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Research article

Exploring The Physiological and Physical Basis of RPE Responses in Soccer: A Comparative Analysis of Internal and External Load Determinants Across Different Training Drills

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Abstract

This study investigated the relationships between Rate of Perceived Exertion (RPE) and various objective internal and external training load measures across multiple drill types in youth academy soccer players, a comparative approach that has been rarely examined. Forty-six male outfield soccer players (16.3 ± 0.4 years) from two under-17 academy-level teams competing in a city-level league, training three times per week with weekend matches, were monitored over two weeks during regular training. Data included RPE (CR-10 scale), heart rate responses (HRaverage, HRmax), and external load variables (total distance per minute, average speed, distance in Z4 [15 - 19 km/h], and Z5 [>19 km/h]) via Polar Team Pro, measured across all drills (3v3, 6v6, 9v9, 11v11, 10x5 positional game, repeated sprint training, muscular endurance circuit training, and slalom exercise). Aerobic capacity (VIFT) was assessed separately using the 30 - 15 IFT. Results indicated that RPE consistently showed large positive correlations with HRaverage (e.g., 3v3: r = 0.977) and HRmax (e.g., 3v3: r = 0.778) across most drills, Conversely, relationships between RPE and the VIFT were varied, showing large negative correlations in larger-sided games (e.g., 11v11: r = -0.446; 9v9: r = -0.585), suggesting fitter players perceived less effort. Correlations between RPE and general distance/speed metrics were inconsistent, while distances covered in high-intensity speed zones (Z4, Z5) showed large positive correlations with RPE (e.g., 3v3 Z4: r = 0.830; 3v3 Z5: r = 0.710), particularly in drills like 3v3, 6v6, repeated sprint training, and slalom. In conclusion, RPE's relationship with training load is drill-specific. It possibly reflects physiological strain in small-sided games and conditioning drills, but shows more variable associations with external load and fitness in large-sided or tactical formats. Coaches should therefore combine RPE with objective metrics and interpret it in light of drill characteristics. These findings should be viewed cautiously given the short two-week monitoring period and absence of additional physiological markers.

Key words: Football, training load monitoring, effort, small-sided games, high-intensity interval training, circuit training.

Introduction

The Rate of Perceived Exertion (RPE), most commonly assessed with Borg's CR10 scale (Borg, 1982), provides a simple, low-cost tool for quantifying athletes' perceived intensity. Although widely validated against physiological markers (e.g., heart rate, blood lactate) (Melloh et al., 2012), its utility in soccer is debated because drill-specific demands can influence how players perceive exertion. Although the CR10 scale is validated against cardiovascular responses such as heart rate (Borg et al., 2010), it also integrates muscular fatigue, breathlessness, and psychological strain, making it a multidimensional construct. This perspective aligns with theoretical frameworks such as the psychobiological model, which views RPE as an effort-based, decision-making signal shaped by motivation, fatigue, and task appraisal (Marcora and Staiano, 2010), and the central governor framework, which posits that perceived exertion reflects a brain-mediated regulation to preserve homeostasis (Noakes, 2012). Beyond physiology, RPE can also be shaped by psychological factors (e.g., motivation, attentional focus, stress), tactical elements (e.g., positional roles, team strategy), and contextual influences (e.g., opponent quality, match vs. training setting, or specific drill constraints) (García-Calvo et al., 2021). In soccer, this multidimensionality is particularly relevant because players' perceived effort may be influenced not only by cardiovascular load but also by neuromuscular demands, tactical roles, and drill-specific external loads (Little and Williams, 2007; Marynowicz et al., 2020).

Research on RPE in soccer training shows mixed results regarding its utility and relationship with other intensity measures. While some studies found RPE to be a valid marker of exercise intensity across various training drills (Little and Williams, 2007), others reported no conclusive evidence supporting the use of differential RPE for monitoring internal load, since seems not vary consistently between different football training drill types (Houtmeyers et al., 2022). These discrepancies may arise from differences in drill type, the methods used to quantify RPE (overall vs. differential ratings), and the populations studied (youth vs. elite players), making it unclear under which conditions RPE best reflects training load.

The relationship between RPE and heart rate (HR) measures varies depending on the type of training session, with some studies finding large to very large correlations in certain drills (Campos-Vazquez et al., 2015). In detail, in professional soccer training, internal training load varied substantially across session types, with the highest loads in skill drills/circuit training + small-sided games and ball-possession games + technical-tactical exercises, and while strong correlations were found between different heart rate-based (HR) measures, only variable-to-very large relationships existed between sRPE and HR-derived measures, highlighting the need for caution when using these measures interchangeably. Thus, caution is advised when using RPE and HR measures interchangeably, as

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their relationship can be inconsistent across different training types (Campos-Vazquez et al., 2015).

One possible cause of the inconsistencies mentioned above is that RPE may capture information not only related to internal load but also to external load, and it can vary depending on each player's specific involvement in a given drill. For instance, a previous study (Zurutuza et al., 2019) showed that training intensity in soccer can be explained by neuromuscular, cardiovascular, and locomotor components, with each drill format emphasizing different demands. While this highlights the complexity of training load, it remains unclear how these objective measures translate into players' subjective perceptions of exertion. Therefore, a clearer understanding of how RPE relates to both internal (e.g., heart rate) and external (e.g., distance, high-speed running) load across different drill types is still needed.

Despite the growing availability of GPS and heart rate monitoring technologies, such resources are not universally accessible, especially for youth teams and under-resourced clubs that lack both equipment and staff expertise (Bokůvka et al., 2025). In these contexts, RPE remains a practical, low-cost alternative. Although the present study (Bokůvka et al., 2025) used GPS and HR monitors to provide objective benchmarks, this was precisely to evaluate how well RPE reflects training load when such technologies are available, thereby clarifying its utility for settings where only RPE can be applied. While RPE is commonly used to assess the overall load of an entire training session - typically calculated as the product of session duration and perceived exertion (Haddad et al., 2017) - coaches increasingly recognize the importance of evaluating the intensity of specific drills. This drill-level insight is essential for adjusting training stimuli effectively. However, since RPE can be influenced by both internal and external load parameters, depending on the nature of the activity (Beato et al., 2023), it becomes crucial to better understand the specific contributions of these parameters in different types of training drills. Prior research (Nijland et al., 2024; Xu et al., 2025) has typically addressed RPE-load correlations in isolated contexts (e.g., single drill types, match play, or adult/professional players). What remains unclear is whether these associations hold consistently across multiple drill formats in youth academy players, and how RPE relates simultaneously to both internal and external load indicators as well as fitness. Such knowledge can help coaches identify which demands contribute most to perceived exertion and adapt training plans accordingly for optimal performance and development.

Therefore, the aim of this study is to compare RPE across different types of soccer training drills - small-sided games, analytical drills, and friendly matches - and to identify the internal (e.g., heart rate-based measures) and external (e.g., total distance, high-speed running, acceleration counts) load variables that most strongly explain variations in RPE, as well as, physical fitness parameters.

Methods

Study design

This study employed a descriptive repeated-measures design in which soccer players were monitored during their regular training routines to assess specific training load demands associated with various types of drills commonly used in soccer. The monitoring period lasted two consecutive weeks, during which researchers collected data on heart rate responses, external load variables, and perceptual effort scores during the selected exercises. To enhance the representativeness and generalizability of the findings, the study was conducted across two teams competing at the same level. Drills were performed repeatedly by the same team (at least twice) and were comparable across both teams. The study was conducted during the early part of the competitive season.

Participants

A total of 46 male outfield soccer players were included in the study. The participants had a mean age of 16.3 ± 0.4 years, a mean height of 1.71 ± 0.09 meters, a mean weight of 63.2 ± 2.7 kilograms, and an average of 3.6 ± 1.1 years of experience in soccer. The players competed in a city-level under-17 league and can be considered academy-level athletes. Both teams trained three times per week (70–90 min per session) and played weekend matches, representing a moderate weekly training volume.

Players were included if they met the following criteria: they participated in all scheduled monitoring sessions, had been part of the team since the beginning of the season, and were not injured or affected by any health conditions at the time of the study. Participants were excluded if they were goalkeepers or if they missed any of the analyzed training sessions. Goalkeepers were excluded because their physical and physiological demands differ substantially from outfield positions, with lower locomotor loads and distinct technical/tactical requirements (White et al., 2020).

The study involved two teams competing at the same category and competitive level in a city-level under-17 male soccer league. Both teams trained three times per week and took part in weekend competitions. Their training routines were similar in structure and varied in duration from 70 to 90 minutes per session, depending on the day.

Before the study began, both players and their parents were informed about its purpose and the procedures involved. Once both parties agreed to participate, the parents signed a written informed consent form in which all procedures were clearly described. The study was approved by the Ethics Committee of of Chengdu Sport University, receiving the approval code (2025)135.

Exercises monitored

Although there is no established framework for classifying types of exercises, to the best of our knowledge, we have referred to previous studies that implemented various classification systems. For example, in a basketball study (Sosa et al., 2025), the authors categorized drills based on the format of play, but they did not include analytical exercises conducted during the strength and conditioning phase of training. In Australian football (Loader et al., 2012), drills were classified as game-specific, skill-refining, and competitive gameplay; however, this approach also excluded exercises focused purely on physical conditioning. In soccer, one study (Gonçalves et al., 2022) proposed categories such as warm-up, small-sided games, positional games, real-game simulations, fitness exercises, large-sided games, and technical drills. Despite these efforts, no established or standardized classification currently exists. Therefore, we proposed our own classification framework, which was evaluated by two independent experts - both experienced coaches and researchers in soccer. After incorporating their feedback, the final classification included four main categories: (1) game-specific drills, including one small-sided game, one medium-sided game, and one large-sided game; (2) skill refinement exercises, including slalom drill and one positional exercise; (3) competitive gameplay, represented by a friendly match on a regular-sized field; and (4) specific conditioning exercises, including one high-intensity interval running session and one muscular endurance circuit.

The drills presented in Table 1 were preceded by a typical team warm-up consisting of 10 minutes of low-intensity jogging followed by 10 minutes of dynamic lower limb stretching. In Training Session 1, which took place on Tuesday, the players performed a slalom drill after the warm-up, followed by a 3v3 small-sided game five minutes later. After another five minutes, they completed a muscular endurance circuit. In Training Session 2, held on Thursday, the players started with a 6v6 format game after the warm-up, followed by a five-minute rest, and then performed a high-intensity interval training drill. After another five-minute rest, they played an 11v11 competitive game. During Training Session 3, following the warm-up, the players engaged in a position game, and after a five-minute rest, completed a 9v9 format game.

Monitoring measurements

In the week prior to the start of the monitoring process during training drills, the players performed an aerobic capacity test. This variable was considered a potential influencer of the physical load demands imposed by the drills. Subsequently, monitoring instruments - including both RPE and measures of internal and external load - were continuously recorded for each observed drill. All internal and external load measures were standardized relative to the duration of each drill to allow for fair comparisons of intensity across different training tasks.

The monitoring procedures were carried out by a consistent team of researchers, each maintaining fixed responsibilities to ensure methodological consistency. Before each training session, players were equipped with the appropriate monitoring devices. Based on the training plan, clear time markings were used in the application to identify the beginning and end of each drill within the data collection systems. Following the completion of each drill, and specifically five minutes afterward, individual RPE values were collected using standardized forms.

Rate of perceived exertion (RPE)

The CR-10 Borg Scale was used to assess perceived exertion during the drills. The scale ranges from 0 to 10, where

Table 1. Description of the training drills monitored over the two weeks (the same drills were used in both weeks), organized by category and specific drill evaluated.

Categories	Training session 1	Training session 2	Training session 3
Game-specific drills	3v3 format, played at 30x20m (100 m2/player) in 2 sets of 4 minutes interspaced by 2 minutes rest. No Goalkeepers and objective of scoring in small-goals.	6v6 format, played at 45x27m (101 m2/player) in 2 sets of 4 minutes interspaced by 2 minutes rest. No Goalkeepers and objective of scoring in small-goals.	9v9 format, played at 51x35m (99 m2/player) in 2 sets of 4 minutes interspaced by 2 minutes rest. No Goalkeepers and objective of scoring in small-goals.
Skill refinement	The slalom dribble drill, as described in a previous study (Stone and Oliver, 2009), was performed in 2 sets of 4 consecutive minutes each.	No	A positional game was conducted in which 5 players followed the ball's movement across the space without actively attempting to recover it from 10 opposing players. The objective was for the team in possession to reach a designated target and return. The drill was performed in three sets of 5 minutes each.
Competitive game play	No	A formal 11v11 match, played on a regulation field with goalkeepers, was conducted in two halves of 10 minutes each.	No
Conditioning exercises	The muscular circuit training consisted of 15 squats performed at a pace of 1 second per phase, followed by 15 plank with alternating leg lifts at the same tempo. This was followed by 8 Bulgarian split squats per leg, also performed at a pace of 1 second per phase, and then 15 jump squats executed at maximum effort. A 15-second rest was given between each exercise, and the players completed two full sets of the entire circuit.	Two sets of five repetitions of repeated sprint training were performed at maximum speed over 20 meters in a straight line, with 20 seconds of rest between each sprint.	No

0 represents "no effort at all" and 10 corresponds to "maximal effort." Verbal anchors were provided to help players accurately gauge their exertion levels, including descriptors such as “light” (2), “moderate” (3), “hard” (5), “very hard” (7), and “extremely hard” (10). Each player individually rated their perceived effort five minutes after completing each drill. It was implemented a short, fixed delay to allow athletes to integrate cardiovascular and neuromuscular sensations while minimizing ‘end-spurt’ effects and logistical interference with drill transitions. Importantly, the timing of post-exercise RPE is temporally robust, since studies in trained individuals report no meaningful differences across post-exercise sampling windows from 5 to 24 h (including 5, 10, 15, 20, 25, 30 min) and across immediate vs 30 min vs 7 h when athletes are familiarized (Christen et al., 2016; Castagna et al., 2017). Ratings were provided on a specific form distributed by the researchers, ensuring confidentiality in responses. These subjective measures of effort were then collected and recorded for further analysis.

Internal and external load

The Polar Team Pro system was used to monitor both internal (cardiovascular) and external (locomotor) loads during the drills. Each athlete was equipped with a Polar Team Pro sensor, which integrates GNSS (Global Navigation Satellite System) technology operating at a sampling frequency of 10 Hz for positional tracking, and a heart rate sensor with a recording frequency of 1 Hz. This dual-sensor system enables the collection of detailed real-time data on physical performance and physiological responses, and has been previously validated for accurately measuring external load demands (Akyildiz et al., 2022). The following outcomes were extracted: average heart rate (HRaverage, bpm), maximum heart rate (HRmax, bpm), total distance covered per minute (m/min), average speed (km/h), as well as high-intensity locomotor metrics including distance per minute covered in Zone 4 (Z4: 15.0 - 18.99 km/h) and Zone 5 (Z5: >19.0 km/h). The data were later downloaded and analyzed, per each drill.

Aerobic capacity

The 30 - 15 Intermittent Fitness Test (30 - 15 IFT) was conducted on an outdoor synthetic field. Prior to the test, players underwent a standardized warm-up including dynamic mobility drills, submaximal accelerations, and short changes of direction. The test consisted of 30-second shuttle runs separated by 15 seconds of passive recovery. Players ran back and forth over a 40-meter distance, turning at each end upon audio cues delivered by a pre-recorded soundtrack played through a speaker system. The running speed began at 8.0 km/h and increased by 0.5 km/h every 45-second stage. Each player was required to touch or cross the 3-meter zone line at each end of the 40-meter track in synchronization with the audio signal. If a player failed to reach the 3-meter zone for two consecutive shuttles, the test was terminated for that individual. The main variable collected was the final velocity attained at exhaustion (VIFT, in km/h), which reflects the player’s aerobic capacity to perform intermittent high-intensity efforts.

Statistical analysis

For each drill, training load measures and RPE were collected and analyzed to explore potential correlations, including the incorporation of VIFT values in the analysis. The normality of the data was assessed using the Shapiro-Wilk test, which confirmed that the outcome variables were normally distributed ($p > 0.05$). Subsequently, Pearson’s product-moment correlation tests were performed for each drill to examine the relationships between RPE and the other variables specific to that drill. The magnitude of the correlations was interpreted using the following thresholds: trivial ($r < 0.1$), small ($0.1 \leq r < 0.3$), moderate ($0.3 \leq r < 0.5$), large ($0.5 \leq r < 0.7$), and very large ($r \geq 0.7$). All statistical analyses were conducted using SPSS version 27.0, with a significance level set at $p \leq 0.05$. In addition to Pearson correlations, it were conducted complementary linear mixed-effects models (LMMs) to account for repeated measures within players. The dataset was reshaped to long format (player × drill), with RPE as the dependent variable. Predictors (internal and external load metrics, VIFT) were standardized. Models included a random intercept for player and fixed effects for drill. We first fit univariable LMMs for each predictor, then a parsimonious multivariable model including HRaverage, Z4, Z5, and VIFT to reduce collinearity. Estimates (β), 95% confidence intervals, and p-values were reported.

Results

Table 2 presents the mean and standard deviation for each monitored measure across the different soccer drills.

Table 3 details the Pearson correlation coefficients (r), their 95% Confidence Intervals (95% CI), and p-values (p) for the relationship between various training measures and RPE across eight different drills. The 30 - 15IFT exhibited varied correlations with RPE across drills; a small-to-moderate positive correlation was observed during the 3v3 format ($r = 0.363$, 95% CI [0.077, 0.583], $p = 0.013$), while conversely, a large negative correlation was found with RPE in the 11v11 format ($r = -0.446$, 95% CI [-0.649, -0.174], $p = 0.002$) and the 9v9 format ($r = -0.585$, 95% CI [-0.745, -0.349], $p < 0.001$). Other drills, including the 10x5 positional game ($r = 0.260$, $p = 0.081$), repeated sprint training ($r = 0.017$, $p = 0.909$), muscular endurance circuit training ($r = -0.027$, $p = 0.857$), 6v6 format ($r = 0.106$, $p = 0.483$), and slalom exercise ($r = 0.039$, $p = 0.795$), showed trivial or small, non-significant correlations with RPE, indicating limited practical relevance.

Heart rate average (HRaverage) consistently showed large-to-very large positive correlations with RPE across most drills, indicating that higher average heart rates are strongly associated with higher perceived exertion. Large and highly significant positive correlations were evident in the 3v3 format ($r = 0.977$, 95% CI [0.957, 0.987], $p < 0.001$), muscular endurance circuit training ($r = 0.968$, 95% CI [0.941, 0.982], $p < 0.001$), 6v6 format ($r = 0.975$, 95% CI [0.959, 0.984], $p < 0.001$), and slalom exercise ($r = 0.951$, 95% CI [0.910, 0.972], $p < 0.001$). Large positive correlations were also seen in repeated sprint training ($r = 0.599$, 95% CI [0.368, 0.755], $p < 0.001$), 11v11 format

Table 2. Mean and standard deviation (SD) for each monitored measure across the different soccer drills.

Measure (Unit)	3v3 Format	6v6 Format	9v9 Format	11v11 Format	10x5 Positional Game	Repeated Sprint Training	Muscular Endurance Circuit	Slalom Exercise
VIFT (km/h)	15.41 ± 1.06	15.41 ± 1.06	15.41 ± 1.06	15.41 ± 1.06	15.41 ± 1.06	15.41 ± 1.06	15.41 ± 1.06	15.41 ± 1.06
HRaverage (bpm)	155.96 ± 16.53	167.65 ± 17.17	150.28 ± 3.30	142.11 ± 4.73	139.15 ± 7.00	183.43 ± 5.54	153.17 ± 7.86	165.89 ± 7.66
HRmax (bpm)	172.65 ± 17.89	183.74 ± 14.59	176.87 ± 2.57	165.30 ± 2.93	161.61 ± 6.60	202.20 ± 4.80	177.91 ± 8.06	181.93 ± 7.92
Distance per minute (m/min)	131.61 ± 23.70	97.83 ± 20.95	132.80 ± 7.17	106.37 ± 6.92	78.24 ± 9.35	118.07 ± 9.45	3.72 ± 1.49	97.43 ± 9.17
Average Speed (km/h)	8.16 ± 1.41	6.13 ± 1.31	7.84 ± 0.58	8.41 ± 0.49	5.22 ± 0.57	7.66 ± 0.95	0.22 ± 0.10	6.93 ± 0.74
Distance between 15.0 - 18.99 km/h (m/min)	19.91 ± 25.30	37.74 ± 25.52	25.41 ± 11.95	41.93 ± 6.82	21.15 ± 9.19	65.33 ± 10.55	0.04 ± 0.21	11.46 ± 8.37
Distance between >19.00 km/h (m/min)	3.72 ± 6.13	10.63 ± 13.23	18.87 ± 13.07	19.74 ± 13.39	5.57 ± 4.50	49.83 ± 9.98	0.00 ± 0.00	2.52 ± 2.49
RPE (0-10)	7.15 ± 0.91	6.20 ± 1.15	5.42 ± 0.60	5.58 ± 0.62	4.80 ± 0.73	8.83 ± 0.68	6.87 ± 1.17	7.13 ± 0.95

VIFT: final velocity at 30-15 intermittent fitness test; HR: heart rate; RPE: rate of perceived exertion; RST: repeated sprint training; *: significant correlation ($p < 0.05$).

Table 3. Correlation matrix (r-values and 95% confidence intervals) between RPE and the other training load variables and aerobic capacity across different drills.

Measure	RPE 10x5 positional game	RPE 3v3	RPE 6v6	RPE 9v9	RPE 11v11	RPE RST	RPE muscular endurance	RPE slalom
VIFT (km/h)	0.260 ([-0.036,0.509]), p = 0.081	0.363* ([0.077,0.583]), p = 0.013	0.106 ([-0.191,0.384]), p = 0.483	-0.585* ([-0.745,-0.349]), p < 0.001	-0.446* ([-0.649,-0.174]), p = 0.002	0.017 ([-0.275,0.306]), p = 0.909	-0.027 ([-0.315,0.265]), p = 0.857	0.039 ([-0.254,0.326]), p = 0.795
HRaverage (bpm)	0.244 ([-0.052,0.497]), p = 0.102	0.977* ([0.957,0.987]), p < 0.001	0.975* ([0.959,0.984]), p < 0.001	0.707* ([0.518,0.825]), p < 0.001	0.435* ([0.161,0.641]), p = 0.003	0.599* ([0.368,0.755]), p < 0.001	0.968* ([0.941,0.982]), p < 0.001	0.951* ([0.910,0.972]), p < 0.001
HRmax (bpm)	0.260 ([-0.036,0.509]), p = 0.081	0.778* ([0.624,0.869]), p < 0.001	0.880* ([0.789,0.931]), p < 0.001	0.450* ([0.179,0.652]), p = 0.002	0.066 ([-0.229,0.349]), p = 0.662	0.592* ([0.359,0.750]), p < 0.001	0.954* ([0.916,0.974]), p < 0.001	0.872* ([0.775,0.926]), p < 0.001
Distance/minute (m/min)	-0.196 ([-0.458,0.102]), p = 0.192	0.686* ([0.488,0.811]), p < 0.001	0.740* ([0.568,0.846]), p < 0.001	-0.305* ([-0.545,-0.013]), p = 0.039	-0.148 ([-0.419,0.150]), p = 0.325	0.231 ([-0.066,0.487]), p = 0.122	-0.060 ([-0.344,0.235]), p = 0.692	0.634* ([0.415,0.778]), p < 0.001
Average speed (km/h)	0.180 ([-0.104,0.445]), p = 0.231	0.698* ([0.504,0.820]), p < 0.001	0.737* ([0.562,0.844]), p < 0.001	-0.197 ([-0.459,0.102]), p = 0.190	-0.200 ([-0.462,0.098]), p = 0.183	0.051 ([-0.244,0.335]), p = 0.738	0.032 ([-0.261,0.319]), p = 0.834	0.598* ([0.366,0.754]), p < 0.001
Distance between 15.0 - 18.99 km/h (m/min)	0.173 ([-0.119,0.439]), p = 0.251	0.830* ([0.706,0.911]), p < 0.001	0.675* ([0.472,0.804]), p < 0.001	0.100 ([-0.197,0.380]), p = 0.510	-0.140 ([-0.412,0.158]), p = 0.354	0.582* ([0.347,0.744]), p < 0.001	0.116 ([-0.182,0.392]), p = 0.443	0.533* ([0.282,0.710]), p < 0.001
Distance between >19.00 km/h (m/min)	0.147 ([-0.151,0.418]), p = 0.330	0.710* ([0.523,0.827]), p < 0.001	0.406* ([0.127,0.620]), p = 0.005	0.086 ([-0.211,0.366]), p = 0.571	-0.141 ([-0.413,0.157]), p = 0.349	0.583* ([0.347,0.744]), p < 0.001	Not possible calculate	-0.138 ([-0.411,0.160]), p = 0.360

VIFT: final velocity at 30-15 intermittent fitness test; HR: heart rate; RPE: rate of perceived exertion; RST: repeated sprint training; *: significant correlation ($p < 0.05$).

($r = 0.435$, 95% CI [0.161, 0.641], $p = 0.003$), and 9v9 format ($r = 0.707$, 95% CI [0.518, 0.825], $p < 0.001$). The 10x5 positional game showed a small, non-significant positive correlation ($r = 0.244$, $p = 0.102$). Peak heart rate (HRmax) generally showed large positive correlations with RPE. Large and highly significant positive correlations were observed in the 3v3 format ($r = 0.778$, 95% CI [0.624, 0.869], $p < 0.001$), repeated sprint training ($r = 0.592$, 95% CI [0.359, 0.750], $p < 0.001$), muscular endurance circuit training (r = 0.954, 95% CI [0.916, 0.974], p < 0.001), 6v6 format (r = 0.880, 95% CI [0.789, 0.931], p < 0.001), and slalom exercise (r = 0.872, 95% CI [0.775, 0.926], p < 0.001). A moderate positive correlation was found in the 9v9 format (r = 0.450, 95% CI [0.179, 0.652], p = 0.002). The 10x5 positional game (r = 0.260, p = 0.081) and 11v11 format (r = 0.066, p = 0.662) showed small, non-significant correlations.

The correlation between distance covered per minute and RPE shows mixed results. Large positive correlations were observed in the 3v3 format (r = 0.686, 95% CI [0.488,0.811], p < 0.001), 6v6 format (r = 0.740, 95% CI [0.568,0.846], p < 0.001), and slalom exercise (r = 0.634, 95% CI [0.415,0.778], p < 0.001), suggesting that covering more distance per minute is associated with higher perceived exertion in these drills. A medium negative correlation was found in the 9v9 format (r = - 0.305, 95% CI [- 0.545, - 0.013], p = 0.039). Other drills, including the 10x5 positional game (r = - 0.196, p = 0.192), repeated sprint training (r = 0.231, p = 0.122), muscular endurance circuit training (r = - 0.060, p = 0.692), and 11v11 format (r = - 0.148, p = 0.325), showed small or trivial, non-significant correlations.

Similar to distance per minute, average speed correlations with RPE are varied. Large positive correlations were found in the 3v3 format (r = 0.698, 95% CI [0.504,0.820], p < 0.001), 6v6 format (r = 0.737, 95% CI [0.562,0.844], p < 0.001), and slalom exercise (r = 0.598, 95% CI [0.366,0.754], p < 0.001). Other drills including the 10x5 positional game (r = 0.180, p = 0.231), repeated sprint training (r = 0.051, p = 0.738), 11v11 format (r = - 0.200, p = 0.183), muscular endurance circuit training (r = 0.032, p = 0.834), and 9v9 format (r = - 0.197, p = 0.190) showed small or trivial, non-significant correlations.

Large positive correlations between Z4 and RPE were consistently observed in the 3v3 format (r = 0.830, 95% CI [0.706,0.911], p < 0.001), repeated sprint training (r = 0.582, 95% CI [0.347,0.744], p < 0.001), 6v6 format (r = 0.675, 95% CI [0.472,0.804], p < 0.001), and slalom exercise (r = 0.533, 95% CI [0.282,0.710], p < 0.001). For Z5, large positive correlations were found in the 3v3 format (r = 0.710, 95% CI [0.523,0.827], p < 0.001) and repeated sprint training (r = 0.583, 95% CI [0.347,0.744], p < 0.001). A medium positive correlation for Z5 was found in the 6v6 format (r = 0.406, 95% CI [0.127,0.620], p = 0.005∗). The muscular endurance circuit training data for Z5 was constant, preventing correlation calculation. The remaining drills showed small or trivial, non-significant correlations for both Z4 and Z5.

Univariable LMMs (controlling for drill and including random intercepts for player) showed that HRaverage was most strongly and positively associated with RPE (β ≈ 0.86 [95% CI ≈ 0.76, 0.96], p < 0.001). HRmax, distance per minute, average speed, Z4, and Z5 were also positively associated with RPE (all p < 0.01), whereas VIFT was not significantly related to RPE (p ≈ 0.95). In a multivariable LMM including HRaverage, Z4, Z5, VIFT and drill (random intercept: player), HRaverage remained a robust positive predictor of RPE (p < 0.001). Z5 retained an independent positive association (p ≈ 0.001 - 0.01), while Z4 remained positive (p < 0.05). VIFT was not significant after adjustment (p > 0.50).

Discussion

The present study aimed to explore the relationships between RPE and various objective training load measures across a diverse range of drills, showing that these correlations are highly context-dependent and vary significantly based on the specific drill performed. Our findings showed that physiological indicators such as heart rate (HRaverage, HRmax) generally exhibited large positive associations with RPE, particularly in small-sided games and conditioning drills, although this pattern was weaker or non-significant in certain formats such as the 10x5 positional game and the 11v11 format. By contrast, the magnitude and even direction of correlations with other variables, including the VIFT and specific high-speed running distances (Z4 and Z5), were highly contingent upon the drill format. This observed variability underscores the importance of considering the specific demands and characteristics of each training drill when interpreting RPE and integrating it into training monitoring strategies.

When grouped by drill type, clearer patterns emerge. Small-sided games (e.g., 3v3, 6v6) consistently showed very large positive correlations between RPE and both internal and external load metrics, reflecting their high-intensity, intermittent nature. In contrast, large-sided games (9v9, 11v11) displayed weaker or even negative associations with certain variables such as VIFT and high-speed running, likely due to pacing strategies, positional roles, and greater tactical complexity. Conditioning-based drills (e.g., repeated sprint training, muscular endurance circuits) showed RPE strongly aligned with heart rate measures but less consistently with locomotor variables. These results indicate that while RPE tracks cardiovascular strain across all drill types, its sensitivity to external load is most evident in small-sided formats and less predictable in larger tactical games.

The present findings reveal a consistent and largely large positive correlation between RPE and heart rate-based measures (HRaverage and HRmax) across most drills, in specific in the 3v3 format, 6v6 format, repeated sprint training, muscular endurance circuit training, and slalom exercise. This strong association aligns with a substantial body of existing literature that consistently reports high correlations between RPE and internal physiological load markers such as heart rate, particularly in soccer as the study which showed very strong correlations between RPE and HR measures during the season (Kelly et al., 2016) or another study which found strong correlations between these variables in small-sided games (David and Julen, 2015). This relationship can be explained by the integrated regulation model of perceived exertion, which posits that RPE is a composite signal arising from both central and peripheral inputs (Hampson et al., 2001). As exercise intensity increases, leading to elevated heart rate responses - a direct reflection of increased cardiovascular demand and metabolic rate - there is a concomitant rise in peripheral signals (e.g., muscle acidosis, temperature, and metabolite accumulation) (Tornero-Aguilera et al., 2022) and central commands (Sarma et al., 2021).

Beyond physiological regulation models, alternative theoretical frameworks also provide useful perspectives for interpreting our findings. The psychobiological model of endurance performance (Marcora and Staiano, 2010) conceptualizes RPE as a conscious effort-based signal shaped not only by physiological strain but also by motivation, prior experience, and perceived ability to sustain the task. From this view, the lower RPE observed in fitter players during larger-sided games may partly reflect greater self-efficacy and pacing strategies.

The present research revealed a varied, yet large negative correlation between RPE and the VIFT in larger-sided game formats (11v11, 9v9), suggesting that a higher level of intermittent aerobic fitness is associated with lower perceived exertion in these contexts. Conversely, a small positive correlation was observed in the 3v3 format. This dominant inverse relationship between aerobic fitness and RPE for a given absolute workload is observed in studies in running (Garcin et al., 2004) and general exercise (Travlos and Marisi, 1996) which suggests that individuals with superior aerobic capacity can perform at a lower relative physiological strain. Possibly, a higher VIFT reflects better locomotor profile, improved efficiency, and recovery kinetics, allowing athletes to execute demands with reduced cardiovascular and metabolic perturbations as observed in a previous study in small-sided games (Clemente et al., 2022). Possibly, these individuals experience attenuated afferent signals from central and peripheral sources - such as lower heart rate responses, reduced lactate accumulation, and less respiratory demand for a given effort - thereby leading to a lower overall perception of effort.

The relationships between RPE and objective measures of movement intensity, specifically distance covered per minute and average speed, showed contrasting with the more consistent correlations observed with heart rate measures. Our findings revealed large positive correlations between these speed/distance outcomes and RPE in certain contexts, particularly the 3v3 and 6v6 formats, and the slalom exercise, suggesting that increased external work and higher movement intensity in these drills may directly contribute to heightened perceived exertion. However, several other drills, including the 10x5 positional game, repeated sprint training, muscular endurance circuit training, and the 11v11 format, exhibited small, trivial, or non-significant correlations, while the 9v9 format showed a medium negative correlation for distance per minute. These weaker associations may reflect contextual factors: in repeated sprint training, recovery intervals may blunt overall cardiovascular strain despite intense bouts, while in the positional game, the tactical emphasis on ball circulation and space management may decouple exertion from locomotor load.

This unexpected inverse relationship may indicate that fitter or more tactically efficient players covered greater distances yet reported lower exertion, consistent with the influence of pacing strategies and positional roles in larger-sided games. This variability shows the non-linear relationship between external load and internal perception as observed previously in a study using machine learning in soccer (Jaspers et al., 2018). Unlike physiological responses like heart rate, which more directly reflect metabolic demand, overall distance covered or average speed may not always fully capture the physiological strain leading to RPE in drills characterized by frequent accelerations, decelerations, changes of direction, or intense bursts of effort. Factors such as the individual movement economy (Dolci et al., 2018), or the intermittent nature of certain activities (Halperin and Vigotsky, 2024) can modulate the relationship between mechanical work (speed/distance) and the subjective perception of effort, leading to a decoupling of these variables in specific contexts.

In addition to physiological strain, RPE may also be influenced by contextual and psychological factors. Tactical complexity in larger-sided games can increase cognitive demands and decision-making load, which may heighten or dampen perceived exertion independent of physical output (Halouani et al., 2017; Nunes et al., 2020). Similarly, motivation and psychological state modulate RPE responses: motivational self-talk has been shown to reduce perceived effort during exercise (Blanchfield et al., 2014), whereas mental fatigue increases RPE and impairs performance (Pageaux et al., 2015). In our dataset, this may help explain why drills with comparable physical demands (e.g., positional games vs. conditioning circuits) yielded divergent RPE-load associations. These perspectives reinforce that perceived exertion in soccer reflects an interplay of physiological, tactical, and psychological determinants rather than a single dimension.

The analysis of RPE's relationship with distances covered in high-intensity speed zones, Z4 (15 - 19 km/h) and Z5 (>19 km/h), revealed large positive correlations across several drills, namely in the 3v3 format, repeated sprint training, 6v6 format, and slalom exercise. This finding may indicate that accumulating greater distances at very high running speeds can impact the heightened perception of effort. This observation aligns well with some evidence suggesting that high-intensity efforts are drived for physiological strain (Pokora and Żebrowska, 2016) and, consequently, perceived exertion. Performing at speeds exceeding 15 km/h likely demands a substantial metabolic output, increasingly relying on anaerobic glycolysis, which leads to rapid glycogen depletion and the accumulation of fatigue-inducing metabolites (Place and Westerblad, 2022). Moreover, the inherent accelerations, decelerations, and changes of direction often associated with covering distance in these high-speed zones, particularly in dynamic drills, may impose significant eccentric and concentric muscular loads, contributing to increased neuromuscular fatigue (Endoh et al., 2005).

Because observations were repeated within players, simple correlations may underestimate uncertainty and inflate type I error. Our complementary LMMs, which modeled random intercepts for player and fixed effects for drill, corroborated the main message: RPE closely reflects cardiovascular strain and is sensitive to high-intensity running, whereas its relationship with general distance/speed and fitness is context-dependent. The non-significant effect of VIFT after adjustment suggests that fitter players may perceive less effort primarily through their reduced physiological strain during drills rather than a direct effect of fitness per se.

A contribution of the present study is its drill-level resolution. Whereas most prior work has aggregated RPE–load relationships at the session level or focused on single drill types, our dataset allowed direct comparison across eight common soccer drills ranging from small-sided games to conditioning circuits and large-sided formats. Moreover, the exclusive focus on academy-level under-17 players provides novel insight into a developmental population that remains underrepresented in the literature compared to professional adult cohorts. Finally, by simultaneously integrating internal (heart rate), external (locomotor), and fitness (VIFT) variables within an ecologically training environment, this study provides a multidimensional perspective on the determinants of perceived exertion that complements and extends earlier research.

Despite providing possible interesting information on the relationships between RPE and various training load measures, this study is not without limitations. While a two-week timeframe enabled consistent data collection across standardized drills, it represents only a snapshot of the training cycle, which may limit generalization of RPE–load relationships across longer competitive periods. Additionally, only training drills were monitored, and competitive matches were not included. Our decision to focus on training ensured standardized and repeatable drill formats within the limited observation period, but future studies should extend this approach to matches to evaluate whether the present findings generalize to competitive play. Another constraint might be the specific cohort studied, potentially limiting the generalizability of these findings to other competitive levels and scenarios. Although chronological age was recorded, maturation status (e.g., biological age) was not assessed, which may influence RPE responses in adolescents. Moreover, because players were clustered within teams, contextual factors such as coaching style, tactical emphasis, and training culture may have influenced RPE and load responses. Although both teams followed similar weekly training structures, this clustering should be considered when interpreting the results. Methodologically, a limitation of the present study is the large number of correlation tests. Although we observed highly consistent and robust associations between RPE and heart rate measures, other isolated significant correlations (e.g., in specific drills) should be interpreted with caution. Furthermore, while objective measures were employed, the absence of additional physiological or neuromuscular markers (e.g., blood lactate, muscle oxygenation, power output) prevents a deeper understanding of the underlying physiological stress driving RPE. In addition, aerobic fitness was assessed solely through the 30 - 15 Intermittent Fitness Test, which although ecologically relevant marker of intermittent aerobic capacity in soccer does not capture other physical qualities such as neuromuscular strength, sprint ability, or fatigue resistance. Future studies should therefore integrate complementary assessments (e.g., sprint tests, countermovement jump, or fatigue-resistance protocols) to provide a more complete picture of the fitness determinants of RPE.

For coaches, one possible implication is that while RPE remains a highly valuable and practical tool for internal load monitoring, its interpretation must be individualized and drill-specific. In drills emphasizing high-speed running, RPE appears to be a good reflection of the accumulated distance in high-intensity zones (Z4 and Z5). However, coaches should be mindful that general speed/distance measures or fitness levels (VIFT) may not always align directly with RPE, particularly in complex game situations, necessitating a broad approach to load management adjusted to the specific demands of each training activity.

Conclusion

In conclusion, this study highlights the drill-specific nature of the relationships between RPE and various objective training load measures. RPE generally served as a valid indicator of internal physiological strain, aligning strongly with heart rate responses, particularly in small-sided games and conditioning drills, though this association was weaker or absent in formats such as the positional game and 11v11. By contrast, the correlations between RPE and external load metrics such as general speed/distance, high-intensity running zones (Z4 and Z5), and fitness level (VIFT) were more variable, emphasizing the influence of drill characteristics and individual fitness profiles on perceived exertion. These findings suggest that while RPE remains a practical and low-cost tool for monitoring training load, its application should be drill-specific and interpreted alongside relevant objective measures. Future research employing regression or predictive modeling approaches would be valuable to formally test the predictive capacity of RPE across different training contexts.

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The author reports no actual or potential conflicts of interest. The datasets generated and analyzed in this study are not publicly available, but are available from the corresponding author who organized the study upon reasonable request. All experimental procedures were conducted in compliance with the relevant legal and ethical standards of the country where the study was performed.

References

Akyildiz, Z., Alvurdu, S., Ceylan, H. I. and Clemente, F. M. (2022) Validity and reliability of 10 Hz GPS sensor for measuring distance and maximal speed in soccer: Possible differences of unit positioning. *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology* **236(3)**, 174-181. https://doi.org/10.1177/17543371221098888

Beato, M., de Keijzer, K. L. and Costin, A. J. (2023) External and internal training load comparison between sided-game drills in professional soccer. *Frontiers in Sports and Active Living* **5**, 1150461. https://doi.org/10.3389/fspor.2023.1150461

Blanchfield, A. W., Hardy, J., De Morree, H. M., Staino, W. and Marcora, S. (2014) Talking yourself out of exhaustion. *Medicine & Science in Sports & Exercise* **46(5)**, 998-1007. https://doi.org/10.1249/MSS.0000000000000184

Bokůvka, D., Hrubý, M., Čuperková, K., Vencúrik, T., Padinha, V. and Paludo, A. C. (2025) Training load and fitness monitoring in Czech football: coach practices and perspectives. *Frontiers in Sports and Active Living* **7**. https://doi.org/10.3389/fspor.2025.1513573

Borg, G. A. V. (1982) Psychophysical bases of perceived exertion. *Medicine & Science in Sports & Exercise* **14(5)**, 377-381. https://doi.org/10.1249/00005768-198205000-00012

Borg, E., Borg, G., Larsson, K., Letzter, M. and Sundblad, B.-M. (2010) An index for breathlessness and leg fatigue. *Scandinavian Journal of Medicine & Science in Sports* **20(4)**, 644-650. https://doi.org/10.1111/j.1600-0838.2009.00947.x

Campos-Vazquez, M. A., Mendez-Villanueva, A., Gonzalez-Jurado, J. A., León-Prados, J. A., Santalla, A. and Suarez-Arrones, L. (2015) Relationships between rating-of-perceived-exertion- and heart-rate-derived internal training load in professional soccer players: A comparison of on-field integrated training sessions. *International Journal of Sports Physiology and Performance* **10(5)**, 587-592. https://doi.org/10.1123/ijspp.2014-0294

Castagna, C., Bizzini, M., Póvoas, S. C. A. and D'Ottavio, S. (2017) Timing effect on training-session rating of perceived exertion in top-class soccer referees. *International Journal of Sports Physiology and Performance* **12(9)**, 1157-1162. https://doi.org/10.1123/ijspp.2016-0626

Christen, J., Foster, C., Porcari, J. P. and Mikat, R. P. (2016) Temporal robustness of the session rating of perceived exertion. *International Journal of Sports Physiology and Performance* **11(8)**, 1088-1093. https://doi.org/10.1123/ijspp.2015-0438

Clemente, F. M., Silva, A.F., Kawczyński, A., Yıldız, M., Chen, Y. S., Birlik, S., Nobari, H. and Akyildiz, Z. (2022) Physiological and locomotor demands during small-sided games are related to match demands and physical fitness? A study conducted on youth soccer players. *BMC Sports Science, Medicine and Rehabilitation* **14**, 138. https://doi.org/10.1186/s13102-022-00535-w

David, C. and Julen, C. (2015) The relationship between intensity indicators in small-sided soccer games. *Journal of Human Kinetics* **46**, 119-128. https://doi.org/10.1515/hukin-2015-0048

Dolci, F., Hart, N. H., Kilding, A., Chivers, P., Piggott, B. and Spiteri, T. (2018) Movement economy in soccer: Current data and limitations. *Sports* **6(4)**, 124. https://doi.org/10.3390/sports6040124

Endoh, T., Nakajima, T., Sakamoto, M. and Komiyama, T. (2005) Effects of muscle damage induced by eccentric exercise on muscle fatigue. *Medicine & Science in Sports & Exercise* **37(7)**, 1151-1156. https://doi.org/10.1249/01.mss.0000170098.26968.eb

García-Calvo, T., Pulido, J. J., Ponce-Bordón, J. C., López-Gajardo, M. Á., Costa, I. T. and Díaz-García, J. (2021) Can rules in technical-tactical decisions influence on physical and mental load during soccer training? A pilot study. *International Journal of Environmental Research and Public Health* **18(2)**, 512. https://doi.org/10.3390/ijerph18020512

Garcin, M., Mille-Hamard, L. and Billat, V. (2004) Influence of aerobic fitness level on measured and estimated perceived exertion during exhausting runs. *International Journal of Sports Medicine* **25(4)**, 270-277. https://doi.org/10.1055/s-2004-815833

Gonçalves, L., Camões, M., Lima, R., Bezerra, P., Nikolaidis, P. T., Rosemann, T., Knechtle, B. and Clemente, F. M. (2022) Characterization of external load in different types of exercise in professional soccer. *Human Movement* **23(4)**, 89-95. https://doi.org/10.5114/hm.2021.104190

Haddad, M., Stylianides, G., Djaoui, L., Dellal, A. and Chamari, K. (2017) Session-RPE method for training load monitoring: Validity, ecological usefulness, and influencing factors. *Frontiers in Neuroscience* **11**, 612. https://doi.org/10.3389/fnins.2017.00612

Halouani, J., Chtourou, H., Dellal, A., Chaouachi, A. and Chamari, K. (2017) Soccer small-sided games in young players: Rule modification to induce higher physiological responses. *Biology of Sport* **34(2)**, 163-168. https://doi.org/10.5114/biolsport.2017.64589

Halperin, I. and Vigotsky, A. D. (2024) An integrated perspective of effort and perception of effort. *Sports Medicine* **54(9)**, 2019-2032. https://doi.org/10.1007/s40279-024-02055-8

Hampson, D. B., Gibson, A. S., Lambert, M. I. and Noakes, T. D. (2001) The influence of sensory cues on the perception of exertion during exercise and central regulation of exercise performance. *Sports Medicine* **31(13)**, 935-952. https://doi.org/10.2165/00007256-200131130-00004

Houtmeyers, K. C., Robberechts, P., Jaspers, A., McLaren, S. J., Brink, M. S., Vanrenterghem, J., Davis, J. J. and Helsen, W. (2022) Differential ratings of perceived exertion: Relationships with external intensity and load in elite men's football. *International Journal of Sports Physiology and Performance* **17(10)**, 1415-1424. https://doi.org/10.1123/ijspp.2021-0550

Jaspers, A., Op De Beéck, T., Brink, M. S., Frencken, W. G. P., Staes, F., Davis, J. J. and Helsen, W. (2018) Relationships between the external and internal training load in professional soccer: What can we learn from machine learning? *International Journal of Sports Physiology and Performance* **13(5)**, 625-630. https://doi.org/10.1123/ijspp.2017-0299

Kelly, D. M., Strudwick, A. J., Atkinson, G., Drust, B. and Gregson, W. (2016) The within-participant correlation between perception of effort and heart rate-based estimations of training load in elite soccer players. *Journal of Sports Sciences* **34(14)**, 1328-1332. https://doi.org/10.1080/02640414.2016.1142669

Little, T. and Williams, A. G. (2007) Measures of exercise intensity during soccer training drills with professional soccer players. *The Journal of Strength and Conditioning Research* **21(2)**, 367-371. https://doi.org/10.1519/R-19445.1

Loader, J., Montgomery, P. G., Williams, M. D., Lorenzen, C. and Kemp, J. G. (2012) Classifying training drills based on movement demands in Australian football. *International Journal of Sports Science & Coaching* **7(1)**, 57-67. https://doi.org/10.1260/1747-9541.7.1.57

Marcora, S. M. and Staiano, W. (2010) The limit to exercise tolerance in humans: Mind over muscle? *European Journal of Applied Physiology* **109(4)**, 763-770. https://doi.org/10.1007/s00421-010-1418-6

Marynowicz, J., Kikut, K., Lango, M., Horna, D. and Andrzejewski, M. (2020) Relationship between the session-RPE and external measures of training load in youth soccer training. *The Journal of Strength and Conditioning Research* **34(10)**, 2800-2804. https://doi.org/10.1519/JSC.0000000000003800

Melloh, M., Theis, J.-C. and Beneke, R. (2012) Variability of blood lactate during and between given constant prolonged cycling power. *The Journal of Sports Medicine and Physical Fitness* **52(5)**, 575-582.

Nijland, R., Toering, T., Watson, C. G., de Jong, J. and Lemmink, K. A. P. M. (2024) A scoping review on the influence of contextual factors on training load in adolescent soccer players: What do we know? *Sports* **12(5)**, 172. https://doi.org/10.3390/sports12050172

Noakes, T. D. (2012) Fatigue is a brain-derived emotion that regulates the exercise behavior to ensure the protection of whole body homeostasis. *Frontiers in Physiology* **3**, 82. https://doi.org/10.3389/fphys.2012.00082

Nunes, N. A., Gonçalves, B., Coutinho, D. and Travassos, B. (2020) How numerical unbalance constraints physical and tactical individual demands of ball possession small-sided soccer games. *Frontiers in Psychology* **11**, 1464. https://doi.org/10.3389/fpsyg.2020.01464

Pageaux, B., Marcora, S. M., Rozand, V. and Lepers, R. (2015) Mental fatigue induced by prolonged self-regulation does not exacerbate central fatigue during subsequent whole-body endurance exercise. *Frontiers in Human Neuroscience* **9**, 67. https://doi.org/10.3389/fnhum.2015.00067

Place, N. and Westerblad, H. (2022) Metabolic factors in skeletal muscle fatigue. *Comprehensive Physiology* **12(1)**, 377-399. https://doi.org/10.1002/cphy.c210015

Pokora, I. and Żebrowska, A. (2016) Application of a physiological strain index in evaluating responses to exercise stress - A comparison between endurance and high intensity intermittent trained athletes. *Journal of Human Kinetics* **50(1)**, 103-114. https://doi.org/10.1515/hukin-2015-0153

Sarma, S., Howden, E., Lawley, J., Samels, M. and Levine, B. D. (2021) Central command and the regulation of exercise heart rate response in heart failure with preserved ejection fraction. *Circulation* **143(8)**, 783-789. https://doi.org/10.1161/CIRCULATIONAHA.120.049124

Sosa, C., Alonso-Pérez-Chao, E., Ribas, C., Schelling, X. and Lorenzo, A. (2025) Description and classification of training drills, based on biomechanical and physiological load, in elite basketball. *Sensors* **25(1)**, 262. https://doi.org/10.3390/s25010262

Stone, K. J. and Oliver, J. L. (2009) The effect of 45 minutes of soccer-specific exercise on the performance of soccer skills. *International Journal of Sports Physiology and Performance* **4(2)**, 163-175. https://doi.org/10.1123/ijspp.4.2.163

Tornero-Aguilera, J. F., Jimenez-Morcillo, J., Rubio-Zarapuz, A. and Clemente-Suárez, V. J. (2022) Central and peripheral fatigue in physical exercise explained: A narrative review. *International*

Journal of Environmental Research and Public Health **19(7)**, 3909. https://doi.org/10.3390/ijerph19073909

Travlos, A. K. and Marisi, D. Q. (1996) Perceived exertion during physical exercise among individuals high and low in fitness. *Perceptual and Motor Skills* **82(2)**, 419-424. https://doi.org/10.2466/pms.1996.82.2.419

White, A., Hills, S. P., Hobbs, M., Cooke, C. B., Kilduff, L. P., Cook, C., Roberts, C. and Russell, M. (2020) The physical demands of professional soccer goalkeepers throughout a week-long competitive microcycle and transiently throughout match-play. *Journal of Sports Sciences* **38(8)**, 848-854. https://doi.org/10.1080/02640414.2020.1736244

Xu, W., Trybulski, R., Luo, L., Trybek, G., Moska, W., Liu, Y. and Clemente, F. M. (2025) Effects of small-sided games and high-intensity interval training on the rating of perceived exertion in soccer players across competitive levels: Controlling for percentage of heart rate reserve. *Journal of Sports Science and Medicine* **24(3)**, 603-612. https://doi.org/10.52082/jssm.2025.603

Zurutuza, U., Castellano, J., Echeazarra, I., Guridi, I. and Casamichana, D. (2019) Selecting training-load measures to explain variability in football training games. *Frontiers in Psychology* **10**, 2897. https://doi.org/10.3389/fpsyg.2019.02897

Key points

- RPE strongly correlates with heart rate in most drills, especially small-sided games (e.g., 3v3, r = 0.977).
- RPE correlates highly with distance in high-speed zones (Z4, Z5), especially in drills like 3v3 and sprint training.
- RPE's relationship with fitness and external load varies across drills, with fitter players reporting lower RPE in larger games (e.g., 11v11).

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