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EXAMINATION OF EXECUTIVE FUNCTIONS AFFECTING SPORTS PERFORMANCE IN THE CONTEXT OF ATHLETE EXPERIENCE

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Abstract

Introduction: In our research, we investigated the components, executive functions, and cognitive abilities underlying decision-making in sports performance using a computer-based test system. To define the athlete experience, we classified athletes according to an exact, unambiguous definition following international terminology, based on their performance, achievement, playing age, and sport's popularity. We hypothesize that team athlete with significant athletic experience will perform better on the executive function test.
Methods: A cross-sectional study was conducted on team athletes N=52. The VTS-DT test was used to measure executive function. The classification of athlete experience was based on an internationally accepted taxonomy defined with scientific precision (SWANNN, 2015).
Results: When classified by athlete experience, the athletes we studied fell into amateur and elite categories. The DT/S2 scores of the two groups were compared based on each factor. We obtained trend-like correlations for the factors 'number of reactions', 'number of stimulations,' and 'number of good responses. Correlation analysis was performed between the factors on a group-by-group basis. When examining the relationship between reaction time, we found that there is a strong relationship with the number of stimulations (amateurs: r = -0.80; elite athletes: r = -0.87) since the faster someone is (i.e., the less reaction time), the more times they can respond to stimulations. Looking at the results for elite athletes, we also observe a moderately strong relationship between reaction time and the number of good responses (r = -0.68). We may suggest that experienced athletes could produce better responses faster than less professional athletes.
Conclusions: Our hypotheses were partially confirmed, as we found a trend-like correlation that elite athletes scored higher on the DT test, which examined athletes' executive functions in a complex, adaptive way. Our research demonstrates that, on the one hand, it is worthwhile for coaches to build on experienced athletes when assembling a team, in addition to the momentum of young athletes, and that the development of executive functions and cognitive skills can improve the performance of athletes.

Keywords*: executive function, cognitive skills, athlete experience, sport performance*

THEORETICAL BACKGROUND

The effective development of sports performance is a complex sports science task and a key area of research in sports science. Researchers use various measurement methods to precisely define athlete performance and improve it through back-measurement.

In the international literature, players are considered athletes with high playing intelligence and a high cognitive ability to make the best possible decisions as quickly as possible. In other words, through perception and perception, attentional selection processes, they can implement the learned and experienced response to the decision situation as quickly as possible, even with the support of anticipation in the case of a high-level athlete (BALOGH-DONKA, 2020).

Sports performance measurement can be effectively implemented in a specific, sport-oriented way. Sports require different skills and therefore need other methods of measurement and development (ALLARD - BURNETT, 1985).

For a long time, outstanding performance was defined as sporting attributes (technical, tactical skills) and physical abilities (anthropometric, physiological, and psychological). However, there has been growing evidence that these factors cannot fully guarantee performance. In ball games, players must make decisions quickly and accurately using the right skills in a constantly changing environment. The constant decision-making situation requires good problem-solving skills and cognitive flexibility. In neuropsychology, these cognitive abilities are called executive functions (EF). Executive functions are a set of mental processes necessary for the cognitive control of behavior: working memory, cognitive flexibility (closely related to creativity), and inhibitory control (self-control, selective or focused attention) (SAKAMOTO et al., 2018).

Executive functions describe the cognitive processes that regulate thinking and action, especially in non-routine situations. Research has shown that the higher the executive function of an athlete, the more effective the player. Executive functions are essential in achieving successful sports performance, especially in team sports, which require quick anticipation and adaptation. In elite and amateur football players, executive functions, control, attention, and visual-spatial working memory were investigated. Elite footballers were more likely to have self-control and alert attention: both are essential for success in football (VERBURGH et al., 2014).

In a meta-analysis of several international studies, national researchers have found that optimal arousal levels, which are a fundamental condition for achieving high sports performance, are also related to cognitive ability. Namely, an increase in arousal level is associated with an increase in the level of nervous system activity, thus contributing to higher levels of cognitive ability (NÉMETH - BALOGH, 2021)

Executive functions are goal-oriented cognitive control processes in our everyday lives (problem-solving, planning). In sport, this can be mapped to three interrelated yet distinct components: switching between tasks, operations, mental sets (e.g., adaptation), control of dominant responses (e.g., suppression of cognitive and behavioral tendencies caused by internal or external stimuli); updating working memory (e.g., exchange of incoming information as well as irrelevant information) (MIYAKE et al., 2000).

The decision quality and a realistic risk assessment are critical factors for successful sporting performance. Athletes differ substantially in their decision-making ability depending on their level of sporting ability. Moreover, the influence of emotions on decision-making is likely influenced by emotional intelligence (VAUGHAN et al., 2019).

There has been a significant interest in the cognitive control processes that regulate executive function, thinking, and behavior in recent years, as research supports that VF influences all aspects of human performance (SAKAMOTO et al., 2018). Further research has shown a link between mood and executive function (MARTINENT-NICOLAS, 2017; DAVIS-JOWETT, 2014; LOWTHER-LANE, 2002).

Research has been conducted comparing athletes and non-athletes in different sports. The sports were selected according to the pace at which the athletes performed the movements. Sports with independent rhythm where the activities are performed to their beat (tennis, football free kicks) and sports with a fixed rhythm (dance, gymnastics) where the movements are performed to the tempo of the music. Athletes scored higher on executive function scores than non-athletes. In a study of sports, athletes with independent rhythm scored highest on the self-control task, and athletes with a set rhythm scored higher on the problem-solving task (JACOBSON-MATTHAEUS, 2014). So, the role of executive function may vary by sport and be of different quality.

Although some researchers have reported no significant difference in their results when comparing elite and amateur athletes, they argue that it is essential to consider assessing executive function alongside physical and technical skills when measuring ability (LUNDGREN et al., 2016).

Several studies have addressed the relationship between executive functions and athlete experience and its impact on sports performance (VANCINI et al., 2019; VAUGHAN-EDWARDS, 2020; VAUGHAN – McCONVILLE, 2021). High VF components are associated with better sports performance, depending on the individual athlete's talents and expertise (HAGYARD et al., 2021).

In a study on the athlete experience, based on 91 studies, researchers concluded that there is no single definition for the classification of athletes. Therefore, a standardized taxonomy of sport types was proposed, which considers the highest level of performance based on athlete experience, sports competitiveness, and global representativeness of the sport (SWANN et al., 2015).

PURPOSE

Our research investigated the components, executive functions, and cognitive abilities underlying decision-making and determining sports performance. To define the athlete experience, we classified athletes according to a clear definition based on their performance, results, playing age, and sport's popularity.

Our research questions and hypotheses are:

Q1: Is there a relationship between executive function and athlete experience?

H1: We hypothesize that there is a relationship between executive function and athlete experience.

Q2: Is a relationship between high executive functions and an athlete's experience?

H2: We hypothesize that the more experienced an athlete is, the higher their level of executive functions.

METHOD

Our research method is experimental. Data were collected at the Complex Sport Behavioural Analysis Laboratory of the DE Institute of Sport Science using a VTS (Schufried, Vienna) system.

Results were processed using general descriptive statistics (MS Excel 2020), and a t-test was used to perform comparative statistics.

Athletes were tested in laboratory conditions while sitting in front of a computer. The Determination Test (DT) is a complex response test consisting of several stimuli, alternating color stimuli, and acoustic signals. The athlete responds by pressing the corresponding buttons on the response panel and using the pedals. The test takes approximately 12 minutes and provides immediate complex results on the number of

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responses of the user (good, inadequate, missed responses, reactions, number of stimuli, reaction time).

The VTS-DT/S2 computer-based test measured executive function because the test presentation was adaptive. Individuals can encounter stimuli with a high enough frequency to make a mistake so that the test can examine behavior under different levels of psychophysical stress. The VTS-DT is an internationally recognized and used test to explore the cognitive abilities and reaction times underlying decision-making.

SAMPLE

A cross-sectional study was performed on team athletes N=52.

- 14 male football players (NB3)
- Nine men's futsal (NB1)
- Four men's volleyball (NB1)
- 13 female volleyball players (NB2)
- 12 handball players (NB1/B)

The classification of athlete experience was based on an internationally accepted taxonomy defined with scientific precision (Table 1) (SWANN et al., 2015).

The definitions should be based on the highest performance of the athletes, their success at that level, and the experience gained at that level. It is essential to consider the competitiveness of the sport within the country and within the sport itself. The following equation and classification system are proposed:

$$\{(A+B+C/2)\ /3\} \times \{(D+E)\ /2\}$$

1. Table: Classification based on athlete experience; source: (SWANN et al., 2015)

1-4	semi-elite
5-8	competitive elite
9-12	successful elite
13-16	world-class elite

Here, semi-elite are those whose highest level of participation is below the highest level possible in their sport (e.g., competing in talent development programs, competing at or below second division level, etc.). Elite (competitive) athletes regularly compete at the highest level of their sport (e.g., elite divisions/championships, Olympic Games, etc.) but have not succeeded. Successful elite athletes not only compete at the highest level but have also experienced some (rare) success at that level (e.g., winning a race or medal). World-class elite athletes achieve sustained success at the highest level and with repeated victories over a long period (e.g., winning a gold medal at consecutive Olympics or significant competitive victories over multiple seasons).

RESULTS

When classifying athletes according to their sporting experience, the athletes we studied fell into two categories: semi-elite and (competitive) elite. Categorization was carried out using the formula mentioned above. The DT/S2 scores of the two groups were compared

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based on each factor (missed responses, wrong responses, reaction time, number of reactions, number of stimulations, and number of adequate responses) (Figure 1-7).

Data were analyzed using MS Excel 2020. After normality testing, it was found that the data were parametric. A parametric independent t-test was then performed. No significant difference was found between the two groups for any of the following: missed responses (p=0.38), incorrect responses (p=0.33), reaction time (p=0.24), number of reactions (p=0.06), number of stimulations (p=0.08) and correct responses (p=0.09). Tendency-like correlations were obtained for the most significant factors 'number of reactions', 'number of stimulations' and 'number of good responses.'

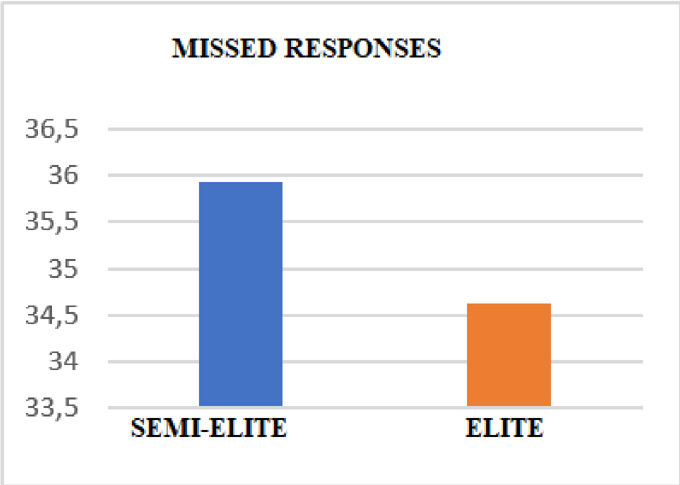

Figure 1: Comparison of average results for semi-elite and elite athletes based on DT/S2 'Missed answers' Source: own source

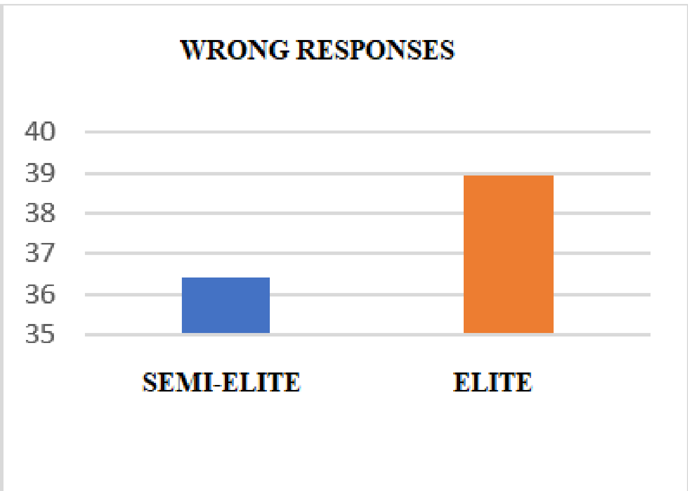

Figure 2: Comparison of average results for semi-elite and elite athletes based on DT/S2 'Wrong Responses' Source: own source

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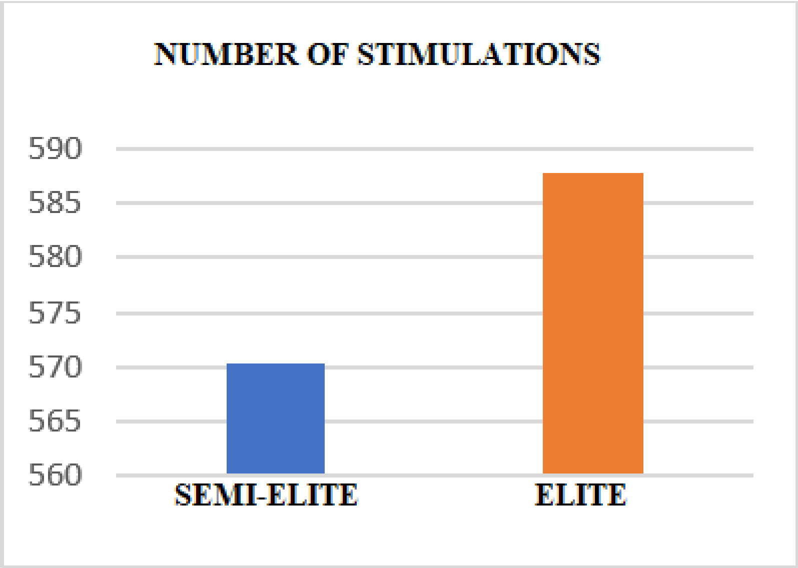

Figure 3: Comparison of average results for semi-elite and elite athletes based on DT/S2 'Number of stimulations' Source: own source

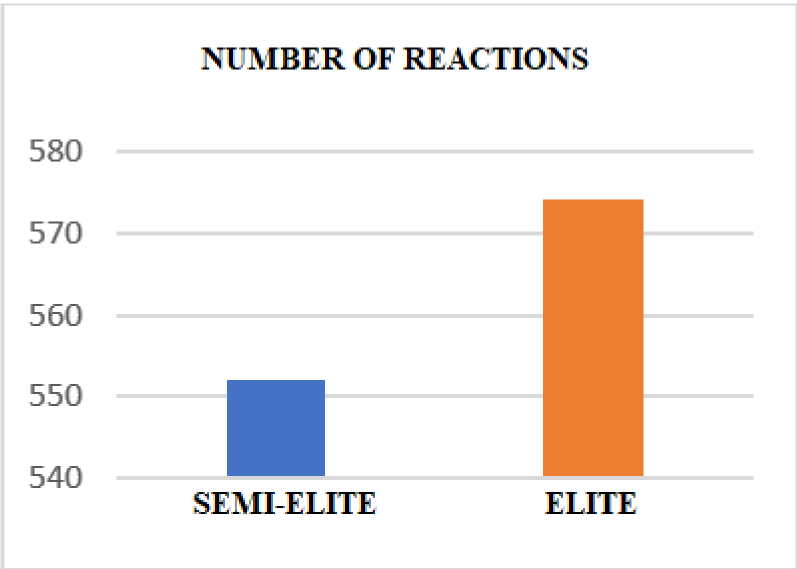

Figure 4: Comparison of average results for semi-elite and elite athletes based on DT/S2 'Number of reactions' Source: own source

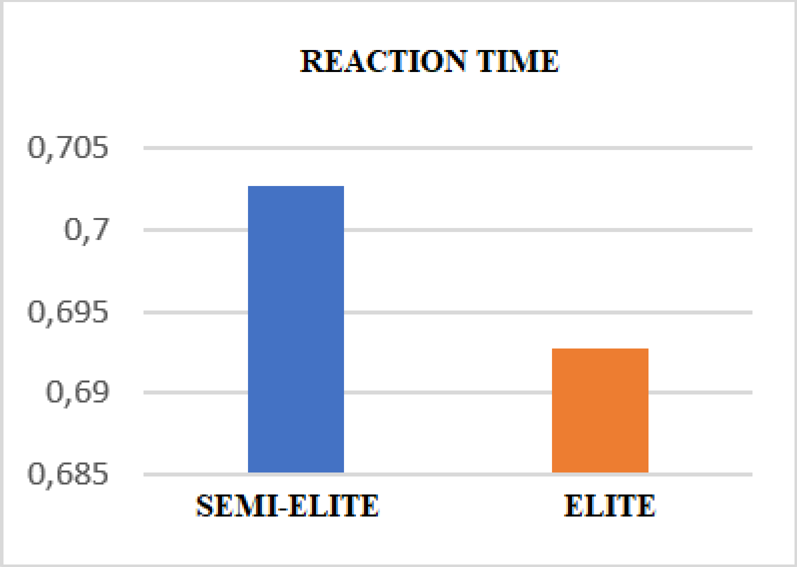

Figure 5: Comparison of average results for semi-elite and elite athletes based on DT/S2 'Reaction Time' Source: own source

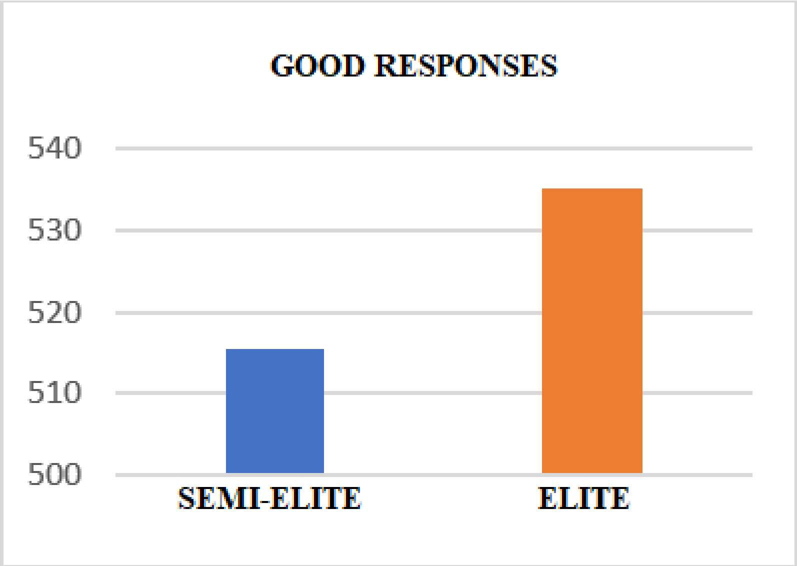

Figure 6: Comparison of average results for semi-elite and elite athletes based on DT/S2 'Good responses' source: own source

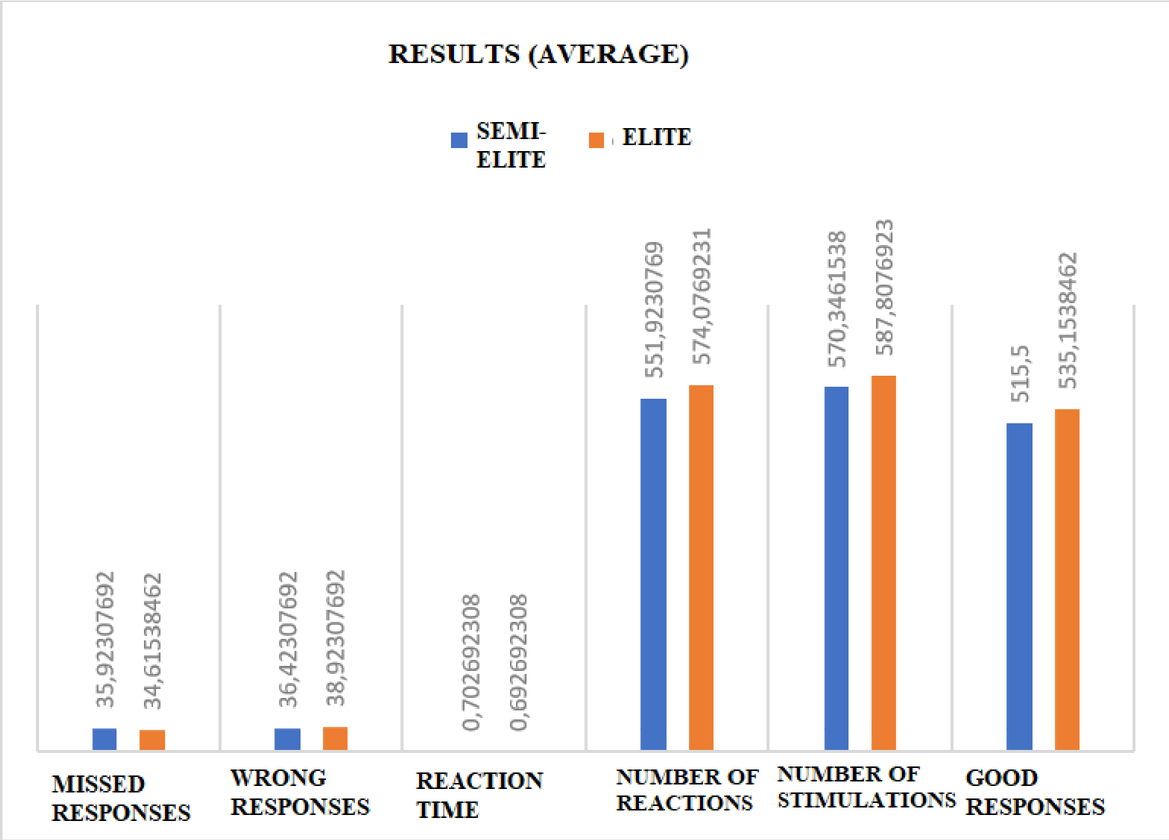

Figure 7: Comparison of average results of semi-elite and elite athletes based on DT/S2 parameters

The relationship between the semi-elite and elite athlete classification groups was tested by correlation analysis. The most robust relationship between the two groups was found between the number of good responses and the number of missed responses. Based on the groups' mean scores, we know that experienced athletes, on average, gave more good answers and were less prone to ignore stimuli than less professional athletes. Since the correlation between these two parameters was the strongest, there is a relationship between the cognitive performance of experienced athletes and their experience as athletes.

Table 2: Correlation coefficients between semi-elite and elite groups by parameter, source: own source

	DT/S2 RawScore Missed responses	DT/S2 RawScore Wrong responses	DT/S2 RawScore Reaction Time	DT/S2 RawScore Number of Reactions	DT/S2 RawScore Number of Stimulations	DT/S2 RawScore Good responses
r=	0,289459	0,170275	0,205208	0,136617	0,276629	0,32598

Table 3: Correlation coefficients between amateur and elite athlete groups by parameter, source: own source

Semi-Elite Athlete	DT/S2 RawScore Missed responses	DT/S2 RawScore Wrong responses	DT/S2 RawScore Reaction Time	DT/S2 RawScore Number of Reactions	DT/S2 RawScore – Number of Stimulations	DT/S2 RawScore Good responses
Missed responses	-	0,490480037	-0,5745902	-0,1644633	0,056461432	-0,352528
Wrong responses	***0,49048***	-	-0,3669865	0,05121869	-0,04913665	-0,357242
Reaction Time	-0,57459	-0,36698653	-	-0,6526442	-0,80139492	-0,461696
Number of reactions	-0,164463	0,051218688	-0,6526442	-	0,936016529	0,914488
Number of stimulations	0,0564614	-0,04913665	***-0,8013949***	0,93601653	-	0,895307
Good responses	-0,352528	-0,35724233	-0,4616961	***0,91448832***	0,895306836	-

Table 4: Correlation coefficients between amateur and elite groups by parameter, source: own source

Elite Athlete	DT/S2 RawScore Missed responses	DT/S2 RawScore Wrong responses	DT/S2 RawScore Reaction Time	DT/S2 RawScore Number of Reactions	DT/S2 RawScore – Number of Stimulations	DT/S2 RawScore Good responses
Missed responses	-	0,2917318	0,0928235	-0,60483	-0,521527	-0,721268
Wrong responses	0,2917318	-	-0,3343807	0,202409	0,02616872	-0,191727
Reaction Time	0,0928235	-0,334381	-	-0,80754	-0,8686294	-0,677367
Number of reactions	-0,60483	0,2024088	-0,8075358	-	0,95791616	0,9223263
Number of stimulations	-0,521527	0,0261687	***-0,8686294***	0,957916	-	0,9496909
Good responses	***-0,7212676***	-0,191727	***-0,6773667***	***0,922326***	0,94969086	-

We also looked for links between factors within semi-elite and elite groups. Correlation analysis was used to examine the relationship between all parameters, shown in (Tables 3 and 4). Positive results show a one-way correlation, and negative results show an opposite-direction correlation. There is a strong relationship between the number of stimulations, number of reactions, and number of correct responses for semi-elite and elite athletes. Regarding the relationship between missed responses, semi-elite athletes show a medium relationship for poor responses (r = 0.49).

In contrast, elite athletes show an almost strong relationship (r = -0.72) with better responses the fewer missed stimuli. Looking at the relationship between reaction time, we find that there is a strong relationship concerning the number of stimuli (semi-elite: r = -0.80; elite athletes: r = -0.87) since the faster someone is (i.e., the less reaction time), the more times they can respond to stimuli. The elite athletes' results show an almost strong relationship between reaction time and the number of good responses (r = -0.68) but moderate relationship for semi-elite athletes (r = -0.46). This suggests that more experienced athletes could produce better responses faster than less professional athletes.

DISCUSSION

Our study aimed to compare groups (semi-elite and elite athletes) based on athlete experience in executive function and cognitive ability.
"H1: We hypothesize that there is a relationship between executive function, cognitive ability, and athletic experience.
H2: We hypothesize that the more experienced an athlete is, the higher their level of executive functions."

Based on our results, our hypotheses were confirmed. We found a trend-like correlation that elite athletes scored higher on the DT test, which examined athletes' executive functions in a complex, adaptive way.

Our research demonstrates the value of classifying elite athletes based on athlete experience in a rigorous, scientifically rigorous manner. The purpose of grouping by athlete experience is to answer questions of team composition, as there is a need for freshness and drive of young players in a team and experienced, seasoned players. The performance of athletes under stress is related to their experience as athletes and their level of executive function.

Technological advances have made it possible to assess motor skills using modern, innovative instruments, and the same approach is needed for cognitive, emotional-affective skills. Therefore, it is vital to test the executive functions with innovative devices that give precise results, use the results obtained, and incorporate their development into training. Furthermore, systematic testing of executive functions can also help select athletes at the post-graduate level and in the selection of national teams. In the future, we consider it essential that the skills and executive functions underlying athletic performance should be given priority in the question of athlete performance, as they play a decisive role in athletes' success.

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ANNEX:

5. Table: Measurement results, source: own source

	athlete experience rating	DT/S2 RawScore - A - Omitted	DT/S2 RawScore - F - Incorrect	DT/S2 RawScore - MDRT - Median reaction time	DT/S2 RawScore - R - Reactions	DT/S2 RawScore - S - Number of stimuli	DT/S2 RawScore - ZV - Correct
d1	2	46	35	0,69	531	560	496
d2	3	44	25	0,75	495	531	470
d3	3	8	10	0,77	542	547	532
d4	3	38	30	0,73	526	547	496
d5	3	57	37	0,69	524	555	487
d6	3	27	45	0,70	610	604	565
d7	3	17	25	0,71	597	600	572
d8	3	34	40	0,76	537	541	497
d9	3	10	21	0,79	511	514	490
d10	3	26	35	0,75	521	538	486
d11	3	58	83	0,67	550	548	467
d12	3	12	6	0,78	547	557	541
d13	3	32	23	0,77	476	505	453
d14	4	30	27	0,69	574	596	547
d15	4	14	28	0,76	553	551	525

d16	4	36	28	0,59	674	699	646
d17	4	34	24	0,69	573	595	549
d18	4	40	72	0,72	541	541	469
d19	4	42	63	0,63	601	612	538
d20	4	52	70	0,71	494	514	424
d21	4	28	41	0,63	638	647	597
d22	4	55	32	0,65	540	586	508
d23	4	47	54	0,64	553	584	499
d24	4	55	19	0,65	552	600	533
d25	4	37	52	0,67	558	580	506
d26	4	55	22	0,68	532	577	510
d27	5	31	75	0,6	656	654	581
d28	5	42	104	0,66	631	600	527
d29	5	23	20	0,7	590	600	570
d30	5	45	41	0,66	591	609	550
d31	5	25	11	0,64	634	658	623
d32	6	26	27	0,7	585	592	558
d33	6	41	3	0,76	503	544	500
d34	6	45	58	0,69	554	563	496
d35	6	26	38	0,67	599	611	561
d36	6	14	20	0,72	589	597	569
d37	7	63	69	0,64	584	604	515
d38	7	60	26	0,71	486	536	460
d39	7	33	50	0,75	541	543	491
d40	7	41	20	0,72	531	566	511
d41	7	27	51	0,69	582	583	531
d42	7	27	32	0,67	603	620	571
d43	7	14	44	0,64	669	660	625
d44	7	41	56	0,8	452	472	396
d45	7	14	44	0,64	669	660	625
d46	7	32	30	0,75	523	542	493
d47	7	12	6	0,69	617	629	611
d48	7	23	49	0,67	617	612	568
d49	7	49	46	0,75	515	526	469
d50	8	66	41	0,68	491	544	450
d51	8	22	16	0,74	551	566	535
d52	8	58	35	0,67	563	592	528