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Physiological and psychological assessment of high-intensity interval training, full-sided and small-sided games in elite handball players

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ABSTRACT

The purpose of the present research was to compare the acute physiological and psychological responses to three different high-intensity training methodologies commonly used in elite handball. Fourteen elite male handball players completed three randomised training protocols during the competitive season: high-intensity intermittent training (HIIT; 15-s work and 15-s rest intervals), 3 vs 3 small-sided games (SSG3), and 6 vs 6 full-sided games (FSG6). All protocols consisted of 4 × 6-min bouts with 3-min passive recovery. Heart rate (HR) and heart rate variability (HRV) were monitored throughout sessions. Subjective measures included the Multi-component Training Distress Scale (MTDS), CR10 RPE scale, and NASA-TLX questionnaires. Significant main effects of training type were found for mean HR ($p < 0.001$) and peak HR ($p < 0.001$). FSG6 elicited significantly lower physiological demands than both HIIT and SSG3. Conversely, FSG6 generated the highest mental demand and lowest perceived exertion. HIIT produced the highest physical perception despite similar physiological loads to SSG3. MTDS revealed greater fatigue and stress responses following HIIT compared to game-based protocols. In conclusion, training modality significantly impacts both physiological and perceptual responses. While HIIT and SSG3 produce similar cardiovascular strain, SSG3 is perceived as less demanding. FSG6 provides the highest cognitive challenge with the lowest physical perception.

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1. Introduction

Handball is an Olympic sport with widespread global participation and a particularly high competitive standard across most European countries. Despite this prominence, the handball performance model has yet to be fully and comprehensively elucidated (Ziv & Lidor, 2009). The literature continues to present several inconsistencies, and multiple aspects of performance remain insufficiently investigated. For instance, relatively few studies have employed motion analysis during official competition settings (Barbero-

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Álvarez et al., 2014; Póvoas et al., 2012). Existing evidence suggests that handball performance is largely determined by explosive actions, including vertical and horizontal jumping, agility, rapid movements in confined spaces, and technical skills such as ball-handling proficiency speed of ball release (Bautista et al., 2016). From a physiological perspective, match play involves substantial contributions from both anaerobic and aerobic energy systems (Delamarche et al., 1987; Loftin et al., 1996; Souhail et al., 2010). Recent studies on the physical and physiological demands of handball using GPS highlight how the specific demands of each role warrant individualisation of training loads according to the differential workloads required during performance (Barbero-Álvarez et al., 2014). Appropriate preparation, particularly through specific warm-up strategies, has also been shown to be a key factor influencing performance differences between the first and second halves of a match (Póvoas et al., 2012) as well as contributing to improvements in jumping performance (Simonelli et al., 2024). In team sports, warm-up protocols frequently conclude with small-sided games (SSG) or full-sided games (FSG) involving a reduced number of players to better approximate the situational and contextual demands of competition in accordance with the principle of specificity (Dellal et al., 2012a; Dellal, Drust, et al., 2012). Nevertheless, traditional intermittent running-based training without the ball has not been fully replaced by game-based intermittent modalities in many team sports, including handball (Dello Iacono et al., 2015), soccer (Clemente, Ramirez-Campillo, Afonso, et al., 2021) and basketball (Arslan et al., 2022), despite the latter being generally preferred by athletes.

In handball specifically, Dechechi and colleagues recently provided a comprehensive review evaluating the acute and chronic effects of SSG and their practical application (Dechechi et al., 2023). Jurišić and colleagues compared the effectiveness of handball-specific SSG and high-intensity interval training (HIIT) on physical performance during the preseason period of an elite female team competing in Serbia's national league (Jurišić et al., 2021). Similarly, Ravier and colleagues investigated the effectiveness of short intermittent SSG relative to matched interval running bouts in replicating match-play demands. In a subsequent study, Ravier and Marcel-Millet examined the acute effects of SSG, repeated sprint ability training, and specific handball skills circuits on parasympathetic reactivation, post-exercise heart rate (HR), and heart rate variability (HRV) in elite male players (Ravier & Marcel-Millet, 2020; Ravier et al., 2019). Over a longer time frame, Wagner et al. analysed how different specific training methodologies implemented across an entire competitive season influenced physical and technical-tactical performance in elite Austrian male handball players (Wagner et al., 2017).

Building on previous research (Bujalance-Moreno et al., 2019; Castagna et al., 2017; Dellal, Impellizzeri et al., 2006; Varliette, et al., 2012) that examined the effects of high-intensity interval training (HIIT), with and without the ball on physiological and match-performance parameters in soccer players, the present study sought to extend these investigations to handball. In soccer, SSGs have consistently been perceived as less demanding than HIIT despite comparable heart rate responses (Bujalance-Moreno et al., 2019; Castagna et al., 2017; Dellal, Varliette, et al., 2012; Impellizzeri et al., 2006) and have also been reported as enjoyable than HIIT (Selmi et al., 2018). Despite this growing body of evidence in soccer, the acute effects of comparable training methodologies in handball players remain poorly understood. Therefore, the aim of this study was to compare the acute physiological and perceptual responses to three high-intensity training approaches commonly employed during the in-season preparation of elite handball players. We hypothesised that high-intensity tactical and technical exercises would elicit responses distinct from those induced by high-intensity intermittent running, characterised by lower perceived exertion and reduced mental and psychological load.

2. Methods

2.1. Subjects

Fourteen male elite handball players (age 24.2 ± 4.7 y, weight 84.4 ± 8.5 kg, height 183.9 ± 7.3 cm, sport practice experience 16.4 ± 3.1 y) playing in the Italian first division in the 2021–2022 season voluntarily participated in the study. One player did not complete all training sessions due to an injury, and two goalkeepers were excluded from the final analysis, leaving a sample of 11 outfield players. The final 11 participants were healthy and free from injury for at least 12 months prior to data collection. The study protocol was approved by the University of Bologna Ethics Committee, and all participants provided written informed consent after receiving a full explanation of the study procedures.

2.2. Experimental approach to the problem and study design

The present study compared three commonly used high-intensity training modalities: two game-based sessions (one focused on technical skills and one on combined technical-tactical components) and one traditional intermittent running session without the ball. All protocols had the same total duration (90 min), work-to-rest ratio (1:1), and recovery time between sets (3 min). The training modalities were performed in a randomised order, and a total of 23 sessions were recorded. Each session was conducted midweek, specifically on match day +4 or −3 (the fourth day after the previous or the third day before the subsequent match) and lasted approximately 90 min. A standardised 20-min warm-up preceded each training session and included running-based mobility drills, activation exercises, accelerations and decelerations, changes of direction, agility tasks, and technical ball drills.

2.3. Training protocols

Three high-intensity conditioning protocols were implemented: (a) high-intensity interval training (HIIT), (b) a 3 vs 3 (plus the goalkeeper) small-sided game (SSG3), and (c) a 6 vs 6 (plus the goalkeeper) full-sided game (FSG6). These protocols were designed to represent increasing levels of specificity: (a) predominantly physical demand, (b) combined physical and technical demand, and (c) integrated physical, technical, and tactical demand. Each protocol consisted of four 6-min bouts (4 × 6 min) separated by 3 min of passive recovery, with a work-to-rest ratio of 1:1.

The HIIT protocol used 15-s work and 15-s rest intervals (15”–15”). During the SSG3 and FSG6, players performed two consecutive counterattacks, aiming to score as quickly as possible. The ball always started from the defending team in the offensive halfcourt. One of the players started the drill by passing the ball to the opponent’s goalkeeper and running back to their halfcourt. There were no defensive constraints. Short walking recovery followed each pair of counterattacks to allow repositioning for the next repetition, while the 3-min intervals between bouts were used for hydration and full recovery. All sessions were conducted at the same time of day on the same indoor court. Coaches and the strength and conditioning staff provided standardised verbal encouragement to maintain effort and motivation, and an audible signal-controlled running pace and timing. No nausea or discomfort occurred, and all athletes completed every session as planned.

2.4. Training monitoring procedures

To assess players' exposure to the psychophysiological demands of each session, subjective status was monitored on the morning of the training and again the following morning using the Multi-component Training Distress Scale (MTDS) (Main & Grove, 2009). The questionnaire comprises 22 items into six subscales: fatigue, vigour, physical symptoms, sleep quality, stress, and depression. Psychometrically, the instrument demonstrates a clear factor structure, high internal consistency across its subscales, and theoretically congruent associations with related constructs (Main & Grove, 2009).

To assess exertion and training effects, approximately 30 min after each session, players completed the CR10 Perceived Exertion Scale (Borg, 1998) and the NASA-TLX workload questionnaire (Hart, 2006). In addition, players wore a Firstbeat Sports Sensor (Firstbeat Technologies Ltd, Jyväskylä, Finland) throughout each session to record heart rate (HR), heart rate variability (HRV), and heart rate recovery (HRR) (Buchheit, 2014). From these recordings, minimum and maximum heart rate values (HRmin and HRmax) were extracted to characterise the cardiovascular load associated with each training drill. To further complement these measures, heart rate variability (HRV) was assessed using a continuous 6-min recording collected over the entire duration of each exercise bout, ensuring that variability indices reflected the physiological demands imposed by the training modality. Two standard time-domain HRV metrics were computed: SDNN (standard deviation of all normal-to-normal intervals), reflecting overall heart rate variability during exercise; and RMSSD (root mean square of successive differences). As HRV was assessed during an exercise bout, these indices should be interpreted as exercise HRV rather than as markers of resting autonomic function. At exercise intensities exceeding approximately 85% of HRmax, vagal efferent activity is largely withdrawn. Consequently, RMSSD no longer reflects parasympathetic modulation in the classical resting sense, while SDNN primarily represents global heart rate variability under conditions of elevated cardiovascular strain rather than integrated autonomic balance. Under these conditions, HRV during exercise is influenced by cardiovascular load, respiratory patterns, sympathetic dominance, and signal non-stationarity. Accordingly, HRV outcomes in the present study should be viewed as complementary indicators of internal load and physiological strain, rather than as direct markers of autonomic recovery or resting autonomic balance. Both metrics have been previously used to characterise internal load during exercise and are relatively robust to short recording durations and moderate motion artefacts (Rossi et al., 2020). Finally, to evaluate autonomic recovery following the drill, HRR was calculated as the reduction in HR from the end of the exercise to 30-, 60-, and 90-s post-exercise, providing an index of short-term cardiac recovery dynamics.

2.5. Statistical analysis

The Shapiro–Wilk test was used to assess the normality of the data. All recorded variables met the assumption of normal distribution, allowing the use of parametric statistical tests.

To detect differences in perception across training types, MTDS questionnaire responses were analysed using a one-way analysis of covariance (ANCOVA), in order to account for individual differences in pre-training status. Conversely, for NASA-TLX, RPE, and HR data, a one-way analysis of variance (ANOVA) was performed. When a significant main effect was found, Tukey's post hoc test was applied.

Data are presented as mean ± SD. The level of significance was set at $p \leq 0.05$ for all analyses. Effect sizes were calculated using partial eta squared (partial η^2) for all ANCOVA and ANOVA models and interpreted according to conventional benchmarks (small: ≥0.01, medium: ≥0.06, large: ≥0.14). All statistical analyses were conducted using Python 3.8, employing the following libraries: pandas (v2.3.3), NumPy (v1.24.4), statsmodels (v0.14.6), and pingouin (v0.5.5).

3. Results

3.1. Objective internal training load: heart rate responses

Heart rate (HR) and heart rate variability (HRV) were monitored throughout all sessions, including the recovery periods. An ANOVA with Greenhouse–Geisser correction showed that mean HR differed significantly across the three training conditions. Post hoc analysis revealed significant differences between HIIT and FSG6 (170.44 ± 13.89 bpm vs. 152.95 ± 14.73 bpm; $p < 0.001$) and between FSG6 and SSG3 (152.95 ± 14.73 bpm vs. 168.94 ± 11.23 bpm; $p < 0.001$).

Maximum HR also showed a significant main effect of training type, with post hoc comparisons confirming differences between HIIT and FSG6 (186.22 ± 13.29 bpm vs. 181.13 ± 13.83 bpm; $p = 0.002$) and between FSG6 and SSG3 (181.13 ± 13.83 bpm vs. 188.64 ± 10.69 bpm; $p < 0.001$).

Regarding HRV, both the standard deviation of NN intervals (SDNN) and the root mean square of successive differences (RMSSD) showed significant main effects of training type ($p < 0.001$). Post hoc tests indicated that FSG6 (40.85 ± 24.6 ms) differed significantly from both HIIT (22.88 ± 11.89 ms; $p < 0.001$) and SSG3 (23.12 ± 13.76 ms; $p < 0.001$) for SDNN. For RMSSD, significant differences were found among all three conditions: FSG6 vs. HIIT (11.00 ± 7.23 ms vs. 5.76 ± 2.58 ms; $p < 0.001$), HIIT vs. SSG3 (5.76 ± 2.58 ms vs. 6.55 ± 3.35 ms; $p = 0.010$), and FSG6 vs. SSG3 (11.00 ± 7.23 ms vs. 6.55 ± 3.35 ms; $p < 0.001$). Heart rate recovery indices after 30 s (HRR30), 60 s (HRR60), and 90 s (HRR90) showed no significant differences across training conditions (Table 1).

3.2. Subjective internal training load: session RPE

After each session, each player was asked to rate his perceived exertion (sRPE) using Borg's CR10 scale. A significant main effect for training type was observed ($p > 0.001$). The descriptive statistics and Tukey post hoc comparison show differences among all three training types (Table 2).

Table 1. Objective internal training load variables (heart rate responses) recorded for different protocols [mean (SD)]. Post-hoc comparison: # significantly different vs HIIT, $ significantly different vs SSG3, £ significantly different vs FSG6. N.S. refer to non-statistically significant difference.

Features	F test	HIIT 15″-15″	SSG3 3 vs 3	FSG6 6 vs 6
HR mean	$F = 25.76$ $p < 0.001$ partial $\eta^2 = 0.72$	170.44 (13.89)£	168.94 (11.23)£	152.95 (14.73)#$
HR max	$F = 5.11$ $p = 0.02$ partial $\eta^2 = 0.34$	186.22 (13.29)£	188.64 (10.69)£	181.13 (13.83)#$
SDNN	$F = 32.56$ $p < 0.001$ partial $\eta^2 = 0.77$	22.88 (11.89)£	23.12 (13.76)£	40.85 (24.63)#$
RMSSD	$F = 30.9$ $p < 0.001$ partial $\eta^2 = 0.76$	5.76 (2.58)$£	6.55 (3.35)#£	11.00 (7.23)#$
HRR30	N.S.	26.03 (8.85)	21.85 (8.88)	23.88 (10.54)
HRR60	N.S.	41.57 (13.00)	40.65 (12.06)	34.17 (15.81)
HRR90	N.S.	49.95 (14.64)	48.90 (12.07)	42.40 (16.40)

Table 2. Subjective internal training load (sRPE) collected for each training protocol [mean (SD)]. Tukey post-hoc comparison: # significantly different vs HIIT, $ significantly different vs SSG3, £ significantly different vs FSG6.

Features	F test	HIIT 15″-15″	SSG3 3 vs 3	FSG6 6 vs 6
sRPE	$F = 19.48$ $p < 0.001$ partial $\eta^2 = 0.66$	8.52 (1.56)$£	7.91 (1.75) #£	5.37 (2.20)#$

3.3. Training effect responses

Beyond the internal training load (e.g. HR and sRPE), the effect on players' mental and psychophysiological workload was assessed through the NASA-TLX questionnaire. Significant ANOVA main effects were found for mental demand ($p < 0.001$), physical demand ($p = 0.001$), temporal demand ($p = 0.004$), and effort ($p = 0.002$). No significant main effects were observed for performance ($p = 0.265$) or frustration ($p = 0.880$). Post hoc analyses for effort, mental, and physical demand revealed significant differences among all three training conditions (Table 3). For temporal demand, no significant difference was found between the HIIT and SSG3 protocols ($p = 0.890$), whereas all other pairwise comparisons were significant ($p < 0.001$) (Table 3).

To further evaluate players' training distress, the MTDS was administered on the morning of the training and again the following morning (Table 3). Post hoc analysis for the depression subscale showed significant differences across all comparisons ($p = 0.020$ for HIIT vs FSG6; $p < 0.001$ for HIIT vs SSG3; $p = 0.010$ for FSG6 vs SSG3). For the sleep, stress, fatigue, and vigour subscales, significant differences were observed between most conditions, except between SSG3 and FSG6 ($p = 0.450$, $p = 0.050$, $p = 0.610$, and $p = 0.870$, respectively). Finally, for physical symptoms, significant differences were found between most training methods except between HIIT and SSG3 ($p = 0.050$).

Table 3. Training effect responses collected during the present research [mean (SD)]. Post-hoc comparison: # significantly different vs HIIT, $ significantly different vs SSG3, £ significantly different vs FSG6. NB: ANOVA was performed for NASA items, while ANCOVA for MTDS. N.S. refer to non-statistically significant difference.

Features	F test	HIIT 15″-15″	SSG3 3 vs 3	FSG6 6 vs 6
NASA Mental demand	$F = 65.72$ $p < 0.001$ partial $\eta^2 = 0.87$	4.70 (2.38)$£	12.19 (3.76)#£	14.91 (2.28)#$
NASA Physical demand	$F = 14.45$ $p < 0.001$ partial $\eta^2 = 0.59$	17.21 (2.03)$£	16.46 (2.33)#£	11.91 (4.41)#$
NASA Temporal demand	$F = 12.48$ $p < 0.001$ partial $\eta^2 = 0.56$	15.06 (3.55)£	15.02 (2.37)£	10.27 (4.12)#$
NASA Effort	$F = 9.90$ $p < 0.001$ partial $\eta^2 = 0.50$	16.64 (3.61)$£	15.77 (2.93)#£	12.14 (4.21)#$
NASA Performance	N.S.	12.58 (5.78)	11.70 (5.58)	10.24 (3.41)
NASA Frustration	N.S.	9.52 (6.01)	9.66 (5.24)	10.06 (4.56)
MTDS Depression	$F = 10.56$ $p < 0.001$ partial $\eta^2 = 0.49$	5.00 (3.87)$£	4.05 (4.01)#£	5.52 (4.44)#$
MTDS Vigour	$F = 14.52$ $p < 0.001$ partial $\eta^2 = 0.19$	7.33 (2.09)$£	7.64 (3.20)#	7.97 (2.64)#
MTDS Physical symptoms	$F = 3.17$ $p = 0.04$ partial $\eta^2 = 0.44$	8.97 (2.70)£	8.23 (3.39)£	7.39 (2.44)#$
MTDS Sleep	$F = 6.65$ $p < 0.001$ partial $\eta^2 = 0.16$	3.88 (3.16)$£	2.87 (3.20)#	3.62 (3.03)#
MTDS Stress	$F = 4.46$ $p = 0.01$ partial $\eta^2 = 0.57$	5.12 (3.13)$£	6.53 (3.77)#	5.53 (3.21)#
MTDS Fatigue	$F = 17.41$ $p < 0.001$ partial $\eta^2 = 0.41$	6.18 (2.16)$£	6.52 (3.15)#	6.55 (3.17)#

4. Discussion

We hypothesised that high-intensity technical and tactical exercises would elicit different responses from high-intensity running intermittent training, characterised by lower perceived exertion and lower mental and psychological demands. In the pre-post subjective monitoring, the physical-only protocol (HIIT) was found to be more fatiguing, showing higher fatigue scores, lower vigour scores, and more physical symptoms. The analysis of the HRR confirmed the scientific literature (Buchheit, 2014). Specifically, the absence of significant statistical difference between the three protocols suggests that cardiorespiratory recovery ability is determined primarily by players' overall fitness status rather than by the specific training modality. HRR values are more appropriately monitored on an individual basis to assess within- and between-session variability, although this aspect was beyond the scope of our study. Overall, when considered individually, most physiological and perceptual variables did not differ significantly across training types, supporting previous evidence in the literature (Schneider et al., 2018).

The objective internal load, assessed through HR data, indicated that the physiological load of the technical-tactical protocol (FSG6) was substantially lower and perceived training effects, measured with sRPE and NASA-TLX questionnaires respectively, showed that the physical-only protocol (HIIT) was perceived as the most physically demanding (exertion, effort, physical and temporal request) and the least mentally demanding (mental request), whilst the physical, technical-tactical protocol (FSG6) was perceived as the most mentally demanding (mental request) and the least physically demanding (exertion, effort, physical and temporal request).

Specifically, the lower physiological intensity of the FSG6 protocol, was likely related to its greater tactical and decision-making load, which reduce continuous physical exertion compared to the SSG3 and HIIT protocols. This pattern mirrors finding in soccer where HR variables show no significant difference between HIIT and SSG (Dellal et al., 2008, 2012a, 2012b; Impellizzeri et al., 2006; Owen et al., 2011, 2014; Selmi et al., 2018). Overall, FSG6 produced the lowest sRPE and physical demand scores but the highest mental demand, consistent with the greater cognitive and tactical engagement required during play. Playing full sided needs tactical rigour and attention because of the lack of spaces for the offensive phase. This also means that more time in passing the ball and trying to find a spot to shoot is needed, hence reducing high speed phases and overall pace, limiting the physiological impact. FSGs require continuous perception-action coupling, decision-making, tactical awareness, and sustained attention, which are known to substantially increase cognitive and executive demands independently of the external or physiological load. Previous research has shown that complex, game-like motor tasks can elicit elevated mental workload due to increased involvement of executive functions and self-regulatory processes, even when exercise intensity is moderate (Schmit & Brisswalter, 2020). Furthermore, game-based games are designed to simultaneously stimulate physical, technical, tactical, and cognitive components, with task complexity playing a key role in shaping perceptual and mental demands (Clemente, Ramirez-Campillo, Sarmento, et al., 2021). Regarding temporal demand, our findings can be explained by the structural characteristics of full-sided game-based modalities. Reduced available space, higher player density, and longer phases of ball circulation typically require more time to create offensive solutions, thereby reducing the frequency of high-speed actions and overall pacing. Previous studies have shown that possession-oriented and larger-sided game formats are characterised by increased technical actions, longer ball possession phases, and a lower occurrence of high-intensity running, which may translate into a lower perceived temporal pressure (Nunes et al., 2024; Yılmaz & Soylu, 2024). In the comparison between SSG3 and HIIT protocols no significant differences were found in mean or peak HR values. However, SSG3 elicited a lower perception of effort, exertion, physical demand and a higher mental demand compared to the HIIT, aligning with previous findings in soccer literature (Impellizzeri et al., 2004; Selmi et al., 2018). Thus, technical sessions appear to impose a similar physical demand like the HIIT, but with a lower perceived exertion.

Similarly, pre-post MTDS monitoring revealed that perception of fatigue and stress of the day post-treatment were significantly higher following HIIT protocol compared with both FSG6 and SSG3. In line with this pattern, vigour (typically negatively associated with fatigue) and perceived sleep quality showed the lowest ratings after HIIT relative to the two game-based protocols. These differences in the psychological state are consistent with findings reported by Selmi et al. (2018) in soccer players when comparing HIIT and SSG-based training. In contrast, physical symptoms were significantly lower following

FSG6 compared with both HIIT and SSG3. Taken together, these findings suggest that game-based training sessions (SSG3 or FSG6) appear to be preferable when the aim is to minimise residual fatigue and stress on the day following training, potentially facilitating recovery through concurrent enhancements in vigour and psychological readiness. Post-session assessment the NASA-TLX questionnaires further revealed significant differences in mental demands across the three protocols. As expected, the HIIT protocol elicited significantly lower mental demand than SSG3, which in turn was significantly lower than FSG6. Accordingly, when the primary goal of a session is to minimise cognitive load or mental effort, an HIIT-based protocol may be most appropriate.

Conversely, perceived effort and physical demand were significantly lower in FSG6 than in SSG3, and lower in SSG3 than in HIIT. This pattern aligns with the HR and sRPE results reported above, indicating a clear inverse relationship between physical and mental workload across the training modalities. Temporal demand also significantly differed for the FSG6 protocol compared with the other two conditions. Collectively, these findings highlight the need for further research to more precisely delineate the interplay between physical and psychological demands in these commonly employed conditioning methods for elite handball players.

5. Limitations

Several limitations of this study should be acknowledged. First, the sample comprised 11 elite male outfield players. While this sample size is typical in high-performance sport settings, it inevitably restricts statistical power and may limit the generalisability of the findings. To strengthen the interpretation of the results despite the small sample, effect sizes (partial eta squared) were reported alongside p-values.

Second, the study did not include objective measures of sleep quality or external stressors. Although the MTDS questionnaire offers a comprehensive subjective assessment of athletes' perceived states, it does not capture these factors through objective monitoring methods. This limitation should be taken into account when interpreting the reported perceptual responses.

Finally, data were collected within a single elite team operating under a specific training methodology and competitive context. As such, the findings should be interpreted with caution, as contextual and organisational factors may differ across teams, leagues, or performance environments.

6. Practical application

In a practical sport-training context, the findings of this psychophysiological study can help coaches and sport scientists prescribe and balance commonly used conditioning methods more effectively within their training plans. Specifically, when aiming to elicit a highly intense session, coaches may employ either HIIT or SSG3, as both produce comparable mean and peak HR responses. Nevertheless, their perceptual outcomes differ substantially: SSG3 sessions are experienced as less demanding in terms of sRPE, NASA Physical, and NASA Effort compared with HIIT. Thus, when the objective is to maximise physiological (objective) internal load while minimising perceived (subjective) internal load and training effects, SSG3 appears to represent the most efficient option. By contrast, FSG6 elicits the highest mental demand of all three protocols, reflecting its greater tactical and cognitive complexity with reduced physiological demand. Similar patterns have been observed in soccer, where SSG3 formats produced higher physical demands than SSG6 (Asín-Izquierdo et al., 2024). Therefore, practitioners can periodise these three training modalities during the "one game per week" in-season microcycle: HIIT and SSG3 in central days between the two matches and FSG6 closer to the subsequent match. Moreover, when competing in congested periods with two games per week, FSG6 could be an interesting option to work tactically avoiding an increase in physical fatigue.

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