree of inter-rater agreement was calculated using the Kappa coefficient, and screening began when the value exceeded 0.8. Articles considered potentially eligible were obtained in full text and evaluated independently. In cases of missing information, the authors were contacted. If the inclusion criteria were met, the study was selected for data extraction. The Rayyan platform was used to support the screening and organization process. [13-17]

Data Extraction and Analysis

Data were extracted and organized in Microsoft Excel, including: author, year, country, sample size, distribution by sex, mean age and BMI, type of intervention and control, duration of follow-up, and injury-related outcomes (e.g., number and location of injuries). When characteristics such as age or BMI were reported as median and interquartile range (IQR), they were converted to mean and standard deviation for use in meta-regression analyses. [18] All statistical analyses were performed using R software (version 4.4.2).

Meta-analyses of injury incidence rates were performed using the metainc function from the meta package, estimating incidence rate ratios (IRRs) based on the number of injuries and exposure time in person-years (PY). Heterogeneity was assessed using I^2 and τ^2 statistics. Publication bias was examined by inspecting funnel plots and using Egger's regression test (metabias with the linreg method), applied when ≥10 studies were available. Meta-regressions were performed using the rma function from the metafor package, with the transformed logarithm of the IRR as the dependent variable. Moderators included mean age, number of male and female participants, and BMI. Results were visualized using the regplot function.

Risk of Bias Assessment

The risk of bias of the included studies was assessed using the Cochrane Risk of Bias Tool version 2 (RoB 2), covering five domains. Two independent reviewers performed the assessments, and disagreements were resolved by consensus or consultation with a third reviewer. The results are presented in tabular and graphical format (Appendix B). [19]

Certainty of Evidence

The certainty of evidence for each primary outcome was assessed using the GRADE approach, considering five domains: risk of bias, inconsistency, imprecision, indirection, and publication bias. Two independent reviewers performed the assessments, and discrepancies were resolved by consensus. The findings were summarized in a Summary of Findings (SoF) table, as recommended by the GRADE Working Group. [20]

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Results

Study Selection

The systematic search resulted in 1,308 records. After removing 564 duplicates, 744 citations were screened by title and abstract. Of these, 712 were excluded for not meeting the eligibility criteria. The remaining 32 articles were evaluated in full text. Nine could not be obtained and 17 were excluded for methodological reasons. Therefore, six randomized controlled trials (RCTs) were included in the systematic review and meta-analysis. The complete screening process, including the reasons for exclusions, is illustrated in Figure 1 (PRISMA Flowchart).

Study Characteristics

The included studies were published between 2016 and 2024 and involved a total of 1,443 participants. The research was conducted in the United States, Iran, Canada, Brazil, and Finland. Sample sizes ranged from 16 to 720 individuals, with a predominance of female participants in four trials. All other data is presented in table 1 with the summary of all included studies.

Risk of Bias Assessment

The risk of bias was assessed using the RoB 2.0 tool. Among the six included studies, four were classified as having a high overall risk of bias, [21-24] and two presented some concerns.[25-26] The most common reasons for downgrading were the absence of blinding in the outcome assessment, missing data without clear explanation, and deviations from the originally planned interventions.

A study by Letafatkar et al. had raised concerns in previous literature regarding possible sample overlap. After correspondence with the original author, who confirmed that the studies were conducted in different years, with different cohorts of participants, but in the same geographic region, our team reached a consensus to exclude one of the trials and retain only the one published in the Scandinavian Journal of Medicine & Science in Sports. This decision was based on methodological rigor and the prevention of sample overlap, ensuring greater robustness to the combined estimates.

Reported Interventions

Interventions included different strength training strategies, such as resistance training, plyometrics, neuromuscular training with feedback, foot strengthening exercises, and conditioning with cognitive enhancement. Control groups received placebo, stretching, sham interventions, or no active intervention.

Total Injuries

Possibly pooled analysis of all follow-up times showed no significant difference between the intervention and control groups (IRR = 0.74; 95% CI = 0.54 to 1.03; $p = 0.0711$). (Figure 2) There was substantial heterogeneity among the studies ($I^2 = 75.7\%$; $p < 0.0001$). Visual inspection of the funnel showed a symmetrical distribution, and Egger's test did not identify publication bias ($p = 0.1741$). Meta-regressions did not show a significant association with age, sex, or BMI, although BMI explained a significant portion of the heterogeneity ($R^2 = 46.08\%$; $p = 0.0623$).

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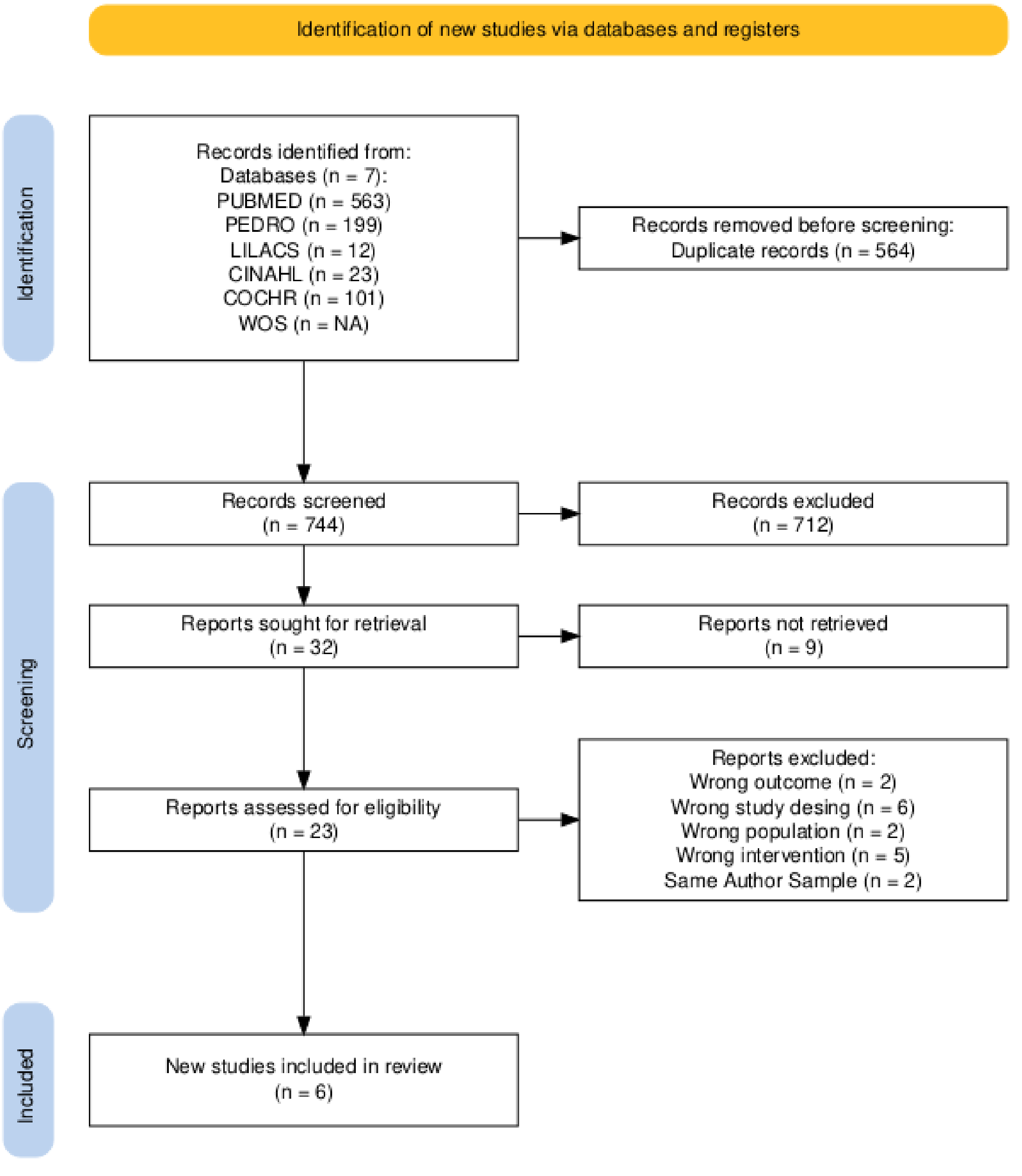

Figure 1 - PRISMA Flowchart

Study	Design	Population	Intervention	Comparator	Outcomes	Key Results
Toresdahl et al., 2020	RCT	720 first-time marathon runners (mean age 35.9 ± 9.4 yrs; 69.4% female)	12-week self-directed strength training (hip abductor, quadriceps, core), 10 min, 3x/week	Usual training (no prescribed program)	Major injuries (overuse-related marathon noncompletion), minor injuries, marathon completion, finishing time	No significant difference in major injury rate (7.1% vs 7.3%, RR=0.97, P=0.90) or finishing time (5:01 vs 4:58, P=0.35); trend toward fewer minor injuries in strength group (46.3% vs 50.5%, P=0.26); compliant participants had fewer minor injuries (41.5% vs 56.2%, P=0.01)
Taddei et al., 2020	Single-blind RCT	118 recreational runners, aged 18–55, running 20–100 km/week	8-week supervised foot-ankle strengthening program + 12-month remote training	Placebo static stretching protocol (5 min, 3x/week for 12 months)	Incidence and time to running-related injury (RRI); foot strength and posture assessments	Intervention group had 2.42x lower RRI risk than control (P = 0.035); benefits observed starting at 4–8 months.
Letafatkar et al., 2019	Randomized Controlled Trial (RCT), 3-arm parallel group design with 1-year follow-up	49 healthy male recreational runners, aged 18–45, with >8 km/week running experience but <2 years, and no current injuries	8-week Conditioning Training (CT) + Biomechanical Feedback program involving strength, flexibility, proprioception exercises and gait retraining with visual and verbal feedback during treadmill running	1. CT without feedback 2. Placebo training (core and upper body stretches with no gait retraining or running)	Biomechanics: Kinetic (VALR, VILR, TS) and kinematic (hip adduction, knee internal rotation, rearfoot inversion) parameters Injury Incidence: Running-related injuries over 1 year	CT + Feedback group had significantly greater improvements in kinetic outcomes vs CT alone Kinematic improvements were similar in both intervention groups, but greater percent change in CT + Feedback group Injury incidence reduction: 64.6% in CT + Feedback vs 32.2% in CT-only vs 15.5% in placebo Long-term efficacy: Most gains retained at 1-year, especially for kinetic outcomes in CT + Feedback group
Leppänen et al. (2024)	3-arm Randomised Controlled Trial	325 adult novice recreational runners (245 female, 80 male), aged 18–55, in Tampere, Finland	(1) Hip and core strengthening programme; (2) Ankle and foot strengthening programme; both physiotherapist-supervised, 24 weeks	Static stretching exercises (control group)	Primary: Running-related all-complaint lower extremity (LE) injuries. Secondary: Overuse LE injuries, substantial overuse injuries, acute LE injuries	Hip and core group had a significantly lower incidence of all LE injuries (HR 0.66; 95% CI 0.45–0.97) and lower weekly prevalence of overuse injuries (PRR 0.61) and substantial overuse injuries (PRR 0.48) compared to control. No significant benefit from the ankle and foot programme; higher acute injury incidence noted in this group (HR 3.60; 95% CI 1.20–10.86).
Baltich et al., 2016	Pilot Randomized Controlled Trial (RCT)	129 novice runners (18–60 years, <2 years running experience)	Resistance strength training or functional strength training (home-based, 8 weeks + 4-month maintenance)	Stretching-only control group	Primary: Running-related injuries (RRIs) per 1000 hours of running	No significant difference in injury rates: Resistance (31.6), Functional (32.9), Control (26.7) per 1000 running hours; most injuries occurred during first 8 weeks; high dropout (~50%)
Harrison et al., 2024	Controlled prospective intervention study	57 novice female runners (18–60 years, no regular prior running)	8 weeks of strength and plyometric training, followed by 8 weeks of running	8 weeks of walking, followed by 8 weeks of running	Kinematic changes (joint angles), injury incidence, training adherence	No group-time interaction in kinematics; both groups ran with more extended knees and hips; lower injury incidence in treatment group (6.7%) vs. control (20%)

Table 1 - Characteristics of the studies

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Subgroup Analyses by Body Region

No significant differences were observed between groups (IRR = 0.74; 95% CI = 0.53–1.03; p = 0.0773), with low heterogeneity (I^2 = 3.7%; p = 0.4013) and absence of publication bias (p = 0.3713). For foot and ankle and lower leg injuries, the results also did not indicate a difference between groups (IRR = 1.08; 95% CI = 0.77–1.53; p = 0.6544), with zero heterogeneity (I^2 = 0%; p = 0.7091) and no publication bias (p = 0.4879). (Figure 3).

Knee injuries showed no significant difference between the groups (IRR = 0.75; 95% CI = 0.53–1.08; p = 0.1218). Heterogeneity was moderate (I^2 = 34.3%; p = 0.1543). Meta-regression demonstrated a significant association between BMI and risk of knee injuries (R^2 = 100%; p = 0.0266).

Regarding thigh injuries, there was no significant difference (IRR = 0.68; 95% CI = 0.35–1.32; p = 0.2550). Heterogeneity was moderate (I^2 = 50.8%; p = 0.0579), with no significant findings in the meta-regressions. Hip injuries did not differ between groups (IRR = 0.68; 95% CI = 0.35–1.34; p = 0.2650), with no heterogeneity (I^2 = 0%; p = 0.5340). Meta-regression identified a significant association between the proportion of women and the risk of injuries in this region (R^2 = 100%; p = 0.0347).

For the lumbar spine, there was no significant difference between groups (IRR = 0.80; 95% CI = 0.46–1.38; p = 0.4209). No heterogeneity was detected (I^2 = 0%; p = 0.6250), but Egger's test indicated asymmetry consistent with publication bias (p = 0.0337). Meta-regression also showed a significant association between the proportion of women and the risk of low back injuries (R^2 = 100%; p = 0.0448).

The risk of dropout did not differ between groups (IRR = 1.03; 95% CI = 0.64–1.64; p = 0.9160). Heterogeneity was substantial (I^2 = 65.3%; p = 0.008), with no evidence of publication bias (p = 0.4508).

Meta-regression

In general, most moderating variables (age, sex, and BMI) did not show a significant association with the results. However, some findings stood out, such as BMI being associated with a higher risk of knee injuries (p = 0.0266), and the proportion of women in the samples being associated with a risk of hip (p = 0.0347) and lumbar spine (p = 0.0448) injuries.

Sensitivity Analysis Regarding Potential Overlapping Data

Two studies by Letafatkar et al. were flagged in previous systematic reviews as potentially involving overlapping participant samples. We contacted the corresponding author, who confirmed that the studies were conducted in different years and involved independent cohorts of participants, although recruitment occurred in the same geographic region. Based on this confirmation, we decided to include only the study by Letafatkar et al. (2019).26

Certainty of Evidence

The certainty of evidence was assessed using the GRADE approach, considering risk of bias, inconsistency, imprecision, indirection, and publication bias. For the primary outcome (total injuries), certainty was classified as low, due to the high risk of bias

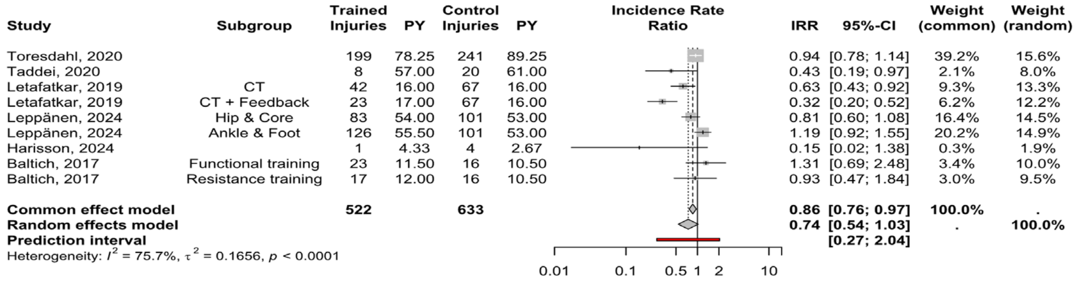
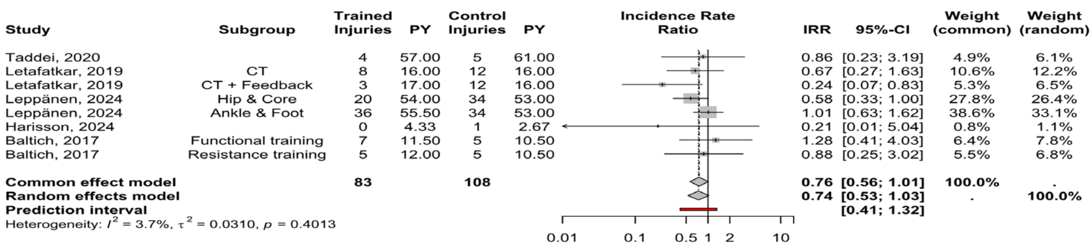


Figure 2. Forest plot of the meta-analysis on the effect of strength training on the total incidence of injuries in recreational runners. The pooled result showed no significant difference between groups (IRR = 0.74; 95% CI = 0.54–1.03; p = 0.0711), with substantial heterogeneity ($I^2 = 75.7\%$).

A



B

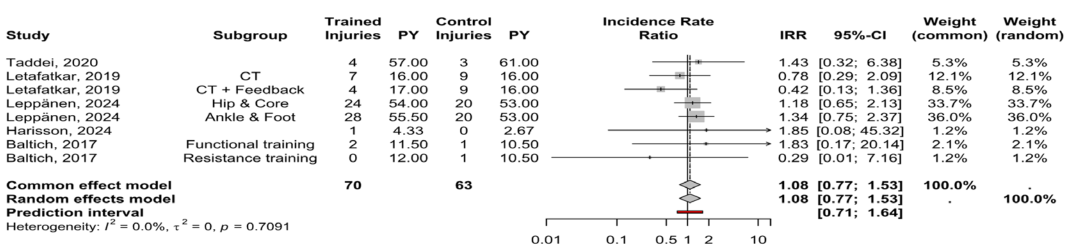


Figure 3. A - Forest plot of the meta-analysis for foot and ankle and lower leg injuries. No significant differences were observed between groups (IRR = 0.74; 95% CI = 0.53–1.03; p = 0.0773), with no relevant heterogeneity ($I^2 = 3.7\%$). **B** - Forest plot of the meta-analysis for leg injuries (lower region). There was no significant difference between groups (IRR = 1.08; 95% CI = 0.77–1.53; p = 0.6544), with zero heterogeneity ($I^2 = 0\%$).

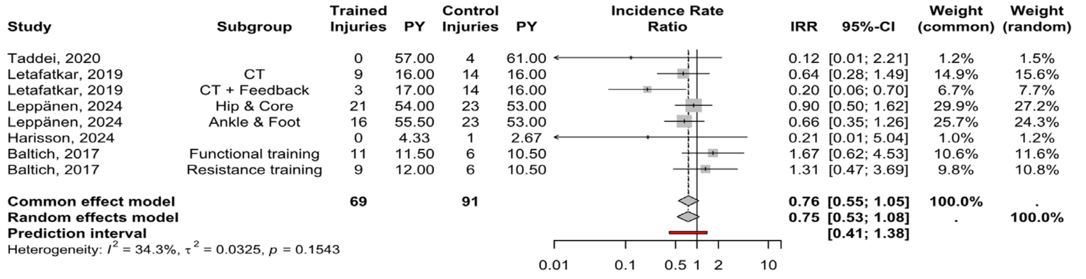


Figure 4. Forest plot of the meta-analysis for knee injuries. No significant difference was observed (IRR = 0.75; 95% CI = 0.53–1.08; p = 0.1218), although a significant association with BMI was identified in the meta-regression analyses.

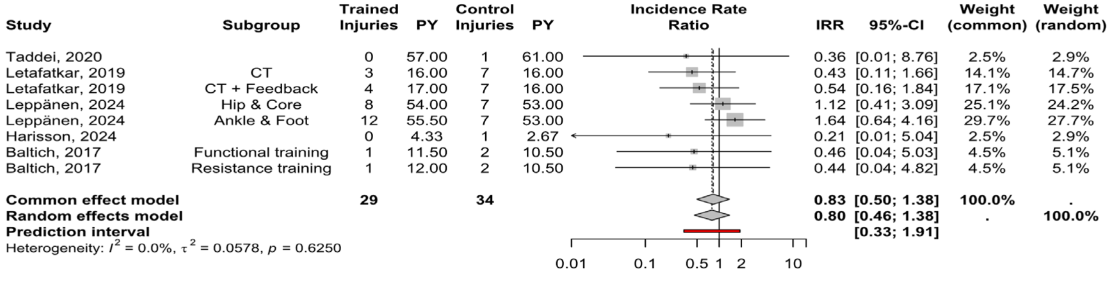


Figure 5. Forest plot of the meta-analysis for lumbar spine injuries. There was no significant difference between groups (IRR = 0.80; 95% CI = 0.46–1.38; p = 0.4209), but publication bias was detected (p = 0.0337) and a significant association between the proportion of women and the risk of injury.

and substantial heterogeneity. Foot/ankle and knee outcomes had moderate certainty, downgraded by risk of bias. Leg, thigh, and hip injury outcomes were classified as low certainty, mainly due to imprecision. Lumbar injuries were classified as very low certainty, due to the combination of risk of bias, imprecision, and publication bias.

Discussion

This meta-analysis evaluated the effect of strength training on injury prevention in recreational runners. In the primary outcome, no statistically significant difference was identified in the overall incidence of injuries between the intervention and control groups (IRR = 0.74; 95% CI = 0.54–1.03; p = 0.0711), although there was a trend towards a 26% reduction. In meta-regression analyses, it was observed that high BMI was significantly associated with a higher risk of knee injuries (p = 0.0266), while a higher proportion of women was associated with an increased risk of hip (p = 0.0347) and lumbar spine (p = 0.0448) injuries. These findings indicate that the effects of strength training may vary according to individual characteristics, suggesting that currently used protocols have limitations in terms of specificity and personalization for preventing injuries in recreational runners.

Running injuries have a multifactorial etiology, involving biomechanical factors, training volume and intensity, injury history, inadequate recovery, and psychosocial components. It is unlikely that a single isolated intervention, such as traditional strength training, will be sufficient to address all these aspects.

Furthermore, many of the protocols included in the analyzed studies were not very specific, with short sessions, low intensity, and a bilateral focus, without load progression or exercises geared towards the functional demands of running. In line with Santos et al. (2024), who evaluated the habits of 801 recreational runners, it was identified that most use traditional strength training focused on performance, and not specifically for injury prevention.[28]

Another critical point is the low integration between strength training and monitoring of running load in the clinical trials analyzed. Excessive aerobic volume or the absence of adequate control of total load can mask potential benefits of strengthening. In addition, many studies presented heterogeneous definitions of injury, short follow-ups, and insensitive measures, such as simple self-reports, which may underestimate the true incidence of injuries.

Finally, there is a misalignment between the exercises used and the actual mechanisms of injury in running. Protocols are often based on rehabilitation or performance programs, and not on specific preventive strategies for overloads characteristic of running such as tendinopathies, stress fractures, or biomechanical syndromes.

Some recent systematic reviews corroborate their findings. For example, Wu et al. (2024) conducted a review and meta-analysis encompassing exercise programs for endurance runners and found that exercise-based interventions did not show a significant reduction in the risk or rate of injuries, except when there is supervision of the protocols. [28]

Another critical, narrative review pointed out that although there is evidence that strength training improves running economy, physiological determinants, and performance, the evidence for injury prevention is "equivocal" in recreational runners, particularly when the protocols adopted are low-intensity or short.[29]

However, there are also discrepancies: some previous reviews or meta-analyses, especially in team sports or modalities with demands distinct from running, found more consistent benefits from prevention training (e.g., multicomponent programs such as FIFA 11+ in soccer). These programs generally combine strength, proprioception, technique, warm-up, etc., suggesting that effectiveness is related to the comprehensive design of the programs. [30-31]

The association between high BMI and increased risk of knee injuries is consistent with the biomechanical literature: excess body weight increases compression and shear load on the joints of the lower limbs, especially in repetitive impact activities such as running.[32]

Such evidence reinforces the importance of developing personalized prevention programs that consider factors such as body composition, sex, injury history, and total training load. Despite the absence of statistically significant effects on the overall incidence of injuries, strength training remains a fundamental component for improving performance, running economy, and musculoskeletal health.[29, 33-34]

To make it more effective as a preventive strategy, it is suggested that future programs incorporate: Adequate progression of training load and volume; Specific running exercises, such as unilateral, eccentric movements, hip/core stability, and postural control; Integration with monitoring of running load, considering the total stress on the musculoskeletal system; Prolonged duration and longitudinal follow-up, with continuous assessment of adherence and response to training.

Limitations

This meta-analysis has several important limitations. There was substantial methodological heterogeneity among the included studies, particularly regarding intervention protocols, definitions of injury, and participant characteristics. Many studies had small sample sizes, with limited representation of relevant subgroups such as women and individuals with higher body mass index. Injury definitions were often inconsistent, and outcome measures demonstrated limited sensitivity. Additionally, adherence and compliance with the prescribed strength training programs were not consistently reported or objectively monitored, which may have influenced the observed effects and limited the interpretation of intervention efficacy. The small number of included studies also precluded a robust assessment of publication bias, particularly for specific injury outcomes. Furthermore, the lack of prospective trial registration in several of the included randomized controlled trials limits the ability to fully assess selective reporting and increases the risk of bias related to incomplete outcome reporting.

Conclusion

In summary, strength training, as evaluated by current studies, did not demonstrate statistically significant effectiveness in the overall prevention of injuries in recreational runners. However, meta-regression findings indicate that individual variables, such as BMI and sex, modify the risk of injury, suggesting the need for more personalized, specific, and integrated preventive protocols within running training. Future clinical trials should consider these nuances to more accurately detect the effects of muscle strengthening on injury prevention in this population.

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PUBMED	(((“recreation”[MeSH Terms] OR “recreation”[All Fields] OR “recreations”[All Fields] OR “recreational”[All Fields] OR “recreator”[All Fields] OR “recreators”[All Fields]) AND (“runner”[All Fields] OR “runner s”[All Fields] OR “runners”[All Fields])) OR ((“amateur”[All Fields] OR “amateurs”[All Fields]) AND (“runner”[All Fields] OR “runner s”[All Fields] OR “runners”[All Fields])) OR (“non-elite”[All Fields] AND (“runner”[All Fields] OR “runner s”[All Fields] OR “runners”[All Fields])) OR “jogger*”[All Fields] OR ((“casual”[All Fields] OR “casuals”[All Fields]) AND (“runner”[All Fields] OR “runner s”[All Fields] OR “runners”[All Fields]))) AND (“resistance training”[MeSH Terms] OR (“resistance”[All Fields] AND “training”[All Fields]) OR “resistance training”[All Fields] OR (“strength”[All Fields] AND “training”[All Fields]) OR “strength training”[All Fields] OR (“resistance training”[MeSH Terms] OR (“resistance”[All Fields] AND “training”[All Fields]) OR “resistance training”[All Fields]) OR (“weight lifting”[MeSH Terms] OR (“weight”[All Fields] AND “lifting”[All Fields]) OR “weight lifting”[All Fields] OR (“weight”[All Fields] AND “training”[All Fields]) OR “weight training”[All Fields]) OR ((“exercise”[MeSH Terms] OR “exercise”[All Fields] OR “exercises”[All Fields] OR “exercise therapy”[MeSH Terms] OR (“exercise”[All Fields] AND “therapy”[All Fields]) OR “exercise therapy”[All Fields] OR “exercising”[All Fields] OR “exercise s”[All Fields] OR “exercised”[All Fields] OR “exerciser”[All Fields] OR “exercisers”[All Fields]) AND “program*”[All Fields]) OR ((“strengthen”[All Fields] OR “strengthened”[All Fields] OR “strengthening”[All Fields] OR “strengthens”[All Fields]) AND “program*”[All Fields])) AND (“inj prev”[Journal] OR (“injury”[All Fields] AND “prevention”[All Fields]) OR “injury prevention”[All Fields] OR ((“injuries”[MeSH Subheading] OR “injuries”[All Fields] OR “wounds”[All Fields] OR “wounds and injuries”[MeSH Terms] OR (“wounds”[All Fields] AND “injuries”[All Fields]) OR “wounds and injuries”[All Fields] OR “wound s”[All Fields] OR “wounded”[All Fields] OR “wounding”[All Fields] OR “woundings”[All Fields] OR “wound”[All Fields]) AND (“prevent”[All Fields] OR “preventability”[All Fields] OR “preventable”[All Fields] OR “preventative”[All Fields] OR “preventatively”[All Fields] OR “preventatives”[All Fields] OR “prevented”[All Fields] OR “preventing”[All Fields] OR “prevention and control”[MeSH Subheading] OR (“prevention”[All Fields] AND “control”[All Fields]) OR “prevention and control”[All Fields] OR “prevention”[All Fields] OR “prevention s”[All Fields] OR “preventions”[All Fields] OR “preventive”[All Fields] OR “preventively”[All Fields] OR “preventives”[All Fields] OR “prevents”[All Fields])) OR (“prevent”[All Fields] OR “preventability”[All Fields] OR “preventable”[All Fields] OR “preventative”[All Fields] OR “preventatively”[All Fields] OR “preventatives”[All Fields] OR “prevented”[All Fields] OR “preventing”[All Fields] OR “prevention and control”[MeSH Subheading] OR (“prevention”[All Fields] AND “control”[All OR (“sports”[All Fields] AND “injuries”[All Fields]) OR “sports injuries”[All Fields]) AND (“prevent”[All Fields] OR “preventability”[All Fields] OR “preventable”[All Fields] OR “preventative”[All Fields] OR “preventatively”[All Fields] OR “preventatives”[All Fields] OR “prevented”[All Fields] OR “preventing”[All Fields] OR “prevention and control”[MeSH Subheading] OR (“prevention”[All Fields] AND “control”[All Fields]) OR “prevention and control”[All Fields] OR “prevention”[All Fields] OR “prevention s”[All Fields] OR “preventions”[All Fields] OR “preventive”[All Fields] OR “preventively”[All Fields] OR “preventives”[All Fields] OR “prevents”[All Fields])) OR (“running-related”[All Fields] AND (“injurie”[All Fields] OR “injuried”[All Fields] OR “injuries”[MeSH Subheading] OR “injuries”[All Fields] OR “wounds and injuries”[MeSH Terms] OR (“wounds”[All Fields] AND “injuries”[All Fields]) OR “wounds and injuries”[All Fields] OR “injurious”[All Fields] OR “injury s”[All Fields] OR “injuryed”[All Fields] OR “injurys”[All Fields] OR “injury”[All Fields]) AND (“prevent”[All Fields] OR “preventability”[All Fields] OR “preventable”[All Fields] OR “preventative”[All Fields] OR “preventatively”[All Fields] OR “preventatives”[All Fields] OR “prevented”[All Fields] OR “preventing”[All Fields] OR “prevention and control”[MeSH Subheading] OR (“prevention”[All Fields] AND “control”[All Fields]) OR “prevention and control”[All Fields] OR “prevention”[All Fields] OR “prevention s”[All Fields] OR “preventions”[All Fields] OR “preventive”[All Fields] OR “preventively”[All Fields] OR “preventives”[All Fields] OR “prevents”[All Fields])) OR (“musculoskeletal”[All Fields] AND (“injurie”[All Fields] OR “injuried”[All Fields] OR “injuries”[MeSH Subheading] OR “injuries”[All Fields] OR “wounds and injuries”[MeSH Terms] OR (“wounds”[All Fields] AND “injuries”[All Fields]) OR “wounds and injuries”[All Fields] OR “injurious”[All Fields] OR “injury s”[All Fields] OR “injuryed”[All Fields] OR “injurys”[All Fields] OR “injury”[All Fields]) AND (“prevent”[All Fields] OR “preventability”[All Fields] OR “preventable”[All Fields] OR “preventative”[All Fields] OR “preventatively”[All Fields]OR “preventatives”[All Fields] OR “prevented”[All Fields] OR “preventing”[All Fields] OR “prevention and control”[MeSH Subheading] OR (“prevention”[All Fields] AND “control”[All Fields]) OR “prevention and control”[All Fields] OR “prevention”[All Fields] OR “prevention s”[All Fields] OR “preventions”[All Fields] OR “preventive”[All Fields] OR “preventively”[All Fields] OR “preventives”[All Fields] OR “prevents”[All Fields])) OR ((“cumulative trauma disorders”[MeSH Terms] OR (“cumulative”[All Fields] AND “trauma”[All Fields] AND “disorders”[All Fields]) OR “cumulative trauma disorders”[All Fields] OR (“overuse”[All Fields] AND “injuries”[All Fields]) OR “overuse injuries”[All Fields]) AND (“prevent”[All Fields] OR “preventability”[All Fields] OR “preventable”[All Fields] OR “preventative”[All Fields] OR “preventatively”[All Fields] OR “preventatives”[All Fields] OR “prevented”[All Fields] OR “preventing”[All Fields] OR “prevention and control”[MeSH Subheading] OR (“prevention”[All Fields] AND “control”[AllFields]) OR “prevention and control”[All Fields] OR “prevention”[All Fields] OR “prevention s”[All Fields] OR “preventions”[All Fields] OR “preventive”[All Fields] OR “preventively”[All Fields] OR “preventives”[All Fields] OR “prevents”[All Fields]) OR ((“athletic injuries”[MeSH Terms] OR (“athletic”[All Fields]

	AND "injuries"[All Fields]) OR "athletic injuries"[All Fields] Fields]) OR "prevention and control"[All Fields] OR "prevention"[All Fields] OR "prevention s"[All Fields] OR "preventions"[All Fields] OR "preventive"[All Fields] OR "preventively"[All Fields] OR "preventives"[All Fields] OR "prevents"[All Fields])) OR ("injurie"[All Fields] OR "injuried"[All Fields] OR "injuries"[MeSH Subheading] OR "injuries"[All Fields] OR "wounds and injuries"[MeSH Terms] OR ("wounds"[All Fields] AND "injuries"[All Fields]) OR "wounds and injuries"[All Fields] OR "injurious"[All Fields] OR "injury s"[All Fields] OR "injuryed"[All Fields] OR "injurys"[All Fields] OR "injury"[All Fields]))
COCHRANE	ID Search Hits #1 (Recreational runners):ti,ab,kw (Word variations have been searched) 380 #2 (Casual runners):ti,ab,kw (Word variations have been searched) 1 #3 MeSH descriptor: [Jogging] explode all trees 70 #4 (non-elite runners):ti,ab,kw (Word variations have been searched) 7 #5 (amateur runners):ti,ab,kw (Word variations have been searched) 71 #6 #1 OR #2 OR #3 OR #4 OR #5 518 #7 (strength training):ti,ab,kw (Word variations have been searched) 24814 #8 MeSH descriptor: [Resistance Training] explode all trees 5977 #9 ("weight-training"):ti,ab,kw (Word variations have been searched) 633 #10 (Exercise Program):ti,ab,kw (Word variations have been searched) 48202 #11 (Strengthening Program):ti,ab,kw (Word variations have been searched) 5400 #12 #7 OR #8 OR #9 OR #10 OR #11 68019 #13 (injury prevention):ti,ab,kw (Word variations have been searched) 19243 #14 (Wound prevention):ti,ab,kw (Word variations have been searched) 11152 #15 ("prevention"):ti,ab,kw (Word variations have been searched) 303410 #16 (performance):ti,ab,kw (Word variations have been searched) 424080 #17 (running economy):ti,ab,kw (Word variations have been searched) 308 #18 (sports injuries prevention):ti,ab,kw (Word variations have been searched) 1112 #19 (running-related injuries prevention):ti,ab,kw (Word variations have been searched) 71 #20 (musculoskeletal injuries prevention):ti,ab,kw (Word variations have been searched) 587 #21 (overuse injuries prevention):ti,ab,kw (Word variations have been searched) 146 #22 MeSH descriptor: [Wounds and Injuries] explode all trees 39978 #23 ("injury"):ti,ab,kw (Word variations have been searched) 84810 #24 #13 OR #14 OR #15 OR #16 OR #17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 728563 #25 #6 AND #12 AND #24 102
WOS	1: ((((ALL=(Recreational runners)) OR ALL=(Casual runners)) OR ALL=(Jogger*)) OR ALL=(non-elite runners)) OR ALL=(amateur runners) Date Run: Sun Jan 26 2025 07:35:40 GMT-0300 (Brasilia Standard Time) Results: 2915 2: ((((ALL=(strength training)) OR ALL=(resistance training)) OR ALL=(weight training)) OR ALL=(Exercise Program*)) OR ALL=(Strengthening Program*) Date Run: Sun Jan 26 2025 07:36:33 GMT-0300 (Brasilia Standard Time) Results: 493850 3: ((((((((((ALL=(injury prevention)) OR ALL=(Wound prevention)) OR ALL=(Prevention)) OR ALL=(performance)) OR ALL=(running economy)) OR ALL=(sports injuries prevention)) OR ALL=(running-related injuries prevention)) OR ALL=(musculoskeletal injuries prevention)) OR ALL=(overuse injuries prevention)) OR ALL=(Injury) Date Run: Sun Jan 26 2025 07:38:13 GMT-0300 (Brasilia Standard Time) Results: 9349984
PEDRO	1.(runn* injur*) 2.(runn* perform*) 3.(runn* prevent*)

CINAHL	(recreational runners OR Casual runners OR Jogger OR non-elite runners OR amateur runners) AND (strength training OR resistance training OR weight training OR Exercise Program* OR Strengthening Program*) AND (injury prevention OR wound prevention OR prevention AND performance OR running economy OR sports injuries prevention OR running-related injuries prevention OR musculoskeletal injuries prevention OR overuse injuries prevention OR injury)
LILACS	((recreational runners) OR (casual runners) OR (jogger) OR (non-elite runners) OR (amateur runners)) AND ((strength training) OR (resistance training) OR (weight training) OR (exercise program*) OR (strengthening program*)) AND ((injury prevention) OR (wound prevention) OR (prevention) OR (performance) (running economy) OR (sports injuries prevention) OR (running-related injuries prevention) (musculoskeletal injuries prevention) OR (overuse injuries prevention) OR (injury)) AND db:("LILACS") AND instance:"lilacsplus"

Table 2 - Complete Search Strategy: