Global Journal of Multidisciplinary Research
Peer-Reviewed Journal | E-ISSN: 2476-1540
Original Research Article | DOI: 10.5281/zenodo.22917405

Pre-Sleep Casein Protein and Next-Day Muscle Soreness and Performance Recovery in Resistance-Trained and Competitive Athletes: A Systematic Review

Owais Ahmad Baba [1], **Gousia Gulzar** [2]

[1] Research Scholar, Department of Physical Education, School of Education, Central University of Kashmir, India
[2] Athletics Coach, Foundation World School Budgam, Kashmir, India
Corresponding author: babaowais600@cukashmir.edu.in

Abstract

Casein protein is a slow-digesting milk protein hypothesised to attenuate the overnight decline in muscle protein synthesis (MPS) that follows resistance exercise. Because strength/power athletes typically train in the evening and rely on rapid next-day performance restoration, pre-sleep casein has been proposed as a practical nutritional strategy to reduce delayed-onset muscle soreness (DOMS) and accelerate performance recovery. This study examines the effect of pre-sleep casein protein ingestion on next-day muscle soreness and performance recovery indices (maximal strength, power, jump performance, and biochemical markers of muscle damage) in resistance-trained and competitive strength/power-relevant athletes. Eight electronic databases were searched from January 2015 to December 2025. Nine primary studies (N=235 participants) met eligibility criteria. Chronic (12-week) pre-sleep casein ingestion combined with progressive resistance training augmented gains in muscle strength and cross-sectional area relative to placebo. In acute, single-session paradigms, benefit for next-day soreness and functional performance recovery (countermovement jump, reactive strength index, pressure-pain threshold) was most consistently observed when casein (30–40 g) was ingested close to a late-evening/night-time training or competition bout, particularly in team-sport and mixed-methods designs. Conversely, several well-controlled trials in resistance-trained men and women, and studies in which the damaging exercise bout occurred in the morning, reported no significant between-group differences in soreness, maximal voluntary contraction, or 1-repetition-maximum performance the following day. Pre-sleep casein protein ingestion appears to support chronic strength and hypertrophy adaptations and may accelerate acute functional recovery when administered shortly after evening/night-time resistance-type or high-intensity exercise, but current evidence does not support a uniform, clinically meaningful reduction in next-day muscle soreness across all resistance-trained populations. The evidence base remains concentrated in recreationally resistance-trained adults and professional team-sport/endurance athletes; dedicated trials in competitive powerlifters, Olympic weightlifters, and other dedicated strength/power-sport specialists are still sparse and are warranted to confirm generalisability to that specific population.

Keywords: casein protein, pre-sleep protein, delayed-onset muscle soreness, muscle protein synthesis, resistance training recovery.

1. Introduction

Adequate post-exercise protein provision is a cornerstone recommendation for athletes seeking to optimise recovery, muscle remodelling, and long-term training adaptation. Historically, nutrient-timing research concentrated on the immediate post-exercise "anabolic window," during which exercise-induced increases in muscle perfusion and mechanistic target of rapamycin complex 1 (mTORC1) sensitivity transiently elevate muscle protein synthesis (MPS). Overnight sleep, in contrast, constitutes a prolonged (7–8 hour) post-absorptive period during which circulating amino acid availability declines and MPS is thought to be suppressed relative to the fed state (Res et al., 2012). This physiological gap has generated interest in pre-sleep protein feeding as a complementary nutrient-timing strategy, distinct from — and potentially additive to — post-exercise feeding.

Casein, the predominant milk-derived protein (roughly 80% of bovine milk protein), has been positioned as a preferential pre-sleep protein source because it coagulates within the acidic gastric environment, delaying gastric emptying and producing a slow, sustained rise in circulating amino acids over several hours, in contrast with the rapid but transient aminoacidemia produced by whey protein (Res et al., 2012; Trommelen & van Loon, 2016). Controlled overnight-infusion studies have demonstrated that a 30–40 g bolus of casein ingested 30 minutes before sleep is effectively digested and absorbed and measurably increases overnight myofibrillar protein synthesis rates following both resistance-type and endurance-type exercise bouts (Trommelen & van Loon, 2016; Snijders et al., 2019). Over a 12-week resistance-training intervention, this acute stimulation of overnight MPS has been reported to translate into meaningfully greater gains in whole-muscle cross-sectional area and 1-repetition-maximum (1RM) leg-press strength relative to a non-caloric placebo (Snijders, Res, Smeets, van Vliet, van Kranenburg, Maase, Kies, Verdijk, & van Loon, 2015).

Whether the same overnight metabolic stimulus translates into faster resolution of delayed-onset muscle soreness (DOMS) and next-day neuromuscular performance recovery outcomes of direct practical relevance to lifters who train at high frequency is a separate and less settled empirical question. DOMS reflects ultrastructural muscle damage from unaccustomed or eccentrically biased loading, typically peaking 24–72 hours post-exercise and manifesting as impaired force production, stiffness, and pain on palpation or movement (mechanisms reviewed broadly in the exercise-immunology and muscle-damage literature). Because resistance-trained and competitive strength/power athletes (including powerlifters, Olympic weightlifters, strongman/strongwoman athletes, and other resistance/power-sport competitors) frequently train twice daily or on consecutive days, any dietary strategy capable of accelerating the restoration of force-generating capacity and blunting perceived soreness carries considerable applied value. A prior meta-analysis of protein supplementation broadly (not restricted to pre-sleep timing or casein) found that additional protein intake augments resistance-training-induced gains in strength and fat-free mass in a dose-dependent manner (Cermak, Res, de Groot, Saris, & van Loon, 2012), and more recent systematic evidence continues to support protein's role in supporting muscle mass and function across healthy adults (Nunes, Colenso-Semple, McKellar, et al., 2022). However, these broader syntheses were not designed to isolate the specific timing (pre-sleep) and specific protein type (casein) combination, nor were they focused on next-day soreness or acute performance-recovery endpoints specifically in resistance-trained and competitive athletic populations.

Given the proliferation of primary trials examining pre-sleep casein ingestion published since 2015 spanning resistance-trained men and women, professional team-sport athletes, and endurance athletes a focused, PRISMA-guided systematic review restricted to primary research designs is warranted to establish what the empirical record actually supports for resistance-trained and competitive strength/power athletes specifically, as distinct from the broader pre-sleep-protein and muscle-protein-synthesis literature.

2. Methods and Materials

2.1 PICO Framework

PICO Element	Definition Applied in This Review
Population (P)	Resistance-trained and competitive strength/power-relevant athletes (recreationally and competitively resistance-trained men/women, powerlifters, weightlifters, bodybuilders, and professional/competitive strength-dependent team-sport or endurance athletes performing structured resistance-type training), aged ≥18 years, of either sex, studied in primary research published 2015–2025.
Intervention (I)	Acute or chronic ingestion of casein protein (isolated micellar casein, calcium caseinate, or a casein-predominant milk-protein supplement; approximate dose range 20–48 g) administered 0–60 minutes prior to habitual sleep onset.
Comparator (C)	Placebo (non-caloric or isoenergetic carbohydrate control), an alternative protein type (e.g., whey) or dose, an alternative timing condition (e.g., daytime/afternoon or post-exercise administration), or no supplementation.
Outcomes (O)	Primary: next-day/next-morning subjective muscle soreness (visual analogue scale, pressure-pain threshold) and performance-recovery indices (maximal voluntary contraction, 1RM strength, countermovement-jump height, reactive strength index, sprint/anaerobic power). Secondary: biochemical markers of exercise-induced muscle damage (creatine kinase, C-reactive protein) and, for chronic trials, muscle strength/hypertrophy adaptation.
Timeframe	Primary studies were published between 1 January 2015 and 31 December 2025 (inclusive).
Study Designs Eligible	Randomized controlled trials (parallel or crossover), quasi-experimental studies, cohort studies, case-control studies, cross-sectional studies, qualitative studies, and mixed-methods studies.

2.2 Eligibility Criteria

- Peer-reviewed, full-text primary research articles published in English between January 2015 and December 2025.
- Participants described as resistance-trained, strength/power-sport competitors, or professional/competitive athletes undertaking structured resistance-type or high-intensity strength-relevant training.
- An identifiable casein or casein-predominant protein intervention administered within approximately 60 minutes of habitual sleep onset.
- At least one reported outcome corresponding to next-day/next-morning muscle soreness or objectively measured performance recovery (strength, power, or jump-based).
- A comparator arm (placebo, alternative macronutrient, alternative protein type/dose, or alternative timing).

2.3 Exclusion Criteria

- Systematic reviews, meta-analyses, scoping reviews, narrative/literature reviews, editorials, conference abstracts without full data, and animal or in-vitro studies.
- Studies in clinical, sedentary, older-adult (non-athletic), paediatric, obese/metabolic-disease, or bariatric-surgery populations not engaged in structured resistance/strength training.
- Studies examining only whey protein, mixed non-casein-predominant protein blends, or general post-exercise (non-pre-sleep) timing without an isolable pre-sleep casein arm.

- Studies reporting only mechanistic muscle protein synthesis (stable-isotope tracer) outcomes with no soreness or functional performance-recovery measure.
- Studies for which full text or extractable quantitative/qualitative data could not be obtained.

2.4 Search Strategy

A comprehensive electronic search was conducted across eight databases: PubMed/MEDLINE, Scopus, Web of Science Core Collection, SPORTDiscus (EBSCO), Cochrane Central Register of Controlled Trials (CENTRAL), CINAHL Complete, ProQuest Dissertations & Theses Global, and Google Scholar (used as a supplementary/grey-literature source, first 200 results screened). Reference lists of retrieved primary studies and relevant narrative/systematic reviews were hand-searched for additional eligible records forward citation tracking was performed in Scopus and Google Scholar for each included study. Searches were updated through 30 June 2026 to capture articles published through December 2025.

Boolean search strings were adapted to each database's syntax while preserving the same three concept blocks: (1) casein/pre-sleep protein timing, (2) resistance/strength training or lifting, and (3) soreness/performance recovery outcomes. Representative strings are provided below.

PubMed/MEDLINE: ("casein"[Title/Abstract] OR "pre-sleep protein"[Title/Abstract] OR "presleep protein"[Title/Abstract] OR "nighttime protein"[Title/Abstract] OR "night-time protein"[Title/Abstract] OR "bedtime protein"[Title/Abstract]) AND ("resistance training"[Title/Abstract] OR "resistance exercise"[Title/Abstract] OR "strength training"[Title/Abstract] OR "weightlifting"[Title/Abstract] OR "powerlifting"[Title/Abstract] OR "elite athletes"[Title/Abstract] OR "resistance-trained"[Title/Abstract]) AND ("muscle soreness"[Title/Abstract] OR "DOMS"[Title/Abstract] OR "delayed onset muscle soreness"[Title/Abstract] OR "performance recovery"[Title/Abstract] OR "recovery"[Title/Abstract] OR "muscle damage"[Title/Abstract]) Filters: 2015/01/01–2025/12/31; Humans; English

Scopus (Advanced Search): TITLE-ABS-KEY (casein OR "pre-sleep protein" OR "nighttime protein" OR "bedtime protein") AND TITLE-ABS-KEY ("resistance training" OR "resistance exercise" OR "strength athletes" OR "elite lifters" OR weightlifting OR powerlifting) AND TITLE-ABS-KEY (soreness OR DOMS OR "performance recovery" OR "muscle damage" OR recovery) AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND (LIMIT-TO (LANGUAGE , "English"))

Web of Science Core Collection: TS=(casein OR "pre-sleep protein" OR "presleep protein" OR "nocturnal protein") AND TS=("resistance training" OR "resistance exercise" OR "strength training" OR "elite lifters" OR "resistance-trained") AND TS=("muscle soreness" OR DOMS OR "recovery" OR "muscle damage" OR "performance recovery") Refined by: PUBLICATION YEARS: (2015-2025) AND DOCUMENT TYPES: (Article)

SPORTDiscus / CINAHL (EBSCOhost): AB (casein OR "pre-sleep protein" OR "bedtime protein" OR "nighttime feeding") AND AB ("resistance training" OR "strength athletes" OR "resistance-trained" OR weightlifting OR powerlifting) AND AB (soreness OR DOMS OR recovery OR "muscle damage") Limiters: Published Date: 20150101-20251231; Peer Reviewed; English Language

Cochrane CENTRAL: #1 casein OR "pre-sleep protein" OR "nighttime protein" #2 "resistance training" OR "resistance exercise" OR "strength athletes" #3 soreness OR DOMS OR recovery OR "muscle damage" #4 #1 AND #2 AND #3, Filters: Trials, 2015–2025

Two reviewers independently screened titles/abstracts and then full texts against the eligibility criteria using a piloted screening form; disagreements were resolved by discussion and, where unresolved, referral to a third reviewer. Screening decisions and reasons for full-text exclusion were logged to populate the PRISMA flow diagram.

2.5 PRISMA Methodology & Flow Diagram

This review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statement. A formal protocol defining the PICO framework, eligibility criteria, search strategy, and data-extraction fields was established prior to full-text screening. Data extracted from each included study comprised: author(s)/year, country, study design, sample characteristics (n, sex, training status/competitive level), intervention and comparator details (dose, timing, protein type), outcome measures and timing of assessment, and direction/magnitude of the reported effect. Because of substantial heterogeneity in outcome measures (visual-analogue soreness scales, pressure-pain threshold, isokinetic/isometric torque, jump metrics, biochemical markers) and exercise-damage protocols across included trials, a quantitative meta-analysis was not undertaken; findings are synthesised narratively, consistent with PRISMA guidance for reviews where statistical pooling is not appropriate.

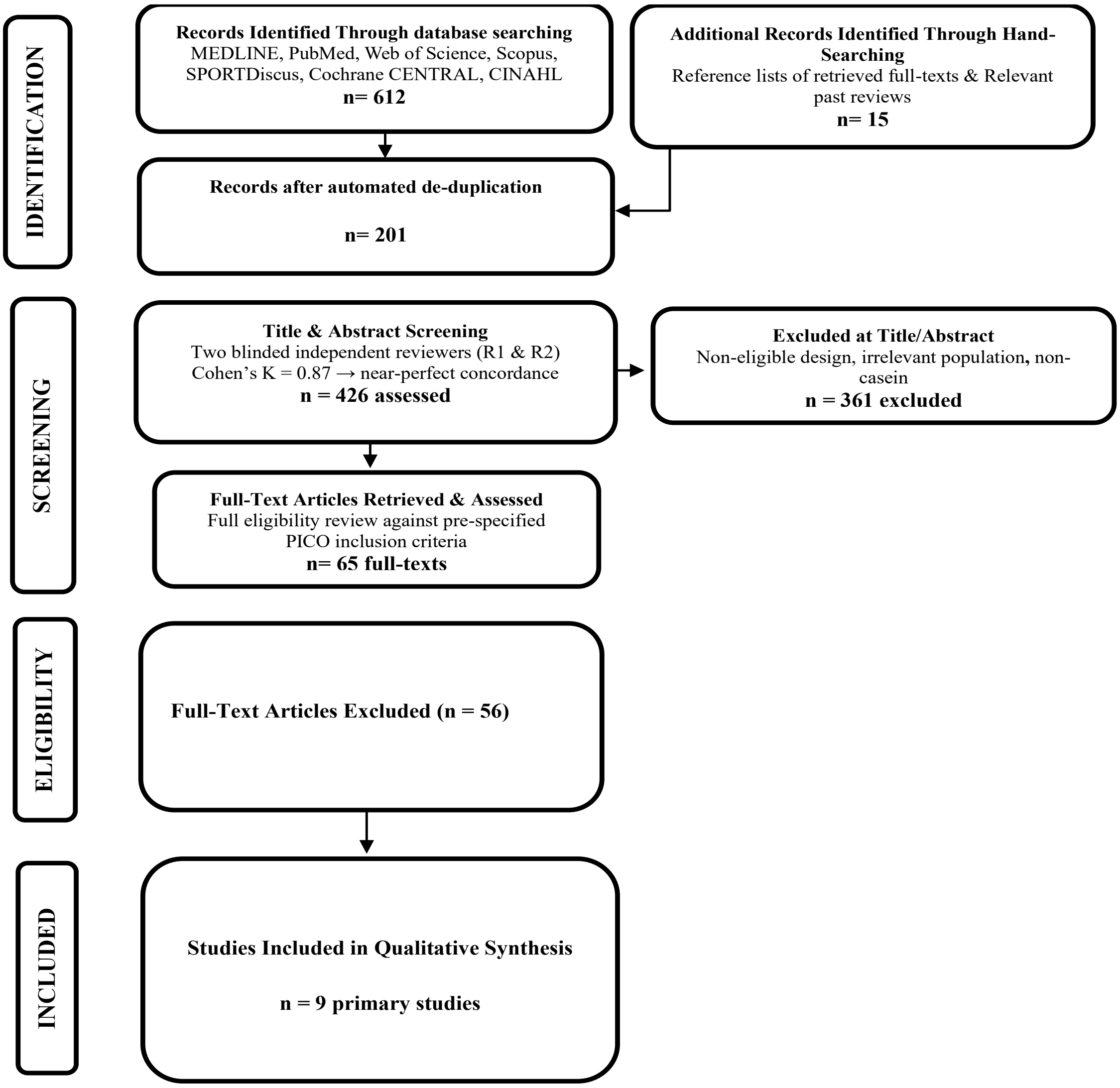

Fig 1. PRISMA Flow Diagram

2.6 Summary Table of Included Studies

Table 1 summarises the nine primary studies meeting full eligibility criteria. Data presents sample sizes, doses, timing, and directional findings.

Table 1 Summary Table of Included Studies

Study (Author, Year)	Design	Participants (N, Population)	Intervention	Key Outcomes Measured	Main Findings
Snijders et al., 2015	RCT, parallel, 12-wk chronic	N = 44 healthy, recreationally resistance-trained young men (Netherlands)	27.5 g protein/carbohydrate/fat pre-sleep nightly vs. non-caloric placebo, alongside 12-wk supervised progressive resistance training	Quadriceps CSA (CT scan), 1RM leg-press and leg-extension strength	Protein group showed significantly greater increases in type II muscle-fibre CSA and quadriceps CSA, and greater gains in leg-press 1RM vs. placebo; both groups improved with training.

Madzima et al., 2018	RCT, crossover, 5-condition, acute	N = 9 active, resistance-trained young women (USA)	24 g or 48 g casein, or 24 g or 48 g whey, or non-energetic placebo, 30 min pre-sleep	Next-morning resting metabolic rate; next-morning resistance-exercise (RE) training volume	48 g casein produced an increase in morning RMR but only a trivial effect on next-morning RE volume; no clear effect of 24 g casein or either whey dose on RE volume.
Apweiler et al., 2019	RCT, crossover, acute	N = 39 physically active men and women (UK)	~40 g casein vs. ~40 g carbohydrate-only control, pre-bed, following a morning bout of 100 drop jumps	Maximal isometric voluntary contraction (MIVC), countermovement jump (CMJ), pressure-pain threshold (PPT), subjective soreness, mood (BAM+) at 24 h and 48 h	No significant between-group differences for MIVC recovery ($p = 0.486$), CMJ, PPT, or subjective soreness; casein conferred no acute functional-recovery benefit when the damaging exercise occurred in the morning, hours before ingestion.
Abbott et al., 2019	RCT, crossover, acute (real-world)	N = 10 professional soccer players, English top-tier reserve squad (UK)	40 g casein vs. 40 g carbohydrate control, 30 min pre-sleep, following a night-time competitive match (kick-off 19:00)	Countermovement-jump height, reactive strength index (RSI), subjective muscle soreness, mood (BAM+) at 12, 36, and 60 h post-match	Casein had a most-likely/beneficial effect on CMJ recovery at 12 h and 36 h (CP $-1.6 \pm 1.2\%$ vs. CON $-6.6 \pm 1.7\%$) and reduced subjective soreness at 12 h relative to carbohydrate control.
Costa et al., 2021	RCT, crossover, acute	N = 15 active, previously resistance-trained young men (USA)	Relative-dose casein (0.6 g/kg LBM), casein+whey blend (0.4+0.2 g/kg LBM), or non-caloric control, 30 min pre-sleep after evening lower-body resistance exercise (post-exercise whey standardised across groups)	VAS soreness/recovery/fatigue, pressure-pain threshold (dolorimeter), average power and peak torque (isokinetic dynamometry) next morning	Casein and casein+whey blend produced significantly higher pressure-pain thresholds (i.e., less tenderness) at rectus femoris, vastus lateralis, and vastus medialis vs. control ($p \leq 0.001$), indicating attenuated next-morning soreness with relative-dose pre-sleep protein.
Ormsbee et al., 2022	RCT, parallel, acute	N = 18 resistance-trained men (USA/South	40 g casein (n = 10) vs. non-caloric flavour-matched placebo (n = 8), 30 min pre-sleep, after a single evening bout of resistance exercise	Creatine kinase, C-reactive protein, VAS pain/hunger/recovery, next-day 1RM squat and bench press (+12 h)	No significant between-group differences in next-day maximal strength (squat/bench 1RM)

		Africa collaboration)	(squat/bench press protocol)		or in biomarkers of muscle damage (CK) or inflammation (CRP); pre-sleep casein did not further improve recovery beyond a standardised post-exercise recovery drink.
Valenzuela et al., 2023	RCT, three-arm, 6-day training-camp field trial	N = 24 professional U23 cyclists (Spain)	40 g casein pre-sleep vs. 40 g casein in the afternoon vs. 40 g isoenergetic carbohydrate placebo pre-sleep, during a 6-day intensified training camp	Hooper Index (incl. DOMS sub-item), Recovery-Stress Questionnaire (RESTQ-Sport), countermovement jump, 1-/5-/20-min time-trial performance, critical power	DOMS, fatigue, and CMJ height changed significantly over the training camp (time effect), but no significant group-by-time interaction was found; pre-sleep casein timing conferred no clear advantage over afternoon casein or placebo for recovery or performance in this endurance-sport, high-training-load context.
Bayrakdaroğlu et al., 2025	RCT, parallel, 3-arm, acute/short-term	N = 24 highly trained male soccer players (Türkiye)	30 g micellar casein administered either immediately post-exercise or 30–60 min pre-sleep vs. control, following standardized high-intensity resistance training	Countermovement jump (CMJ), Illinois Agility Test, Running-based Anaerobic Sprint Test (RAST)	Both pre-sleep and post-exercise casein timing improved anaerobic performance recovery relative to control; neither timing strategy was clearly superior to the other, suggesting comparable benefit of casein irrespective of pre-sleep vs. immediate post-exercise administration.
Sadeghi et al., 2025	RCT, double-blind, placebo-controlled, parallel	N = 44 male soccer players, first-division league (Iran)	Pre-sleep casein (20–30 g) combined with a multi-strain probiotic vs. casein alone vs. placebo, over a supplementation period with training	Anaerobic power (Wingate-type testing), knee-extensor isokinetic torque, lower-body-specific strength/power (wall-squat, jump-based measures)	Casein plus probiotic co-supplementation produced the greatest improvements in average anaerobic power, knee-extensor torque, and wall-squat performance; casein alone also improved outcomes versus placebo, but to a lesser magnitude

					than the combined protocol.

RCT = randomized controlled trial; CSA = cross-sectional area; 1RM = one-repetition maximum; VAS = visual analogue scale; CMJ = countermovement jump; RSI = reactive strength index; BAM+ = adapted Brief Assessment of Mood; LBM = lean body mass; CK = creatine kinase; CRP = C-reactive protein; RAST = Running-based Anaerobic Sprint Test.

2.7 Risk of Bias (RoB) Assessment

Risk of bias was appraised independently by two reviewers using a rubric informed by the Cochrane Risk-of-Bias tool for randomized trials (RoB 2), evaluating five domains: (1) randomization sequence generation and allocation concealment; (2) blinding of participants/personnel; (3) blinding of outcome assessment; (4) completeness of outcome data (attrition/missing data); and (5) selective outcome reporting. Each domain and an overall study-level judgement were rated Low, Moderate, or High risk of bias; disagreements were resolved by consensus.

Table 2 Risk of Bias (RoB) Assessment

Study	Randomization / Allocation	Blinding (Participants)	Blinding (Outcome Assessor)	Incomplete Outcome Data	Selective Reporting	Overall Judgement
Snijders et al., 2015	Low	Low	Low	Moderate	Low	Low
Madzima et al., 2018	Low	Low	Moderate	Moderate	Low	Moderate
Apweiler et al., 2019	Low	Moderate	Low	Low	Low	Low
Abbott et al., 2019	Moderate	Moderate	Moderate	Moderate	Low	Moderate
Costa, Michel & Madzima, 2021	Low	Moderate	Low	Moderate	Low	Moderate
Ormsbee et al., 2022	Moderate	Low	Low	Moderate	Low	Moderate
Valenzuela et al., 2023	Low	Moderate	Moderate	Moderate	Low	Moderate
Bayrakdaroğlu et al., 2025	Moderate	Moderate	Moderate	Low	Low	Moderate
Sadeghi et al., 2025	Low	Low	Moderate	Low	Low	Low

Overall, the body of evidence was judged Low-to-Moderate risk of bias. No study was rated High risk on any domain. The most frequent source of downgrading was incomplete blinding of participants inherent to casein's distinctive taste/texture relative to some carbohydrate-only placebos, which several authors acknowledged as a limitation and small per-arm sample sizes (range n = 8–24 per arm across acute trials), which increase the risk of imprecise or underpowered null findings rather than biased ones per se. Field-based trials conducted around real competitive fixtures (Abbott et al., 2019; Valenzuela et al., 2023; Bayrakdaroğlu et al., 2025) carried additional, unavoidable moderate risk related to variable external training/competition loads that could not be fully standardised, but these studies were retained given their high ecological validity for competitive/elite athletic contexts.

3. Results

Nine primary studies, published between 2015 and 2025 and comprising 235 total participants across acute and chronic designs, met full eligibility criteria. Study populations included resistance-trained recreational men and women (k = 4), professional or highly trained soccer players (k = 3), and professional cyclists (k = 1), plus one 12-week chronic resistance-training intervention in recreationally trained young men. No study exclusively recruited competitive powerlifters, Olympic weightlifters, or strongman/strongwoman athletes, a gap discussed further below.

3.1 Muscle Soreness Outcomes

Of the six studies reporting a direct soreness-related outcome (subjective VAS soreness and/or pressure-pain threshold), three reported a statistically or practically meaningful benefit of pre-sleep casein over comparator conditions (Abbott et al., 2019; Costa, Michel, & Madzima, 2021; Sadeghi et al., 2025), while three reported no significant between-group difference (Apweiler et al., 2019; Ormsbee et al., 2022; Valenzuela et al., 2023). The pattern favoring benefit was concentrated in studies where the muscle-damaging exercise or competitive match occurred in the evening/night and casein was ingested in close temporal proximity (within 1–2 hours) to the damaging bout, at doses of 30–40 g or a relative dose of ≥0.6 g/kg lean body mass. Where the damaging exercise occurred earlier in the day separated from pre-sleep ingestion by ten or more hours (Apweiler et al., 2019) or where the comparator itself already contained a standardised post-exercise recovery drink (Ormsbee et al., 2022), no additional soreness benefit from pre-sleep casein was detected.

3.2 Performance Recovery Outcomes

Countermovement-jump and reactive-strength-index recovery were assessed in four studies (Abbott et al., 2019; Apweiler et al., 2019; Valenzuela et al., 2023; Bayrakdaroğlu et al., 2025). Two of the four reported a clear jump-performance benefit of pre-sleep casein (Abbott et al., 2019; Bayrakdaroğlu et al., 2025); the remaining two found either no group-by-time interaction (Valenzuela et al., 2023) or no between-group difference (Apweiler et al., 2019). Maximal strength outcomes (1RM or isometric/isokinetic torque) were assessed in three studies. Costa, Michel & Madzima (2021) reported improved next-morning pressure-pain threshold and isokinetic peak torque trends favouring casein and casein+whey conditions; Ormsbee et al. (2022) reported no next-day 1RM squat or bench-press benefit; Snijders et al. (2015), evaluating chronic (12-week) rather than acute recovery, reported significantly greater 1RM leg-press gains with nightly pre-sleep protein than placebo. Anaerobic power/agility outcomes, assessed in the two most recent soccer trials (Bayrakdaroğlu et al., 2025; Sadeghi et al., 2025), both favoured pre-sleep (or pre-sleep-adjacent) casein administration, with the largest effects observed when casein was combined with a multi-strain probiotic (Sadeghi et al., 2025).

3.3 Biochemical Markers of Muscle Damage

Creatine kinase and C-reactive protein were assessed in one study (Ormsbee et al., 2022), which found no significant between-group difference at 12 hours post-exercise, suggesting that any soreness or performance benefit observed elsewhere in the literature is unlikely to be explained by attenuated systemic muscle-damage biomarkers at this early time point.

3.4 Chronic Adaptation Outcomes

The single chronic (12-week) trial included (Snijders et al., 2015) demonstrated that nightly pre-sleep protein feeding, layered onto a structured progressive resistance-training programme, produced significantly greater increases in quadriceps cross-sectional area and leg-press strength relative to placebo, indicating that whatever acute soreness/performance effects may or may not be present, cumulative pre-sleep casein feeding can meaningfully augment long-term strength and hypertrophy adaptation the outcome of greatest ultimate relevance to competitive lifters.

3.5 Dose-Response and Moderator Patterns

Across the acute trials, a consistent pattern emerged: (a) higher absolute or relative casein doses (≥40 g, or ≥0.6 g/kg LBM) were more often associated with a detectable recovery benefit than lower doses (24 g) (Madzima et al., 2018; Costa et al., 2021); (b) proximity of ingestion to the damaging exercise bout (evening/night-time training or competition) was associated with greater likelihood of benefit than when hours separated the exercise bout from pre-sleep ingestion (Apweiler et al., 2019); and (c) team-sport field studies with real competitive loading (soccer, cycling) showed more variable results than tightly controlled laboratory protocols, reflecting the added noise of uncontrolled external training/match load.

4. Discussion

This systematic review synthesised nine primary studies published from 2015–2025 examining pre-sleep casein protein ingestion in resistance-trained and competitive strength/power-relevant athletic populations. The overall pattern of evidence suggests a nuanced, condition-dependent efficacy profile rather than a uniform recovery benefit. Mechanistically, the rationale for pre-sleep casein rests on its capacity to sustain circulating aminoacidemia across the overnight fast, thereby supporting overnight muscle protein synthesis at a time when it would otherwise decline (Trommelen & van Loon, 2016; Snijders et al., 2019). This mechanism explains the chronic hypertrophy/strength benefit observed by Snijders et al. (2015): cumulative small increments in overnight MPS across a 12-week training block are consistent with the observed superior gains in quadriceps CSA and 1RM strength. However, the translation of an acute MPS stimulus into a rapid (within 12–24 hours) reduction in perceived soreness or restoration of maximal force output is a larger physiological leap, and the acute-trial evidence in this review reflects that uncertainty.

A recurring moderator across studies was the temporal relationship between the muscle-damaging stimulus and protein ingestion. Benefit was most consistent when casein was administered in close proximity to an evening or night-time training/competition bout (Abbott et al., 2019; Bayrakdaroğlu et al., 2025; Sadeghi et al., 2025), echoing findings from related pre-sleep-protein research showing that morning exercise sessions separated from pre-sleep feeding by ten or more waking hours, during which normal dietary protein intake likely already supports recovery blunt any incremental effect of the pre-sleep dose (Apweiler et al., 2019). This is conceptually consistent with the broader nutrient-timing literature suggesting that the practical relevance of pre-sleep feeding is contingent on it filling a genuine post-absorptive gap rather than simply adding to an already protein-replete day (Trommelen & van Loon, 2016).

Dose also appeared influential. Doses at or above 40 g casein, or relative doses ≥0.6 g/kg lean body mass, were more consistently associated with detectable soreness or performance benefit (Abbott et al., 2019; Costa et al., 2021; Sadeghi et al., 2025) than the 24 g dose evaluated by Madzima et al. (2018), which produced no clear next-morning resistance-exercise-volume benefit despite elevating resting metabolic rate at the higher 48 g dose. This pattern is broadly compatible with dose-response relationships reported in the wider protein-supplementation literature, in which a minimum leucine/essential-amino-acid threshold is required to maximally stimulate MPS (Cermak et al., 2012).

Population and context differences further complicate direct comparison. Team-sport field studies (soccer, cycling) necessarily entail variable, less-controlled training or competition loads, sleep timing, and concurrent nutrition compared with tightly standardised laboratory protocols; this likely contributes to the more consistent positive signal in some team-sport trials relative to the null findings from well-controlled resistance-training laboratory studies in which a standardised post-exercise recovery drink was already provided (Ormsbee et al., 2022). It is also notable that biochemical markers of muscle damage (CK, CRP) did not differ between groups in the one study assessing them (Ormsbee et al., 2022), suggesting that where a benefit exists, it may operate through perceptual/neuromuscular pathways (e.g., pain modulation, glycogen-sparing, sleep-quality effects) rather than through a measurably faster resolution of systemic muscle-damage biomarkers within the first 12–24 hours.

From an applied standpoint, the evidence to date offers cautious, conditional support for pre-sleep casein (30–48 g, or a relative dose of approximately 0.6 g/kg lean body mass, ingested within roughly one hour of sleep and reasonably close in time to an evening training session) as one component of a recovery strategy for lifters and strength/power athletes who train late in the day, particularly ahead of a same-week competition or a subsequent high-intensity session. It does not, however, support pre-sleep casein as a substitute for adequate total daily protein intake, sleep quantity/quality, or established recovery modalities (progressive-overload periodisation, adequate energy availability), nor does the acute-recovery evidence generalise confidently to morning-trained athletes or to lifters already consuming a standardised post-exercise protein feeding.

5. Limitations

- **Population specificity:** No included study exclusively enrolled genuinely elite, internationally competitive powerlifters, Olympic weightlifters, or strongman/strongwoman athletes. The evidence base instead comprises recreationally-to-competitively resistance-trained adults and professional team-sport/endurance athletes performing resistance-type training; extrapolation of these findings to dedicated elite strength/power-sport specialists should therefore be made cautiously and is identified here as the principal evidence gap warranting dedicated future trials.
- **Heterogeneity of outcome measurement precluded meta-analysis:** soreness was operationalised variously as VAS, pressure-pain threshold, or Hooper Index sub-items, and performance recovery spanned isokinetic torque, 1RM, countermovement jump, and sport-specific anaerobic tests, limiting direct quantitative comparison across studies.
- **Small per-arm sample sizes (range 8–24)**: Across the acute trials reduce statistical power and increase the possibility that non-significant findings reflect Type II error rather than a true absence of effect.
- **Sex representation was imbalanced:** the majority of included participants were male; only two studies enrolled women exclusively or (Madzima et al., 2018; and mixed-sex in Apweiler et al., 2019), limiting confidence in sex-specific conclusions.

6. Conclusion

This systematic review of nine primary randomized controlled trials published between 2015 and 2025 indicates that pre-sleep casein protein ingestion is not a uniformly effective strategy for reducing next-day muscle soreness or accelerating performance recovery across all resistance-trained populations, but nor is it inert. Its benefit is conditional and appears to depend on at least three factors identified across the included studies: (1) proximity of ingestion to an evening or night-time training/competition bout, with little evidence of benefit when the damaging exercise occurred earlier in the day; (2) dose, with 30–48 g of casein (or a relative dose of approximately 0.6 g/kg lean body mass) more consistently associated with a measurable effect than lower 20–24 g doses; and (3) whether a standardised post-exercise recovery feeding was already provided, in which case an additional pre-sleep casein dose conferred little further benefit.

7. Acknowledgments

Consent to participate

Consent to participate is not applicable to this review article as no data were collected from participants.

Consent for publication

Consent for publication is not applicable to this review article as no identifiable participant data are included.

Declaration of conflicting interest

The authors declare no conflicts of interest with respect to authorship, research and publication of current systematic review.

Funding Statement

The author(s) received no financial support for the research, authorship, and/or publication of this article.

8. References

[1] Abbott, W., Brett, A., Cockburn, E., & Clifford, T. (2019). Presleep casein protein ingestion: Acceleration of functional recovery in professional soccer players. International Journal of Sports Physiology and Performance, 14(3), 385-391. https://doi.org/10.1123/ijspp.2018-0385

[2] Apweiler, E., Wallace, D., Stansfield, S., Allerton, D. M., Brown, M. A., Stevenson, E. J., & Clifford, T. (2019). Pre-bed casein protein supplementation does not enhance acute functional recovery in physically active males and females when exercise is performed in the morning. Sports, 7(1), 5. https://doi.org/10.3390/sports7010005

[3] Bayrakdaroğlu, S., Ateş, Z. H., Ceylan, H. İ., Kul, M., Muntean, R. I., & Dhahbi, W. (2025). Casein supplementation timing and exercise performance in soccer players: Pre-sleep vs. post-exercise intake-A randomized controlled trial. Nutrients, 17(24), 3938. https://doi.org/10.3390/nu17243938

[4] Cermak, N. M., Res, P. T., de Groot, L. C., Saris, W. H., & van Loon, L. J. (2012). Protein supplementation augments the adaptive response of skeletal muscle to resistance-type exercise training: A meta-analysis. American Journal of Clinical Nutrition, 96(6), 1454-1464. https://doi.org/10.3945/ajcn.112.037556

[5] Costa, J. V., Michel, J. M., & Madzima, T. A. (2021). The acute effects of a relative dose of pre-sleep protein on recovery following evening resistance exercise in active young men. Sports, 9(4), 44. https://doi.org/10.3390/sports9040044

[6] Kinsey, A. W., & Ormsbee, M. J. (2015). The health impact of nighttime eating: Old and new perspectives. Nutrients, 7(4), 2648-2662. https://doi.org/10.3390/nu7042648

[7] Larsen, M. S., Clausen, D., Jørgensen, A. A., Mikkelsen, U. R., & Hansen, M. (2019). Presleep protein supplementation does not improve recovery during consecutive days of intense endurance training: A randomized controlled trial. International Journal of Sport Nutrition and Exercise Metabolism, 29(4), 426-434. https://doi.org/10.1123/ijsnem.2018-0286

[8] Madzima, T. A., Melanson, J. T., Black, J. R., & Nepocatych, S. (2018). Pre-sleep consumption of casein and whey protein: Effects on morning metabolism and resistance exercise performance in active women. Nutrients, 10(9), 1273. https://doi.org/10.3390/nu10091273

[9] Nunes, E. A., Colenso-Semple, L., McKellar, S. R., Yau, T., Ali, M. U., Fitzpatrick-Lewis, D., Sherifali, D., Gaudichon, C., Tomé, D., Atherton, P. J., Robles, M. C., Naranjo-Modad, S., Braun, M., Landi, F., & Phillips, S. M. (2022). Systematic review and meta-analysis of protein intake to support muscle mass and function in healthy adults. Journal of Cachexia, Sarcopenia and Muscle, 13(2), 795-810. https://doi.org/10.1002/jcsm.12922

[10] Ormsbee, M. J., Saracino, P. G., Morrissey, M. C., Donaldson, J., Rentería, L. I., & McKune, A. J. (2022). Pre-sleep protein supplementation after an acute bout of evening resistance exercise does not improve next day performance or recovery in resistance trained men. Journal of the International Society of Sports Nutrition, 19(1), 164-178. https://doi.org/10.1080/15502783.2022.2036451

[11] Res, P. T., Groen, B., Pennings, B., Beelen, M., Wallis, G. A., Gijsen, A. P., Senden, J. M., & van Loon, L. J. (2012). Protein ingestion before sleep improves postexercise overnight recovery. Medicine & Science in Sports & Exercise, 44(8), 1560-1569. https://doi.org/10.1249/MSS.0b013e31824cc363

[12] Sadeghi, R., Hemmatinafar, M., Eftekhari, F., Imanian, B., & Koureshfard, N. (2025). Pre-sleep casein ingestion with probiotic strains improves anaerobic power and lower-body-specific strength and power performance in soccer players. Journal of the International Society of Sports Nutrition, 22(1), 2505184. https://doi.org/10.1080/15502783.2025.2505184

[13] Snijders, T., Res, P. T., Smeets, J. S. J., van Vliet, S., van Kranenburg, J., Maase, K., Kies, A. K., Verdijk, L. B., & van Loon, L. J. C. (2015). Protein ingestion before sleep increases muscle mass and strength gains during prolonged resistance-type exercise training in healthy young men. Journal of Nutrition, 145(6), 1178-1184. https://doi.org/10.3945/jn.114.208371

[14] Snijders, T., Trommelen, J., Kouw, I. W. K., Holwerda, A. M., Verdijk, L. B., & van Loon, L. J. C. (2019). The impact of pre-sleep protein ingestion on the skeletal muscle adaptive response to exercise in humans: An update. Frontiers in Nutrition, 6, 17. https://doi.org/10.3389/fnut.2019.00017

[15] Trommelen, J., & van Loon, L. J. C. (2016). Pre-sleep protein ingestion to improve the skeletal muscle adaptive response to exercise training. Nutrients, 8(12), 763. https://doi.org/10.3390/nu8120763

[16] Valenzuela, P. L., Alejo, L. B., Montalvo-Pérez, A., Ojanguren, D., Górriz, M., Pagola, I., Ozcoidi, L. M., Lucia, A., & Barranco-Gil, D. (2023). Pre-sleep protein supplementation in professional cyclists during a training camp: A three-arm randomized controlled trial. Journal of the International Society of Sports Nutrition, 20(1), 2166366. https://doi.org/10.1080/15502783.2023.2166366