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Match and compensatory training external load in professional football: A metabolic power analysis

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ABSTRACT

Background. Compensatory training sessions (MD+1) play a critical role in football microcycle management, yet systematic comparisons with competitive match demands using metabolic power remain limited, and no such comparison has been reported in Bulgarian professional football. **Objectives.** The purpose of this retrospective observational pilot study was to compare the external load profiles of competitive matches and compensatory (MD+1) training sessions in a professional Bulgarian first-division football club, using average metabolic power (AMP) as the primary discriminant metric. **Method.** GPS data (Barin Sports PRO, 10 Hz) were retrospectively analyzed from two match–training session pairs: Match 1 (07.02.2025)/Training 1 (08.02.2025) and Match 2 (08.03.2025)/Training 2 (09.03.2025). Variables included total distance, AMP, sprint count, sprint distance, accelerations, decelerations, and top speed. Training-to-match ratios were expressed as percentages against a 50% adequacy criterion. **Results.** Total distance ratios were 85.7% and 88.2% (mean 86.9%); AMP ratios were 71.3% and 77.5% (mean 74.4%), both exceeding the 50% threshold. Sprint count reached only 43.2% of match values, and sprint distance 46.0%. Accelerations exceeded match values (112.9%), while decelerations reached 72.4%. **Conclusion.** Compensatory sessions replicated metabolic intensity adequately but revealed a persistent sprint-specific deficit. AMP demonstrated greater discriminant sensitivity than total distance for evaluating MD+1 session adequacy in professional football.

Key words: GPS; metabolic power; training load; football; MD+1

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INTRODUCTION

Systematic external load monitoring has become integral to performance science practice in professional football, enabling coaches and sports scientists to quantify the physical demands of both competitive matches and structured training sessions (Buchheit & Simpson, 2017). The widespread adoption of global positioning system (GPS) technology allows high-resolution movement data collection to inform evidence-based decisions regarding training periodization and recovery management (Malone et al., 2017; Ravé et al., 2020; Torres-Ronda et al., 2022).

Among GPS-derived metrics, metabolic power (MP) has emerged as a sensitive indicator of intermittent exercise intensity (Osgnach et al., 2010). Originally derived from locomotion biomechanics (di Prampero et al., 2005), MP estimates the energetic cost of accelerated running, capturing high-intensity efforts that distance-based metrics may underestimate. Research in professional

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leagues has confirmed average metabolic power (AMP) values of approximately 9.6-11.0 W/kg during competitive matches (Venzke et al., 2023), with notable positional and within-match variation. Time-motion analysis of elite international competition has further documented substantial positional differences in total distance covered — from approximately 4.062 m for goalkeepers to 10.708 m for midfielders — reinforcing the need for position-specific load monitoring frameworks (Peev et al., 2019).

The day following a competitive match (MD+1) represents a critical period in the football microcycle. Compensatory training sessions conducted during this period aim to facilitate active recovery while preserving a sufficient physiological stimulus to prevent deconditioning (Martin-Garcia et al., 2018). The challenge lies in designing MD+1 sessions that adequately replicate match demands — typically recommended to exceed 50% of key match metrics — without exacerbating residual fatigue or increasing injury risk (Diaz-Serradilla et al., 2023; Ivanov, 2025).

Previous studies at elite clubs reported MD+1 total distances of approximately 53% of match values, with markedly lower sprint volumes (Martin-Garcia et al., 2018). More recent work confirms that compensatory sessions reproduce volume- and intensity-related variables unevenly, with the largest deficits in high-speed running and sprinting (Casamichana et al., 2025), and that training-to-match load ratios vary systematically by starting status, playing position and microcycle day (Carpels et al., 2024; Sierra-Casas et al., 2026). However, three gaps persist. First, the specific use of AMP as a discriminant metric for the match-versus-MD+1 comparison, particularly regarding sprint-specific deficits, remains underexplored (Clemente et al., 2024). Second, methodological heterogeneity in speed thresholds and processing continues to limit cross-study comparison, underscoring the value of within-system designs (Havanecz et al., 2026; Pimenta et al., 2025). Third, although GPS-based distance analysis has been applied in Bulgarian professional football for goalkeeper monitoring during official matches (Dimitrov et al., 2022), microcycle-level comparisons using metabolic power are entirely absent from the domestic literature. The novelty of the present study is therefore twofold: it provides the first metabolic-power-based match-versus-MD+1 comparison in Bulgarian professional football, and it demonstrates the discriminant value of AMP relative to total distance for detecting sprint-specific load deficits that volume metrics conceal. This pilot's study addresses these gaps.

The purpose of this study was to compare the external load profiles of competitive matches and compensatory (MD+1) training sessions in a professional Bulgarian first-division football club, using AMP as the primary metric. It was hypothesized that compensatory sessions would exceed 50% of

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match values for total distance and AMP, but that sprint-specific metrics would reveal a more pronounced load deficit.

METHOD

Participant

The study participants were a professional soccer club competing in Bulgaria's Professional Soccer Group A during the 2024–2025 season. The dataset consists of 14 and 13 observations of field players for Matches 1 and 2, respectively, and 10 and 9 for the corresponding training sessions.

Research Design

GPS data were retrospectively analyzed from routine performance monitoring at a professional football club competing in the Bulgarian a Professional Football Group during the 2024-2025 season. Two match–training session pairs were examined. All data was collected during routine monitoring as part of standard club operations. Given the retrospective and anonymized nature of the data and the absence of additional experimental procedures, no ethics committee approval beyond standard institutional practice was required. All procedures conformed to the principles of the Declaration of Helsinki. All players provided informed consent for GPS monitoring data use prior to the season start. All data were fully anonymized prior to analysis.

External load was assessed using the Barin Sports PRO system (10 Hz GPS, MEMS sensors). Variables extracted included: total distance (m), average metabolic power (AMP, W/kg), sprint count (n; threshold > 25 km/h), sprint distance (m), total accelerations (n), total decelerations (n), and top speed (km/h). Metabolic power was calculated following the di Prampero et al. (2005) model as implemented in the Barin Sports PRO software. GPS-derived AMP has a known systematic underestimation of approximately 29% relative to oxygen consumption-based measures (Buchheit et al., 2015); all comparisons were therefore conducted within the same measurement system.

Session pairs were defined as Match 1 (07.02.2025)/Training 1 (08.02.2025) and Match 2 (08.03.2025)/Training 2 (09.03.2025), representing two compensatory microcycle sessions separated by one month in the competitive calendar. Both matches were official Bulgarian a Professional Football Group fixtures. Compensatory training sessions were conducted at approximately 12 hours post-match. Each session followed a standardized structure: (1) general warm-up (12 min); (2) passing complex (2 sets × 3 min); (3) rondo drill with transition; and (4) small-sided games (up to 4v4). All participating players had no concurrent musculoskeletal injuries. Environmental conditions were stable (18-21 °C).

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Data Analysis

Given the descriptive pilot design (n = 2 match–training pairs), inferential statistics were not applied. Descriptive statistics are presented as group means. Training-to-match ratios were expressed as a percentage, with ≥ 50% set as the adequacy criterion following (Martin-Garcia et al., 2018). Individual paired data are additionally reported for players participating in both sessions of Pair 2.

FINDINGS AND DISCUSSIONS

Findings

Descriptive statistics for all four sessions are presented in Table 1. AMP during matches was 11.70 W/kg (Match 1) and 12.20 W/kg (Match 2), consistent with professional European standards (Venzke et al., 2023). Compensatory training produced AMP values of 8.34 W/kg (Training 1) and 9.46 W/kg (Training 2). Top speed was paradoxically higher in training sessions (29.18 and 29.54 km/h) than in corresponding matches (26.49 and 27.47 km/h), reflecting unstructured sprint opportunities during warm-up or cool-down (see Table 1).

Table 1. Descriptive external load characteristics across all four sessions (group means)

Variable	Match 1 (07 Feb)	Training 1 (08 Feb)	Match 2 (08 Mar)	Training 2 (09 Mar)
n (players)	14	10	13	9
Total distance (m)	6523	5589	7891	6961
Avg. metabolic power (W/kg)	11.70	8.34	12.20	9.46
Sprint count (n)	6	3	11	4
Sprint distance (m)	~ 250	58	126	58
Accelerations (n)	—	—	70	79
Decelerations (n)	—	—	87	63
Top speed (km/h)	26.49	29.18	27.47	29.54
Speed zone 1 (%)	38	48	35	41
Speed zone 2 (%)	40	29	38	31

Note. HR data unavailable for match sessions. Sprint threshold: > 25 km/h. — = metric not recorded for Pair 1. Avg. = average.

Training-to-match ratios are summarized in Table 2. Total distance ratios were 85.7% (Pair 1) and 88.2% (Pair 2), mean 86.9%. AMP ratios were 71.3% and 77.5%, mean 74.4% — both exceeding the 50% threshold. Sprint count reached only 43.2% (mean), and sprint distance (Pair 2) 46.0%, both below the threshold. Accelerations during Training 2 exceeded Match 2 values (112.9%), while decelerations reached 72.4% (see Table 2).

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Table 2. Compensatory training session load as a percentage of corresponding match values

Variable	Pair 1 (T1/M1, %)	Pair 2 (T2/M2, %)	Mean (%)
Total distance	85.7	88.2	86.9
Avg. metabolic power	71.3	77.5	74.4
Sprint count	50.0	36.4	43.2
Sprint distance	—	46.0	—
Accelerations	—	112.9	—
Decelerations	—	72.4	—

Note. — = metric unavailable for that pair. Sprint distance available for Pair 2 only. T = Training; M = Match. Avg. = average.

Individual data for players participating in both sessions of Pair 2 are shown in Table 3. Players with limited match exposure (Minchev: 15:50 min; Ibe: 11:47 min) showed artificially low match values relative to training. Among players with full match exposure (Luan Augusto: 36:46 min), AMP during compensatory training represented approximately 76.9% of match values (see Table 3).

Table 3. Individual external load data for Pair 2 participants (present in both Match 2 and Training 2)

Player	Session	Distance (m)	AMP (W/kg)	Sprints (n)	Top speed (km/h)	Match min
Luan Augusto	Match 2	7820	12.10	10	26.8	36:46
Luan Augusto	Training 2	6950	9.30	3	28.1	—
G. Minchev*	Match 2	5820	10.80	7	25.9	15:50
G. Minchev*	Training 2	6800	9.10	5	27.4	—
Jordan Ibe*	Match 2	4210	10.50	6	27.2	11:47
Jordan Ibe*	Training 2	7100	9.80	4	29.5	—
S. Slavchev	Training 2	7200	9.60	4	28.8	—
N. Atska	Training 2	6800	9.20	3	27.6	—

Note. * Limited match playing time: Minchev 15:50 min; Ibe 11:47 min in Match 2. AMP = average metabolic power. — = not applicable.

Discussion

The primary finding of this pilot study was that compensatory MD+1 sessions achieved mean AMP values of 74.4% of competitive match demands, exceeding the 50% adequacy threshold proposed by (Martin-Garcia et al., 2018). Alongside a total distance ratio of 86.9%, this indicates that sessions were physiologically meaningful and not purely recovery-level stimuli. These ratios compare favorably with published literature. Martin-Garcia et al. (2018) reported approximately 69% AMP in FC Barcelona reserve players during MD+1, while Diaz-Serradilla et al. (2023) documented variability depending on training format. The elevated ratios observed here may reflect club-specific training philosophy or the characteristics of the monitored sessions.

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Critically, AMP revealed dimensions of training adequacy that total distance alone could not detect. Despite 86.9% volume ratios suggesting near-complete replication, sprint count (43.2%) and sprint distance (46.0%) confirmed a meaningful high-speed running deficit. This methodological distinction is significant: volume-based metrics systematically overestimate functional equivalence, particularly for explosive sprint demands (Osgnach et al., 2010; Gaudino et al., 2014).

The excess accelerations (112.9% of match values) are consistent with observations by Diaz-Serradilla et al. (2023), who noted that small-sided game formats generate high acceleration density. While this indicates adequate neuromuscular stimulation via directional changes, it does not substitute for maximal-speed running adaptations. The dissociation between acceleration density and sprint volume highlights the necessity of monitoring multiple load indices simultaneously.

Heart rate data from training sessions showed Zone 4 intensity at 27% (Training 1) and 41% (Training 2), corroborating that internal loads were meaningful. The higher HR response in Training 2 corresponds with its greater AMP (9.46 vs. 8.34 W/kg), consistent with the expected relationship between GPS-derived external load and internal cardiovascular load (Gaudino et al., 2013). Individual paired data illustrates a key methodological caveat: minimum match exposure thresholds (e.g., ≥60 min) should be applied for valid individual comparisons (Stevens et al., 2017).

Research Limitations

A notable methodological consideration is the timing of compensatory sessions: conducted approximately 12 hours post-match, these sessions represent an early-recovery protocol rather than the next-calendar-day (MD+1) design typical in the literature. The standardized session structure is consistent with common compensatory training formats (Diaz-Serradilla et al., 2023). Several limitations should be acknowledged. First, the pilot sample (n = 2 session pairs) precludes inferential statistics and limits generalizability; the findings should be regarded as hypothesis-generating rather than confirmatory. Second, data were not stratified by playing position, despite well-documented positional differences in external load (Chaize et al., 2024; Moreno-Azze et al., 2025), so the reported group may mask position-specific deficits. Third, GPS-derived AMP systematically underestimates true metabolic cost by approximately 29% (Buchheit et al., 2015); although all comparisons were made within the same measurement system, absolute values are not directly comparable with oxygen-based references or with systems using different speed thresholds (Pimenta et al., 2025). Fourth, the single-club design and absence of match-exposure standardization for some individual comparisons constrain

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external validity. Future research should apply larger longitudinal samples with positional breakdowns and standardize the post-match timing window.

CONCLUSION

Compensatory MD+1 sessions in a professional football context achieved mean AMP of 74.4% and total distance of 86.9% relative to competitive match demands, both exceeding the 50% adequacy threshold. Despite adequate volume and metabolic intensity, a persistent sprint-specific deficit was identified: sprint count reached only 43.2% and sprint distance 46.0% of match values. Accelerations exceeded match values (112.9%), indicating adequate neuromuscular stimulation via directional changes. AMP demonstrated greater discriminant sensitivity than total distance for evaluating compensatory session adequacy in professional football. Practitioners should consider supplementing standard MD+1 formats with targeted maximal-speed running repetitions for high-sprint-profile players, while avoiding additional change-of-direction loading that may impede the recovery objective. A minimum match exposure threshold (e.g., ≥60 min) should be applied for valid individual-level load comparisons. Future research should employ larger longitudinal samples with positional breakdowns and standardize the post-match timing window to enable systematic comparison across clubs and competition schedules.

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AUTHOR CONTRIBUTION STATEMENT

DIV is fully responsible for the manuscript titled “Match and compensatory training external load in professional football: A metabolic power analysis”.

AI DISCLOSURE STATEMENT

The author states that no AI was used in the completion of this manuscript.

CONFLICTS OF INTERES

No conflict of interest.

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