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Relationship between technical–tactical indicators of attention and creativity and effort zones in youth football players during competitions

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Abstract

Background and Study Aim Cognitive performance, specifically attention and creativity, contributes to the tactical effectiveness of youth football players. This contribution becomes evident when actions are executed under competitive physiological constraints. Examining how physical demands interact with perceptual and cognitive processes may support the development of training methodologies and competitive decision-making strategies. This study aims to analyze the relationship between technical–tactical indicators of attention and creativity and effort-zone parameters in young football players.

Material and Methods Twelve male football players (10–12 years old) from CSS1 Pajura Bucharest participated voluntarily in the study. Competition monitoring was conducted in 2022 and included 15 official matches in Series I and 14 matches in Series II. Functional parameters were assessed using Polar Vantage V devices. These parameters included heart rate (HR), running speed, total distance, and effort-zone distribution (Z1–Z5). Technical–tactical indicators of attention (CARR%) and creativity (ICV%) were quantified through video analysis. Descriptive statistics and Pearson correlation coefficients ($p < 0.05$) were calculated using KyPlot 6.0.

Results Competition effort showed a predominantly aerobic profile (Z1 + Z2 ≈ 53% by HR), interspersed with repeated short anaerobic episodes (Z3–Z5 ≈ 39%). Speed zones revealed mainly slow-to-moderate movements. This indicates that physiological intensity was largely generated by frequent game actions rather than locomotor velocity. Attention performance remained high and stable across matches (CARR 71.95–78.69%). Creativity values were consistently higher in Series II (ICV 7.69–9.09%). Correlation analysis revealed both positive and negative associations between cognitive and physical indicators. Moderate positive correlations were observed between attention and creativity indicators and moderate-intensity zones ($R = 0.30$–0.46). In contrast, high effort (HR-Z5) was associated with reduced cognitive efficiency ($R = -0.25$ to -0.43).

Conclusions The interaction between physiological load and cognitive–tactical performance should be considered when planning training and competition strategies for young football players. Attention to effort-zone regulation and its cognitive implications may assist coaches in structuring training tasks that account for both physical and cognitive demands. The combined assessment of physiological and technical–tactical indicators provides a framework for informed training design and decision-making support.

Keywords: youth football, cognitive performance, effort zones, attention, creativity

Introduction

In youth football, performance development is a key objective for coaches and researchers. This focus is related to the complexity of learning, development, and early specialization processes in young athletes. The development of technical–tactical competences and cognitive abilities, such as attention and creativity, is considered important during formative stages. These factors influence decision-making quality and the effectiveness of collective actions in football games

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[1]. The evaluation of tactical expertise through representative tasks has highlighted the relevance of integrating decision-making processes and creativity into the development of young football players. This approach supports the analysis of performance in realistic game environments [2]. In addition, previous studies indicate the need for a systematic development of tactical creativity from early ages to support cognitive flexibility and adaptation to the dynamic demands of football [3].

Recent research examines the interaction between technical–tactical demands and higher-order cognitive functions. Such functions, particularly attention and creativity, are involved in the assessment of competitive performance. The results of football games are not determined solely by physical training or technical skills. They are also influenced by players' ability to rapidly perceive game-specific information, make efficient decisions, and generate appropriate tactical solutions. Several studies have shown that perceptual–cognitive processes form the basis of tactical creativity and decision-making in sport. These processes include anticipation, selective attention, and working memory [4]. Cognitive models of decision-making suggest that athletes with greater attentional control can use environmental cues more effectively and select appropriate tactical actions [5]. In addition, individual differences in attentional capacity have been associated with creative decision-making processes. This supports an integrative view of cognitive mechanisms in the generation of tactical solutions during football play [6].

Attention, as a cognitive function in invasion sports, influences reaction speed, decision accuracy, and anticipatory behavior. These elements are involved in the execution of technical–tactical actions. In addition, in-game creativity is related to performance outcomes, particularly in youth football, where cognitive development and competitive experience are still developing. Creativity is defined by flexible solutions, original decisions, and the ability to select actions that are unexpected but effective [7, 8].

Another research direction concerns the analysis of effort zones during competition. This analysis provides objective data on the physiological intensity and physical demands experienced by players. In football, internal and external load indicators are routinely monitored. These indicators include speed, accelerations, distance covered in different intensity zones, and heart rate dynamics. This approach allows the examination of how players respond to the physical requirements of the game. Recent studies indicate the need to combine internal and external load metrics to obtain a valid assessment of training and competition load. These components may respond differently to competitive demands and may influence physiological adaptations and fatigue risk in distinct ways [9]. Modern tracking technologies, such as GPS systems and wearable devices, allow quantification of intensity zones and biomechanical and physiological demands during games. They support integrated performance analysis [10]. The association of these data with technical–tactical and cognitive indicators is increasingly addressed in research. This approach enables the examination of how young players manage physical, decisional, and tactical demands during competition [11].

A gap remains in research concerning the simultaneous examination of attention, creativity, and technical–tactical performance. These variables are not commonly analyzed in relation to effort-zone parameters during real competitive contexts in youth football. Most investigations address cognitive aspects or tactical effectiveness separately. They do not include physiological or external load indicators within the same analytical model. Previous studies have examined perceptual and cognitive processes related to decision-making and tactical performance in youth athletes [8, 12, 13]. In addition, research on tactical skill development indicates that experiential learning and exploratory behaviors are involved in performance. However, these aspects are rarely examined in relation to intensity-zone distribution under competitive conditions [14]. An integrated approach may allow the identification of multidimensional performance profiles and support training planning for young football players.

The aim of this study is to examine the relationships between technical–tactical indicators of attention and creativity and competition-related effort-zone parameters in young football players. The analysis focuses on identifying interaction patterns relevant to training processes and tactical strategies in youth football competitions.

Research hypotheses:

1. Relationships exist between attentional indicators (reaction performance and decision accuracy) and effort-zone parameters during competition. These relationships reflect the association between attentional control and the management of physical demands.
2. Technical–tactical creativity is associated with the intensity and distribution of effort zones. Creative actions are observed under varying load conditions.
3. Technical–tactical performance indicators are influenced by both attention and creativity. This suggests a multidimensional performance profile in competitive settings.

Materials and Methods

Participants

The study involved 12 football players aged 10–12 years from School Sports Club No. 1 Pajura, Bucharest. All participants and their parents were informed about the research procedures and provided voluntary consent. The study protocol was approved by the Ethics Committee of the Doctoral School of Sport Science and Physical Education, National University of Science and Technology "Politehnica Bucharest", University Center Pitești (ID: 19/18.10.2024).

Research Design

The research was conducted from September to December 2022 at School Sports Club No. 1 Pajura "Biruința" sports facility, Bucharest. The study was carried out in two stages (S):
– S1 (22 October 2022): assessment of attention and creativity through video recording, together with functional monitoring using Polar heart rate devices during competition;
– S2 (December 2022): analysis of an unofficial performance ranking from the first round of the Bucharest Municipal Championship for youth football players (2012 age group).

The total duration of the observation period was 15 weeks. This period included 15 matches in Series I and 14 matches in Series II of the competition. The general objective of the training program during the observation period was the strengthening and application of fundamental technical skills in directed game conditions (Table 1).

Assessment of functional indicators during competition

To monitor physiological and functional parameters during competitions, a Polar Vantage V sports watch was used. This high-precision device (Human Performance Research Center, University Center Pitești) is designed for performance evaluation in endurance sports. The system provided monitoring data on the following effort-related parameters:

– Monitoring duration (minutes);
– Total distance covered (km);
– Heart rate (HR): average (avg.), maximum (max.), minimum (min.);
– Running speed (km/h): average (avg.) and maximum (max.);
– Running pace (min/km): average (avg.) and maximum (slowest time per km);
– Cardio Load (%): an index expressing myocardial strain induced by exercise, based on a five-level scale: Very low (<20%); Low (20–39%); Medium (40–59%); High (60–79%); Very high (80–100%).

Effort zones used in the analysis

Monitoring was also performed per effort zones, both for heart rate (HR) and running velocity, based on the following classification:

Table 1. Thematic content of technical training – observational stage (Period: September – December 2022)

Week	Main technical theme	Specific objectives	Competition / testing observations
1-2	Ball control and dribbling with both feet	Directional control, changes of pace, use of both feet	Match E1: CSS1 vs. FCSB Match E2: Champion vs. CSS1
3	Basic dribbling and obstacle evasion	Controlled dribbling, simple feints	Match E3: CSS1 vs. Pro Luceafărul
4	Short passing (inside of the foot)	Accuracy, execution speed, synchronization with teammates	Match E4: Chelsea vs. CSS1
5	Oriented first touch (inside/ outside of the foot)	Ball redirection, efficient movements after reception	Match E5: CSS1 vs. Voinicelul
6-7	Finalization from movement	Proper striking technique using laces/inside, timing of the shooting	Match E6: Best Boys vs. CSS1 Match E7: CSS1 vs. CSA Steaua (1–1)
8	Long passing (laces/ exterior)	Ball transmission over long distances, precision and power	Match E8: CSU Știința vs. CSS1
9-10	Ball shielding	Body positioning, stability, game intelligence	Match E9: CSS1 vs. Lazio Celest Match E10: ACS Juniorul 2014 vs. CSS1
11-12	Combination plays 2 vs 1 / 3 vs 1	Cooperation, quick passing, rapid decision-making	Match E11: CSS1 vs. FC Rapid 1923 Match E12: New Stars vs. CSS1
13-14	Finishing with the head and volleying	Coordination, timing, confidence in aerial duels	Match E13: CSS1 vs. CS Dinamo Match E14: Progresul 1944 vs. CSS1
15	Review of technical skills and mini-competition	Enhancement and application of technical skills in game situations	CSS1 vs. FCSB Academy

– Heart rate zones (bpm): Z1: 100–120 bpm; Z2: 121–140 bpm; Z3: 141–160 bpm; Z4: 161–180 bpm; Z5: 181–200 bpm.
– Running speed zones (km/h): Z1: 3–6.9 km/h; Z2: 7–8.9 km/h; Z3: 9–10.9 km/h; Z4: 11–14.9 km/h; Z5: 15–19 km/h.

Both the percentage (%) and the absolute duration (minutes) spent within each intensity range were analyzed for each zone. Thus, an insight into the players' physiological adaptations and their ability to regulate effort under varying competitive demands was provided.

Technical–tactical tests for assessing attention and creativity indicators

The technical–tactical indicators of attention included:

- Simple passes (successful – R; unsuccessful – NR);
- Anticipation actions (number of executions);
- Loss of marking position (number of executions);
- Defensive duels initiated by the player (R and NR).

The technical–tactical indicators of creativity included:

- Complex passes (R and NR);
- Offensive duels initiated by the player (R and NR);
- Anticipation actions (number of executions).

To quantify the attention coefficient based on the results of successful and unsuccessful simple actions, a percentage ratio (%) was calculated. This reflected the efficiency and attentional focus of the players. In that regard, the Successful Action Rate (CA_{RR}) was applied as an objective measure of attention performance.

Attention coefficient based on the successful action rate (CA_{RR}%)

$$CA_{RR} = \frac{A_{\text{successful}}(R)}{A_{\text{successful}}(R) + A_{\text{unsuccessful}}} \times 100\%$$

where:

$A_{successful}$ = number of successful simple actions;
$A_{unsuccessful}$ = number of unsuccessful simple actions.

Interpretation:

- A higher coefficient highlights superior attentional control and more accurate execution of technical actions under competitive demands.
- A lower coefficient may reflect reduced attentional efficiency, difficulties in maintaining focus, or increased susceptibility to cognitive interference during play.

A calculation method was employed for quantifying the creativity indicator based on complex actions (complex passes, anticipatory movements, offensive duels). This method accounts for the intentionality, efficiency, diversity and difficulty of tactical executions. This approach relies on the video-based recording and coding of all complex and simple actions performed by the players. It aims not only to capture the frequency of executions but also their variability within the game context. In this way, the indicator reflects the players' ability to adapt, innovate and demonstrate decision-making flexibility under competitive constraints. Accordingly, the following calculation method is proposed:

Decision variability creativity index (ICV%):

$$IC_V = \frac{A_{\text{individual}}}{A_{\text{group}}} \times 100\%$$

where:

$A_{individual}$ – total number of individual complex actions;
A_{group} – total number of complex actions performed by the group.

Interpretation: A player who uses a wide range of tactical solutions to respond to diverse game situations has a higher ICV value. This indicates an enhanced creative performance.

Statistical analysis

Statistical analysis was performed using KyPlot 6.0. Descriptive statistics included mean, standard error of mean (SEM), standard deviation (SD), coefficient of variation (CV%) and Confidence level of mean (0.95) (CLM0.95). The relations between indicators of attentional and creative involvement in technical–tactical actions and the physiological monitoring parameters were examined. This analysis was performed by calculating the Pearson's correlation coefficients. Statistical significance was established at $p < 0.05$.

Results

An analysis of attentional and creativity indicators related to physiological effort parameters and effort-zone distribution in 10–12-year-old footballers was conducted. The data were collected under competitive conditions. The results are presented in Tables 2–5 and Figures 1–3. These include the evolution of values across consecutive matches. They also include the correlation relationships between physical demands and cognitive performance in a real competitive context.

Table 2 summarizes the comparative results between Competitive Series I and II of the 2022–2023 Municipal Championship (second half). Football players aged 10–12 were monitored in terms of attentional and creative performance across five official matches (M1–M5). The evaluation involved two key indices: Attention Coefficient (CARR %) and Creativity Variability Index (ICV %), both expressed as percentages.

Analyzing the technical–tactical indicators of attention (CARR%) and creativity (ICV%) reveals

Table 2. Comparative results of the technical–tactical indicators of attention and creativity in competition

Descriptive statistical indicators	Series of competition	CA_{RR} (%)					IC_V (%)				
		M1	M2	M3	M4	M5	M1	M2	M3	M4	M5
Mean	I	71.95	78.69	72.82	72.96	75.85	6.67	6.67	7.69	7.69	7.69
	II	74.59	76.71	70.32	73.07	77.17	8.33	7.69	8.80	9.09	8.33
SEM	I	4.29	4.05	2.89	4.26	3.03	0.85	0.88	1.11	1.04	0.68
	II	3.08	3.54	5.61	4.60	3.05	0.92	1.28	1.79	1.14	0.98
SD	I	16.62	15.67	10.43	15.35	10.91	3.28	3.40	4.01	3.75	2.44
	II	10.67	12.75	18.61	15.26	10.57	3.19	4.60	5.95	3.76	3.40
CV (%)	I	23.10	19.92	14.32	21.0	14.39	49.17	50.98	52.15	48.76	31.77
	II	14.31	16.62	26.46	20.88	13.70	38.33	59.77	67.68	41.41	40.86
CLM (0.95)	I	9.21	8.68	6.30	9.27	6.59	1.82	1.88	2.42	2.27	1.48
	II	6.78	7.70	12.50	10.25	6.72	2.03	2.78	4.00	2.53	2.16

Notes: Th-Ta – technical-tactical, CARR – coefficient of attention – success rate; ICV –creativity indicator – variation of decisions; M – match; Confidence level of mean (0.95) – CLM (0.95); Series I: M1 and M2, n=15, M3-5, n=13; Series II: M3 and 4, n=11; M1 and M5, n=12, M2, n=13

Table 3. Results of competitive effort parameters in Series I

Effort parameters		Descriptive statistical indicators				
		mean	SEM	SD	CV (%)	CLM(0.95)
Effort duration monitoring (min)		69.54	0.86	2.97	4.27	1.88
Total distance covered (km)		2.19	0.07	0.25	11.56	0.16
HR (bpm)	Avg.	136.58	2.95	10.23	7.49	6.50
	Max	190.83	3.44	11.92	6.25	7.58
	Min	68.00	4.02	13.92	20.46	8.84
Speed (km/h)	Avg.	1.83	0.07	0.23	12.39	0.14
	Max	18.55	0.71	2.48	13.35	1.57
Pace (min/km)	Avg.	32.02	1.23	4.27	13.34	2.71
	Max	3.10	0.14	0.49	15.68	0.31
Cardio load (%)		90.33	8.12	28.11	31.12	17.86

Note: n=12, Heart rate (HR; bpm), Confidence level of mean (0.95) – CLM (0.95)

Table 4. Proportion of time spent in effort zones based on heart rate (HR) and running speed (V) during competitive play in Series I

Parameters / effort zones		mean	SEM	SD	CV (%)	CLM (0.95)
HR (bpm, %)	Z5	10.17	2.84	9.83	96.72	6.25
	Z4	12.83	2.36	8.17	63.64	5.19
	Z3	15.67	1.58	5.48	35.00	3.48
	Z2	30.00	3.00	14.88	49.60	9.46
	Z1	22.58	2.50	8.65	38.30	5.50
Speed (km/h, %)	Z5	0.00	0.00	0.00	0.00	0.00
	Z4	0.58	0.15	0.51	88.27	0.33
	Z3	1.83	0.30	1.03	56.17	0.65
	Z2	7.42	0.62	2.15	29.01	1.37
	Z1	25.33	0.77	2.67	10.56	1.70

Note. Z – zones of effort

Table 5. Duration of effort zones during competition based on heart rate and speed (Series I)

Parameters / effort zones		mean	SEM	SD	CV (%)	CLM (0.95)
HR (bpm, min)	Z5	6.90	2.01	6.98	101.20	4.43
	Z4	8.68	1.55	5.37	61.90	3.41
	Z3	10.84	1.16	4.01	36.95	2.54
	Z2	20.89	3.09	10.72	51.31	6.81
	Z1	15.57	1.69	5.85	37.57	3.72
Speed (km/h, min)	Z5	0.02	0.01	0.02	118.17	0.01
	Z4	0.19	0.04	0.13	68.00	0.08
	Z3	1.10	0.20	0.70	63.88	0.45
	Z2	4.90	0.45	1.55	31.64	0.98
	Z1	17.37	0.45	1.57	9.03	1.00

Note. Z – zones of effort

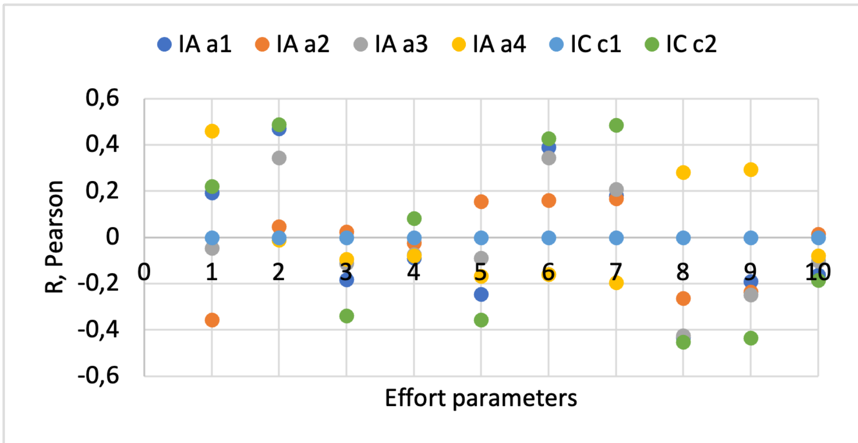

Figure 1. Analysis of correlations between attention and creativity indicators and competitive effort parameters (Series I). Notes: Effort parameters (1–10): 1 – effort monitoring duration; 2 – total distance; 3–5 – HR (bpm): avg., max., min.; 6–7 – speed (km/h): avg., max.; 8–9 – pace (min/km): avg., max.; 10 – cardio load (%). IA – indicators of attention (a1–a4): a1 – successful simple actions; a2 – unsuccessful simple actions; a3 – total simple actions; a4 – CARR (%) – coefficient of attention. IC – indicators of creativity: c1 – total complex actions; c2 – ICV (%).

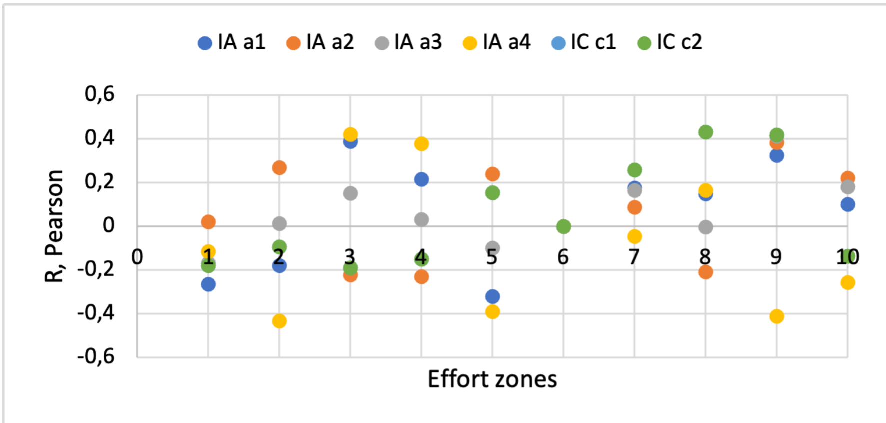

Figure 2. Correlations between attention and creativity indicators and the proportion of effort zones during competition (Series I). Notes: IA – indicators of attention (a1–a4): a1 – successful simple actions; a2 – unsuccessful simple actions; a3 – total simple actions; a4 – CARR (%) – coefficient of attention. IC – indicators of creativity: c1 – total complex actions; c2 – ICV (%). HR zones: 1 – Z5; 2 – Z4; 3 – Z3; 4 – Z2; 5 – Z1. Movement speed zones: 6 – Z5; 7 – Z4; 8 – Z3; 9 – Z2; 10 – Z1.

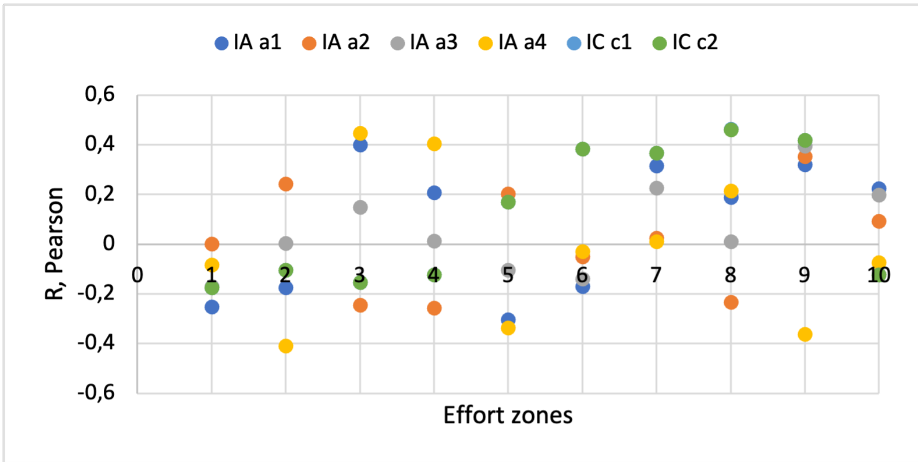

Figure 3. Correlations between attention and creativity indicators and the duration of effort zones during competition (Series I). Note. IA – indicators of attention (a1–a4): a1 – successful simple actions; a2 – unsuccessful simple actions; a3 – total simple actions; a4 – CARR (%) – coefficient of attention. IC – indicators of creativity: c1 – total complex actions; c2 – ICV (%). HR zones: 1 – Z5; 2 – Z4; 3 – Z3; 4 – Z2; 5 – Z1. Movement speed zones: 6 – Z5; 7 – Z4; 8 – Z3; 9 – Z2; 10 – Z1.

differences between the two series across the competitive sequence (M1–M5). Regarding the attention coefficient (CARR%), both series showed high and relatively stable values. Mean values ranged between 71.95% and 78.69% in Series I and between 70.32% and 77.17% in Series II. Series I reached a peak in M2, followed by a moderate decline. In contrast, Series II showed a slight increasing trend, indicating progressive adaptation to competitive demands.

In contrast, the creativity indicator (ICV%) showed clearer differences between the two series. Series I increased gradually from 6.67% (M1–M2) to 7.69% (M3–M5), whereas Series II consistently showed higher values. Series II values ranged from 7.69% to 9.09%, reflecting greater decision-making flexibility and tactical variability.

Variability analysis (SEM, SD, CV%) indicated greater dispersion of creative performance in Series II, particularly in M3 (CV = 67.68%). This suggests pronounced individual differences in the expression of creativity under competitive conditions.

Table 3 provides an overview of the intensity and efficiency of physical effort exerted by 10–12-year-old football players. Data were collected during Match 4 of the first competitive round of the 2022–2023 Championship. For this purpose, heart rate (HR), locomotor speed, running pace, and cardiovascular load ("Cardio Load") were monitored.

The analysis of the physiological parameters monitored during competition indicates a medium-to-high intensity effort profile. This profile is characterized by alternations between maximal exertion episodes and phases of active recovery. The average duration of effort was 69.54 minutes, with low variability (CV = 4.27%), reflecting a consistent level of competitive engagement. The average total distance covered was 2.19 km, suggesting moderate involvement in high-intensity locomotor actions.

Cardiovascular parameters indicate a substantial demand on the cardiorespiratory system. The mean heart rate was 136.58 bpm, the peak value was 190.83 bpm, and the cardio load level was high (90.33%). The variability observed in minimum heart rate and cardiovascular load (CV ⩾ 20%) indicates individual differences in effort regulation capacity. The average running speed was low (1.83 km/h), which is consistent with the intermittent nature of football at this age. Peak speed (18.55 km/h) indicates the occurrence of high-acceleration actions during specific phases of the game.

Overall, the effort profile reflects a mixed aerobic–anaerobic model determined by the rapid alternation of game phases. These data provide a physiological basis for interpreting the interplay between physical demands and cognitive performance (attention and creativity). This interaction is further examined in the following sections.

Table 4 presents the percentage distribution of time spent by 10–12-year-old football players in different effort zones. The results are based on both heart rate (HR) and running speed (V) during competitive games. Analysis of these data allows the examination of relative intensity of physical exertion and physiological engagement strategies throughout the competition.

Results on effort distribution across physiological zones (Series I)

The percentage distribution of effort reflects a predominantly aerobic competitive profile with distinct episodes of high-intensity activity. Based on heart rate (HR) data, athletes spent the largest proportion of time in Zone 2 (30.00%). A smaller proportion was observed in Zone 1 (22.58%). This indicates a predominance of moderate effort and active recovery (cumulative 52.58%). In addition, 38.67% of the competition duration occurred in higher-intensity zones (Z3–Z5). This confirms the involvement of anaerobic mechanisms during tactical situations requiring high effort.

From the perspective of movement speed, effort was concentrated almost exclusively in low-speed zones (Z1–Z2 = 32.75%). Zones 3–5 recorded minimal values, with maximal sprints absent (Z5 = 0%). This discrepancy suggests that physiological intensity was determined more by the frequency and nature of game actions than by locomotor speed. High variability was observed in maximal intensity zones (CV > 60% in Z4–Z5). This indicates marked individual differences in effort profiles and tactical roles of the players.

The data demonstrate a mixed aerobic–anaerobic effort pattern characteristic of youth football. This pattern includes intermittent sequences of maximal-intensity activity combined with periods of moderate activity. These data provide a basis for further correlation with attention and creativity indicators to examine competitive performance.

Table 5 presents the temporal distribution of effort during competition. The table is based on the time (in minutes) spent in each intensity zone according to both heart rate and running speed. These data describe the physical characteristics of effort and reflect the predominance of specific physiological activity regimes.

Results on the duration of effort zones during competition (Series I)

Analyzing the effort duration across physiological zones confirms the predominance of an aerobic regime. Players spent most of the time in Zone 2 (20.89 min) and Zone 1 (15.57 min). This indicates a moderate activity pace with frequent periods of active recovery. High-intensity episodes also contributed to the competitive profile. Zones 3–5 accounted for a total of 26.42 minutes, including approximately 7 minutes in Zone 5. This indicates the presence of anaerobic demands during decisive phases of the game.

Regarding movement speed, time was mainly spent in low-speed zones (Z1–Z2), with only occasional engagement in faster actions. Zones 3–5 together accounted for less than 8% of the total duration, and maximal sprints were almost absent (Z5 = 0.02 min). High variability in these zones (CV > 60%) indicates individual differences in tactical roles and fitness levels. A contrast was observed between high cardiovascular demand and low average speed. This suggests that competitive intensity is generated by the frequency and nature of game actions rather than by fast movement alone. The resulting profile reflects a mixed aerobic–anaerobic pattern of effort characteristic of youth football. This allows correlations with indicators of attention and creativity.

The influence of technical–tactical indicators of attention and creativity on effort parameters and effort zones during competition was examined. For this purpose, linear correlation analysis (Pearson's R) was conducted.

Figures 1–3 present the statistical relationships between attention and creativity indicators and selected effort parameters during competition (Series I). These figures illustrate the association between cognitive processes and overall effort intensity, as well as effort distribution and duration across physiological stress zones.

Figure 1 presents the Pearson correlation matrix between cognitive variables (attention and creativity) and physiological effort parameters. A total of 60 correlations were analyzed, of which 26 (43.3%) were positive and 34 (56.7%) were negative. These values indicate a general tendency toward inverse associations between physical exertion intensity and cognitive performance.

Positive correlations were mainly observed between attention and creativity indicators and selected effort parameters. This suggests that moderate-to-high levels of physiological activation may be associated with attentional engagement in competitive situations. Examples include total duration (2) and successful simple actions (a1) ($r = 0.472$), indicating a moderate association between effort involvement and attentional processes. Average speed (km/h, Avg., 6) showed a positive association with a1 ($R = 0.391$), while maximum speed (km/h, Max., 7) was weakly associated with unsuccessful simple actions (a2) ($R = 0.169$). In addition, effort monitoring duration (1) and parameter (7) showed moderate positive correlations with creativity indicators c1 (total complex actions) and c2 (ICV %) ($R = 0.48–0.49$), suggesting increased cognitive engagement during demanding phases of play.

Most negative correlations were observed between movement speed parameters (pace, min/km: Avg. (8) and Max (9)) or maximal intensity indicators and sustained attention indicators (a1), average heart rate (HR Avg., 3), and minimum heart rate (HR Min., 5). Representative examples include correlations between parameter 8 and a1 ($R = -0.431$) and between pace Max (9) and a2 ($R = -0.236$). These moderate associations suggest a possible inhibitory effect of higher effort intensity on attentional accuracy. A moderate negative correlation was also observed between parameter 5 and c1 ($R = -0.357$), indicating reduced creative expression under higher load conditions. In addition, correlations between parameter 3 and cardiovascular indicators ($R = -0.11$ to -0.18) were weak but consistent, suggesting gradual cognitive fatigue.

The predominance of negative correlations indicates that high-intensity (anaerobic) episodes may interfere with executive functions. Such interference may affect reaction speed, cognitive flexibility, and creative processes. No correlation exceeded the threshold of $R \geqslant 0.50$, indicating a complex and multifactorial relationship between physiological effort and cognitive functions at this age.

Figure 2 illustrates the Pearson correlations between attention (AI), creativity (CI) parameters and the proportion of time spent in different effort zones defined by heart rate (HR) and movement speed (V). A total of 60 correlations were analyzed. Of these, 27 (45%) were positive, while 33 (55%) were negative. This indicates a predominantly inverse relationship between high physical exertion and cognitive performance.

Positive correlations were more frequently associated with moderate-intensity zones (V-Z2–Z4) and intermediate cardiac effort zones (HR-Z3–Z4). This indicates an association between physiological activation and vigilance and creativity. Representative examples include correlations between Z3 and a1 (r = 0.389) and between Z3 and a4 (r = 0.420), which indicate that cardiovascular activation is associated with attentional processes during tactically demanding moments. Positive associations were also observed between Z2 and a1 (R = 0.215) and between Z2 and a4 (R = 0.378), reflecting relationships between effort and distributive attention. Creativity indicators (c1–c2) showed moderate positive correlations with average speed zones, including Z3 with c1/c2 (R = 0.432) and Z2 with c1/c2 (R = 0.418). These associations indicate that creative actions tend to occur during short accelerations and dynamic game situations. These patterns are consistent with the optimal arousal framework, which describes improved cognitive performance at moderate levels of effort intensity.

Negative correlations were predominantly observed in extreme physiological zones (HR-Z1 and HR-Z5) and sustained attention indicators, reflecting interference associated with overload. Representative examples include Z2 with a4 (R = −0.432), indicating reduced selective attention at high cardiac intensity, and Z1 with a1 (R = −0.320) and Z1 with a4 (R = −0.389), indicating reduced attentional control under maximal effort. Zone 5 showed weak negative correlations across cognitive–tactical parameters (R = −0.11 to −0.26), suggesting cognitive fatigue during periods of high-intensity play. For movement speed, the correlation between Z2 and a4 (R = −0.411) indicates that involvement in explosive actions is associated with reduced decision-making control.

The predominance of negative correlations indicates that repeated anaerobic effort may adversely affect cognitive flexibility, reaction time, and decision-making creativity.

Figure 3 presents Pearson correlations between attention (AI) and creativity (CI) indicators and the time spent by athletes in different physiological effort zones. These zones are defined by heart rate (HR: Z1–Z5) and movement speed (V: Z1–Z5). A total of 60 correlations were analyzed, of which 29 (48.3%) were positive and 31 (51.7%) were negative. This reflects a balance between associations indicating facilitation and interference of physical load with cognitive functions.

Positive correlations were mainly observed in moderate effort zones. For heart rate, correlations were found between Z3 and a1 (R = 0.401) and between Z3 and a4 (R = 0.448). These moderate associations indicate that longer durations at upper-aerobic intensity are associated with attention during dynamic tactical situations. A positive correlation was also observed between Z2 and a4 (R = 0.404), indicating an association between sustained submaximal effort and attentional control.

For movement speed, correlations were identified between Z2 and a1 (R = 0.321) and between Z2 and a3 (R = 0.395). These results indicate that short-duration accelerations are associated with vigilance and reaction processes. Moderate effort durations, particularly in zones Z3–Z4, are associated with levels of physiological activation related to selective attention and information processing (Th–Ta).

Positive correlations associated with durations in speed zones were more numerous and consistent: Z3–c1/c2 (R = 0.463), which was the highest positive correlation in the series; Z2–c1/c2 (R = 0.418); Z5–c1/c2 (R = 0.383); and Z4–c1/c2 (R = 0.367). Short periods of medium- or high-speed movement are associated with the generation of varied technical–tactical solutions, reflecting operative creativity during play.

Comparative analysis of the results shows concordance in the distribution of correlations between Th–Ta parameters (attention and creativity) and physical effort indicators. These are expressed through effort parameters, the proportion of time spent in different physiological zones, and the duration within these zones.

Discussion

The study results indicate specific relationships between cognitive technical–tactical performance (attention and creativity) and physiological demands during competition in football players aged 10–12 years. The convergence of comparative and correlation analyses reflects the mixed nature of competitive effort and its association with cognitive mechanisms involved in decision-making.

Repeated exposure to competitive situations is associated with changes in decision-making processes and cognitive flexibility. This assumption is supported by the upward trend observed in sustained attention (CARR%) and the differentiation of decision-making creativity (ICV%) in Series II.

These observations are consistent with previous research showing that tactical experience and repeated engagement in unpredictable contexts reduce cognitive load during decision-making [15, 16]. Such conditions are also associated with the expression of technical–tactical creativity in young athletes [4, 17, 18].

Analyzing effort zones reveals a predominantly aerobic profile, interspersed with short bouts of high intensity, reflecting the intermittent nature of youth football. Accordingly, the hypothesis that physical demand is not solely dependent on locomotion speed but also influenced by neuromuscular, decisional, and emotional factors is supported. This observation is consistent with studies indicating the role of aerobic endurance in the development of tactical performance in young football players [19, 20].

Correlation analysis showed a substantial proportion of negative relationships (52–57%). These associations indicate that high physiological demands may interfere with attentional control and tactical creativity. This pattern corresponds to the inverted-U model describing the relationship between effort and cognition [21], according to which cognitive performance is highest at moderate activation levels and decreases under lower or excessive activation. In contrast, moderate positive correlations (R = 0.30–0.46) indicate an association between dynamic engagement and decision-making processes and tactical–creative flexibility in young players. These correlations were related to upper-aerobic zones (HR-Z2–Z3) and medium movement speeds [19, 22, 23].

The present findings expand previous football research by indicating that physiological load alone does not fully explain performance variability in young players. Studies focusing on body composition and biomotor parameters [24] as well as on player load and anaerobic performance [25] emphasize physical determinants of performance. In contrast, the current results suggest that high or prolonged intensity may interfere with attentional stability and creative decision-making, whereas moderate-intensity effort appears more favorable for optimal cognitive–tactical functioning. This perspective supports a more integrated interpretation of performance regulation under competitive conditions.

The findings of this study confirm the need for optimal synchronization of physical demand intensity and cognitive requirements when designing tasks for young footballers. Alternating moderate-effort sequences with highly unpredictable tactical situations can enhance both physical and decision-making performance [8, 26, 27, 28]. Objective monitoring using physiological parameters such as heart rate and internal load enables the individualized and real-time optimization of competitive regulation [29].

Overall, the present study adds to the existing literature by demonstrating the interdependence between physiological load and cognitive–tactical performance in football. The findings indicate that the regulation of effort intensity is relevant not only for physical efficiency but also for attentional control and creative decision-making under competitive conditions. From a practical perspective, the results support the consideration of combined physiological and cognitive demands when structuring training tasks and competitive preparation. Such an approach may assist in aligning physical load management with the development of tactical and decisional performance.

Limitations of the Study and Future Research

This study has several limitations that should be considered when interpreting the findings. The relatively small sample size and the focus on a single age group may limit the generalizability of the results to other competitive levels or age categories. In addition, the observational design restricts causal inference between physiological load and cognitive–tactical performance. Future research should include larger and more diverse samples, longitudinal designs, and experimental task manipulations to further clarify the interaction between physical demands, attentional processes, and creative decision-making in football.

Conclusions

1. The competitive effort profile in 10–12-year-old players is predominantly aerobic, with short episodes of maximal intensity. This profile reflects physiological characteristics of youth football and provides conditions for functional adaptation.
2. Moderate-intensity effort is positively associated with attention and creativity. This association indicates that psychophysiological activation at moderate levels is related to decision-making processes and tactical flexibility during play.
3. Maximal intensity or prolonged exertion is associated with interference in information processing and creativity. This reflects limitations of cognitive control when physiological load exceeds self-regulation capacity in young athletes.
4. Competitive experience is associated with greater stability of cognitive functions. Repeated exposure to real-game situations is accompanied by more consistent levels of selective attention and tactical–decisional creativity.
5. Joint analysis of physiological, attentional, and creative indicators supports the use of a multidimensional approach to evaluating youth performance. This approach allows the consideration of individual cognitive–physiological profiles in training design.

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Conflict of interest

The authors declare no conflict of interest.

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