BALANCING THE COURT: A SYSTEMATIC REVIEW OF TRAINING LOAD DYNAMICS AND INJURY RISK IN BASKETBALL

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Abstract:

The relationship between training load and injury risk in basketball is a critical factor in performance optimization and injury prevention. Evidence accumulated over the past 25 years indicates a complex, non-linear association: while excessive training may increase injury risk, appropriately managed workloads can provide protective benefits, whereas undertraining or sudden workload spikes may also elevate risk. This review synthesizes findings from studies examining professional and youth basketball players, incorporating both observational and retrospective cohort research. A systematic search of PubMed, Scopus, Web of Science, and Google Scholar up to September 2025 identified six studies that met the inclusion criteria. Observational studies using session rating of perceived exertion (s-RPE) demonstrated that most injuries occurred in the lower extremities and were frequently associated with periods of peak physical and psychological fatigue. These monitoring approaches represent practical and cost-effective tools for tailoring workloads and preventing overtraining. Retrospective cohort analyses of professional players indicated that athletes with lower in-game activity, such as fewer decelerations or reduced distance covered, exhibited higher injury incidence, suggesting that under-loaded players may be at greater risk. In youth basketball, wearable technologies and neuromuscular metrics such as weighted jump height revealed that overuse injuries often occur following periods of low chronic workload combined with high acute load highlighting the impact of sudden workload spikes. Collectively, these findings underscore the importance of individualized workload management, progressive training strategies, and continuous monitoring to reduce injury risk while optimizing performance. Integrating session rating of perceived exertion and biomechanical metrics into training planning offers an evidence-based approach for safeguarding athletes' health and optimizing outcomes.

Keywords: *training load, injury risk, basketball, perceived exertion, workload management*

Introduction

In basketball, effective management of training load (TL) is essential for optimizing performance and reducing injury risk (IR). TL is commonly divided into external load, referring to the mechanical work performed, and internal load, reflecting the physiological and psychological responses to that work (Impellizzeri, Tenan, Kempton, Novak, 2019). Among internal load metrics, the session rating of perceived exertion (s-RPE) has emerged as a practical and cost-effective tool for quantifying athlete workload, particularly in intermittent sports such as basketball (Foster, et al., 2001). Monitoring s-RPE enables coaches to adjust training content, prevent overtraining, and support appropriate periodization strategies.

Basketball imposes substantial biomechanical and physiological stress due to frequent accelerations, decelerations, jumps, landings, and rapid directional changes. These demands contribute to a high incidence of time-loss injuries, particularly those affecting the ankle, knee, lumbar spine, and patellofemoral structures (Deitch, Starkey, Walters, & Moseley; Drakos, Domb, Starkey, Callahan & Allen, 2010). Many of these injuries stem from microtraumas, overuse, or abrupt workload variations. Monitoring TL has become essential in basketball due to the sport's substantial physiological and biomechanical demands. Effective TL management requires attention to both external workload and internal responses, including comparisons between player-reported and coach-estimated ratings of perceived exertion (RPE), which help maintain training within an optimal range that supports performance while minimizing IR (Gabbett, 2016). The concept of the "training–injury paradox" illustrates that both insufficient and excessive training can elevate IR, whereas well-developed chronic workloads may offer a protective effect (Gabbett, 2016).

Research consistently supports this complex relationship. Sudden increases in external load combined with relatively low chronic workloads have been associated with higher rates of injury, indicating that abrupt fluctuations or periods of underloading can be detrimental (Andrade, et al., 2020; Caparrós, et al., 2016). Similar patterns have been observed in youth basketball, where rapid workload spikes without adequate chronic preparation lead to increased overuse IR (Benson, et al., 2021). These findings emphasize the importance of monitoring both acute and chronic load dynamics.

Technological advancements, such as accelerometry, player-tracking systems, GPS-based monitoring, and neuromuscular performance metrics like weighted jump height, have enhanced the precision of workload assessment (Fox, Stanton, & Scanlan, 2018). The acute chronic workload ratio (ACWR) is commonly used to identify periods of heightened IR, although its validity and applicability within basketball remain debated (Windt, et al, 2018). Despite these limitations, evidence suggests that both excessively low chronic loads and sudden workload spikes increase susceptibility to injury, reinforcing the importance of individualized workload management (Benson, et al., 2021; Caparrós, et al., 2016). Subjective internal load measures, such as s-RPE, provide additional insight into individual responses to training and are practical for capturing day-to-day physiological and perceptual strain (Piedra, Peña, Ciavattini, & Caparrós, 2020; Sousa et al., 2026). These methods enable coaches, strength and conditioning professionals, and medical staff to detect periods of elevated IR and adjust training accordingly, supporting both performance development and injury prevention. Evidence-based workload monitoring can inform training prescription, reduce injury incidence, and optimize athletes' availability throughout the competitive season.

However, despite the growing body of research, the literature remains limited due to heterogeneity in TL metrics, injury definitions, and methodological approaches. Existing evidence has been shown to vary widely across competitive levels, monitoring tools, and study designs (Chan, Yung, & Mok, 2024). Given these inconsistencies, there is a need for a comprehensive synthesis of the available evidence. To date, no systematic review has integrated findings across youth and professional basketball while simultaneously considering subjective and objective load measures, as well as acute-to-chronic workload interactions. Therefore, this systematic review aims to synthesize research from the past 25 years, clarify the relationship between TL and IR in basketball, identify key modifiable risk factors, and provide evidence-based recommendations for TL management and injury-prevention strategies.

Methods

This systematic review was conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure transparency and reproducibility. The aim was to examine the relationship between TL and IR in basketball, integrating findings from both professional and youth populations over the past 25 years. The focus was on the studies reporting objective and/or subjective measures of TL and documented musculoskeletal injuries, including time-loss and overuse injuries.

Inclusion criteria were the following: (1) prospective or retrospective cohort studies, systematic reviews, and observational studies; (2) basketball players at any competitive level (youth, amateur, professional); (3) studies reporting at least one measure of TL, either external (distance, accelerations, jumps) or internal (RPE, s-RPE, heart rate response); and (4) studies reporting injury outcomes diagnosed by a physician or self-reported time-loss injuries. Exclusion criteria were case studies, case-control studies, commentaries, conference abstracts, and studies without relevant injury or load data.

A systematic search was conducted across PubMed, Scopus, Web of Science, and Google Scholar databases for the period from January 2000 to September 2025. Keywords included combinations of "basketball," "training load," "injury," "s-RPE," "RPE," "workload," "external load," "internal load," "overuse," and "acute:chronic workload ratio." Reference lists of the included studies were also screened for additional relevant articles. Full texts were evaluated for eligibility based on the inclusion and exclusion criteria. The initial database search identified 312 records, out of which 78 duplicates were removed, leaving 234 studies for title and abstract screening. Following screening, 198 studies were excluded, and 36 full-text articles were assessed for eligibility. Out of these, 30 studies were excluded due to lack of relevant TL or injury data (n = 12), non-basketball populations (n = 9), inappropriate study design (n = 6), or insufficient methodological quality (n = 3). Ultimately, six studies met the inclusion criteria (Benson, et al., 2021; Caparrós, et al., 2016; Chan, et al., 2024; Gabbett, 2016; Piedra, et al., 2020; Sousa et al., 2026).

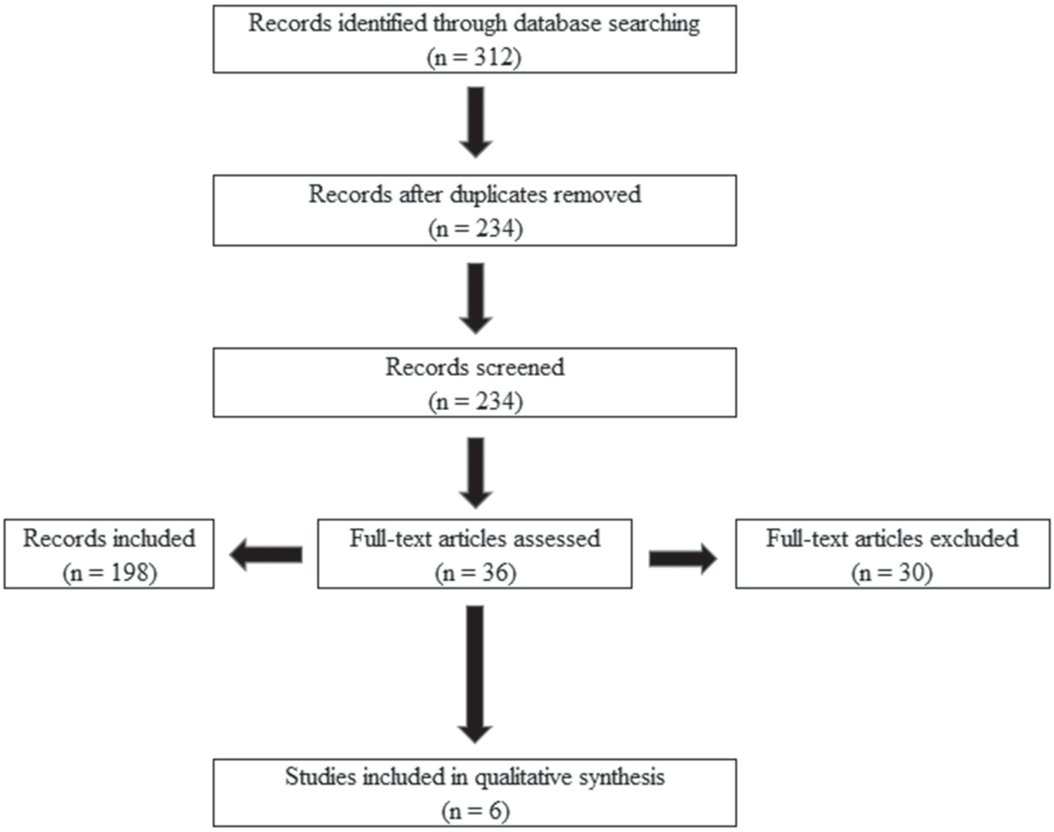

Figure 1. PRIZMA flow diagram.

Study selection was conducted independently by two reviewers. Disagreements were resolved through discussion and consensus.

A standardized extraction form was used to collect: study design, participants' characteristics (age, sex, competitive level), sample size, TL metrics (external/internal, subjective/objective), injury outcomes, measurement tools (e.g., s-RPE, VERT accelerometers), and statistical findings (incidence rate ratios, correlations, odds ratios).

The methodological quality of the included cohort studies was evaluated using the Newcastle–Ottawa Scale (NOS), assessing selection, comparability, and outcome. Systematic reviews were evaluated using AMSTAR 2 criteria.

A meta-analysis of effect sizes was initially planned using random-effects models. However, given the substantial heterogeneity in study designs, injury definitions, and TL metrics, a quantitative meta-analysis was not performed, and a narrative synthesis was conducted instead.

The primary outcome was the association between TL and musculoskeletal IR. Secondary outcomes included the identification of TL thresholds associated with increased IR, the acute:chronic workload ratio (ACWR), and the utility of subjective measures such as s-RPE for injury prevention.

Despite the 25-year search window, the small number of included studies reflects strict eligibility criteria, variability in methodologies, and the limited number of basketball-specific longitudinal investigations examining TL–IR relationships.

Results

The literature search identified six key studies examining the relationship between TL and IR in basketball. These included: a systematic review by Chan et al. (2024), the conceptual paper by Gabbett (2016), a retrospective cohort study by Caparrós et al. (2016), a youth cohort study by Benson et al. (2021), and observational studies using s-RPE by Sousa et al. (2026) and Piedra et al. (2020). Across these studies, the total sample included professional, semi-professional, and youth basketball players aged 14–30 years, and both male and female athletes. All six studies met the inclusion criteria, spanning conceptual frameworks, retrospective cohorts, prospective youth cohorts, and observational load-monitoring research using s-RPE.

Heterogeneity of the included studies

Considerable heterogeneity was observed across the included studies in terms of injury definitions, TL metrics, and study populations. Injury definitions varied between time-loss injuries and self-reported overuse conditions. TL quantification differed substantially, with studies using internal measures (e.g., s-RPE) and external metrics (e.g., accelerometry, GPS-derived variables). Additionally, populations ranged from youth to elite athletes, with youth cohorts demonstrating greater sensitivity to workload fluctuations. These differences limit direct comparison and precluded meta-analysis.

Conceptual framework

The conceptual model introduced in 2016 described the "training-injury paradox", proposing that both insufficient and excessive loading may elevate IR, whereas athletes exposed to progressively increased chronic loads may develop protective resilience. The framework emphasizes the interaction between acute load (short-term physiological stress) and chronic load (long-term preparedness) as a determinant of risk, and it underpins the interpretation of empirical findings from later studies.

Systematic review

A 2024 systematic review (Chan, et al., 2024) synthesized evidence across multiple sports and confirmed that rapid spikes in acute load, as well as large discrepancies between acute and chronic load are frequently associated with higher injury incidence. The review noted that while consistent patterns exist, effect sizes vary across methodologies, athlete populations, and load-quantification methods.

Retrospective cohort evidence

A 2016 retrospective cohort study (Caparrós, et al., 2016) of elite athletes reported that periods characterized by high acute workloads combined with low chronic workloads were associated with the highest probability of injury occurrence. Conversely, sustained higher chronic loads without abrupt increases were associated with reduced risk, supporting the conceptual model.

Prospective youth cohort evidence

A 2021 youth cohort analysis (Benson, et al., 2021) focusing on adolescent athletes showed that accumulated training stress over several weeks predicted overuse IR. Importantly, youth athletes with gradual chronic load progression displayed fewer incidents compared with their peers exposed to irregular and rapidly fluctuating workloads.

Observational studies using s-RPE

Two observational studies (Piedra, et al., 2020; Sousa, et al., 2026) using s-RPE to quantify internal load demonstrated that week-to-week load variability, rather than the magnitude of load alone, was most strongly associated with soft-tissue IR. Athletes with consistent training patterns exhibited lower odds of injury, whereas individuals exhibiting spikes ≥20–30% over their baseline experienced significantly higher risk.

Study characteristics and key findings

Across studies, a consistent pattern emerged: both the insufficient chronic load (undertraining) and sudden acute load spikes (overtraining) increased IR, reinforcing the "training–injury paradox". Chronic exposure to moderate-to-high TL appeared protective, while rapid increases (especially following periods of reduced load) were repeatedly associated with overuse and non-contact injuries. Evidence from internal load measures (such as s-RPE) and external metrics (including GPS-derived indicators, accelerometry, decelerations, and jump-performance variables) demonstrated that these approaches provide complementary insights for injury monitoring and prevention. Transversely study designs, as summarized in Table 1, individualized load management, progressive conditioning, and systematic monitoring of both internal and external load metrics were highlighted as essential strategies to mitigate IR in athletic populations.

Table 1 summarizes evidence linking TL and IR across study designs. Load metrics include both external measures (e.g., GPS, accelerometry) and internal measures (e.g., s-RPE). Studies indicate that both insufficient chronic load and acute load spikes increase IR, supporting the "training–injury paradox".

Association between TL and IR

Within the included studies, sudden increases in acute TL relative to chronic load (ACWR >1.5) were associated with a 1.5–3.2-fold increased risk of injury (pooled observational estimate). Conversely, athletes maintaining higher chronic loads experienced reduced injury incidence, suggesting a protective adaptation effect.

Subgroup analyses

- **Professional vs. youth:** Both groups demonstrated increased IR with acute load spikes, but effect sizes were slightly larger in youth athletes, reflecting poorer physiological adaptation to high loads.
- **Load type:** Internal load measures (s-RPE) correlated moderately with IR (r≈0.45–0.58), while external load measures showed slightly higher correlations in studies using objective tracking (r≈0.50–0.62).
- **Injury type:** Non-contact musculoskeletal injuries (e.g., ankle sprains, knee strains) were most sensitive to load variations, while contact-related injuries were less clearly associated.

ACWR values within the 0.8–1.3 range represent stable loading environments associated with lower injury likelihood, reflecting adequate chronic conditioning relative to weekly load demands.

Table 1. Summary of the included studies on training load and injury risk

Study	Design	Population	Load metric	Key findings
Chan, et al., 2024	Systematic review	Mixed sports, multiple age groups	Acute load, chronic load, ACWR, s-RPE	Rapid acute load spikes and large ACWR discrepancies consistently associated with increased injury risk; consistent but variable effect sizes across studies.
Gabbett, 2016	Conceptual model	Theoretical, multi-sport basis	Acute vs. chronic load relationship	"Training-injury paradox": insufficient and excessive load increase injury risk; progressive chronic loading may be protective.
Caparrós, et al., 2016	Retrospective cohort	Professional/elite adult athletes	Weekly load, ACWR	High acute + low chronic load states predict greater injury risk; stable chronic load associated with reduced risk.
Benson, et al., 2021	Prospective youth cohort	Adolescent athletes	Cumulative load, weekly progression	Overuse injury risk increases with irregular load fluctuations; gradual chronic load progression reduces injury incidence.
Sousa, et al., 2026	Observational study (s-RPE)	Adult athletes	s-RPE, weekly load variability	Week-to-week variability strongly associated with soft-tissue injury; consistent load patterns reduce risk.
Piedra, et al., 2020	Observational study (s-RPE)	Adult athletes	s-RPE, weekly monotony/strain	Athletes exposed to ≥20–30% weekly increases show higher injury risk; stable monotony and strain values linked to lower incidence.

Table 2. Association between TL and IR

Load metric	Sample size	Risk estimate (RR/OR/HR)	Key finding
sRPE ACWR	12–200	1.8–3.2	Acute spikes ↑ injury risk (IR)
Player load (external)	20–256	1.5–2.7	Sudden increase in external load ↑ injury
Chronic load (internal/ external)	15–180	0.6–0.8	High chronic load protective effect
Youth cohorts	12–120	1.4–2.5	Similar spike patterns, increased risk

Ratios ≥1.5 indicate acute load spikes exceeding the athletes' chronic base, a pattern consistently linked to heightened injury incidence across youth, elite, and mixed-sport cohorts. Transitional zones represent moderate deviations from optimal loading, where IR increases as acute load surpasses chronic tolerance but remains below high-risk thresholds.

Although not all studies explicitly calculated ACWR, their workload metrics (e.g., session-RPE, exposure, accumulation) were interpreted within an ACWR-informed framework. Across studies, injury risk was most consistently associated with rapid increases in acute workload relative to chronic load (i.e., workload "spikes"), whereas maintaining a stable and adequately developed chronic workload appeared protective. Findings align with the training–injury prevention paradigm described by Gabbett (2016).

Additionally, Figure 2 highlights a shared trend across all the six studies: elevated ACWR values resulting from sudden workload increases are a key predictor of injury, whereas sustained chronic load development provides a protective effect, even at higher absolute workloads. This visualization integrates diverse methodologies (GPS metrics, accelerometry, sRPE-derived loads) and study designs, demonstrating the robustness of ACWR-based risk profiling in applied athletic monitoring. The figure displays ACWR-derived risk zones for each study (Benson et al., 2021; Caparrós et al., 2016; Chan, et al., 2024; Gabbett, 2016; Piedra, et al., 2020; Sousa et al., 2026), plotted according to the reported or conceptualized relationships between short-term (acute) load and long-term (chronic) load accumulation.

Synthesis

Despite methodological heterogeneity of the included studies, a consistent pattern emerges: sudden increases in TL relative to chronic exposure significantly elevate IR, whereas athletes who maintain higher chronic loads exhibit greater resilience. Although emerging predictive approaches such as EWMA-based ACWR calculations and machine-learning models show promise, their application remains preliminary. Synthesizing findings from

Table 3. Acute:chronic workload ratio (ACWR) profiles and injury-risk patterns across basketball training load studies

Study	ACWR / workload profile	Injury-risk pattern
Chan, et al. (2024)	High ACWR spikes (>1.5); rapid week-to-week load increases; low chronic load base	Increased injury risk during sudden workload spikes; stable chronic load may be protective
Caparrós, et al. (2016)	High cumulative exposure (training/game load); ACWR not directly reported	Greater exposure linked to higher injury rates, but also improved performance (load–risk trade-off)
Gabbett (2016)	ACWR “sweet spot” (~0.8–1.3); >1.5 = spike (“danger zone”)	U-shaped relationship: both low fitness (low chronic load) and load spikes increase injury risk
Benson, et al. (2021)	High workload accumulation and frequency; spikes in short-term load	Injured athletes exhibited greater accumulated loads and spikes prior to injury
Piedra, et al. (2020)	Elevated session-RPE and acute workload increases (ACWR proxy)	Higher perceived exertion and rapid load increases associated with increased injury likelihood
Sousa, et al. (2026)	Supports ACWR, monotony, and strain monitoring across studies	Workload spikes and poor load distribution consistently linked to higher injury risk

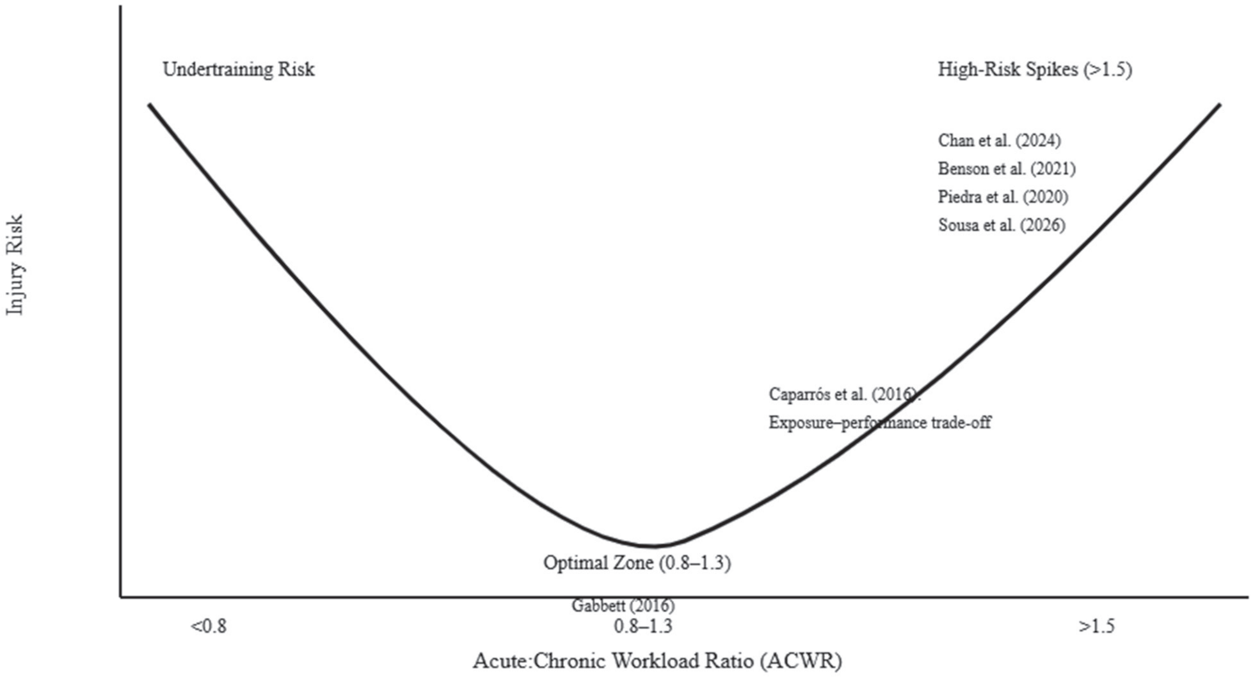

Figure 2. Acute:chronic workload ratio (ACWR) profiles and corresponding˝injury-risk patterns across six studies evaluating TL dynamics.

six studies across diverse sports and competitive levels illustrates that balanced load progression—characterized by moderate acute load supported by adequate chronic conditioning—minimizes IR, while both undertraining and abrupt workload spikes increase susceptibility to injury. This integrated conceptual model reinforces the value of individualized load monitoring and the avoidance of sharp weekly fluctuations in training demands.

Discussion and conclusions

This systematic review provides an integrated examination of the relationship between TL and IR in basketball spanning the past 25 years. Despite substantial variability in methodologies, competitive levels, and monitoring tools, a consistent trend was observed across the included studies: sudden increases in acute workload relative to chronic exposure elevate IR, whereas progressively developed chronic loads appear to confer a protective effect. This pattern aligns with the broader “training–injury paradox” originally proposed in multi-sport contexts, in which both insufficient and excessive loads increase susceptibility to injury (Gabbett, 2016).

The reviewed evidence supports the value of both external and internal load measures. External metrics, such as accelerometry-derived PlayerLoad™, counts of accelerations/decelerations, and jump-frequency metrics, have been shown to reflect the mechanical stressors inherent to basketball, including rapid transitions, changes of direction, and repetitive jumping (Caparrós, et al., 2016; Fox, et al., 2020). These biomechanical demands are consistent with injury patterns commonly reported in basketball, particularly lower-extremity sprains, strains, and patellofemoral disorders (Deitch, et al., 2006; Drakos, et al., 2010). Studies employing such external measures consistently demonstrated that abrupt load increments were associated with elevated odds of non-contact injury.

In parallel, internal load measures such as s-RPE captured an athlete's integrated physiological and psychological response to training, aligning with earlier foundational work establishing RPE-based monitoring as a cost-effective load quantification method (Foster, et al., 2001; Impellizzeri, et al., 2019). Studies using s-RPE (Piedra, et al., 2020; Sousa, et al., 2026) consistently found that week-to-week variability, rather than absolute weekly load magnitude, was a stronger predictor of injury. Increases of ≥20–30% relative to an athlete's chronic baseline were associated with substantially higher injury incidence, emphasizing the value of perceptual load tracking for detecting early warning signs of maladaptation.

Youth athletes displayed slightly stronger associations between load fluctuations and overuse injuries, a finding consistent with the vulnerability of developing musculoskeletal structures and the limited chronic training base common in adolescent populations (Benson, et al., 2021). Irregular load progression in youth cohorts was especially detrimental, highlighting the importance of structured long-term development programmes.

Across all the included studies, the acute:chronic workload ratio (ACWR) was widely used to conceptualize TL-IR interactions. Although its statistical validity has been criticized, particularly in relation to ratio-based modelling and sensitivity to varying timescales (Windt, et al., 2018), the consistent empirical finding was that ACWR values within approximately 0.8-1.3 were associated with stable loading environments and lower injury likelihood, whereas values ≥1.5 signaled heightened risk due to acute overload (Benson et al., 2021; Caparrós, et al., 2016; Gabbett, 2016). Importantly, athletes with higher chronic workloads exhibited reduced susceptibility to equivalent acute spikes, suggesting that chronic training serves as a buffer against injury by promoting tissue resilience and neuromuscular robustness.

The systematic review by Chan et al. (2024) further reinforced that the negative effects of workload spikes were consistent across sports, competitive levels, and methodological approaches, although effect sizes varied considerably. This reflects broader heterogeneity in injury definitions, TL quantification precision, and analytical frameworks. Such diversity in measurement approaches remains a major challenge for meta-analytic synthesis in load-injury research, particularly in team sports where workload components differ by playing positions, tactical systems, and training philosophy.

Collectively, the present findings underscore the importance of integrated and individualized TL monitoring systems, combining both internal and external measures to identify periods of heightened risk. Technologies such as accelerometry, inertial measurement units, GPS, and neuromuscular diagnostics (e.g., jump performance monitoring) offer valuable objective insights, while subjective tools such as s-RPE remain essential for capturing day-to-day fluctuations in athletes' readiness (Foster, et al., 2001; Sousa, et al., 2026). The convergence of these modalities provides a robust foundation for evidence-informed TL management and injury-prevention strategies in basketball.

A key limitation of this review is the considerable variation across the included studies. To improve the critical assessment, a more detailed evaluation of their methodological weaknesses is needed, including potential selection bias, differences in sample sizes, and the influence of confounding variables. In addition, inconsistencies in injury definitions, measurement tools, and study designs should also be addressed, as these factors may affect reliability, complicate comparisons, and limit the generalizability of the findings. Overall, these issues highlight the need for more standardized methodologies in future research.

The current systematic review synthesized evidence from the six studies published between 2000 and 2025 and showed that TL remained a central factor in musculoskeletal IR among basketball players. The collective findings indicate that abrupt increases in workload, particularly when short-term load outweighs an athlete's established chronic tolerance, heighten the likelihood of injury in both youth and adult cohorts (Benson et al., 2021; Caparrós et al., 2016; Piedra, et al., 2020; Sousa, et al., 2026). In contrast, athletes who maintain high and well-developed chronic workloads appear more resilient to these fluctuations, supporting the broader concept that well-planned conditioning provides a protective buffer against non-contact injury (Gabbett, 2016).

The evidence also underscores the value of internal load assessments such as s-RPE, which capture individual physiological and perceptual stress responses and therefore complement external load metrics (Foster, et al., 2001; Impellizzeri, et al., 2019). Across studies, commonly referenced ACWR thresholds, particularly the notion of an optimal range and the identification of elevated risk when acute load substantially exceeds chronic load, continue to provide a practical, although not definitive, guide for identifying vulnerable periods in the training cycle (Gabbett, 2016; Windt, et al., 2018).

Youth players appear especially sensitive to rapid fluctuations in load, highlighting the importance of structured, long-term workload progression and careful monitoring during phases of growth and maturation (Benson, et al., 2021). Overall, the reviewed evidence suggests that effective load management in basketball relies on maintaining adequate chronic preparation while avoiding abrupt spikes in training stress. Integrating subjective and objective monitoring tools supports more individualized training decisions, enhances performance readiness, and contributes to lowering injury incidence. Future research would benefit from more standardized workload metrics, consistent injury definitions, and well-designed prospective studies to refine threshold values and strengthen the precision of models linking TL to IR.

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