INPLASY

# Biomechanical and Physiological Demands of CrossFit: a Systematic Review

INPLASY202560108
doi: 10.37766/inplasy2025.6.0108
Received: 26 June 2025
Published: 27 June 2025

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**ADMINISTRATIVE INFORMATION**

**Support -** No financial support.

**Review Stage at time of this submission -** Completed but not published.

**Conflicts of interest -** None declared.

**INPLASY registration number:** INPLASY202560108

**Amendments -** This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 27 June 2025 and was last updated on 27 June 2025.

## INTRODUCTION

**Review question / Objective** The study aims to analyze scientific literature findings related to CrossFit's biomechanical and physiological demands via systematic review.
What are the physiological and biomechanical effects of high-intensity functional training (such as CrossFit) on physical performance and internal/external training load parameters in healthy adults?

PICOS breakdown:

P (Population): Healthy adults engaged in CrossFit, high-intensity functional training, or functional fitness programs.

I (Intervention): Exposure to CrossFit or other high-intensity functional training strategies.

C (Comparison): No training, traditional training methods, or pre/post comparisons (depending on included studies).

O (Outcomes): Internal and external training load, physiological response (e.g., heart rate, lactate, $VO_2$max), biomechanical response (e.g., movement velocity, power output), and physical performance indicators.

S (Study Design): Experimental and quasi-experimental studies, including randomized controlled trials, crossover trials, and pre-post intervention studies.

**Condition being studied** The acute and/or chronic physiological and biomechanical responses to high-intensity functional training (e.g., CrossFit), including variables related to training load, physical performance, metabolic stress, and neuromuscular function in healthy adults.

## METHODS

**Participant or population** Healthy adult individuals engaged in CrossFit or high-intensity functional training (HIFT), including recreational practitioners, trained athletes, and sedentary or

inactive adults participating in structured CrossFit programs. Studies included both male and female participants across various levels of fitness and training experience.

**Intervention** The included studies examined CrossFit training or high-intensity functional training (HIFT) as the primary intervention. These interventions typically involved multi-joint, high-intensity workouts combining resistance, aerobic, and gymnastic exercises, delivered through WODs (Workouts of the Day), either as acute sessions or structured training programs of varying durations.

**Comparator** The included studies used various comparators, including:

Baseline measurements (pre- vs post-training comparisons)

Other exercise modalities (e.g., traditional resistance training, aerobic training)

Different CrossFit protocols (e.g., short vs long WODs)

Performance levels (e.g., experienced vs novice practitioners)

Some studies did not include a formal comparator but assessed acute responses or correlational outcomes within a single group.

**Study designs to be included** This systematic review includes experimental (randomized and non-randomized trials), observational (cross-sectional, cohort, and case-control), and descriptive studies examining physiological and biomechanical responses to CrossFit training.

**Eligibility criteria** Peer-reviewed studies involving healthy adults participating in CrossFit or high-intensity functional training (HIFT), using experimental, observational, or descriptive designs, and reporting quantitative outcomes related to physiological or biomechanical responses; studies had to describe at least part of the training protocol (e.g., frequency, load, duration) and could include both acute and chronic training effects.

**Information sources** The literature search was conducted in the following electronic databases: PubMed, Web of Science, ScienceDirect, Scopus, and SciELO, covering publications up to February 2024. These sources were selected to ensure broad coverage of both international and regional studies relevant to physiological and biomechanical aspects of CrossFit.

**Main outcome(s)** The primary outcomes of this systematic review were physiological and biomechanical performance indicators associated with CrossFit and high-intensity functional training (HIFT). Specifically, physiological outcomes included cardiorespiratory measures (e.g., $VO_2$max, heart rate, heart rate variability), metabolic markers (e.g., blood lactate concentration, salivary cortisol), and perceptual responses (e.g., rating of perceived exertion). Biomechanical outcomes included neuromuscular performance variables, such as movement velocity, peak power, propulsive velocity, countermovement jump (CMJ) height, and 1-repetition maximum (1RM) in key exercises. These outcomes were selected to reflect acute and chronic adaptations to CrossFit training and their relevance to monitoring fatigue, workload, and performance optimization.

**Quality assessment / Risk of bias analysis** The methodological quality and risk of bias of the included studies were assessed using validated tools appropriate to each study design. For randomized controlled trials (RCTs), the Physiotherapy Evidence Database (PEDro) scale was used, consisting of 11 items (with a maximum score of 10, excluding the first item), where studies scoring ≥6 were considered high quality. For cross-sectional studies, the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Analytical Cross-Sectional Studies was applied, comprising eight items evaluating aspects such as sample selection, measurement validity, and statistical analysis. Two independent reviewers conducted the assessments, and any disagreements were resolved through discussion or by consulting a third reviewer. Full agreement was reached in all cases. No studies were excluded based on quality, but scores were reported to aid interpretation of findings.

**Strategy of data synthesis** A narrative synthesis approach was used to analyze and integrate findings from the included studies, given the heterogeneity in study designs, intervention protocols, and outcome measures. Data were extracted regarding sample characteristics, training intervention details, and physiological and biomechanical outcomes. Results were grouped into two main domains: physiological and biomechanical performance parameters. Within each domain, studies were categorized by type (e.g., intervention, acute response, correlational), and key findings were summarized to identify

consistent patterns, differences, and gaps in the literature. Due to methodological variability and insufficient statistical homogeneity across studies, meta-analysis was not performed. Where applicable, effect sizes, correlations, and relevant statistical results were reported to highlight trends in training responses and performance indicators.

**Subgroup analysis** Subgroup analyses were considered based on participant and training characteristics potentially influencing physiological and biomechanical responses to CrossFit training, including training experience (novice vs experienced), sex (male vs female), competitive level (recreational vs competitive athletes), and training frequency or program duration (short-term vs long-term interventions). Due to heterogeneity in study designs, outcome measures, and limited reporting, formal statistical subgroup analysis was not feasible; however, notable differences observed within individual studies were qualitatively described to explore potential moderating effects on performance and adaptation outcomes.

**Sensitivity analysis** A formal sensitivity analysis was not conducted due to the limited number of high-quality randomized controlled trials and the methodological heterogeneity across included studies. However, study quality scores (assessed via the PEDro and JBI tools) were considered during the interpretation of results to assess the robustness of findings. Studies with higher methodological quality were given greater interpretive weight in the narrative synthesis to minimize potential bias in conclusions.

**Country(ies) involved** Portugal (University of Beira Interior).

**Keywords** CrossFit, high-intensity functional training, biomechanics, physiology, physical performance, training load, fatigue, velocity loss, $VO_2$max, strength, power, WOD, neuromuscular fatigue, movement.

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