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Section III – Sports and Physical Activity

Discrepancies in Sprint and High-Speed Running Loads between Training and Match Play in U17 and U19 Soccer Players

by
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The purpose of the study was to compare training-to-match load ratios between U17 and U19 soccer players, focusing on effective training time, external load, and intensity. Two youth academy teams were assessed: U19 (n = 22; 6 weeks; 59 training weeks) and U17 (n = 21; 11 weeks; 112 training weeks). The external load was tracked using a 10-Hz GPS and included total distance (TD), high-speed running (HSR), sprint distance (SPRm), sprint entries (SPRn), accelerations, decelerations, and impacts (>5 g). Total and effective training time were recorded separately to calculate relative intensities. Generalized linear mixed model was used to compare U17, U19, and U19 excluding one session (U19 MD-2) to ensure equivalent weekly structure. U17 players showed significantly higher training efficiency (ET%: 71.0 ± 7.3%) than U19 players (68.5 ± 4.0%). U19 players demonstrated higher training-to-match load ratios, particularly in HSR (U19: 1.5 ± 0.4; U19 MD-2: 1.2 ± 0.4; U17: 1.0 ± 0.4; $p < 0.01$) and SPRm (U19: 2.0 ± 1.0; U19 MD-2: 1.8 ± 0.9; U17: 1.0 ± 0.8; $p < 0.01$). U17 players struggled to replicate match intensities in sprinting and high-speed running. Differences were also observed in acceleration and deceleration profiles. Effect sizes ranged from moderate to large across sprint and HSR metrics. Training-to-match load ratios varied substantially between U17 and U19 players. While U19 players exceeded match intensities in most metrics, U17 players fell short, especially of sprinting demands. These findings support the use of structured high-intensity training and individualized load management to optimize development and prepare youth players for professional demands.

Keywords: *load management; academy players; training intensity; effective training time; external match demands*

Introduction

Training load management is a fundamental aspect of athletic preparation, with a significant impact on performance, recovery, and injury prevention (Bourdon et al., 2017; Impellizzeri et al., 2019; Pimenta et al., 2026). Achieving the right balance is essential as insufficient training load may lead to under-preparation, while excessive training load increases the risk of fatigue and injury (Clemente et al., 2019a; Gabbett, 2016). In team sports, this process is particularly complex due to varying training schedules, individual recovery needs, and position-specific demands (Teixeira et al., 2021). Recent research has highlighted the importance of individualized workload strategies, as substantial differences exist not only between positions but also among particular players (Ammann and Altmann, 2023; Castellano et al., 2025). These variations reflect unique physiological and tactical demands, which should be further adapted to each athlete's performance level and stage of development.

Weekly load management strategies are commonly applied to balance training and recovery, aiming to optimize readiness for the physical and tactical demands of soccer (Clemente

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et al., 2019a; Owen et al., 2017). Load-to-match ratios have emerged as a key tool for tailoring training programs, aligning workloads with positional demands and match intensities (Clemente et al., 2019b; Oliveira et al., 2023). While training loads have been widely studied, research specifically targeting youth soccer players remains limited (de Dios-Álvarez et al., 2021, 2025; Perroni et al., 2024). Evidence is particularly scarce for U17 and U19 categories, which require tailored approaches due to ongoing maturation (Clemente et al., 2019a) with the need for age-specific analysis (Kokstejn et al., 2024). Youth athletes face unique challenges that require training programs that support physiological development while minimizing injury risk (Long et al., 2024). Targeted high-speed running loads have been shown to reduce injury risk among elite players (Buchheit et al., 2023), whereas no such association has been observed in youth populations (Verstappen et al., 2021). This contrast raises a key question: whether training in youth soccer prioritizes load or intensity?

Training-to-match load ratios require a multidimensional approach to accurately capture external load dynamics and align them with performance and development goals (Halson, 2014). This is typically achieved by focusing on variables that reflect the complex demands of soccer and support more effective load management (Akenhead and Nassis, 2015). Traditionally, external load monitoring has emphasized three core dimensions: locomotor, metabolic, and mechanical variables (Buchheit and Simpson, 2016). Recent perspectives highlight three interrelated categories: (1) accelerations and decelerations, (2) high-speed and sprinting efforts, and (3) physical impacts during training and matches, providing a more comprehensive view of the player's load (Casamichana et al., 2019). Training intensity—defined through metrics such as high-speed running, sprint distance, and acceleration density—plays a key role in assessing training quality and adaptive stimulus (Taylor et al., 2017). In addition, effective training time (ET) is increasingly used to assess relative intensity and evaluate training quality (O'Connor et al., 2017). The same observation further indicates that approximately two-thirds of youth soccer training sessions are spent in active practice (O'Connor et al., 2017). However, the relationship between ET and training intensity across a full microcycle remains underexplored in youth soccer, despite its relevance for improving load evaluation (Lago-Peñas, 2012).

Understanding the developmental needs of youth players requires examining how training-to-match ratios differ between consecutive age groups (Morgans et al., 2022; Santos et al., 2021), with highlights of differences in training intensities and workloads across broader age ranges (Morgans et al., 2022; Taylor et al., 2022). Variations in physical capacities in high-speed running and acceleration suggest a need for age-specific training adaptations (Morgans et al., 2022; Riboli et al., 2021) including differences in weekly training loads for players' developmental stages (Connolly et al., 2024; Vieira et al., 2019). Addressing these gaps may enhance awareness of age-specific demands and inform training practices that support the long-term development of youth athletes.

Despite notable changes in training and match demands between U17 and U19 players, these differences remain poorly quantified. Therefore, this study aimed to assess training-to-match load ratios across two consecutive academy age categories (U17 and U19) by integrating effective training time with external load and intensity metrics. The following hypotheses were proposed: (1) there would be no significant difference in effective training time (%) between U17, U19 MD-2, and U19 players; (2) training-to-match load ratios would significantly differ between U17 and U19 players; (3) training intensity metrics (e.g., high-speed running, sprint distance) would show significant differences in training-to-match ratios between U17 and U19 players.

Methods

Participants

This study included 43 male soccer players from two youth academy teams competing in the Czech Republic's top-tier youth leagues during the 2022/2023 season. The U19 team comprised 22 players (mean age: 18.0 ± 0.7 years; body height: 179.7 ± 5.2 cm; body mass: 68.6 ± 5.8 kg; max speed: 33.2 ± 0.7 km/h), while the U17 team included 21 players (mean age: 16.0 ± 0.5 years; body height: 178.5 ± 5.5 cm; body mass: 67.1 ± 6.6 kg; max speed: 33.0 ± 0.9 km/h). Several U19 players also

participated in U18 matches within the second-tier U19 league, reflecting the club's internal developmental structure.

Positional roles were distributed as follows: U19: six full-backs (FBs), four centre-backs (CBs), four central midfielders (CMs), five wingers (Ws), and three central forwards (CFs); U17: three FBs, six CBs, six CMs, three Ws, and three CFs. Positional data were recorded for reference only and were not included in the statistical analysis, as no meaningful differences in training-to-match ratios were observed between positions. Goalkeepers were excluded due to the unique physical demands of their role.

All players were actively involved in the club's structured academy training system, had more than 10 years of organized soccer experience, and competed in the highest national youth league for their age category. Several players also represented national youth teams during the observation period.

Eligibility criteria were defined as follows: (1) outfield male players registered in the U17 or U19 squads of a Czech first-division youth academy during the 2022/2023 season; (2) participation in at least one full official match (≥90 min, excluding the warm-up); (3) completion of one full training microcycle including all scheduled sessions; (4) availability of complete GPS data for both training and match exposure; and (5) absence of injury or return-to-play status during the observation period. Players were excluded if they (1) were goalkeepers, due to the distinct physical demands of their role; (2) changed playing positions frequently during matches; (3) had incomplete data records; or (4) were undergoing post-injury rehabilitation. All participants and their legal guardians (if under 18) provided written informed consent. The study was approved by the Ethics Committee of the Faculty of Physical Education and Sport, Charles University, Prague, Czech Republic (approval code: 277/2021; approval date: 24 May 2022), and adhered to the Declaration of Helsinki and institutional research guidelines.

Study Design

A repeated-measures design was employed to compare workload dynamics between U17 and U19 academy players. An overview of the study procedure is illustrated in Figure 1. Data were collected during the in-season periods (August–November and March–June) of the 2022/2023 season, focusing on standardized Saturday-to-Saturday microcycles to align training and recovery across age groups. Each player's external workload was monitored repeatedly across multiple weeks, with both training and match data recorded for every complete microcycle. Training data were included only for players who completed all scheduled sessions within the respective week. Training and match sessions were conducted on natural grass during summer and on artificial turf during winter, under typical Central European conditions. Both squads were coached and supported by consistent club staff following standardized methodological procedures. The monitoring process was supervised by researchers with academic backgrounds in sports science.

The U19 squad followed a five-session weekly schedule, while U17 players completed four sessions per week, based on the club's age-specific planning. To enable direct comparison with the U17 training structure, a modified U19 condition (U19 MD-2) was created by removing the Thursday tactical session, the only additional session not present in the U17 program. This adjustment allowed for a fair comparison of training-to-match ratios and session intensities under equivalent weekly volumes.

The final dataset comprised 383 complete match records and 171 full training weeks (U17: 112 weeks over 11 monitored calendar weeks; U19: 59 weeks over 6 weeks). Training and match data were synchronized across teams within the same periods to ensure comparability.

The typical microcycle structure for both teams was as follows:

- Monday (Recovery): Technical drills and medium-sided games
- Tuesday (Strength and Speed): Eccentric strength training, sprint mechanics, and small-sided games
- Wednesday (High-Intensity Play): Large-sided games emphasizing high-speed running
- Thursday (Tactical: MD-2, U19 only): Positional play and team strategy
- Friday (Match Preparation): Set-piece drills, pressing, and goalkeeper build-up

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Measures

Players' movements were monitored using validated 10-Hz GPS devices (Playertek Pod v2, Catapult Sports, Melbourne, Australia). These units have demonstrated high reliability for measuring external load variables, including high-speed running (HSR; >19.8 km/h), sprint distance (SPRm; >25.2 km/h), and physical impacts (>5 g) (Scott et al., 2016). Players were familiarized with the GPS system through routine in-season use.

ET was calculated as the ratio of net exercise time to total session duration and was used to normalize training load and intensity metrics.

For each player, the following metrics were aggregated weekly:

- Distance metrics: total distance (TD), high-speed running (HSR; >19.8 km/h), sprint distance (SPRm; >25.2 km/h), and the number of sprint efforts (SPRn; entries >25.2 km/h)
- Acceleration/deceleration metrics: moderate accelerations (ACC24; 2–4 m/s²), high accelerations (ACC4; >4 m/s²), moderate decelerations (DEC24; −2 to −4 m/s²), and high decelerations (DEC4; <−4 m/s²)
- Impact metrics: number of impacts exceeding 5 g

Training intensity was calculated by dividing the weekly total of each metric by effective training time (in minutes). Match intensity was calculated by dividing each metric by the number of minutes played in a given match. The training-to-match ratio for each variable was then computed by dividing the training value by the corresponding match value. A ratio greater than 1 indicated that training intensity exceeded match intensity, whereas a ratio below 1 indicated the opposite.

Statistical Analysis

We assessed data distribution using the Shapiro-Wilk test applied to residuals of each dependent variable. Given the repeated-measures nature of the dataset and small sample sizes within groups, several variables violated normality assumptions. Therefore, we employed statistical methods robust to non-normality and capable of accounting for hierarchical data structures.

Training-to-match load ratios were analyzed using generalized linear mixed models (GLMMs), with age category (U17, U19, U19 MD-2) specified as a fixed effect. Preliminary analyses revealed no significant differences in training-to-match ratios between playing positions; therefore, position was not included as a random or fixed effect in the final models. GLMMs were selected for their suitability in modeling non-normally distributed data, accommodating unbalanced designs, and handling repeated measures nested within individual players' features commonly encountered in applied sports science research (Bates et al., 2015). Model fit was evaluated using likelihood ratio tests to compare nested models. Post hoc pairwise comparisons were adjusted using the Bonferroni correction to control the risk of Type I error due to multiple testing.

Effect sizes were calculated and interpreted using Cohen's f, with thresholds defined as trivial (<0.02), small (0.02–0.14), medium (0.15–0.34), or large (>0.35), following established conventions (Cohen, 1990; Selya et al., 2012). For pairwise comparisons, Cohen's d was used and interpreted as small (d = 0.2–0.5), medium (d = 0.5–0.8), or large (d > 0.8) (Cohen, 1990). Statistical significance was set at $p < 0.05$. All analyses were conducted in R (version 4.4.1) using the 'lme4' package for GLMM implementation (Bates et al., 2015).

Results

Accumulated Weekly Load

Table 1 presents the comparison of average values and weekly training-to-match load ratios between the U17 and U19 groups. Although several differences were observed, the effect size for effective training time was small (Cohen's f = 0.18), indicating limited disparity. Notably, despite U19 players completing one additional training session per week, no significant difference was found in the total weekly training time between the groups.

Table 2 summarizes the absolute weekly training load (SUM) and corresponding training-to-match load ratios (RATIO) for U17, U19 MD-2, and U19 players. Significant differences emerged in HSR and sprint metrics, with U19 players showing higher values compared to U17 ($p < 0.01$; d = 1.0–1.3). In contrast, U19 MD-2 recorded significantly lower values in total distance, HSR, and all acceleration/deceleration metrics compared to U19 ($p < 0.01$; d = 0.6–1.5). These intermediate

values reflect the reduced workload associated with a shorter training schedule. Overall, the distinct patterns in sprinting and acceleration-deceleration metrics highlight differences in physical demands across the three groups.

Intensity Weekly Load

Table 3 shows relative weekly training loads normalized per minute of effective training time. U17 players consistently exhibited lower intensities in sprinting (>25.2 km/h/min) and high-speed running (>19.8 km/h/min) compared to U19 and U19 MD-2 players (p < 0.01). The most pronounced difference was observed in HSR intensity, reflecting lower training demands placed on the U17 squad. U19 MD-2 displayed intermediate intensities, while U17 players recorded the lowest values across all metrics. These findings confirm distinct intensity profiles characteristic of each training structure.

Table 4 displays Cohen's d effect sizes for weekly training volume and intensity. Volume metrics revealed medium to large effects, particularly in comparisons involving U19 MD-2. The largest differences were observed in time (d = 2.0), total distance (d = 1.53), and DEC24 (d = 1.34). For intensity, the most pronounced effects were between U17 and U19 players, especially in HSR (d = 1.3), SPRm (d = 1.1), and SPRn (d = 1.0). Conversely, ACC24, ACC4, DEC24, and impacts showed small or trivial effects across all group comparisons.

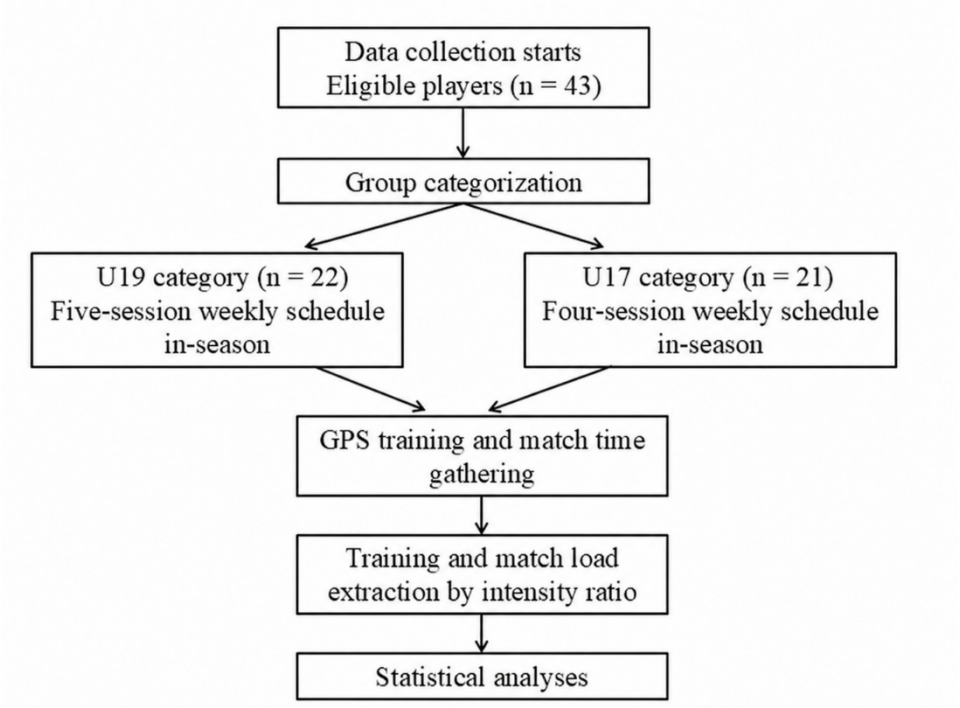


Figure 1. Flowchart of the study procedure including data collection, player categorization, and statistical analysis.

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Table 1. Training time volumes and training-to-match ratios across age groups.

Teams	model	U17		U19 MD-2		U19	
Variable	f^2	SUM	ratio	SUM	ratio	SUM	ratio
Time (h)	**0.8**	5.7 ± 0.8	3.7 ± 0.5**	4.5 ± 0.6	2.9 ± 0.4**,##	6.0 ± 0.7	3.8 ± 0.5##
ET (%)		71.0 ± 7.3**	-	68.5 ± 4.0**	-	69.9 ± 3.7	-

Notes: Time = total weekly training time (hours); ET = effective training time (%). Significant differences are indicated for U17 vs. U19 MD-2 (p < 0.05, ** p < 0.01), U17 vs. U19 († p < 0.05, †† p < 0.01), and U19 MD-2 vs. U19 (## p < 0.01, ‡ p < 0.05). Cohen's f values represent effect sizes; bold values indicate at least medium effect size (f ≥ 0.25)*

Table 2. Weekly training load and training-to-match ratios across age groups.

Teams	model	U17		U19 MD-2		U19	
Variables	*f*	SUM	ratio	SUM	ratio	SUM	ratio
TD (m)	**0.6**	21 694.8 ± 3 794.4	2.0 ± 0.3**,†	17 922.6 ± 2 618.7	1.6 ± 0.2**,##	23 322.4 ± 3 538.5	2.1 ± 0.3##,†
HSR (m)	**0.5**	834.3 ± 382.3	1.0 ± 0.4**,††	1114.1 ± 338.9	1.2 ± 0.4**,##	1353.5 ± 418.0	1.5 ± 0.4††,##
SPRm (m)	**0.5**	162.1 ± 105.0	1.0 ± 0.8**,††	316.4 ± 110.4	1.8 ± 0.9**	348.0 ± 120.5	2.0 ± 1.0††
SPRn (n)	**0.5**	3.5 ± 2.6	1.0 ± 1.0**,††	7.5 ± 3.2	1.9 ± 1.2**	8.2 ± 3.4	2.1 ± 1.2††
ACC24 (n)	**0.6**	657.7 ± 122.9	2.7 ± 0.5**	509.7 ± 75.5	2.1 ± 0.4**,##	657.2 ± 117.4	2.7 ± 0.5##
ACC4 (n)	**0.3**	93.6 ± 32.0	3.5 ± 1.2†	82.6 ± 24.9	3.1 ± 0.9##	106.2 ± 35.3	3.9 ± 1.2†,##
DEC24 (n)	**0.6**	624.5 ± 112.1	3.1 ± 0.5**	483.2 ± 75.6	2.3 ± 0.4**,##	621.2 ± 109.1	3.0 ± 0.6##
DEC4 (n)	0.2	91.7 ± 35.0	2.4 ± 0.8†	83.3 ± 19.9	2.2 ± 0.7##	103.2 ± 26.7	2.7 ± 0.9##,†
Impacts (n)	0.0	14.8 ± 12.3	3.1 ± 2.4	8.7 ± 11.6	2.8 ± 3.2	8.6 ± 11.6	2.9 ± 3.2

Notes: TD = total distance (m); HSR = high-speed running (>19.8 km/h); SPRm = sprint distance (>25.2 km/h); SPRn = sprint entries (>25.2 km/h); ACC24 = moderate accelerations (2–4 m/s²); ACC4 = high accelerations (>4 m/s²); DEC24 = moderate decelerations (–2 to –4 m/s²); DEC4 = high decelerations (<–4 m/s²); Impacts = number of impacts >5 g. SUM = total weekly training load; ratio = training-to-match ratio. Significant differences are indicated for U17 vs. U19 MD-2 (p < 0.05, ** p < 0.01), U17 vs. U19 († p < 0.05, †† p < 0.01), and U19 MD-2 vs. U19 (# p < 0.05, ## p < 0.01). Bold f values denote medium or larger effect sizes (f ≥ 0.25)*

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Table 3. Training intensity and training-to-match ratios across age groups.

Teams	model	U17		U19 MD-2		U19	
Variables	*f*	AVERAGE	ratio	AVERAGE	ratio	AVERAGE	ratio
TD (m/min)	0.2	90.0 ± 13.9	0.8 ± 0.1**	97.1 ± 7.4	0.8 ± 0.1**	92.6 ± 6.1	0.8 ± 0.1
HSR (m/min)	**0.7**	3.4 ± 1.4	0.4 ± 0.1**,††	6.1 ± 1.7	0.6 ± 0.2**	5.4 ± 1.6	0.6 ± 0.2††
SPRm (m/min)	**0.6**	0.7 ± 0.4	0.4 ± 0.3**,††	1.8 ± 0.8	1.0 ± 0.6**,#	1.4 ± 0.6	0.8 ± 0.5††,#
SPRn (n/min)	**0.6**	0.0 ± 0.0	0.4 ± 0.4**,††	0.0 ± 0.0	1.0 ± 0.7**,#	0.0 ± 0.0	0.8 ± 0.5††,#
ACC24 (n/min)	0.2	2.7 ± 0.5	1.1 ± 0.2	2.8 ± 0.4	1.1 ± 0.2	2.6 ± 0.3	1.0 ± 0.1
ACC4 (n/min)	0.2	0.4 ± 0.1	1.3 ± 0.5**	0.4 ± 0.1	1.5 ± 0.4**	0.4 ± 0.1	1.4 ± 0.4
DEC24 (n/min)	0.2	2.6 ± 0.5	1.2 ± 0.2†	2.6 ± 0.4	1.2 ± 0.2	2.5 ± 0.3	1.1 ± 0.1†
DEC4 (n/min)	0.3	0.4 ± 0.1	0.9 ± 0.3**	0.5 ± 0.1	1.1 ± 0.4**	0.4 ± 0.1	1.0 ± 0.3
Impacts (n/min)	0.1	0.1 ± 0.0	1.2 ± 0.9**	0.0 ± 0.1	1.4 ± 1.6**	0.0 ± 0.0	1.1 ± 1.1

Notes: Distance (m), High-Speed Running (HSR; >19.8 km/h), Sprint Distance (SPRm; >25.2 km/h), Sprint Entries (SPRn; n of >25.2 km/h), Moderate Accelerations (ACC24; 2–4 m/s²), High Accelerations (ACC4; >4 m/s²), Moderate Decelerations (DEC24; -2–(-4) m/s²), High Decelerations (DEC4; <-4 m/s²), and Impacts (>5 g), all normalized per minute of training time. Significant differences are indicated for U17 vs. U19 MD-2 (p < 0.05, ** p < 0.01), U17 vs. U19 († p < 0.05, †† p < 0.01), and U19 MD-2 vs. U19 (# p < 0.05, ## p < 0.01), f denotes Cohen's f effect size, bold values indicate at least medium effect sizes (f > 0.25)*

Table 4. Cohen's *d* effect sizes between groups with 95% confidence intervals (CI) for training load and intensity metrics.

Groups	U17 vs. U19		U17 vs. U19 MD-2		U19 vs. U19 MD-2	
Parameters	Cohen's *d* (95 % CI)		Cohen's *d* (95 % CI)		Cohen's *d* (95 % CI)	
	volume	intensity	volume	Intensity	volume	intensity
Time	0.3 [0–0.6]	-	**1.6 [1.3–2.0]**	-	**2.0 [1.5–2.4]**	-
TD	0.4 [0.1–0.7]	0.2 [-0.2–0.5]	**1.1 [0.8–1.4]**	**0.6 [0.3–0.9]**	**1.5 [1.1–1.9]**	0.4 [0.1–0.8]
HSR	**1.3 [0.9–1.6]**	**1.1 [0.8–1.5]**	**0.6 [0.3–1.0]**	**1.6 [1.2–1.9]**	**0.6 [0.3–1.0]**	0.4 [0.1–0.8]
SPRm	**1.1 [0.8–1.5]**	**0.9 [0.6–1.2]**	**0.9 [0.6–1.3]**	**1.4 [1.0–1.7]**	0.2 [-0.2–0.6]	0.5 [0.1–0.8]
SPRn	**1.0 [0.7–1.4]**	**0.9 [0.5–1.2]**	**0.9 [0.6–1.2]**	**1.3 [1.0–1.6]**	0.1 [−0.3–0.5]	0.4 [0.1–0.8]
ACC24	0.0 [−0.3–0.4]	0.3 [0.0–0.6]	**1.4 [1.0–1.7]**	0.1 [−0.2–0.4]	**1.3 [0.9–1.7]**	0.4 [0.1–0.8]
ACC4	0.4 [0.1–0.7]	0.3 [−0.1–0.6]	0.3 [0.0–0.7]	0.5 [0.2–0.8]	**0.7 [0.4–1.1]**	0.2 [−0.1–0.6]
DEC24	0.1 [−0.2–0.4]	0.4 [0.1–0.7]	**1.4 [1.0–1.7]**	0.0 [−0.3–0.4]	**1.3 [0.9–1.7]**	0.4 [0.1–0.8]
DEC4	0.4 [0.1–0.7]	0.3 [−0.1–0.6]	0.3 [−0.1–0.6]	**0.6 [0.3–0.9]**	**0.7 [0.3–1.0]**	0.3 [0.0–0.7]
Impacts	0.1 [−0.3–0.4]	0.1 [−0.2–0.4]	0.1 [−0.2–0.4]	0.2 [−0.1–0.5]	0.0 [−0.3–0.4]	0.3 [−0.1–0.7]

Notes: Time (hours), Distance (m), High-Speed Running (HSR; >19.8 km/h), Sprint Distance (SPRm; >25.2 km/h), Sprint Entries (SPRn; n of >25.2 km/h), Moderate Accelerations (ACC24; 2–4 m/s²), High Accelerations (ACC4; >4 m/s²), Moderate Decelerations (DEC24; −2–(−4) m/s²), High Decelerations (DEC4; <-4 m/s²), and Impacts (>5 g). Bold values indicate at least medium effect sizes (d > 0.5)

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Discussion

U17 players showed greater training efficiency, while U19 players experienced higher cumulative external loads and training intensities. Therefore, our first hypothesis, which predicted no significant difference in ET among the U17, U19 MD-2, and U19 groups, was not supported. Although total training time was similar between U17 and U19, a difference appeared when focusing on the U19 MD-2 condition. Despite having the same number of sessions, U19 players demonstrated lower training efficiency. This indicates that the structure and execution of sessions—not just their duration—may influence ET. U17 players achieved similar total training time despite having one fewer weekly session, suggesting different approaches to balancing load and recovery. One possible explanation is the advantage of rest days in U17 (Orlando et al., 2010) or an emphasis on low-intensity recovery sessions (Trecroci et al., 2019), such as U19's MD-2. U17 players exhibited significantly higher training efficiency (71.2 ± 2.1%) compared to U19 MD-2 (68.4 ± 1.8%), although this difference decreased when including MD-2. Previous studies reported higher (Guridi et al., 2021) and lower (O'Connor et al., 2017) ET than ours. Additionally, our training sessions seemed more efficient than matches (~60%) (Lago-Peñas, 2012). These variations occurred within the same academy, indicating that monitoring ET could enhance consistency and session quality across age groups. Tracking ET as a percentage of total session duration can help detect inefficiencies in the session design. Addressing issues such as prolonged inactivity or excessive transitions may improve training density and lead to more uniform stimulus delivery across different age categories.

Our second hypothesis, that training-to-match load ratios would differ between U17 and U19 players, was confirmed. Comparing neighboring categories is especially relevant for managing training progression, as older players typically face more structured and intensive workloads (Connolly et al., 2024). If training load remains the same, more mature players might find it insufficient (Salter et al., 2022), which could limit adaptation. Conversely, a sharp increase in training load might raise injury risk, especially during transitional periods (Bahdur and Pruna, 2017). Studying a single academy minimized variability and enhanced internal validity. U19 players had higher ratios in TD, HSR, SPRm, and SPRn, covering nearly twice as many sprint meters and 1.5 times more HSR than U17, exceeding previous reference values (Buchheit et al., 2023) and aligning with developmental differences (Kokstejn et al., 2024). These results align with findings by Hannon et al. (2021) who also reported greater sprint exposure in older age groups and highlighted the importance of progressive load development throughout the season. While ACC24 and DEC24 ratios were similar, U19 outperformed U17 in ACC4 and DEC4, likely due to greater physical maturity (Marinho et al., 2020; Thoseby et al., 2023). Even when volume was matched (U19 MD-2), U19 maintained higher HSR and sprint values. Visual inspection revealed higher ACC4 than ACC24 ratios, and the opposite was observed for decelerations. These findings may guide coaches in designing drills that better balance accelerative and decelerative demands by incorporating more high-intensity braking tasks in youth sessions to mirror match demands and support long-term neuromuscular development. Such patterns suggest the need for more targeted deceleration stimuli in training including high-intensity braking tasks, particularly in younger age groups (Iacono et al., 2016).

Our third hypothesis, that training-to-match ratios would differ between age groups, was also supported. To our knowledge, this is the first study to examine full-session intensity and intensity ratios in youth soccer with precise accounting for net training duration, excluding inactive periods. While Marynowicz et al. (2023) demonstrated that simple metrics such as meters per minute can explain most of the variability in external load, our study advances this approach by focusing specifically on net intensity values, thereby eliminating the influence of non-exercise time and enabling more precise comparisons. Intensity ratios >1.0 suggest that training exceeds match demands, while the value <1.0 implies underexposure. U19 players exceeded match intensity in most metrics except TD, HSR, and sprinting, though these ratios normalized when MD-2 was excluded. U17 players consistently underperformed in all high-intensity metrics, with HSR and sprinting often below 0.5. U19 players trained at higher intensities in HSR, SPRm, SPRn, ACC4, and DEC4—even without MD-2. U19 MD-2

players also recorded more impacts per minute than U17, despite lower volume. This suggests the importance of gradually integrating high-intensity elements into weekly sessions, including game-relevant sprint actions and impacts, to facilitate a smoother transition toward U19 performance demands. In contrast, U17 players may benefit from targeted exposure to high-speed and sprint efforts. Our findings support replacing low-intensity training with match-relevant stimuli, particularly in younger age groups (Ispyrlidis et al., 2022). While professional players often train below match intensity (Oliva-Lozano et al., 2021), our U19 players approached or exceeded it in several metrics, indicating a developmental emphasis on high-speed actions.

Our approach focusing on elite youth players from a single academy limits generalizability, as training conditions such as the coaching style, facility quality, weekly schedule structure, and periodization models may vary considerably across different academies. Future studies should involve players from various academies and competitive levels to capture broader variability in training and match demands, and consider more players' anthropometry (Radaković et al., 2026). Future research could explore how different types of training content—such as technical-tactical drills, conditioning blocks, or small-sided games—affect effective training time and intensity ratios. Incorporating internal load measures (e.g., heart rate) would also enhance understanding of individual responses. Although multiple weeks were analyzed, longitudinal research—preferably involving full-season tracking or pre-post intervention designs—would provide a clearer understanding of how training adaptations develop and relate to injury risk and performance. Lastly, since running metrics are not always linked to match success, they should be interpreted cautiously (Barthelemy et al., 2024).

Conclusions

This study highlights key differences in training-to-match load ratios and intensity profiles between U17 and U19 academy players. U19 players were systematically exposed to higher sprint and high-speed demands—often exceeding match intensity, while U17 players consistently failed to replicate this output. Acceleration and deceleration loads were adequately targeted across both groups. These findings emphasize the need for age- and intensity-specific conditioning strategies that move beyond volume-based planning. Effective training time emerged as a valuable indicator of relative intensity and should be integrated into routine monitoring. To prepare players for elite-level demands, training must deliberately replicate match realities through targeted overloading and individualized progression, especially during key developmental transitions.

In reference to our data:

1. Coaches should pay particular attention to sprint and high-speed running ratios, as substantial differences between age groups may exist even within a shared training environment.
2. Younger players require progressive exposure to sprinting, high-speed running, and impacts throughout the season to prepare for the demands of older age categories adequately. These sessions should also aim to exceed match-level intensity in HSR and sprint metrics to build appropriate tolerance.
3. For more accurate benchmarking, we recommend using intensity metrics like meters per minute calculated from net exercise time instead of total session duration, as this better reflects the actual work performed. Additionally, an effective training time around 70% may serve as a practical reference point in youth soccer.

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