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Invited review article

Acute and Residual Physical Fatigue, Along With Recovery Time Following Sided Games: A Scoping Review and Evidence Gap Map Focusing on Methodological Aspects

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Abstract

This scoping review aimed to (i) map methodological characteristics of studies investigating acute and residual fatigue and recovery after small-sided games (SSGs), (ii) identify outcomes, measures, and timings assessed across neuromuscular, psychophysiological, and biochemical/endocrine domains, and (iii) highlight evidence gaps to inform future research. Following a registered protocol (OSF: osf.io/73rzs) and PRISMA-ScR guidelines, three databases (PubMed, Scopus, Web of Science) were searched to July 2025. Eligible studies included Tier ≥2 athletes, examined SSGs as interventions, and reported pre–post neuromuscular, psychophysiological and biochemical/endocrine outcomes. Data were extracted on populations, competitive level, SSG formats, outcomes, and timings, and synthesized descriptively with evidence gap maps. From 3,842 records, 32 studies were included. Most involved men soccer players at Tier 3, with fewer on women, other sports, or adaptive contexts. SSG formats clustered around 3v3 - 4v4. Psychophysiological measures were most frequently reported, generally showing acute elevations in heart rate and rating of perceived exertion and short-lived reductions in heart rate variability. Neuromuscular outcomes included sprint and hamstring strength, often reduced up to 48 - 72 h, while countermovement jump results were inconsistent. Biochemical/endocrine measures typically showed acute rises in lactate and short-term creatine kinase elevations, with hormonal findings less consistent. Assessments were concentrated immediately post and at 24 h, with fewer extending beyond 48 h. As conclusion, current evidence suggests that SSGs are associated with acute psychophysiological strain and, in some cases, short-term neuromuscular and biochemical disturbances, but findings vary across studies. Given the methodological heterogeneity and narrow scope of populations, conclusions must be interpreted with caution.

Key words: Sided-games, fatigue, recovery, team sports, conditioned games.

Introduction

Sided games (SSGs) are modified formats of gameplay commonly used by team sport coaches in training routines (Clemente et al., 2024). These games are valued for their specificity, as they allow coaches to target technical and tactical objectives while preserving the dynamics of real matches. However, in some cases, they may underestimate certain aspects of physical demands (Davids et al., 2013). At the same time, they offer opportunities to exaggerate certain tactical behaviors in line with specific training goals (Torrents et al., 2016). Typically played on smaller fields and with fewer players, SSGs increase the frequency of individual technical actions (Clemente and Sarmento, 2020) and create a more intense physiological environment (Rampinini et al., 2007). While the intensity of these games can vary depending on task constraints set by the coach, research has shown that both physiological and physical demands can be high (Bujalance-Moreno et al., 2019). For example, heart rate and blood lactate levels during SSGs are often reported to be higher than in formal matches (Asci, 2016; Köklü and Alemdaroğlu, 2016). However, physical demands tend to depend on the specific variables being measured (Clemente, 2020). SSGs usually impose greater demands on acceleration and deceleration due to limited space (Clemente et al., 2019), while demands for high-speed running are typically lower (Asian-Clemente et al., 2021).

Research on SSGs has grown steadily in recent years (Clemente, 2023). While traditionally used to achieve technical or tactical objectives (Ferreira-Ruiz et al., 2022), a substantial body of research has also emerged focusing on the physiological and physical demands of these games, particularly in relation to various task constraints. This strong and sustained interest is evident in the increasing number of review articles on the topic (Hill-Haas et al., 2011; Halouani et al., 2014; Bujalance-Moreno et al., 2019; Clemente et al., 2022; Praca et al., 2022). Furthermore, experimental studies exploring how SSGs may drive physical adaptations have become a prominent research trend, contributing to the development of new systematic reviews and meta-analysis (Hammami et al., 2018a; Moran et al., 2019; Clemente et al., 2023). The research traction in SSGs and impacts on physiological and physical demands is likely due to the recognition that these games can be used strategically to deliver specific physical stimuli (Owen et al., 2012; Dellal et al., 2012). As such, research has begun to investigate the acute and residual

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fatigue associated with SSGs—specifically how these games affect recovery processes and how long their impact may last (Sparkes et al., 2018; Papanikolaou et al., 2021). Studies have assessed acute neuromuscular impairments post-SSG (Johnston et al., 2014), tracked biochemical markers related to inflammation (Bekris et al., 2022), and monitored muscle function to determine how long impairments persist (Sparkes et al., 2020b). Although in real-world training contexts it is difficult to isolate the effects of SSGs -since they are typically integrated into broader training routines- there is growing interest in understanding their individual contributions to player fatigue and recovery. This is especially relevant compared to the more established body of research on post-match fatigue (Silva et al., 2018).

The growing emphasis on understanding how SSGs influence physical recovery may have practical implications, particularly when it comes to planning training schedules. Identifying which formats of SSGs are more suitable closer to match days -and which should be used earlier in the week- can support planning. Given the emerging interest in acute (i.e., immediate post-exercise) and residual (i.e., delayed) physical fatigue and recovery time following SSG implementation, a scoping review with an evidence gap map is timely. As the evidence base is still emerging and methodologically diverse, a scoping review is well-suited to define the boundaries of the current literature, highlight methodological limitations, and guide future research through clearer, more refined study designs (Peters et al., 2015; Munn et al., 2018). Therefore, the aims of this review were to: (i) summarize the main methodological characteristics of studies investigating acute and residual physical fatigue and recovery time following SSGs in team sport athletes, regardless of sex or competition level; (ii) identify and catalog the outcomes assessed, the measurement tests and time points used, and the characteristics of the implemented SSGs; (iii) briefly summarize the main findings and trends from the existing body of research; and (iv) map current research gaps and outline directions for future investigations.

Table 1. Methodological characteristics of the individual studies.

Study	Sport	Sample (n, sex; age)	Tier	Study design	SSG format	Training regimen	Field / area	Task constraints	Neuromuscular	Physiological	Biochemical/ Endocrine	Timing
(Alashti et al., 2021)	Soccer	24 M; 17.1 ± 1.1	T2	Quasi-experimental + control	2v2; 4v4	2v2: 8×2 min/1 min; 4v4: 4×4 min/2 min	2v2: 20×25 m; 4v4: 28×35 m	Stop-ball; no GK; coach encouragement	—	HR, %HRmax, RPE	BLa, GH, IGF-1	Pre, post
(Ascondo et al., 2024)	Wheelchair basketball	13 M; 28.8 ± 9.2	T3	Repeated measures (5 wk)	4v4	4 bouts per session; 1×/wk ×5	28 × 15 m	Wheelchairs; SCI vs non-SCI	Acceleration capacity	HR, RPE (muscular/resp.), tympanic temp	—	End of each bout
(Baseri et al., 2022)	Soccer	24 M; 22.3 ± 2.6	T3	Crossover (recovery after SSG)	3v3 + 4 support players	4×4 min; 3-min passive rest	18×20 m (60 m²/plyr)	ball-possession; 4 neutrals; coach encouragement; spare balls	20 m sprint	HRV (SDNN, lnRMSSD), HR, RPE, Hooper	—	Pre, post-SSG, post-recovery, 48 h
(Bekris et al., 2022)	Soccer	22 M; 22.3 ± 3.9	T3	Controlled trial	3v3	8×3 min; 3-min active recovery	20 × 25 m	No GK; standard rules	SJ, 20 m sprint	HR, RPE	CK, IL-6, Cortisol, Testosterone, BLa	Pre, post, 24/48/72 h
(Bonato et al., 2020)	Soccer	32 M; 24 ± 6	T2	RCT (SSG vs HIIT)	4v4	4×4 min; 3-min active recovery; evening (20:00)	36×24 m	ball-possession; coaches' encouragement; HR monitored	—	Sleep (actigraphy: AST, SE, SL, IT, MT, FI); HR	Salivary Cortisol; Cortisol Awakening Response	PRE, POST (cortisol); POST1 & POST2 nights (sleep)
(Chmura et al., 2019)	Soccer	18 M; 17.2 ± 0.8	T2	Randomized (2 groups)	1v1	6×30 s/2 min vs 6×45 s/3 min	10×15 m	Maximal effort; coach encouragement	—	—	Serum TT, FT, Cortisol	Rest, post, +15, +30 min
(Clemente et al., 2017)	Soccer	6 M; 20.3 ± 4.8	T2	Within-subject	1v1; 3v3	1v1: 3×2 min; 3v3: 2×3 min (1:1.5)	1v1: 10×15 m; 3v3: 19×24 m	Small goals	SJ, CMJ	HR, RPE, GPS load	—	Pre and post bouts

Table 1. **Continue…**

Study	Sport	Sample (n, sex; age)	Tier	Study design	SSG format	Training regimen	Field / area	Task constraints	Neuromuscular	Physiological	Biochemical/ Endocrine	Timing
(Dellal et al., 2015)	Soccer	22 M; 24.3 ± 4.2	T5	Within-subject	2v2; 3v3; 4v4	2v2: 4×2 min; 3v3: 4×3 min; 4v4: 4×4 min	2v2: 20×15 m; 3v3: 25×18 m; 4v4: 30×20 m	With and without GK	—	HR recovery (parasympathetic)	—	1–3 min post
(Dello Iacono et al., 2017)	Handball	12 M; 19.3 ± 0.4	T4	Counterbalanced	3v3	Two sessions 5 d apart; 5×3 min/1 min rest	40×20 m	contact vs no-contact; Contact allowed vs prohibited; multiple balls; 20 s attack limit	Upper/lower neuromuscular performance	HR-derived internal load	IL-6	Pre, post
(Iturricastillo et al., 2018)	Wheelchair basketball	13 M; 31 ± 9	T3	Experimental	4v4	4×4 min separated by 2 min of passive recovery	28×15 m (standard court)	Wheelchairs	Muscle function	HR, RPE (methods compared)	—	During/after SSG
(Johnston et al., 2014)	Rugby league	23 M; 19.1 ± 0.8	T3	Cross-over, counterbalanced	6v6	2×8 min halves; 72 h apart	30×70 m	contact vs no-contact; Contact bouts every 50 s in contact game	Upper/lower power	GPS, HR, RPE	CK	Pre, post, 12/24 h
(Karadağ et al., 2024)	Soccer	28 M; 24.9 ± 4.6	T2	Between-groups	2v2; 4v4; 8v8	2v2: 3×4 min; 3v3: 3×4 min; 8v8: 3×4 min /3 min passive rest for all	2v2: 20x25 m; 3v3: 30x35 m; 8v8: 40x45 m	Standard rules	—	HR, RPE	BLa	Pre, post, +30 min
(Kryściak et al., 2023)	Soccer	20 M; 17.2 ± 0.8	T2	Parallel groups	1v1	6×30 s vs 6×45 s	10×15 m	Standard rules	—	HR, GPS EL, RPE	BLa, pH, HCO_3^-, BE	Rest, post each bout, +15/+30 min
(Madison et al., 2019)	Soccer	10 M; 23 ± 5	T3	Counterbalanced cross-over	3v3; 4v4	6×4 min/90 s	20×15 m (300 m²) vs. 40×25 m (1000 m²)	Standard rules	NordBord hamstring isometric torque	HR, GPS EL	—	Pre, post
(Martínez-Serrano et al., 2023)	Soccer	34 M; 17.1 ± 0.8	T3	Observational (in-season)	4v4+3; 6v6+2GK; 7v7+3; 10v8	Multiple sessions	6v6+2GK: 40×40 m; 7v7+3: 90×60m; 10v8: ¾ of the field	Not detailed	MVIC (KE; posterior chain)	RPE, EL (distance, HSR, acc/dec)	—	BL, post-SSG, +6 h, +24 h
(Mascarin et al., 2018)	Soccer	13 W; 18.8 ± 0.8	T3	Single-group repeated	4v4	4×4 min/3 min	120 m² per player	end-line invasion scoring	—	HRV (RMSSD, LF/HF, pNN50)	CK, LDH, T, C	Pre, +10 min, 24/48/72 h
(McLean et al., 2016)	Soccer	12 M; 21 ± 3	T2	Cross-over	3v3	6×2 min; rec 30 s vs 120 s	20×15 m	Standard rules	—	HR, RPE, GPS distance/speed; VL-NIRS	—	Continuous per bout

Table 1. Continue…

Study	Sport	Sample (n, sex; age)	Tier	Study design	SSG format	Training regimen	Field / area	Task constraints	Neuromuscular	Physiological	Biochemical/ Endocrine	Timing
(Mitrotasios et al., 2021)	Soccer	8 M; 18.4 ± 1	T4	Observational	4v4 + 2 GK	6×4 min/ 3 min rest	30×20 m	Coach encouragement; multiple balls	—	HR	CK, LDH, T, C; enzymes/lipids profile	Pre, post
(Modena and Schena, 2024)	Soccer	12 M; 18.3 ± 0.7	T2	Observational	3v3; 6v6	4×4 min/ 2 min	3v3: 30×20 m (100 m²/plyr); 6v6: 60×40 m (200 m²/plyr)	Small goals (2×1 m); ball always available	CMJ; sprint; DOMS	RPE; TQR; GPS EL (distance, speed, acc/dec)	—	Pre, post, 24 h
(Hidalgo de Mora et al., 2024)	Soccer	14 M; 17.1 ± 0.6	T2	Within-subject	7v7 + GK	(a) 3×8 min/5 min; (b) 6×4 min/2 min (large); (c) 6×4 min/2 min (small)	68×40 m (194 m²); 40×34 m (97 m²)	GK present	Vertical jump; sprint; kick velocity	—	—	Pre, post
(Papanikolaou et al., 2021)	Soccer	10 M; 21.7 ± 2.1	T3	Repeated measures	4v4; 8v8	4v4: 6×4 min/180 s; 8v8: 3×8 min/90 s	4v4: 20×25 m; 8v8: 70×65 m	No GK; 2-touch limit; ball-possession; standardized warm-up/cool-down	MVIC (KE/KF); CMJ; 30 m sprint; DOMS	HR; BLa; RPE; GPS EL	CK	BL, 1–3 h, 24/48/72 h
(Calderón Pellegrino et al., 2020)	Soccer	16 M; 16.9 ± 0.32	T3	Pre–post	4v4	8 min	125, 150, 250, and 300 m²	Standard play	Sprint count; accelerations	HR; GPS EL	—	Pre, post-RSA
(Ravier and Marcel-Millet, 2020)	Handball	14 M; 25.4 ± 4.9	T4	Repeated measures	3v3 + GK	2×8 min; internal 30 s play/30 s rest; 2-min inter-period	40×20 m	Modified rules; immediate GK restart; coaches return balls	—	HR, HRR; HRV (RMSSD/HF); time-varying RMSSD	—	Pre, post, +10 min
(Sansone et al., 2019)	Basketball	12 M; 21 ± 2	T3	Randomized, repeated measures	3v3	Long: 3×4 min/2 min; Short: 6×2 min/1 min	15×14 m	Offense vs defense tactical tasks	—	%HRmax; PlayerLoad; RPE	T; C	Pre, post
(Sjokvist et al., 2011)	Soccer	20 W; 20.3 ± 2.3	T3	Repeated measures	4v4	4×4 min/3 min active	32×22.5 m	With vs without ball	CMJ; 5BT; 20 m sprint	HR; S-RPE	—	BL, 24/48/ 72 h
(Skala and Zemková, 2023)	Soccer	16 M; 13.6 ± 0.5	T2	Pre–post	4v4 + GK	30 min continuous	40×25 m	Standard rules	CMJ; Planned/Reactive agility; Go/ No-Go	HR; GPS EL	—	Pre, post
(Sparkes et al., 2018)	Soccer	16 M; 21 ± 2	T4	Repeated measures	4v4 + GK	6×7 min/2 min	24x29 m	Standard rules	CMJ (JH); PPO	HR; RPE; GPS EL	CK; BLa; T; C	Pre, 0 h, +2 h, +24 h
(Sparkes et al., 2020a)	Soccer	12 M; 21 ± 2	T3	Repeated measures (single vs double day)	4v4 + GK	6×7 min/2 min; + RT 2 h later on double day	24×29 m	Standard rules	CMJ (JH); PPO	Mood disturbance	T; C	Pre, 0 h, +24 h
(Sparkes et al., 2020b)	Soccer	14 M; 22.1 ± 3.1	T3	Repeated measures (order)	4v4 + GK	6×7 min/2 min; RT 2 h apart (SSG+ RT vs RT+SSG)	24×29 m	Standard rules	CMJ (JH); PPO	Mood disturbance	T; C	Pre, 0 h, +2 h, +24 h

Table 1. Continue…

Study	Sport	Sample (n, sex; age)	Tier	Study design	SSG format	Training regimen	Field / area	Task constraints	Neuromuscular	Physiological	Biochemical/ Endocrine	Timing
(Sparkes et al., 2022)	Soccer	12 M; 21 ± 2	T3	Reliability (wk-to-wk)	4v4 + GK	6×7 min/ 2 min	24×29 m	Standard rules	CMJ (JH); PPO	GPS EL	T; C	Pre, post
(Trecroci et al., 2020)	Soccer	9 M; 17.7 ± 0.5	T3	Crossover (SST vs AR) in MD+2	4v4	4×3 min; 3-min rest; + tactical drills	18×24 m	No GK reported	MVF knee extensors/flexors (isometric)	RSA (5×30 m); HR; GPS EL; RPE	—	BL (−72 h), 0 h post-match, +72 h post-match
(Trecroci et al., 2021)	Soccer	9 M; 17.7 ± 0.5	T3	Crossover (SST vs AR) in MD+2	4v4	4×3 min SSG (3-min rest) + tactical drills	18×24 m	No GK reported	—	Perceptual: soreness (VAS); TQR	CK; CRP; IL-6; WBC, Neut, Lymph, Mono; Cortisol	BL (−72 h), 0 h post-match, +72 h post-match

Tier 2 (T2): Trained/Developmental; Tier 3 (T3): Highly Trained/National level; Tier 4 (T4): Elite/International level; Tier 5 (T5): World-class; SSG: Small-sided game; GK: Goalkeeper; RS: Repeated sprints; CT: Circuit training; RT: Resistance training; EL: External load; HSR: High-speed running; GPS: Global Positioning System (tracking); HR: Heart rate; HRR: Heart rate recovery; %HRmax: Percent of maximal heart rate; HRV: Heart rate variability; RMSSD: Root-mean-square of successive differences; pNN50: Percentage of NN intervals differing >50 ms; LF/HF: Low-/High-frequency power ratio; NIRS: Near-infrared spectroscopy; VL-NIRS: Vastus lateralis NIRS; RPE: Rating of perceived exertion; S-RPE: Session RPE; TQR: Total quality of recovery; DOMS: Delayed-onset muscle soreness; CMJ: Countermovement jump; SJ: Squat jump; PPO: Peak power output; MVF: Maximal voluntary force; MVIC: Maximal voluntary isometric contraction; NR: not reported; NordBord: Nordic hamstring strength device; KE/KF: Knee extensors/flexors; RSA: Repeated sprint ability; VAS: Visual analogue scale; BLa: Blood lactate; CK: Creatine kinase; LDH: Lactate dehydrogenase; IL-6: Interleukin-6; CRP: C-reactive protein; GH: Growth hormone; IGF-1: Insulin-like growth factor-1; T: Testosterone; TT: Total testosterone; FT: Free testosterone; C: Cortisol; CAR: Cortisol awakening response; WBC: White blood cell count; Neut: Neutrophils; Lymph: Lymphocytes; M: men; Mono: Monocytes; pH: Acid–base measure; HCO_3^-: Bicarbonate; BE: Base excess; AST: Actual sleep time; SE: Sleep efficiency; SL: Sleep latency; IT: In-bed time; MT: Movement time; FI: Fragmentation index; MD+2: Match day plus two; BL: Baseline; ACC/DEC: Accelerations/decelerations; m^2/player: Square meters per player; SCI: Spinal cord injury; IWBF: International Wheelchair Basketball Federation; W: women; YYIRTL1: Yo-Yo Intermittent Recovery Test Level 1.

Methods

Our protocol was registered in advance in the Open Science Framework (OSF) under the identifier osf.io/73rzs (date: 02 july, 2025). The review aligns with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA-ScR) recommendations (Tricco et al., 2018), albeit with some updates based on PRISMA 2020 (Page et al., 2021).

Eligibility criteria

Peer-reviewed original studies (including ahead of print) were considered for inclusion. No restrictions were placed on language or year of publication, to ensure a comprehensive and unbiased selection process (Rechenchosky et al., 2021). Further criteria for study inclusion were structured around the PICOS framework:

Population (P): Team ball sport players who met at least

Tier 2 classification according to the Participants Classification Framework (PCF) (McKay et al., 2022). Athletes of all ages, competitive levels, and physical conditions -including para-athletes- were eligible. Studies focusing on injured athletes were excluded from consideration.

Intervention (I): SSGs (including small, medium, and large), regardless of the number of sets, repetitions, or training sessions involved. Research that combined SSGs with other training methods was also accepted, as long as SSGs were the differentiating factor in the research and training context.

Comparators (C): Not mandatory.

Outcomes (O): Assessed before and after the implementation of SSGs. Acceptable outcome measures included, but were not limited to, neuromuscular performance (e.g., strength, power output, sprint performance, jump height), physiological responses (e.g., heart rate variability, blood pressure, lactate concentration, biochemical markers and endocrine responses). Socio-psychological variables (e.g., motivation, mood), technical or tactical performance, or decision-making processes were not considered for this review.

Study Design (S): Experimental designs, controlled or uncontrolled, including single-cohort studies or case reports are eligible.

Information sources

Three major databases -PubMed, Scopus, and Web of Science (Core Collection)- were used to capture publications available up to July 03, 2025. To strengthen the methodological accuracy and minimize the possibility of missing pertinent literature, additional manual searches were conducted by reviewing the reference lists of all included articles. Citation chaining (snowballing) was also applied using the Web of Science platform to further enrich the search process. To ensure completeness and methodological soundness, feedback was sought from two internationally recognized experts in team sports, identified through the Expertscape platform (https://expertscape.com/ex/team+sports). Furthermore, each included study was checked for associated errata or retractions to ensure data integrity.

Search strategy

To maximize the retrieval of relevant studies, the search strategy employed the Boolean operators “OR” and “AND.” The search was conducted without any restrictions related to publication date or language, and no additional filters were used, thereby enabling a wide-ranging and inclusive search. This method was intended to gather a diverse selection of applicable studies without limiting the scope. The details of the search procedure are presented below:

[Ti/Ab]: ("baseball" OR basketball OR "cricket" OR frisbee OR football* OR futsal OR hockey OR handball OR korfball OR lacrosse OR netball OR polo OR player* OR rugby OR "soccer" OR softball OR "team-based sport*" OR "team sport*" OR volleyball)
AND
[Ti/Ab]: ("conditioned game*" OR "constrained game" OR "game-based drill*" OR "game-based training" OR "game-based training" OR "modified game*" OR "reduced-format game*" OR "sided game*" OR "small-sided game*" OR "situational game*")

Selection process

The initial screening of studies, based on titles and abstracts, was performed independently by two authors (FMC and RT). Abstracts that met the predefined inclusion criteria led to the retrieval of full-text articles when needed. Subsequently, the same authors independently conducted a detailed evaluation of the full texts for all studies passing the preliminary screening. In cases of disagreement, discussions were held to reach consensus; if unresolved, a third reviewer (MB) was consulted to adjudicate. The process of managing records and removing duplicate entries was facilitated through EndNote™ software (version 20.5, Clarivate Analytics, Philadelphia, PA), combining both automated and manual approaches.

Data collection process

To ensure a systematic and organized data extraction process, a dedicated Microsoft Excel spreadsheet (Microsoft®, USA) was created and made available in the OSF registration area to capture all relevant information.

The initial data collection was performed by one author (FMC) and subsequently reviewed for accuracy and completeness by two additional authors (RT and RMS). When essential data were missing from full-text articles, FMC reached out to the corresponding authors via email and ResearchGate to request the required information. If no reply was received within four weeks, the study’s data were excluded from the review.

Data items

Data extracted from each study included the following: (i) the number of participants; (ii) competitive level according to the Participants Classification Framework [42]; (iv) participant sex; (v) age; and (vi) key methodological details such as study design, randomization procedures, number of assessments, and timing of data collection.

Regarding SSGs, information gathered encompassed: (i) the format of play; (ii) the training regimen (sets, repetitions, minutes of work, minutes of rest); (iii) characteristics of the field, and other rules; and (v) details of the number of sessions analyzed. Additionally, any other relevant information, if available, will be collected. This includes details of any training conducted concurrently with the SSGs or information regarding any remaining sessions (which is common in training scenarios), as these could potentially interfere with the regular recovery process.

Outcomes were organized into two primary categories, but were not limited to: (i) neuromuscular performance (e.g., strength, power output, sprint performance, jump height); (ii) physiological responses (e.g., heart rate variability, blood pressure, lactate concentration, biochemical markers, and endocrine responses.

Data synthesis methods and evidence gap map

The analysis involved a descriptive synthesis alongside numerical summaries, such as frequencies and proportions, for the collected data points. To clearly depict the current state of knowledge and pinpoint where research is lacking, an evidence gap map was produced. This graphic tool was designed to visually convey both the breadth of existing findings and highlight significant voids in the literature.

Results

Selection of sources of evidence

The electronic searches across PubMed, Scopus, and Web of Science yielded a total of 3,842 records, with 764 retrieved from PubMed, 1,551 from Scopus, and 1,527 from Web of Science. After automatic and manual deduplication, 2,025 unique records remained and were screened based on titles and abstracts. Of these, 1,992 records were excluded as they did not meet the eligibility criteria outlined in the protocol.

Following this stage, 33 full-text reports were sought for retrieval and all were successfully obtained. Full-text screening resulted in the exclusion of six reports. The reasons for exclusion were as follows: three studies involved populations that did not meet the minimum Tier 2 classification according to the Participants Classification Framework (PCF) (Hammami et al., 2017; 2018b; Panduro et al., 2022), one study (Emirzeoğlu and Ülger, 2021) did not implement SSGs but rather another type of game-based intervention, and two studies did not provide outcomes assessed pre- and post-SSGs (Delextrat et al., 2018; Reinhardt et al., 2020). In addition to database searching, five additional records (Sjokvist et al., 2011; Trecroci et al., 2020; 2021; Mitrotasios et al., 2021; Karadağ et al., 2024) were identified through citation searching. All five reports were retrieved and assessed for eligibility, and none were excluded at this stage. In total, thirty-two studies met all inclusion criteria and were included in the review (Figure 1).

Characteristics of sources of evidence

The majority of the studies investigated in this review focused on men, with 30 of the 33 samples consisting exclusively of men (Table 1). Only a very small proportion involved women (Bonato et al., 2020; Alashti et al., 2021; Bekris et al., 2022). With respect to age, most samples (23 studies) involved athletes 18 years old or older, while only 9 studies recruited participants under 18 years old. In terms of competitive tier, most studies recruited athletes from Tier 3 (17 studies), which represents semi-professional or well-trained players, followed by Tier 2 (10 studies) and fewer contributions from Tier 4 and Tier 5 (Dellal et al., 2015; Dello Iacono et al., 2017; Sparkes et al., 2018; Ravier and Marcel-Millet, 2020; Mitrotasios et al., 2021). Across the included studies, the most frequently employed SSG formats were 4v4 (20 studies) and 3v3 (10 studies). Smaller formats such as 2v2 and 1v1 appeared less often (three studies each). Larger-sided formats, including 6v6, 7v7, and 8v8, were rarely used, together representing five studies.

Regarding the domains analyzed, the most common focus was on physiological outcomes, reported in 30 studies, with measures such as heart rate, percentage of HRmax, and rating of perceived exertion appearing consistently. Neuromuscular markers (e.g., sprint performance, jump ability) were considered in 20 studies, revealing substantial emphasis. Finally, biochemical/endocrine markers such as cortisol, lactate, and hormonal responses were examined in 17 studies.

Results of individual sources of evidence

Table 2 summarizes the neuromuscular outcomes reported across the included studies. The most frequent measures were countermovement jump height and peak power, short sprint times (5 - 30 m), repeated-sprint ability, hamstring and quadriceps strength (isometric and isokinetic), and change-of-direction or agility tests.

Table 3 presents the psychophysiological responses to SSGs, including internal load indicators such as heart rate, heart-rate recovery, and heart-rate variability, as well as perceptual measures like RPE (rating of perceived exertion), DOMS (delayed onset muscle soreness), TQR (total quality recovery), and mood, alongside external load variables (total distance, high-intensity running, sprinting, accelerations). Autonomic measures typically showed acute parasympathetic suppression, and perceptual fatigue often peaked immediately or at 24 h post.

Table 4 compiles the biochemical and endocrine measures assessed across studies. The most common outcomes were blood lactate, creatine kinase, lactate dehydrogenase, testosterone, and cortisol, with a smaller number of studies examining inflammatory cytokines, immune cell counts, or other enzymes.

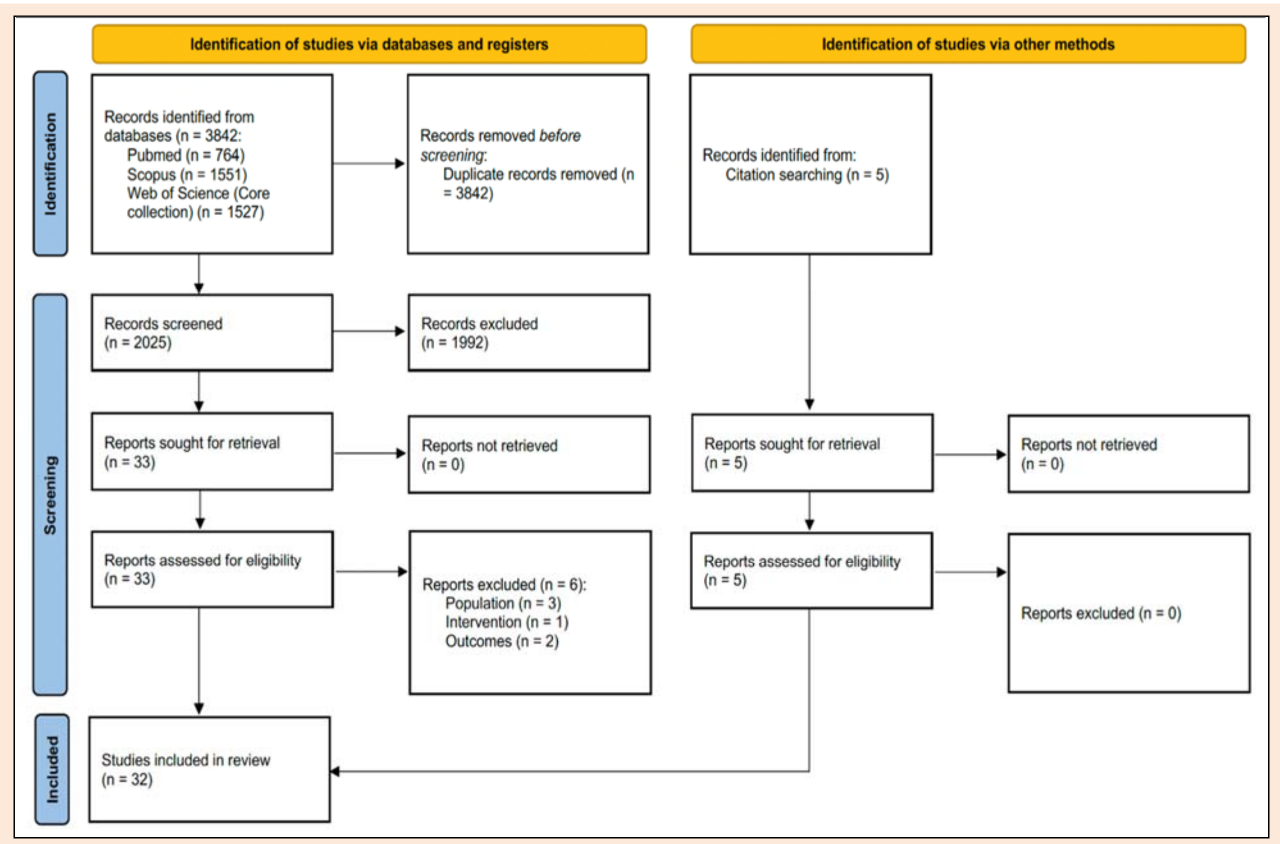

Figure 1. PRISMA flowchart (Page et al., 2021a).

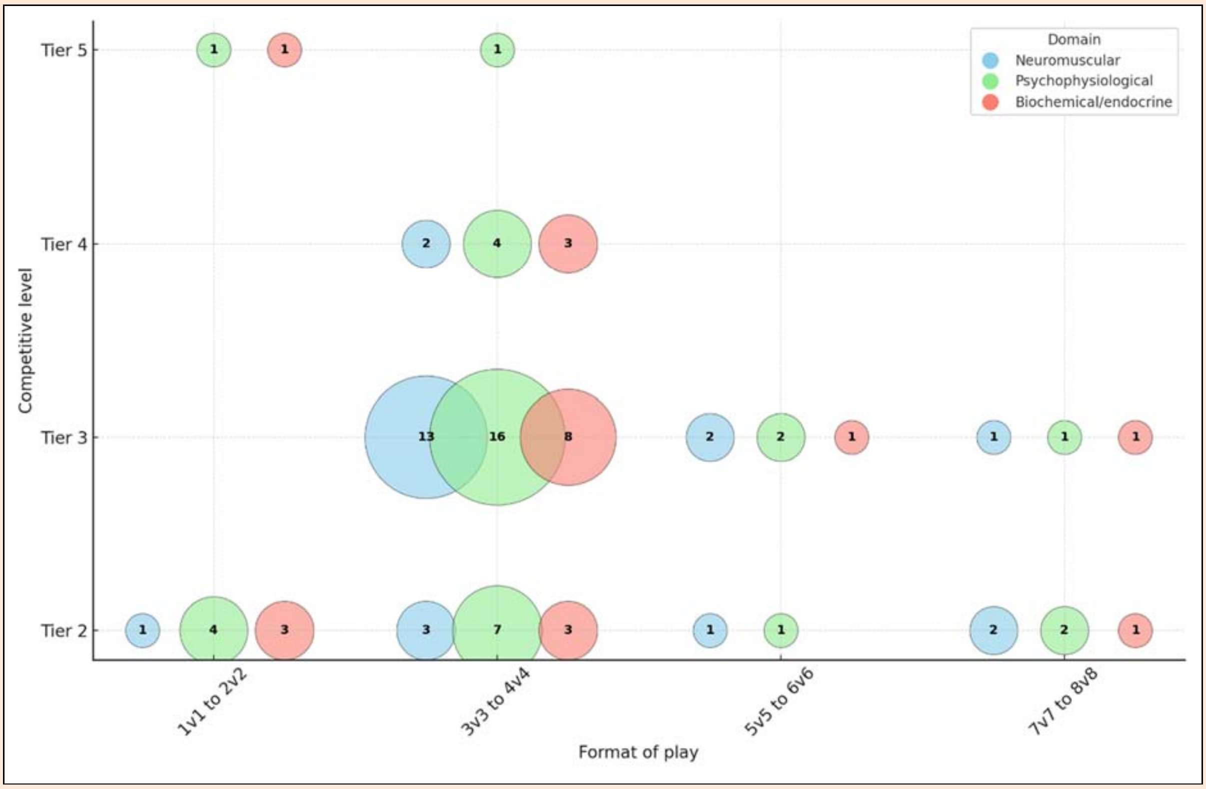

Figure 2. Evidence gap map showing SSG formats, competitive levels, and outcome domains.

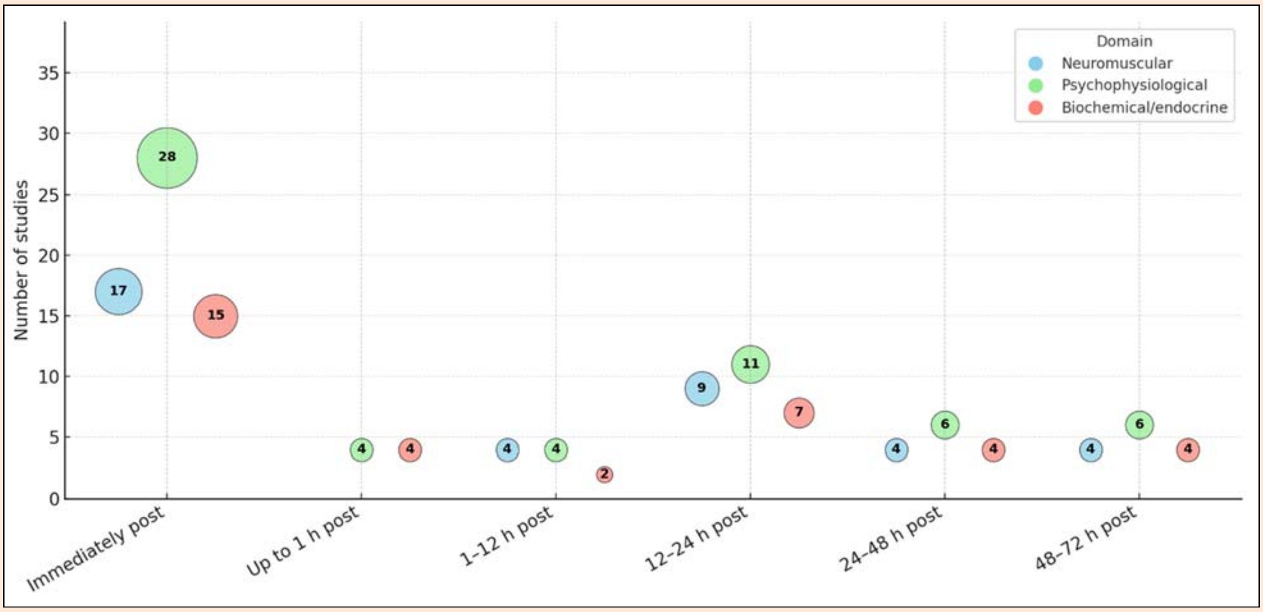

Figure 3. Evidence gap map showing timing of data collection across outcome domains.

Evidence gap map

Figure 2 presents an evidence gap map of the studies included, organized by format of play, competitive level, and outcome domain (neuromuscular, psychophysiological, biochemical/endocrine). The descriptive overview shows a strong concentration of evidence in 3v3 - 4v4 formats, particularly at Tier 3 level, where psychophysiological measures are most frequently reported (n = 16), followed by neuromuscular (n = 13) and biochemical/endocrine (n = 8). By contrast, evidence is sparse for 1v1 - 2v2 and 5v5 - 6v6, with only a handful of studies at Tier 2 and Tier 3 and almost none at higher tiers. 7v7 - 8v8 is also underrepresented, with only one or two studies per domain at Tier 2 - 3 and none at Tiers 4 - 5.

Figure 3 illustrates the distribution of studies according to the timing of assessment and the domain of outcomes investigated (neuromuscular, psychophysiological, biochemical/endocrine). The map highlights that the majority of assessments were performed immediately post-SSG, with psychophysiological measures most common (n = 28), followed by neuromuscular (n = 17) and biochemical/endocrine (n = 15). Considerably fewer studies examined responses within the first hour post-exercise (n = 4 in psychophysiological and biochemical/endocrine each), or in the 1 - 12 h window (n = 4 neuromuscular, n = 4 psychophysiological, n = 2 biochemical/endocrine). Monitoring at 12 - 24 h was relatively frequent, especially for psychophysiological (n = 11) and neuromuscular (n = 9) markers, with biochemical/endocrine outcomes also represented (n = 7). Beyond 24 h, the evidence base is more limited, with only 4 - 6 studies per domain between 24 - 48 h and 48 - 72 h, indicating that longer-term recovery trajectories remain underexplored.

Discussion

This scoping review mapped the acute and short-term responses to SSGs across neuromuscular, psychophysiological, and biochemical/endocrine domains. The studies included span different sports, ages, and competitive levels, and collected a variety of measures and assessment timings. While this methodological diversity enriches the evidence base, it also explains the variability observed in reported outcomes.

Methodological aspects

Most studies were conducted in men soccer players. Women were less represented, with only a small number of research targeting female players (Sjokvist et al., 2011; Mascarin et al., 2018), and nearly all were soccer-based. One exception was the use of basketball SSGs (Sansone et al., 2019), which allowed exploration of tactical offense/defense regimes and endocrine responses, and another was handball (Dello Iacono et al., 2017; Ravier and Marcel-Millet, 2020), where contact elements and autonomic recovery were highlighted. In addition, two studies investigated wheelchair basketball (Iturricastillo, Yanci and Granados, 2018; Ascondo et al., 2024), enabling comparison between athletes with spinal cord injury (SCI) and non-SCI peers.

In terms of age groups, participants ranged from youth players (Madison et al., 2019; Skala and Zemková, 2023) to elite senior professionals (Dellal et al., 2015; Sparkes et al., 2018). Youth cohorts were often examined for external load and recovery sensitivity (Calderón Pellegrino et al., 2020), while professional cohorts were usually monitored for endocrine, neuromuscular, and biochemical markers under congested or match-like schedules (Sansone et al., 2019; Bekris et al., 2022). Regarding competitive levels, most soccer studies sampled academy or semi-professional athletes (Bekris et al., 2022; Kryściak et al., 2023; Karadağ et al., 2024), with fewer in professional environments (Dellal et al., 2015; Sparkes et al., 2018; Madison et al., 2019).

In the neuromuscular domain, CMJ and sprint times (0 - 10, 10 - 20, 0 - 20, 30 m) were most common, alongside hamstring/quadriceps MVIC or isokinetics, and change-of-direction agility (Johnston et al., 2014; Baseri et al., 2022; Bekris et al., 2022; Martínez-Serrano et al., 2023). In the psychophysiological domain, nearly all studies collected HR and RPE, with several applying HRV and HRR for autonomic recovery (Dellal et al., 2015; Mascarin et al., 2018; Ravier and Marcel-Millet, 2020). GPS-derived external load was frequently integrated (Madison et al., 2019; Papanikolaou et al., 2021). In the biochemical and endocrine domain, CK and lactate were the most widely adopted, often accompanied by testosterone and cortisol (Sparkes et al., 2018; 2020b; a; Sansone et al., 2019), while fewer studies examined inflammatory cytokines or immune markers (Dello Iacono et al., 2017; Trecroci et al., 2021).

The majority of studies evaluated immediate responses (0 - 2 h post), typically for neuromuscular, perceptual, and metabolic markers (e.g., lactate, CMJ, HRV). Short-term (24 h) assessments were frequent, especially for neuromuscular and biochemical endpoints (Sparkes et al., 2018; Modena and Schena, 2024), while extended follow-ups to 48 - 72 h were less common but critical for muscle damage markers and strength recovery (Papanikolaou et al., 2021; Trecroci et al., 2021). Only a minority of studies incorporated multiple follow-ups beyond 24 h, which limits the analysis of recovery timelines. Furthermore, very few examined intra-session kinetics (McLean et al., 2016; Kryściak et al., 2023) or next-day morning responses such as cortisol awakening response (Bonato et al., 2020).

Neuromuscular responses

Across studies, neuromuscular status was tracked using countermovement/squat jumps, short sprint splits (0 - 10, 10 - 20, 0 - 20 m), hamstring and knee extensor strength (isometric and isokinetic), change-of-direction and agility tests, and (in wheelchair sport) push sprints and sled-towing.

Immediately post-SSG, decrements were frequent but not universal: CMJ height and peak power fell acutely in professional players after 4v4+GK (with a characteristic dip at 0 - 2 h, transient recovery, and a second dip by 24 h) (Sparkes et al., 2018), and the same format produced small but consistent post-session CMJ/sprint decrements that were more persistent during congested periods (Sparkes et al., 2020a) or when resistance training preceded SSG (Sparkes et al., 2020b). Youth players showed clear post-SSG impairments in CMJ (-6.6%) and agility, alongside more errors in a go/no-go task (Skala and Zemková, 2023). In wheelchair basketball, small post-SSG decrements emerged in 5 - 20 m push sprints and sled-towing (Iturricastillo et al., 2018), and during bout-by-bout monitoring, athletes with spinal cord injury (SCI) displayed mid-session sprint losses that were absent in non-SCI peers (Ascondo et al., 2024). However, several studies did not detect immediate neuromuscular impairment despite high cardiovascular strain: repeated 1v1 and 3v3 bouts left SJ/CMJ unchanged (Clemente et al., 2017), CMJ was stable across multiple large-sided formats (Hidalgo de Mora et al., 2024), and a demanding 3v3 protocol in trained men produced no post- or 72 h decrements in squat jump or 20 m sprint (Bekris et al., 2022). By <24 h, sensitivity diverged by test and format: hamstring isometric force fell more after a larger-area 4v4 than a tight 3v3 and correlated with acceleration counts (Madison et al., 2019); contact elements amplified neuromuscular loss - upper-body press-up power and lower-body CMJ were substantially depressed after contact vs non-contact small-sided rugby (Johnston et al., 2014) and after contact handball SSGs (Dello Iacono et al., 2017).

Table 2. Summary of the main findings regarding neuromuscular responses.

Study	Format of play (SSG)	Assessment timings	Main findings
Ascondo et al., 2024	4v4 wheelchair basketball, 4×4 min bouts, 2 min rest, 28×15 m court	20 m sprints (S5 m, S20 m, S5–20 m) before SSG (T0) and after each bout (T1–T4)	SCI players showed significant loss of sprint capacity: ↑ S20 m and S5–20 m times at T2 and T3 vs T0 ($p < .05$, ES = 0.28–0.35, small). SCI players consistently slower than Non-SCI across tests ($p < .01$, ES = 1.52–2.12, large). Non-SCI showed no significant decrements across bouts. Correlations in SCI group: total RPEresTL correlated with decline in S5 m ($r = 0.72$, $p < .01$) and S20 m ($r = 0.66$, $p < .05$) between T0–T4. No significant correlations in Non-SCI.
Baseri et al., 2022	3v3 + 4 support players, 4×4 min, 3-min rest, 18×20 m, ball-possession with coach encouragement	20 m sprint at baseline and 48 h post	No significant differences between recovery strategies for 20 m sprint ($F = 0.361$, $p = 0.78$, $\eta^2 = 0.02$). Within-condition analysis showed significant improvement from baseline to 48 h ($p = 0.001$, $\eta^2 = 0.37$, moderate effect).
Bekris et al., 2022	3v3, 8×3 min, 3-min rest, 20×25 m, no GK, ball possession	Squat jump, 20 m sprint at PRE, POST, 24 h, 48 h, 72 h	No significant impairments in squat jump ($F(1.68,18.45)=1.40$, $p \geq 0.05$, $\eta^2=0.11$) or 20 m sprint ($F(2.02,22.20)=2.65$, $p \geq 0.05$, $\eta^2=0.19$). Performance remained stable across time points.
Clemente et al., 2017	1v1 (3×2 min) and 3v3 (3×3 min), 1:1.5 work-to-rest	Squat jump (SJ) and countermovement jump (CMJ) before, after each bout	No significant differences across bouts in SJ ($p = 0.981$, ES = 0.415, moderate) or CMJ ($p = 0.307$, ES = 0.112, minimum). No significant interaction with format. Neuromuscular output not impaired despite increased HR and RPE.
Dello Iacono et al., 2016	3v3 handball, 5×3 min bouts, 1-min rest, with vs without contact	CMJ and plyometric press-up before and immediately after SSG	Contact SSG (C-SSG): Significant impairments in CMJ: Fpeak-ecc −6.4% ($p<0.001$, $\eta^2=0.979$), Secc −3.3% ($p<0.001$, $\eta^2=0.961$), Fpeak-con −2.4% ($p<0.001$, $\eta^2=0.992$), Ppeak-con −3.2% ($p<0.001$, $\eta^2=0.995$), JH −5.2% ($p=0.001$, $\eta^2=0.381$). Upper-body PP: Fpeak-ecc −9.6% ($p<0.001$, $\eta^2=0.989$), Fpeak-con −6.4% ($p<0.001$, $\eta^2=0.989$), Ppeak-con −11.5% ($p<0.001$, $\eta^2=0.911$). No-contact SSG (NC-SSG): Small improvements: CMJ JH +2.5% ($p<0.05$), Ppeak-con +8.1% ($p<0.001$); PP Fpeak-con +2.3% ($p<0.05$).
Iturricastillo et al., 2018	4v4 WB, 4×4 min bouts, 2-min passive recovery	5 m & 20 m sprints, 5 m & 20 m sled towing, CODA pre vs post	Sprint performance declined 1.10% at 5 m and 20 m ($p < .01$; ES ≤ 0.14). Sled towing declined 1.82% at 5 m ($p < .05$; ES = 0.18) and 2.68% at 20 m ($p < .01$; ES = 0.27). CODA showed trivial change (−0.41%, $p > .05$, ES = −0.04). Δ% LS–ST significantly ↑ post at 20 m ($p < .05$, ES = 0.38), but not 5 m ($p > .05$, ES = 0.06). Negative correlations: Δ% sprint (5 m $r = -0.42$; 20 m $r = -0.55$, $p < .01$) with Δ% blood lactate; Δ% sled towing (20 m) with Δ% tympanic temperature ($r = -0.45$) and lactate ($r = -0.46$).
Johnston et al., 2014	Rugby league, "offside" 6v6 SSG (2×8 min halves, 70×30 m), with vs without contact (16 × 10 s bouts/half)	CMJ and plyometric press-up PRE, POST, 12 h, 24 h	CMJ (lower body): Reductions POST in both games: contact ES = −0.88; non-contact ES = −1.42. At 12 h: contact ES = −1.40; non-contact ES = −2.25. At 24 h: contact ES = −0.35 vs non-contact ES = −1.13. Differences between games were practically meaningful (likelihood ≥75–92%). PP (upper body): No change in non-contact. Contact game → large reduction POST (ES = −1.86), moderate reductions at 12 h (ES = −0.74) and 24 h (ES = −0.74). Between-group differences: POST (ES = −1.31, almost certain), 12 h (ES = −0.68, very likely), 24 h (ES = −0.87, likely).
Madison et al., 2019	3v3 (20×15 m, 300 m², ~50 m²/player) vs 4v4 (40×25 m, 1000 m², ~125 m²/player), 6×4 min, 90 s rest	Isometric hamstring torque (NordBord) at 90° and 30° knee flexion, pre vs post	Larger-area 4v4 SSG induced greater decrements. Peak hamstring force at 90°: −13.62 N vs −5.78 N in 3v3 ($p<0.05$, $d=0.60$). Mean hamstring force at 90°: −24.78 N vs −11.11 N ($p<0.05$, $d=0.51$). Relationship between total accelerations and peak torque decrement at 90°: $r=0.46$, $p=0.039$. Interpretation: higher external loads in larger SSGs produce greater hamstring fatigue.
Martínez-Serrano et al., 2023	4v4 + 3 floaters SSG on MD-4 (~activation microcycle), followed by TR1 (6v6 + 2 GK on 40×40 m and 10v8 transitions in ¾ pitch) and TR2 (7v7 + GK on 90×60 m and 10v8 transitions in ¾ pitch)	Isometric MVIC of knee extensors and posterior chain: baseline, post-ACT, post-SSG, post-TR1, post-6h, post-24h, post-PREV, post-TR2	Posterior chain (90:20 MVIC): significant ↓ in "HIGH" HSR group after TR1 (−14.08%, 337.7 ± 105.8 N → 290.2 ± 104.2 N, $p = 0.037$, ES = 0.45). Recovery incomplete at 6h (−9.4%) and 24h (−5.0%) vs baseline. "LOW" HSR group showed no impairment (Δ = +0.2 to +6.5%). Knee extensor MVIC unaffected by training load ($F = 1.155$, $p = 0.332$).

Table 2. **Continue…**

Study	Format of play (SSG)	Assessment timings	Main findings
Modena & Schena, 2024	3v3 (30×20 m, 100 m²/player) vs 6v6 (60×40 m, 200 m²/player), 4×4 min bouts, 2-min rest, no GK	Sprint (10, 20, 30 m) and CMJ pre, post, 24 h	Sprint: Both formats impaired sprint performance post (10 m: +0.02–0.04 s, $p<0.05$; 20 m: +0.04–0.05 s, $p<0.01$; 30 m: +0.07–0.08 s, $p<0.001$). At 24 h, 3v3 recovered to baseline (no sig. diffs), but 6v6 remained slower at 30 m (Δ+0.03 s vs pre, p=0.021, g=−0.29). CMJ: 3v3: trivial ↑ at 24 h (35.9 → 38.4 cm, p=0.001, g=0.40). 6v6: ↓ post (37.9 → 36.3 cm, p=0.038, g=−0.28), remained ↓ at 24 h (36.1 cm, p=0.021, g=−0.29).
Mora et al., 2025	7v7 + 2 GK, 3×8 min (LSG8, 68×40 m, 194 m²/player, 5-min rest) vs 6×4 min (LSG4, 68×40 m, 194 m²/player, 2-min rest) vs 6×4 min (SSG4, 40×34 m, 97 m²/player, 2-min rest)	CMJ, kick velocity (KV), 20-m sprint (split 0–10 m, 10–20 m) pre vs post	CMJ: No sig. changes post in any format (LSG8 ES = −0.16; LSG4 ES = −0.10; SSG4 ES = −0.06; all $p > 0.05$). KV: Small ↓ after SSG4 (p = 0.04, ES = −0.54). Sprint: All formats impaired sprint performance. 0–10 m: small impairment after LSG4 ($p < 0.01$, ES = 0.29). 10–20 m and 0–20 m: moderate-to-large impairments after all formats (p = 0.00–0.01, ES = 0.60–1.50). Greater 0–10 m impairment observed in LSG4 vs LSG8 (p = 0.03).
Papanikolaou et al., 2021	4v4 (20×25 m, 62.5 m²/player, 6×4 min, 180-s rest) vs 8v8 (70×65 m, 284.4 m²/player, 3×8 min, 90-s rest), no GK	MVIC KE/KF at baseline, 1h, 2h, 3h; isokinetic concentric/eccentric strength, CMJ, 30-m sprint at baseline, 24h, 48h, 72h	MVIC: ↓ KE + KF at 1h–2h in both formats; extended to 3h in 8v8. Isokinetic strength: KE concentric ↓ 24h in both formats; KE eccentric ↓ up to 72h in 8v8 ($p<0.05$). KF concentric ↓ 24h; KF eccentric ↓ 24–72h ($p<0.05$). CMJ: ↓ 24h in 4v4; ↓ post, 24h, 48h in 8v8. Sprint: ↓ 24–48h in 4v4; ↓ 24–72h in 8v8.
Pellegrino et al., 2020	4v4, U18 elite males, 8-min bouts, pitches 125, 150, 250, 300 m²; pre and post repeated-sprint ability (RSA) test (10×40 m shuttles, 25 s recovery)	External load from GPS (sprints, accelerations, distances, Vmax, Vmean) pre vs post RSA	125 m²: Post-RSA decrements: Vmax −1.81 km/h (CI −3.05 to −0.57, ES=0.97, p=0.005), Vmean −0.69 km/h (CI −1.16 to −0.23, ES=1.26, p=0.004), sprint number −6.56 (CI −10.13 to −3.00, ES=1.13, $p<0.001$), accelerations zone 2 −2.69 (CI −5.13 to −0.24, ES=0.68, p=0.032), sprint distance −65.44 m (CI −103.73 to −27.16, ES=1.20, p=0.001). 150 m²: Distance ↓ −88.3 m (ES=0.95, p=0.018). 250–300 m²: Larger pitches allowed higher high-intensity running; post-RSA, Vmean ↓ in 300 m² (−0.88 km/h, ES=1.17, $p<0.001$), sprints ↓ in 250 m² (−3.69, ES=0.72, p=0.043). Overall, fatigue impaired high-intensity actions most in the smallest pitch (125 m²).
Sjökvist et al., 2011	4v4 SSG (32×22.5 m, 4×4 min, 3-min active recovery) + soccer-specific interval running (4×4 min, 3-min recovery), with and without the ball	CMJ, 5BT, 20-m sprint pre, 24 h, 48 h, 72 h post	CMJ: ↓ after 24 h vs baseline (48.8 ± 7.9 → 46.9 ± 7.6 cm, $p<0.04$), recovered by 48 h (48.7 ± 7.9) and 72 h (49.3 ± 8.3). 5BT, 20SP: No sig. changes across recovery intervals ($p>0.05$).
Skala & Zemková, 2023	4v4 + GK, 40×25 m pitch (125 m²/player), 6×4 min bouts, 1-min rest	CMJ, planned agility (PA), reactive agility (RA) pre vs post	CMJ: ↓ −6.65% (29.7 → 27.7 cm, p=0.014, g=0.56). PA: ↑ +4.04% (1.98 → 2.06 s, p=0.002, g=0.97). RA: ↑ +6.45% (2.17 → 2.31 s, p=0.003, g=1.16). Fatigue impaired explosive strength and agility.
Sparkes et al., 2018	4v4 + GK, 6×7 min bouts, 2-min rest, 24×29 m pitch	CMJ (PPO, JH) pre, 0h, +2h, +24h	PPO: ↓ at 0h (−1.1 W·kg⁻¹, ±0.9, possibly small), recovered at +2h (+0.7, trivial), ↓ again at +24h (−0.9, ±0.8, small). JH: ↓ at 0h (−3.2 cm, ±1.9, moderate), recovered at +2h (+0.1 cm, trivial), ↓ again at +24h (−2.5 cm, ±1.2, small). Shows bimodal recovery pattern.
Sparkes et al., 2020a	4v4 + GK, 6×7 min, 2-min rest, 24×29 m pitch, compared across 2 sessions	CMJ (PPO, JH) pre, 0h, 24h	PPO: Session 1 ↓ 0h (−0.9 W·kg⁻¹, ±0.8, small), recovered at 24h (−0.3, ±0.6, trivial). Session 2 ↓ 0h (−0.9, ±0.8, small), ↓ at 24h (−0.9, ±0.6, small). JH: Session 1 ↓ 0h (−3.4 cm, ±2.2, moderate), recovered 24h (−0.4, ±2.0, trivial). Session 2 ↓ 0h (−3.3, ±2.2, moderate), ↓ 24h (−1.9, ±2.0, small). Findings suggest greater fatigue persistence when players were in congested periods .
Sparkes et al., 2020b	4v4 + GK, 6×7 min bouts, 2-min rest, 24×29 m pitch; compared two orders: (a) SSG → resistance (SSG+RES), (b) resistance → SSG (RES+SSG), 2-h interval	CMJ (JH, PPO) pre, 0h, +24h	JH: RES+SSG ↓ 0h (−4.1 ± 2.6 cm, $p<0.001$, d=0.67, moderate), recovered +24h (−1.3 ± 2.0 cm, ns). SSG+RES ↓ 0h (−2.2 ± 3.1 cm, p=0.061), residual at +24h (−2.6 ± 4.9 cm, ns). PPO: RES+SSG ↓ 0h (−3.53 ± 2.48 W·kg⁻¹, $p<0.001$, d=0.50), recovered +24h (−1.56 ± 2.30, ns). SSG+RES minimal change (−0.84 ± 2.75, ns). Significant protocol × time interaction for PPO (p=0.009).

Table 2. Continue…

Study	Format of play (SSG)	Assessment timings	Main findings
Sparkes et al., 2022	4v4 + GK, 6×7 min, 2-min rest, 24×29 m pitch, repeated on consecutive weeks	CMJ (JH, PPO) pre vs post	Reliability: Pre SSG ICC very high for PPO (0.95, CV=2.1%), high for JH (0.82, CV=3.9%). Response consistency: Pre→post change ICC moderate (PPO 0.68; JH 0.77). JH ↓ −1.5 to −1.8 cm across weeks; PPO ↓ −41 to −80 W.
Trecroci et al., 2019	Postmatch interventions: (a) Soccer-specific training (SST: 4×3-min 4v4 SSG, tactical drills, set plays, ~60 min); (b) Active recovery (AR: low-intensity circle drills + jogging, ~30 min)	Assessments: PRE (−72 h), Postmatch (0 h), Postintervention (+72 h)	30-m sprint: Impaired 0 h (↑ time, ES=1.3–2.4), recovered by +72 h under both SST (−4.47 ± 0.21 → 4.28 ± 0.13 s, p=0.005) and AR (4.51 ± 0.15 → 4.28 ± 0.22 s, p=0.016). RSA (5×30 m): Impaired 0 h (ES=0.8), recovered by +72 h under both interventions (p<0.01). MVF knee extensors: Impaired 0 h (ES=0.8–1.3), recovered similarly in both SST (+7.2%, p=0.045) and AR (+11.1%, p=0.004). MVF knee flexors: Impaired 0 h (ES=1.0–2.0). Recovered only under AR (+25.7%, p=0.001); no sig. recovery in SST (+9.4%, p=0.083). Significant time×intervention interaction (p=0.036). AR > SST in restoring hamstring strength (ES=−0.60).

CMJ: countermovement jump; SJ: squat jump; JH: jump height; PPO: peak power output; MVF: maximal voluntary force; MVIC: maximal voluntary isometric contraction; KE: knee extensors; KF: knee flexors; RSA: repeated-sprint ability; 5BT: five-bound test; 20SP: 20-m sprint performance; PA: planned agility; RA: reactive agility; PP: plyometric press-up; Fpeak-ecc: peak eccentric force; Secc: eccentric impulse; Fpeak-con: peak concentric force; Ppeak-con: peak concentric power; CODA: change-of-direction ability; KV: kick velocity; S5 m: 5-m sprint time; S20 m: 20-m sprint time; S5–20 m: flying 5–20 m sprint segment; LSG: large-sided game; SSG: small-sided game; GK: goalkeeper; WB: wheelchair basketball; SCI: spinal cord injury; Non-SCI: non–spinal-cord-injured.

From 24 - 72 h, larger or more open formats tended to prolong impairment: 8v8 produced longer-lasting decrements than 4v4 in CMJ, sprint, and isokinetic strength (Papanikolaou et al., 2021), and 6v6 (200 $m^2 \cdot player^{-1}$) induced residual 24 h sprint and CMJ deficits that were absent or smaller after 3v3 (Modena and Schena, 2024). Acceleration ability was the most consistently sensitive metric across formats (Hidalgo de Mora et al., 2024), whereas CMJ was notably variable (depressed in (Sparkes et al., 2018); persistent after 6v6 in (Modena and Schena, 2024); stable in (Hidalgo de Mora et al., 2024) and (Clemente et al., 2017)).

Recovery strategies also mattered: after matches, an MD+2 active-recovery (AR) session restored hamstring force more effectively by 72 h than a soccer-specific training (SST) session (Trecroci et al., 2020), mirroring biochemical and soreness advantages seen in the companion study (Trecroci et al., 2021). These data suggest sprint-based measures -especially acceleration (0 - 10 m)- and knee flexor strength are the clearest barometers of residual fatigue, while CMJ can under-detect fatigue depending on SSG format, bout structure, and scheduling (Clemente et al., 2017; Sparkes et al., 2018; Bekris et al., 2022; Modena and Schena, 2024; Hidalgo de Mora et al., 2024).

Psychophysiological responses

SSGs consistently elicited match-like cardiovascular strain during play, with mean heart rates typically ~85 - 90% HRmax and frequent time >90% HRmax, particularly in smaller formats (Mitrotasios et al., 2021; Skala and Zemková, 2023). At the same time, perceived exertion did not always track HR: in a direct 4v4 vs 8v8 comparison, HR and lactate were higher in 4v4, yet RPE was higher in 8v8, signaling that space, density, and tactical demands shape perception beyond pure physiological load (Papanikolaou et al., 2021). Format manipulations showed expected gradients -2v2 and 4v4 drove higher post-exercise HR and lactate than 8v8, with partial recovery within 30 min but incomplete return to baseline (Karadağ et al., 2024)- while bout architecture and recovery altered internal kinetics without changing external output: shortening inter-bout recovery (30 s vs 120 s) elevated recovery HR and muscle deoxygenation (NIRS), yet total distance and speed-zone distribution were preserved via pacing (McLean et al., 2016).

Autonomic measures showed acute parasympathetic withdrawal: lnRMSSD, lnSDNN, and related HRV indices plummeted immediately post-SSG (Mascarin et al., 2018; Ravier and Marcel-Millet, 2020) and typically normalized or rebounded within 24 h in women after 4v4 (Mascarin et al., 2018). Heart-rate recovery (HRR) was format-sensitive across 2v2 - 4v4 and goalkeeping conditions (Dellal et al., 2015), and handball SSGs induced greater post-exercise autonomic depression than repeated-sprint or circuit conditioning of similar duration (Ravier and Marcel-Millet, 2020). Perceptual and mood responses followed a rapid time course: mood disturbance spiked immediately post and resolved by 24 h in a standard session (Sparkes et al., 2018), although it lingered under congestion (Sparkes et al., 2020a) or when SSG preceded resistance training within the same day (Sparkes et al., 2020b).

DOMS increased after both small and large formats and was still elevated at 24 h (Modena and Schena, 2024), while in women a CMJ decrement and higher session RPE were evident at 24 h but recovered by 48 - 72 h (Sjokvist et al., 2011). Task constraints in basketball shaped load and HR -offense exceeded defense and short-intermittent exceeded long-intermittent in PlayerLoad- with modest HR differences (Sansone et al., 2019). These findings indicate that during SSGs the cardiovascular load is consistently high but the recovery of autonomic and perceptual systems is generally rapid (<24 h), while perceptions can diverge from HR depending on format and task, and global RPE may fail to detect muscle-specific fatigue (Papanikolaou et al., 2021; Martínez-Serrano et al., 2023).

Table 3. Summary of the main findings regarding physiological responses.

Study	Format of play (SSG)	Assessment timings	Main findings
Alashti et al., 2021	2v2 (8×2 min / 1 min rest, 20×25 m), 4v4 (4×4 min / 2 min rest, 28×35 m), no GK, stop-ball rule	HR measured pre, 2nd, 8th, 14th, 20th min, and immediately post	HR significantly increased in both SSGs compared with control ($p \leq 0.05$). Example: in 2v2, HR rose from 71.27 ± 2.5 bpm pre to 187.51 ± 3.20 bpm at 20th min (~90% HRmax). In 4v4, HR increased from 69.09 ± 2.32 bpm pre to 182.45 ± 8.11 bpm at 20th min (~89% HRmax). Larger SSG (4v4) elicited lower HR/%HRmax compared to 2v2.
Ascondo et al., 2024	4v4 wheelchair basketball, 4×4 min bouts, 2 min rest	HR continuously during bouts; tympanic temp, RPEres, RPEmus after each bout (S1–S4)	Non-SCI group had higher HRpeak and HRmean than SCI across all bouts ($p < .05$–$.01$, ES = 0.73–1.39, moderate-large). SCI reported higher muscular perceived load in S1–S2 ($p < .05$, ES = 0.75–0.82, moderate) and higher respiratory perceived load in S4 ($p < .05$, ES = 0.97). Within-group changes: SCI showed stable HR and Temp across bouts; Non-SCI showed ↑ HRmean (S2, S3 vs S1, $p < .05$, ES = 0.29–0.57), ↑ HRpeak (S3, S4 vs S1, $p < .05$, ES = 0.42–0.65), ↑ RPEmusTL (S2–S4 vs S1, $p < .05$–$.01$, ES = 0.29–0.70). Temp increased S4 vs S1 for pooled players ($p < .01$, ES = 0.28, small).
Baseri et al., 2022	3v3 + 4 support players	HRV (SDNN, lnRMSSD) pre-SSG, post-SSG, post-recovery (24 h, 48 h)	Significant differences in SDNN HRV between AR vs. CWI ($F = 4.86$, $p = 0.03$, $\eta^2 = 0.31$, moderate). CWI better restored vagal-related HRV: mean difference +23.2, +242%. Within-condition changes ($F = 60.82$, $p = 0.001$, $\eta^2 = 0.85$, strong) confirmed significant drops from pre to post-SSG ($p = 0.001$) and recovery improvements ($p = 0.001$). lnRMSSD also differed between AR vs. CWI ($F = 2.41$, $p = 0.033$, $\eta^2 = 0.29$); CWI showed greater effect (mean difference +0.81, +185.7%).
Bekris et al., 2022	3v3	HR continuously across 8 sets; RPE PRE, during sets 2 & 5, POST, and 24–72 h; blood lactate PRE, after set 2, set 5, and POST	HR reached 168 ± 7 bpm (~87 ± 4% HRmax), peaking at 92 ± 3% HRmax after the 8th set ($F(1.00,11.04)=5647.93$, $p < 0.001$, $\eta^2=1.00$). Blood lactate increased significantly: 11.13 ± 2.23 mmol/L (after set 2), 10.79 ± 2.24 mmol/L (set 5), 13.02 ± 1.60 mmol/L POST ($F(1.81,19.97)=44.06$, $p < 0.001$, $\eta^2=0.80$). RPE progressively increased, peaking POST (~15 ± 1, Borg scale) ($F(3.43,37.76)=292.98$, $p < 0.001$, $\eta^2=0.96$), returning to baseline by 72 h.
Bonato et al., 2020	4v4, 4×4 min, 3-min rest, 36×24 m, no GK, evening session (20:00)	HR monitored continuously	HRmean across bouts: 172 bpm (90% HRmax), 174 bpm (91%), 178 bpm (94%), 173 bpm (91%). No significant differences compared to HIIT.
Clemente et al., 2017	1v1 (3×2 min) and 3v3 (3×3 min)	HR monitored across bouts; RPE pre and post bouts	HRaverage differed between bouts ($p = 0.026$, ES = 0.306, minimum). Bout 3 > Bout 2 ($p = 0.027$). %HRmax also higher in Bout 3 vs Bout 2 ($p = 0.026$, ES = 0.313). No differences between formats ($p = 0.953$). RPE increased significantly across bouts ($p = 0.001$, ES = 0.843).
Dellal et al., 2015	2v2 (4×2 min, 20×15 m), 3v3 (4×3 min, 25×18 m), 4v4 (4×4 min, 30×20 m), with/without GK; 3-min passive recovery	HRR measured at 1, 2, 3 min post-exercise (beats lost/min)	SSGs: HRR1 greater in 4v4 w/ GK, 3v3 w/ GK, and 4v4 vs 2v2 ($F(5,126)=6.26$, $p<0.01$). HRR2 greater in 2v2 w/ GK, 2v2, 3v3 vs 4v4 ($F(5,126)=4.51$, $p<0.01$). HRR3 lower in 3v3 w/ GK vs other SSGs ($F(5,126)=7.09$, $p<0.01$). End-exercise HR: 2v2 = 186.4 bpm (89% HRmax), 2v2+GK = 183.7 (87.7%), 3v3 = 183.4 (87.5%), 3v3+GK = 180.2 (86.0%), 4v4 = 178.3 (85.1%), 4v4+GK = 173.6 (82.9%).
Dello Iacono et al., 2016	3v3 handball	HR during bouts	No differences between C-SSG and NC-SSG in %HRmean (85.6 vs 86.2%) and HRmax (192 vs 193 bpm).
Iturricastillo et al., 2018	4v4 WB, 4×4 min	Tympanic temperature pre vs post; HRmean, HRpeak, Edwards' TL, TRIMPMOD, RPEres, RPEmus across bouts; Capillary blood lactate pre vs post	Tympanic temperature ↑ from 36.21 ± 0.60 °C to 36.97 ± 0.59 °C (Δ = +2.11%, $p < .001$, ES = 1.27). Internal load: HRmean 156 ± 11 bpm, HRpeak 179 ± 13 bpm. Edwards' TL = 67.5 ± 6.7 AU; TRIMPMOD = 55.3 ± 12.5 AU; RPEres TL = 100.6 ± 25.9 AU; RPEmus TL = 102.3 ± 29.7 AU. Negative associations: Δ% sled towing correlated with Δ% temperature ($r = -0.45$, $p < .01$). Lactate ↑ from 1.95 ± 1.30 mmol/L to 5.84 ± 2.04 mmol/L (Δ = +199.5%, $p < .001$, ES = 2.99). Higher lactate changes correlated with smaller declines in sprint and sled towing ($r = -0.42$ to -0.55, $p < .01$).
Johnston et al., 2014	Rugby league, "offside" 6v6 SSG (2×8 min halves, 70×30 m), with vs without contact (16 × 10 s bouts/half)	Session RPE 30 min post; wellness scale PRE, POST, 12 h, 24 h	RPE higher in contact (6.9 ± 0.4) vs non-contact (6.3 ± 0.6), $p = 0.05$, ES = 0.41 (small). Wellbeing: greater reductions after contact ($F(1,22)=10.88$, $p=0.03$, $\eta^2=0.338$). Muscle soreness moderately higher after contact (ES = 0.71).

Table 3. Continue…

Study	Format of play (SSG)	Assessment timings	Main findings
Karadağ et al., 2024	2v2 (20×25 m, 3×4 min, 3-min rest), 4v4 (30×35 m, 3×4 min), 8v8 (40×45 m, 3×4 min)	HR measured pre, immediately post, and 30 min post	Intragroup: MHR significantly ↑ post vs pre ($p<0.05$) and ↓ at 30 min vs post ($p<0.05$), but remained above pre ($p<0.05$). Example: 2v2 → 63.0 ± 3.46 (pre) → 181.5 ± 3.00 (post) → 78.0 ± 4.89 (30 min). 4v4 → 68.25 ± 4.46 → 175.25 ± 20.05 → 87.0 ± 11.56. 8v8 → 66.5 ± 5.77 → 125.7 ± 18.41 → 88.5 ± 9.33. Intergroup: Post values higher in 2v2 & 4v4 vs 8v8 ($p<0.05$). No differences pre or 30 min post between formats.
Kryściak et al., 2023	1v1, 6×30 s (E1) vs 6×45 s (E2), 1:4 work-to-rest, 10×15 m pitch, side-boards, no GK	HR (%HRmax) measured at rest (T0), after each bout (T1–T6), +15 min (T7), +30 min (T8)	%HRmax: time effect ($F(8,144)=1252.84$, $p\leq0.0001$, $\eta^2=0.99$). Mean 86.7–90.8% across bouts. No group effect during SSGs ($F(1,18)=3.85$, $p=0.065$, $\eta^2=0.18$). Post-exercise recovery faster in 45 s SSGs: at T7 (57.2% vs 63.5%, $p=0.021$, $d=1.01$) and T8 (52.4% vs 60.1%, $p=0.043$, $d=0.87$).
Madison et al., 2019	3v3 vs 4v4, as above	HR monitored continuously	Large SSGs showed higher internal load: HRmean 163 ± 16 bpm vs 157 ± 25 bpm ($p=0.003$, $d=0.26$), HRmax 194 ± 13 vs 188 ± 28 bpm ($p=0.001$, $d=0.27$). GPS: greater distance in high-speed zones, max speed (26.1 ± 2.0 vs 23.7 ± 1.8 km/h, $p=0.001$, $d=1.29$), and metabolic power (8.7 ± 0.9 vs 8.1 ± 1 W/kg, $p=0.003$, $d=0.38$) in large vs small SSG.
Martínez-Serrano et al., 2023	4v4 + 3 floaters SSG, TR1 (6v6+GK, 10v8 transitions), TR2 (7v7+GK, 10v8 transitions)	RPE after TR1 and TR2	No significant differences between "HIGH" and "LOW" HSR groups: TR1 RPE 6.82 ± 1.29 vs 6.00 ± 1.46 ($p = 0.637$, ES = 0.58). TR2 RPE 6.71 ± 1.38 vs 6.00 ± 1.60 ($p = 0.109$, ES = 0.62). Suggests RPE underestimated localized neuromuscular fatigue.
Mascarin et al., 2018	4v4, 4×4 min, 3 min rest, ~120 m²/player	HRV (LF, HF, LF/HF, RMSSD, pNN50, SDNN) pre, 10 min, 24 h, 48 h, 72 h	10 min post: LF ↑ +92.5% (very likely), HF ↓ −65.7% (very likely), LF/HF ↑ +386.2% (very likely). RMSSD ↓ −61.4% (very likely), pNN50 ↓ −90% (very likely). SDNN trivial (−13.5%). By 24 h, indices returned near baseline; 48–72 h showed parasympathetic rebound (HF, RMSSD, pNN50 ↑; LF, LF/HF ↓).
McLean et al., 2016	3v3, 6×2 min bouts, 15×20 m pitch, no goals/GK, unlimited touches; recovery = 30 s (REC-30) vs 120 s (REC-120)	Vastus lateralis oxygenation (HHb, O_2Hb, tHb), HR, RPE during bouts and recovery	HHb: Higher during recovery in REC-30 vs REC-120 ($p<0.001$, $\eta^2=0.725$). No differences during bouts. HR: Higher during recovery in REC-30 vs REC-120 ($p=0.001$, $\eta^2=0.849$). HR during bouts ~80–90% HRmax in both conditions; no condition effect ($p=0.295$). RPE: Increased across bouts ($p<0.001$, $\eta^2=0.610$). Condition × bout interaction ($p=0.016$): REC-30 showed earlier increases (from B1→B4, B5, B6, $p<0.01$). Time-motion (GPS): No differences between conditions in total distance (REC-30: 1365 ± 37.7 m vs REC-120: 1347 ± 37.7 m, $p=0.638$) or % time in speed zones (all $p>0.05$).
Mitrotasios et al., 2021	4v4 + 2 GK, 6×4 min, 30×20 m	HR during games	Mean HR ~89% HRmax, replicating competitive demands.
Modena & Schena, 2024	3v3 vs 6v6, 4×4 min	RPE post; DOMS pre, post, 24 h; TQR pre, 24 h	RPE: No differences between formats (3v3: 5.5 ± 1.5 vs 6v6: 5.3 ± 0.7, $p=0.328$, trivial). DOMS: ↑ in both formats post (3v3: 17.7 → 33.2 mm, $p=0.002$; 6v6: 14.8 → 33.6 mm, $p<0.001$) and remained ↑ at 24 h (3v3: 25.4 mm, $p=0.040$; 6v6: 24.1 mm, $p=0.015$). TQR: ↓ at 24 h vs pre (3v3: 16.1 → 14.1, $p=0.013$, $g=-0.75$; 6v6: 16.2 → 13.6, $p=0.002$, $g=-1.21$).
Mora et al., 2025	7v7 + 2 GK, same as above	GPS (TD, LIR, HIR, VHIR, Sprinting, Vmean, Vmax, Acc, Dec) across 3×8-min periods	Pitch size effect: LSG4 > SSG4 for TD (2709 ± 228 vs 2252 ± 156 m), HIR (295 ± 68 vs 150 ± 44 m), VHIR (164 ± 47 vs 55 ± 33 m), Sprinting (125 ± 69 vs 18 ± 23 m), Vmean (113 ± 10 vs 94 ± 7 m/min), Vmax (25.2 ± 2.1 vs 21.4 ± 1.9 km/h), all $p < 0.05$. Bout duration effect: LSG4 vs LSG8: LSG4 showed higher VHIR (164 ± 47 vs 118 ± 45 m, $p = 0.01$). Time effects: LSG8 showed decrements in TD, LIR, Vmean across bouts 2–3 vs bout 1 ($p < 0.05$). LSG4 only dropped in bout 3. SSG4 remained constant across bouts. No sig. differences in accelerations or decelerations among formats ($p > 0.05$).
Papanikolaou et al., 2021	4v4 vs 8v8 (as above)	HR, RPE, blood lactate post	HR: Mean %HRmax higher in 4v4 (88.7 ± 6.6%) vs 8v8 (81.5 ± 8.7%, $p=0.024$). Peak HR 93.8% vs 88.6% HRmax ($p=0.047$). Time >90%HRmax: 14.6 ± 8.3 s vs 7.7 ± 8.2 s ($p=0.027$). RPE: Higher in 8v8 (8.7 ± 1.2) vs 4v4 (6.2 ± 1.1, $p=0.000$). Lactate: ↑ post in both, higher in 4v4 ($p=0.002$).
Pellegrino et al., 2020	4v4, 125–300 m², pre/post RSA	Distances covered in locomotor zones (0–21+ km/h)	125 m²: Post-RSA, distance in 7–14 km/h zone ↓ −129.98 m (CI −193.49 to −66.46, ES=1.38, $p<0.001$). 250–300 m²: Compared with 125–150 m², players covered significantly more high-intensity distance (>18 km/h): pre (250 vs 125: +48.3 m, ES=2.03; 300 vs 125: +45.5 m, ES=2.27), post (250 vs 125: +65.6 m, ES=2.58; 300 vs 125: +70.3 m, ES=3.15), all $p<0.05$.

Table 3. Continue…

Study	Format of play (SSG)	Assessment timings	Main findings
Ravier & Marcel-Millet, 2020	3v3 handball SSG with GK, intermittent 30 s play/30 s rest, 2×8 min, 2-min rest between halves	HR (mean, peak, end), HRR30, HRR60, HRR300, HRR600; HRV (lnRMSSD, lnSDNN, lnSD1, lnHF, lnLF) pre (10 min) vs post (10 min seated recovery)	HR: HRmean 164.9 ± 8.3 bpm (85.7 ± 3.7% HRmax), HRpeak 179.9 ± 8.3, HRend 171.1 ± 7.6. Higher than RS (HRmean 146.4) and CT (129.2). HRR: SSG HRR30 = 27.6 bpm, HRR60 = 50.0 bpm, nHRR60 = 29.2%. RS > SSG in HRR30/60 ($p < 0.05$–0.001). HRV: lnRMSSD ↓ from 4.10 ± 0.37 → 2.94 ± 0.69 ($p < 0.0001$, large ES). lnSDNN ↓ 4.37 ± 0.30 → 3.54 ± 0.35 ($p < 0.0001$). lnSD1 ↓ 3.75 ± 0.37 → 2.59 ± 0.71 ($p < 0.0001$). lnHF ↓ 3.59 ± 0.30 → 3.10 ± 0.77 ($p < 0.01$). Parasympathetic disruption greater than RS (lnRMSSD 2.94 vs 3.38, $p < 0.01$) and CT (3.65, $p < 0.001$).
Sansone et al., 2019	3v3 basketball, half-court (14×15 m), offense vs defense, long-intermittent (3×4 min, 2′ rest) vs short-intermittent (6×2 min, 1′ rest)	External load (PlayerLoad), %HRmax, Edwards' TL during games	PlayerLoad: Offense > defense (148.0 ± 16.8 vs 137.1 ± 15.5 AU, p=0.008, η^2=0.517). Short > long regime (147.0 ± 18.2 vs 137.9 ± 14.6 AU, p=0.026, η^2=0.404). %HRmax: Offense > defense (91.1 ± 4.1% vs 88.7 ± 5.4%, p=0.020, η^2=0.433). No regime effect (90.0 ± 5.6 vs 89.8 ± 4.2%, p=0.893). Strong task × regime interaction (p=0.002, η^2=0.632). Edwards' TL: Offense-long > defense-short (56.6 ± 2.4 vs 52.4 ± 4.4 AU, p=0.004, r=0.25).
Sjökvist et al., 2011	4v4 SSG + interval running, as above	HR response (mean HR, %HRmax, time in HR zones), session-RPE	HR: Mean session HR = 76.7 ± 4.3% HRmax. Players spent 23.4 ± 1.1 min >90% HRmax. No differences in HR responses across recovery intervals. S-RPE: ↑ after 24 h vs baseline (7.9 ± 0.4 → 8.4 ± 0.5, p<0.02), recovered by 48 h and 72 h.
Skala & Zemková, 2023	4v4 + GK, as above	HR, GPS load, fatigue VAS; Go/no-go task (GNG) pre vs post	HR: HRavg 171.7 ± 7.1 bpm (86.6% HRmax), time >90%HRmax = 45.9% of SSG. External load: TD 2753 m (91.8 m/min); HSR 379 m; VHSR 13.5 m; MSP 22.3 km/h. Fatigue VAS: ↑ +41.6 AU (p<0.001, g=4.15). Response time (GNGt): −3.36% (ns, p=0.119). Errors (GNGe): ↑ +87.1% (0.93 → 1.71 errors, p=0.023, r=0.57).
Sparkes et al., 2020a	4v4 + GK	Mood disturbance questionnaire (BAM+) pre, 0h, 24h	Session 1: Mood ↑ 0h (+14.4 AU, ±5.3, moderate), recovered 24h. Session 2: Mood ↑ 0h (+12.8 AU, ±4.7, moderate), remained ↑ 24h (+5.2 AU, ±3.8, small).
Sparkes et al., 2020b	4v4 + GK, same as above	Mood (BAM+) pre, 0h, +24h	Mood disturbance: ↑ at 0h after SSG+RES (+8.6 ± 9.1 AU, p=0.011, d=0.72), recovered at +24h. RES+SSG: no sig. mood change (pre → 0h +3.2 ± 11.4 AU, ns). No differences between protocols at +24h.
Sparkes et al., 2022	4v4 + GK, same format repeated 1 week apart	GPS (TD, MSR, HSR, MV, PlayerLoad, HI Acc, HI Dec)	Repeatability: TD ICC=0.63, CV=5.9%; MV ICC=0.55, CV=4.4%; PlayerLoad ICC=0.70, CV=7.5%. Poor repeatability in MSR (CV=22.1%), HSR (CV=62.4%), HI Dec (ICC=0.30, CV=29.0%). HI Acc ICC=0.81 (high).
Trecroci et al., 2019	SST vs AR, as above	Internal load (RPE), GPS (TD, metabolic power, HR, accelerations)	SST vs AR: Higher demands in SST (RPE 3.6 ± 1.2 vs 1.1 ± 0.6, p<0.0001; TD 4.25 ± 0.51 vs 1.88 ± 0.33 km; metabolic power 3.74 ± 0.67 vs 1.90 ± 0.36 $W \cdot kg^{-1}$; HR >75% HRmax: 1103 s vs 102 s). Distances at accelerations/decelerations >1 $m \cdot s^{-2}$ also higher in SST (all p<0.0001).
Trecroci et al., 2021	SST vs AR	GPS, HR, RPE during interventions; Muscle soreness (VAS), Total Quality Recovery (TQR) at −72 h, 0 h, +72 h	SST: RPE 3.6 ±1.1 AU vs AR 1.1 ±0.4 (p<0.001). Total distance SST 4.1 ±0.4 km vs AR 1.8 ±0.3. HR>85%HRmax: 270 s SST vs 0 s AR. Acc/Dec 2–3 $m \cdot s^{-2}$: 102 ±38 m /133 ±42 m in SST vs 0 m AR. Confirms much higher physiological load in SST. Muscle soreness: Significant interaction (F(1,16)=7.901, p=0.004, η^2p=0.497). AR ↓ soreness more from 0h→+72h (5.00 ±0.82 → 1.83 ±0.96 AU, p<0.0001, ES=4.2) vs SST (5.22 ±0.83 → 3.61 ±0.61 AU, p=0.033, ES=2.2). TQR: No sig. differences (baseline 16.3 ±1.7 → +72h 15.4 ±1.4 SST; 16.4 ±1.7 → 16.5 ±1.1 AR, p>0.05).

HR: heart rate; HRmax: maximal heart rate; HRmean: mean heart rate; HRpeak: peak heart rate; HRend: end-exercise heart rate; HRR: heart-rate recovery; HRR1/HRR2/HRR3: beats recovered in minutes 1/2/3 post-exercise; HRR30/HRR60/HRR300/HRR600: heart-rate recovery at 30/60/300/600 s; nHRR60: normalized HRR at 60 s; RPE: rating of perceived exertion; S-RPE: session RPE; TQR: total quality of recovery; DOMS: delayed-onset muscle soreness; VAS: visual analogue scale; BAM+: Brief Assessment of Mood; PlayerLoad: accelerometer-derived external-load metric (arbitrary units); TD: total distance; Vmean: mean speed; Vmax: maximum speed; MSP: maximal sprinting speed; HIR: high-intensity running; VHIR: very high-intensity running; HSR: high-speed running; VHSR: very high-speed running; Sprint: distance or count above sprint threshold; Acc: accelerations; Dec: decelerations; HI Acc/HI Dec: high-intensity accelerations/decelerations; TRIMPMOD: modified training impulse (HR-based); Edwards' TL: heart-rate-zone weighted training load; RPEres TL: respiratory RPE-based training load; RPEmus TL: muscular RPE-based training load; HHb: deoxygenated hemoglobin; O_2Hb: oxygenated hemoglobin; tHb: total hemoglobin; HRV: heart-rate variability; RMSSD: root mean square of successive differences; pNN50: percentage of NN intervals differing by >50 ms; SDNN: standard deviation of NN intervals; LF: low-frequency HRV power; HF: high-frequency HRV power; LF/HF: low- to high-frequency power ratio; lnRMSSD/lnSDNN/lnSD1/lnHF/lnLF: log-transformed HRV indices; Temp: tympanic temperature; GNG: go/no-go task; GNGt: go/no-go response time; GNGe: go/no-go errors; MSR: moderate-speed running; MV: mean velocity; MD-4: match day minus four.

Biochemical and endocrine responses

Acid–base variables were more discriminating than HR or lactate for bout-length effects: 30-s bouts induced more pronounced bicarbonate depletion and negative base-excess than 45-s bouts despite similar HR and lactate, flagging these as sensitive fatigue markers for short-burst SSGs (Kryściak et al., 2023).

Markers of muscle damage frequently peaked later: CK and LDH increased immediately after intensive 4v4+GK (Mitrotasios et al., 2021) and remained elevated for ≥24 h after 4v4+GK in pros, with additive rises across congested exposures (Sparkes et al., 2018; 2020a). Between formats, higher-density 4v4 elicited greater CK responses than 8v8 at 48 - 72 h, consistent with higher mechanical stress per area (Papanikolaou et al., 2021). After matches, the choice of MD+2 session influenced biochemical recovery: compared with a 60-min soccer-specific session including SSGs, a 30-min active-recovery session produced a larger CK decline and greater resolution of soreness by +72 h, while inflammatory, immune, and endocrine markers followed similar time courses in both conditions (Trecroci et al., 2021).

Inflammatory cytokines and immune counts exhibited the expected short-lived spikes -IL-6 rose acutely after contact-rich SSGs (Dello Iacono et al., 2017) and after matches (Trecroci et al., 2021)- and generally normalized by 72 h (Trecroci et al., 2021).

Endocrine responses varied by sport and task: in soccer, T often showed a small acute rise followed by suppression at 2 - 24 h, with cortisol falling or returning to baseline by 24 h (Sparkes et al., 2018, 2020a; 2020b; 2022), whereas in basketball cortisol rose across offense/defense and regime conditions and testosterone moved in opposite directions depending on tactical task (Sansone et al., 2019). Short, intense 1v1 soccer drills transiently increased total and free testosterone and cortisol with depressed TT/C ratios at 15 - 30 min post (Chmura et al., 2019), and an evening 4v4 session elicited a robust salivary cortisol surge with a clear next-morning cortisol awakening response, albeit smaller than matched-load HIIT (Bonato et al., 2020).

Several studies reported no change in selected biochemical domains: lipids were stable across 4v4+GK (Mitrotasios et al., 2021), CK did not rise in women after 4v4 across 10 - 72 h (Mascarin et al., 2018), and growth-axis hormones increased acutely with SSGs (GH, IGF-1) without indicating prolonged disruption (Alashti et al., 2021). In sum, lactate and acid–base indices map the immediate (<30 - 60 min) metabolic stress, hormonal perturbations are typically short-to-mid-lived (resolving by ~24 - 48 h unless exposure is congested), and CK/LDH reflect residual damage that can persist to 48 - 72 h and is sensitive to format, density, and post-match training choice (Sparkes et al., 2018; Papanikolaou et al., 2021; (Sparkes et al., 2018; Papanikolaou et al., 2021; Trecroci et al., 2021).

Table 4. Summary of the main findings regarding biochemical/endocrine responses.

Study	Format of play (SSG)	Assessment timings	Main findings
Alashti et al., 2021	2v2; 4v4	Blood samples pre and immediately post SSG	GH: significant increase post in both groups (2v2, $p < 0.001$; 4v4, $p < 0.003$). IGF-1: significant increase post in both groups ($p < 0.001$). ANOVA showed group effect for GH ($F = 9.113$, $p = 0.0014$), IGF-1 ($F = 11.34$, $p = 0.0005$). Lactate increased significantly in both SSGs ($p < 0.001$), ~8-fold in 2v2 and ~7-fold in 4v4. Correlation: lactate positively correlated with IGF-1 in 4v4 ($r = 0.722$, $p = 0.43$) but not with GH.
Bekris et al., 2022	3v3	Blood samples PRE, POST, 24 h, 48 h, 72 h	IL-6 peaked POST (3.52 ± 0.43 pg/mL) and returned to baseline by 24 h ($F(1.04,11.50)=504.82$, $p < 0.001$, $\eta^2=0.98$). CK peaked at 24 h (536.58 ± 124.73 U/L) and remained elevated at 48 h and 72 h ($F(1.76,19.32)=93.96$, $p < 0.001$, $\eta^2=0.90$). Cortisol peaked POST (14.62 ± 4.58 µg/dL), still elevated at 24 h, returned to baseline 48–72 h ($F(1.00,11.00)=122.21$, $p < 0.001$, $\eta^2=0.92$). Testosterone peaked POST (6.00 ± 1.55 ng/mL), normalized within 24 h ($F(1.69,18.62)=47.39$, $p < 0.001$, $\eta^2=0.81$). T/C ratio lowest POST (0.44 ± 0.16), returned to baseline by 24 h ($F(1.73,19.05)=12.12$, $p < 0.001$, $\eta^2=0.52$).
Bonato et al., 2020	4v4	Salivary cortisol PRE, POST, and morning after (CAR)	PRE: 1.79 ± 0.48 ng/mL → POST: 3.37 ± 1.42 ng/mL ($p = 0.0003$, ES = 1.4, very large). CAR: 4.21 ± 0.60 ng/mL ($p < 0.0001$, ES ≥ 2.0, very large). POST cortisol lower in SSG than HIIT (3.37 vs 5.63 ng/mL, $p < 0.0001$, ES ≥ 2.0).

CK: creatine kinase; CK-MB: creatine kinase muscle-brain isoenzyme; LDH: lactate dehydrogenase; γ-GT: gamma-glutamyl transferase; ALT: alanine aminotransferase; AST: aspartate aminotransferase; UA: uric acid; sCr: serum creatinine; WBC: white blood cell count; Neu: neutrophils; Ly: lymphocytes; Mo: monocytes; La^-: blood lactate; pH: blood acidity; HCO_3^-: bicarbonate; BE: base excess; CRP: C-reactive protein; IL-6: interleukin-6; T: testosterone; TT: total testosterone; FT: free testosterone; C: cortisol; T/C: testosterone-to-cortisol ratio; TT/C: total-testosterone-to-cortisol ratio; FT/C: free-testosterone-to-cortisol ratio; CAR: cortisol awakening response; GH: growth hormone; IGF-1: insulin-like growth factor-1; CI: confidence interval; CV: coefficient of variation; ICC: intraclass correlation coefficient; ES: effect size; d: Cohen's d; g: Hedges' g; $\eta^2/\eta p^2$: eta-squared/partial eta-squared; AU: arbitrary units.

Table 4. Continue…

Study	Format of play (SSG)	Assessment timings	Main findings
Chmura et al., 2019	1v1, six × 30 s / 2 min rest (E1) vs six × 45 s / 3 min rest (E2), 10×15 m field	Capillary blood at rest, immediately post, +15 min, +30 min	Total Testosterone (TT): Significant effect of time ($F(3,48)=15.26$, $p \leq 0.0001$). TT peaked immediately post (E1: 5.50 ± 1.58; E2: 4.66 ± 0.94 ng/mL) vs rest and declined at +30 min (E1: 3.86 ± 1.14; E2: 3.62 ± 0.73). Large effect sizes: immediate vs 30 min (d=1.16), rest vs 30 min (d=0.96). Free Testosterone (FT): Effect of time ($F(3,48)=6.86$, $p=0.0006$). FT peaked post (E1: 14.77 ± 6.41 pg/mL; E2: 13.82 ± 3.67) then declined by +30 min (E1: 10.94 ± 5.23; E2: 11.60 ± 2.45). Medium effect: post vs 30 min (d=0.66). Cortisol (C): Effect of time ($F(3,48)=11.16$, $p \leq 0.0001$). Post values ↑ vs rest (E1: 189.76 ± 63.65 vs 147.39 ± 32.15 ng/mL; E2: 185.77 ± 46.68 vs 127.43 ± 38.56). In E1, C peaked at +15 min (251.40 ± 80.55 ng/mL), higher than rest and post (d=1.70 and d=0.85). Ratios (TT/C, FT/C): Significant time effects (TT/C $F(3,48)=7.45$, $p=0.0003$; FT/C $F(3,48)=5.11$, $p=0.0038$). Ratios decreased 15–30 min post vs rest (TT/C rest 0.035 ± 0.011 → 0.020 ± 0.014 at +15 min; FT/C rest 0.089 ± 0.033 → 0.058 ± 0.034 at +15 min).
Dello Iacono et al., 2016	3v3 handball, with vs without contact	IL-6 pre and immediately post	IL-6 increased 46.1% after C-SSG ($p<0.05$), but not after NC-SSG (+16.5%, $p=0.12$). Very strong correlation between number of contacts and IL-6 response ($r=0.971$, $p<0.001$).
Johnston et al., 2014	Rugby league, "offside" 6v6 SSG (2×8 min halves, 70×30 m), with vs without contact (16 × 10 s bouts/half)	Whole blood CK PRE, POST, 12 h, 24 h	CK increased in both games. Non-contact: peak POST (ES = 1.27), declined at 12 h (ES = 0.78) and 24 h (ES = 0.95). Contact: continued to rise at 12 h (ES = 1.25) and 24 h (ES = 1.64). At 24 h, contact CK increase (54 ± 32%) > non-contact (22 ± 13%), ES = 0.86, likelihood = likely (82%).
Karadağ et al., 2024	2v2, 4v4, 8v8	Blood lactate pre, immediately post, 30 min post | RPE (Borg 6–20) post-training	Intragroup: Lactate significantly ↑ post vs pre ($p<0.05$), ↓ at 30 min vs post ($p<0.05$), but remained above pre ($p<0.05$). 2v2: 1.35 ± 0.26 → 11.65 ± 2.73 → 3.1 ± 1.03 mmol/L. 4v4: 1.47 ± 0.27 → 7.72 ± 1.89 → 2.38 ± 0.49. 8v8: 1.44 ± 0.25 → 6.22 ± 2.38 → 2.09 ± 0.50. Intergroup: Post and 30-min values lower in 2v2 vs 4v4 & 8v8 ($p<0.05$). RPE significantly higher in 2v2 (17.0 ± 0.81) vs 8v8 (14.56 ± 0.96) and 4v4 (16.0 ± 0.53) vs 8v8 ($p<0.05$). No difference between 2v2 and 4v4 ($p>0.05$).
Kryściak et al., 2023	1v1, 6×30 s vs 6×45 s	Blood lactate, pH, HCO_3^-, base excess (BE) at T0, T1–T6, T7, T8	Lactate: ↑ significantly across bouts ($F(8,144)=162.72$, $p\leq0.0001$, $\eta^2=0.90$), peaked T6 ~17 mmol/L, remained >pre at T8 (6.2 mmol/L). No group effect ($F(1,18)=0.01$, $p=0.923$). pH: ↓ progressively ($F(8,144)=101.9$, $p\leq0.0001$, $\eta^2=0.85$), returned to baseline by 30 min. HCO_3^-: Group effect ($F(1,18)=8.84$, $p=0.008$, $\eta^2=0.33$). Lower in 30 s SSGs from T2–T8 (e.g., T6: 12.3 vs 15.2 mmol/L, $p=0.0007$, d=2.41). BE: ↓ significantly across time ($F(8,144)=292.77$, $p\leq0.0001$, $\eta^2=0.94$), more negative in 30 s SSGs at T6 and T7 (−16.7 vs −13.9 mmol/L, $p=0.046–0.010$).
Mascarin et al., 2018	4v4, 4×4 min	CK and LDH, Testosterone & cortisol, pre, 10 min, 24 h, 48 h, 72 h	CK unchanged 10 min (+2.7%, trivial), ↓ progressively: 24 h −19.6% (likely), 48 h −36.3% (likely), 72 h −53.2% (very likely). LDH ↑ 10 min +19.2% (likely), ↓ by 24–72 h (−7.7% to −13.5%); T and C unchanged at 10 min (<0.4%, trivial). Both ↓ at 24 h (T −32.7%, C −32.6%, very likely), ↓ at 48 h (T −8.9%, C −14.5%, likely), returned to baseline at 72 h. T/C ratio unchanged.
Mitrotasios et al., 2021	4v4 + 2 GK, 6×4 min, 3-min passive rest, 30×20 m pitch, U20 elite males	Blood pre vs immediately post	Lipids: No significant changes: T-C (171.9 → 162.5 mg/dL, $p=0.20$), HDL-C (63.1 → 64.1, $p=0.28$), LDL-C (92.0 → 86.3, $p=0.46$), TG (83.6 → 60.8, $p=0.11$). Enzymes: CK ↑ 22.9% (273.1 → 335.6 U/L, $Z=-2.38$, $p=0.02$, $r=0.84$), CK-MB ↑ 21.8% (10.9 → 13.3 U/L, $Z=-2.54$, $p=0.01$, $r=0.90$), LDH ↑ 9.6% (257.1 → 281.8 U/L, $Z=-2.10$, $p=0.04$, $r=0.74$). No significant changes in γ-GT, ALT, AST ($p=0.25–0.75$). Hormones: Cortisol ↑ 65.1% (9.2 → 15.2 μg/dL, $Z=-2.53$, $p=0.01$, $r=0.89$). Testosterone ↓ −23.4% (432.4 → 331.4 ng/dL, $Z=-2.52$, $p=0.01$, $r=0.89$).
Papanikolaou et al., 2021	4v4 vs 8v8	CK baseline, 24h, 48h, 72h	CK ↑ 24–72h in 4v4 ($p=0.001–0.000$). CK ↑ only 24h in 8v8 ($p=0.011$). Higher CK in 4v4 vs 8v8 at 48h ($p=0.004$) and 72h ($p=0.009$). Indicates more muscle damage in high-density SSG.

CK: creatine kinase; CK-MB: creatine kinase muscle-brain isoenzyme; LDH: lactate dehydrogenase; γ-GT: gamma-glutamyl transferase; ALT: alanine aminotransferase; AST: aspartate aminotransferase; UA: uric acid; sCr: serum creatinine; WBC: white blood cell count; Neu: neutrophils; Ly: lymphocytes; Mo: monocytes; La^-: blood lactate; pH: blood acidity; HCO_3^-: bicarbonate; BE: base excess; CRP: C-reactive protein; IL-6: interleukin-6; T: testosterone; TT: total testosterone; FT: free testosterone; C: cortisol; T/C: testosterone-to-cortisol ratio; TT/C: total-testosterone-to-cortisol ratio; FT/C: free-testosterone-to-cortisol ratio; CAR: cortisol awakening response; GH: growth hormone; IGF-1: insulin-like growth factor-1; CI: confidence interval; CV: coefficient of variation; ICC: intraclass correlation coefficient; ES: effect size; d: Cohen's d; g: Hedges' g; $\eta^2/\eta p^2$: eta-squared/partial eta-squared; AU: arbitrary units.

Table 4. Continue…

Study	Format of play (SSG)	Assessment timings	Main findings
Sansone et al., 2019	3v3, offense/defense × long/short	Salivary cortisol (C) & testosterone (T) pre vs post	Cortisol: Significant ↑ overall (pre 7.2 ± 0.7 ng/ml → post 11.4 ± 0.8 ng/ml, p=0.001, η^2=0.702). No interaction effects. Testosterone: Increased after defense-long (159.3 ± 94.7 → 251.8 ± 104.3 pg/ml, p=0.037, r=0.47). Decreased after offense-short (260.5 ± 155.9 → 192.2 ± 152.9 pg/ml, p=0.028, r=0.49). Stable in other conditions.
Sparkes et al., 2018	4v4 + GK, as above	Blood lactate, CK, Salivary testosterone (T), cortisol (C) at baseline, 0h, +2h, +24h	Lactate: ↑ at 0h (+1.3 mmol·L⁻¹, ±0.5, large), ↓ at +2h (−0.5, ±0.2, small), back to baseline at +24h (+0.1, trivial). CK: ↑ at 0h (+97 U·L⁻¹, ±28, small), ↑ at +2h (+118, ±24, moderate), ↑ at +24h (+94, ±49, small). CK remained elevated for 24h. T: ↑ at 0h (+20 pg·ml⁻¹, ±29, small), ↓ at +2h (−61, ±21, moderate), baseline at +24h (+2, trivial). C: ↓ at 0h (−0.09 µg·dl⁻¹, ±0.16, small), ↓ at +2h (−0.39, ±0.12, large), ↓ at +24h (−0.12, ±0.11, small)
Sparkes et al., 2020a	4v4 + GK, as above	CK, Salivary testosterone, cortisol at pre, 0h, 24h	Session 1: CK ↑ at 0h (+123 U·L⁻¹, ±63, small), remained ↑ 24h (+113, ±67, small). Session 2: CK ↑ at 0h (+154, ±72, moderate), remained ↑ 24h (+173, ±63, moderate). Indicates additive effect of congested schedules on muscle damage. Session 1: T ↑ 0h (+36 pg·ml⁻¹, ±32, small), ↓ 24h (−42, ±30, small). C ↓ 0h (−0.14 µg·dl⁻¹, ±0.09, small), ↓ 24h (−0.10, ±0.11, small). Session 2: T ↑ 0h (+41, ±38, small), ↓ 24h (−76, ±37, moderate). C ↓ 0h (−0.16, ±0.12, small), ↓ 24h (−0.23, ±0.14, moderate). Confirms hormonal suppression with congested SSGs.
Sparkes et al., 2020b	4v4 + GK, same as above	Salivary testosterone (T), cortisol (C), T/C ratio pre, 0h, +2h, +24h	T: RES+SSG ↑ at 0h (+17.0 ± 25.3 pg/ml, ns) vs SSG+RES (−4.4 ± 32.5). Protocol difference at 0h = +21.4 ± 26.7 pg/ml (p=0.010, d=0.73, moderate). Both protocols ↓ at +2h (−48.0 ± 35.9 pg/ml SSG+RES, p=0.001; −33.2 ± 34.3 RES+SSG, p=0.019). At +24h, no difference. C: Both protocols ↓ at +2h (SSG+RES −0.310 ± 0.192 µg/dl, p<0.001; RES+SSG −0.251 ± 0.178, p=0.001), recovered +24h. No protocol differences. T/C ratio: Increased at +2h in both (SSG+RES +322 AU, p<0.001; RES+SSG +262 AU, p=0.006). No protocol difference.
Sparkes et al., 2022	4v4 + GK, same as above	Salivary T, C, T/C pre vs post, across 2 weeks	Pre reliability: ICC very high (T 0.98, C 0.94, T/C 0.93). Pre→post reliability: ICC very high (T 0.93, C 0.99, T/C 0.85). Typical changes: T stable (+3.5, +3.1 pg/ml), C ↓ small (−0.038, −0.018 µg/dl), T/C ↑ (+137, +75 AU).
Trecroci et al., 2021	Match play +48 h SST vs AR	Blood at −72 h, 0 h, +72 h: CK, CRP, IL-6, UA, sCr, cortisol, WBC, neutrophils, lymphocytes, monocytes	CK: Significant interaction (F(1,16)=4.096, p=0.04, η^2_p=0.369). AR ↓ CK more (680 ±343 → 209 ±98 U/L, p<0.0001, ES=1.9) vs SST (570 ±232 → 284 ±98, p=0.06, ES=1.6). Other markers: Time effects (all ↑ 0h then ↓ +72h, p<0.01), but no SST vs AR differences (p>0.05). E.g., cortisol ↑ pre→0h (6.41 ±1.84 → 14.0 ±6.4 µg/dl), returned +72h (5.52 ±1.29). IL-6 ↑ pre<1.84 → 3.74 ±2.3 pg/ml 0h, back <1.84 at +72h. UA ↑ 4.8 → 5.9 mg/dl 0h, back 5.0 +72h.

CK: creatine kinase; CK-MB: creatine kinase muscle-brain isoenzyme; LDH: lactate dehydrogenase; γ-GT: gamma-glutamyl transferase; ALT: alanine aminotransferase; AST: aspartate aminotransferase; UA: uric acid; sCr: serum creatinine; WBC: white blood cell count; Neu: neutrophils; Ly: lymphocytes; Mo: monocytes; La⁻: blood lactate; pH: blood acidity; HCO_3^-: bicarbonate; BE: base excess; CRP: C-reactive protein; IL-6: interleukin-6; T: testosterone; TT: total testosterone; FT: free testosterone; C: cortisol; T/C: testosterone-to-cortisol ratio; TT/C: total-testosterone-to-cortisol ratio; FT/C: free-testosterone-to-cortisol ratio; CAR: cortisol awakening response; GH: growth hormone; IGF-1: insulin-like growth factor-1; CI: confidence interval; CV: coefficient of variation; ICC: intraclass correlation coefficient; ES: effect size; d: Cohen's d; g: Hedges' g; η^2/η_p^2: eta-squared/partial eta-squared; AU: arbitrary units.

Limitations and future directions

Some methodological limitations should be acknowledged. First, the evidence base is dominated by male soccer players, with relatively few investigations in female athletes, and other team sports such as basketball or handball. This sex and sport imbalance restricts the generalizability of findings and limits understanding of whether recovery kinetics differ by biological sex, sport-specific demands, or disability status. Second, there is substantial heterogeneity in SSG formats and bout structures, ranging from 1v1 to 8v8, with and without goalkeepers, and with varying pitch dimensions and work-to-rest ratios. Although this variety reflects ecological practice, it complicates comparisons across studies and makes it difficult to isolate the impact of single design variables.

Another common limitation lies in the reporting and control of overall training load. In many studies, SSGs were not isolated from the remaining training contents of the session or microcycle, and the additional drills, conditioning, or tactical work were either insufficiently described or not reported at all. This lack of contextualization makes it difficult to attribute observed responses solely to SSG exposure and raises the possibility that neuromuscular, biochemical, or perceptual outcomes were influenced by concurrent training.

A further limitation concerns the choice of measures. Most investigations employed accessible field-based markers such as CMJ, sprint times, HR, and RPE, while fewer incorporated biochemical, endocrine, or advanced autonomic measures. This reliance on a narrow set of indicators may under-detect certain types of fatigue, as shown by discrepancies between global perceptual scales and localized muscle fatigue. Assessment timings also limit interpretation: the majority of studies assessed immediate or 24-h responses, with relatively few extending to 48 - 72 h, and very few examining intra-session kinetics or next-morning endocrine dynamics. Finally, many studies had small sample sizes, and effect estimates were often reported without standardized thresholds or with variable statistical approaches, reducing comparability.

Future research should address these limitations by broadening the scope of populations studied, including female, youth, recreational, and adaptive athletes, and extending investigations to sports beyond soccer. Greater methodological consistency in SSG formats, pitch dimensions, and bout structures would aid comparability, while adjusted designs could isolate the effects of specific game constraints. Expanding the range of outcome measures is equally important: alongside traditional neuromuscular and perceptual tests, researchers should integrate biochemical, endocrine, and cognitive assessments to capture multidimensional fatigue. Longitudinal designs with extended follow-up windows (48 - 96 h) are needed to map full recovery timelines, and studies should include larger sample sizes from multiple centers.

Conclusion

This scoping review mapped how SSGs influence acute and short-term responses across neuromuscular, psychophysiological, and biochemical/endocrine domains. The literature is dominated by studies in men soccer players, with limited research in women, youth-to-senior comparisons, or other team sports, and most investigations relied on field-based measures (CMJ, sprint times, HR, RPE) with fewer including biochemical, endocrine, or cognitive markers. Across domains, the evidence suggest that SSGs may elicit high cardiovascular and perceptual loads and acute autonomic suppression, often accompanied by transient decrements in neuromuscular performance and increases in biochemical markers of muscle damage and hormonal disturbance. Recovery timelines vary: autonomic and perceptual fatigue generally resolve within 24 h, whereas neuromuscular and biochemical markers frequently persist for 48 - 72 h, particularly following larger formats, contact elements, or congested schedules. At the same time, findings are heterogeneous, with some studies reporting no neuromuscular impairment or hormonal changes, reflecting differences in format, scheduling, and measurement sensitivity. A further limitation is that many studies did not isolate SSGs from the remaining training load or failed to report concurrent training activities, complicating the attribution of observed responses specifically to SSG exposure. Other common methodological limitations include the narrow populations studied, variability in SSG design, short follow-up windows, and reliance on small sample sizes. Future research should expand to more diverse populations and sports, employ standardized SSG protocols, integrate multidimensional outcome measures (including cognitive and biochemical markers), systematically report overall training load, and extend monitoring to 48 - 96 h to map recovery trajectories.

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Key points

- Most studies examined men Tier 3 soccer players in 3v3 - 4v4 formats, with limited data in women, other sports, or higher tiers.
- Evidence shows acute psychophysiological strain and sometimes short-term neuromuscular or biochemical disturbances, but findings are inconsistent.
- Research is methodologically diverse; standardized designs, broader populations, and longer follow-ups are needed.

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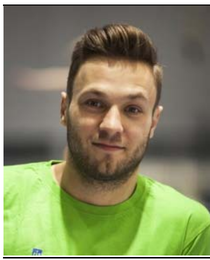

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