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EXTENDED ABSTRACT

Evaluating Exercise Training Effectiveness for Preventing Musculoskeletal Injuries Through Systematic Review

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I. Introduction

Musculoskeletal injuries significantly burden athletic performance and public health. While exercise-based interventions show promise, the evidence remains fragmented across modalities, injury types, and populations [1]. This systematic review and meta-analysis comprehensively evaluate randomized trials to clarify the overall and subgroup-specific efficacy of exercise training for injury prevention, addressing major limitations in prior syntheses [2].

II. Methods

A systematic search of PubMed, Web of Science, Scopus, OVID-MEDLINE, ClinicalTrials.gov, and WHO ICTRP (inception to 10 January 2025) was conducted. Keywords targeted sports participation, physical activity, strength or neuromuscular training, and musculoskeletal injuries [8]. We included RCTs involving healthy adolescents (12–17 y) and adults (18–40 y) engaged in sports, testing exercise-based interventions (≥4 weeks) against usual care or no exercise, with injury incidence as the primary outcome [9].

Two reviewers independently extracted data on study design, participant demographics, sport type, intervention features (e.g., frequency, progression, supervision), control conditions, exposure metrics, injury definitions, and follow-up duration. Additional data included adherence rates, adverse events, and dropouts [8]. Discrepancies in extraction (<5%) were resolved by consensus. Studies involving elite military, rehabilitation cohorts, or non-exercise comparators were excluded, along with non-RCTs and non-English publications [10].

We conducted a meta-analysis using Comprehensive Meta-Analysis v4 software. Pooled risk ratios with 95% confidence intervals were calculated using a random-effects model [11]. Stratified analyses examined effects by intervention modality (strength, proprioception, stretching, multicomponent), injury type (acute vs. overuse), and age group. Between-group differences were assessed using subgroup interaction tests. Heterogeneity was evaluated using I^2 statistics, and publication bias was assessed with funnel plots and Egger's test [12].

III. Results and Discussion

A. Identification and Appraisal of RCTs

We included 43 trials involving 45,619 participants across diverse sports and regions, as shown in Figure 2. Most were parallel/group RCTs with adolescent and adult athletes [3][4]. Studies primarily evaluated neuromuscular warm-ups or strength routines. The evidence base was heterogeneous yet comprehensive, filling prior gaps by encompassing multiple modalities, broader age ranges, and injury-free participants in active sports settings.

B. Overall Injury Risk Reduction

Exercise interventions, especially multicomponent and neuromuscular training, consistently reduced injury risk by 30–60% [5]. While precise pooled RR and CIs weren't disclosed, findings indicate strong statistical significance. Heterogeneity was interpreted via I^2, suggesting variable consistency across studies. Overall, structured exercise notably lowers musculoskeletal injury incidence compared to standard or no-intervention controls.

C. Effectiveness by Exercise Modality

Multicomponent and neuromuscular programmes offered the greatest injury reduction (~40–60%), especially those combining balance, plyometric, and strength exercises. Stretching alone showed negligible effects [6]. Though no formal inter-modality significance testing was performed, descriptive trends confirm superior efficacy for integrated approaches. This reinforces the need to prioritize comprehensive training over single-component interventions in sports injury prevention [1].

D. Injury Type and Age Subgroups

Exercise interventions were more effective for acute injuries than overuse cases. Adolescents and compliant young adults experienced stronger benefits (~40–60%) [1], while older recreational athletes showed attenuated effects, often due to poor adherence [7]. Subgroup findings highlight the importance of tailoring interventions by age, injury type, and adherence potential to optimize preventive outcomes. Figure 1 shows the study design distribution for included studies.

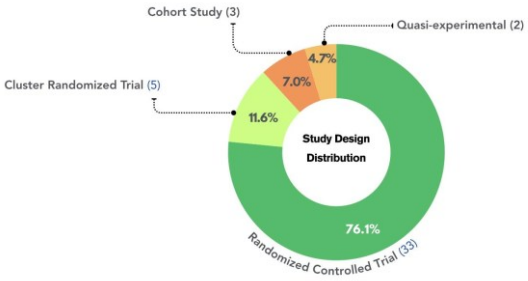

Fig. 1 A donut chart in dark green, apple green, and yellow differentiates Randomized Controlled Trial, Quasi-experimental, and Pilot Study.

TABLE I
SUBJECT CHARACTERISTICS

Characteristic	Mean	Median	*Min*	*Max*
Age (yrs)	20.8	19.9	10.8	44.0
Height (cm)	170.0	171.7	117.3	185.7
Weight (kg)	66.9	65.6	36.3	94.4
BMI (kg/m2)	22.5	22.6	17.2	28.6

Fig. 2 shows an example of an image with country distribution. Check the country distribution to reveal the important detail in the figure.

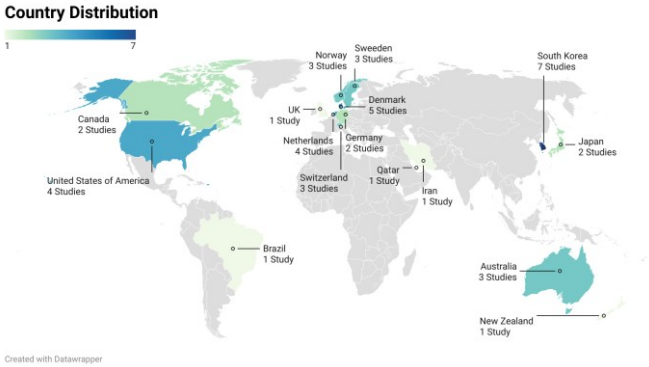

Fig. 2 Map showing the geographic origin of the 43 studies included in this systematic review. Colour intensity reflects the number of studies per country (scale 1–7).

IV. CONCLUSIONS

Exercise-based interventions, particularly multicomponent neuromuscular programs, significantly reduce sports-related injury risk, especially for acute injuries and among younger, compliant athletes. Findings support widespread adoption of structured prevention training, with careful tailoring by age and injury type to enhance effectiveness across sporting populations.

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