Universidade do Minho

Escola de Psicologia

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Cognitive Functioning and Sports Performance in Young Footballers: Exploring Potential Influences

october 2025

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UMinho | 2025

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Master's Dissertation Report

Master's in Human Cognition

Work performed under the supervision of

Professor Dr. Pedro B. Albuquerque

october 2025

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Acknowledgements

For me, expressing words of gratitude is a practice of respect, fairness, and the creation of an atmosphere of prosperity. After two incredible years, during which I challenged myself academically by studying an area that has always fascinated me, I will try to be concise but deeply meaningful in addressing those to whom I owe my thanks.

First and foremost, I will never tire of thanking my community. To my closest family and friends, who not only supported me and helped me maintain happiness along my journey but stood by me no matter which path I chose to follow. To my loved ones, Teresa, Marco, and Francisca. To the best housemates I could have asked for, Duarte, Mota, and Américo. To those who inspire me to have the courage to seek adventure and a truly meaningful life – José Francisco, Nuno, Rui, Jota, Rodrigo, Alex, Guida, Paula, Mariz, Gabriela, and Gonçalo. To one of the most important people in my life, Sofia. To Dr. Ana Sofia, who helped me maintain my confidence, sense of worth, and stability.

Unfortunately, this is one of the most overlooked pages in thesis reports, but I wish everyone could read this paragraph. To Professor Pedro B. Albuquerque, who agreed to guide me over the past year and a half. He was one of the best professors I have ever met, with an incredible sense of teaching, outstanding knowledge, and remarkable explanatory skills, and he exceeded all these qualities as a mentor. His exceptional patience, dedication, availability, organization, methodical approach, and high standards were a true inspiration. Professor Pedro will remain in my life and memory, not only as a professional example but also as a life example for his values and behavior.

No individual work is as enjoyable as one that is open to collaboration. Therefore, I want to thank Bruno and Cristiana, two young students and psychologists who were part of this journey with their critical thinking, interest, and time.

Finally, to everyone whose name I cannot mention but who crossed my path over the past two years, personally or professionally, and who, in some way, helped me realize all the important lessons I have learned.

Statement of Integrity

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration. I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.

Cognitive Functioning and Sports Performance in Young Footballers: Exploring Potential Influences

Abstract

The present study explored the relationship between cognitive functioning and sports performance in elite youth football players. The participants were male players from a professional football academy, divided into two teams of different age groups (U15 and U17). The first stage of the study involved the administration of a standardized cognitive test battery assessing cognitive abilities such as attention, inhibitory control, processing speed, and working memory. Subsequently, sports performance indicators, such as match appearances, minutes played, and national team participation, were collected and used to construct a sports performance evaluation metric. The exploratory analysis results did not reveal significant correlations between cognitive task performance and sports performance, suggesting that domain-general cognitive abilities may not directly predict success in elite youth football. However, U17 players demonstrated faster reaction and response times in several cognitive tasks, reflecting age-related improvements in processing speed without loss of accuracy. These findings highlight the developmental progression of executive functions during adolescence and emphasize the importance of incorporating specific and ecologically valid cognitive assessments in the sports context in future research.

Keywords: Cognition, Cognitive Functioning, Executive Functions, Youth Football, Sports Performance

Funcionamento Cognitivo e Desempenho Desportivo em Jovens Futebolistas: A Exploração de Potenciais Influências

Resumo

O presente estudo explorou a relação entre o funcionamento cognitivo e o desempenho desportivo em jovens jogadores de futebol de elite. Os participantes, jogadores do sexo masculino de uma academia profissional de futebol, dividiram-se em dois diferentes grupos etários (Sub-15 e Sub-17). A primeira etapa do estudo consistiu na realização de uma bateria de testes cognitivos padronizados que avaliavam as capacidades cognitivas de atenção, controlo inibitório, velocidade de processamento e memória de trabalho. Posteriormente foram recolhidos indicadores de desempenho desportivo, tais como presenças em jogos, minutos jogados e participação na seleção nacional, que serviram de base para a construção de uma métrica de avaliação de desempenho desportivo. Os resultados da análise exploratória não revelaram correlações significativas entre o desempenho nas tarefas cognitivas e o desempenho desportivo, sugerindo que as capacidades cognitivas de domínio geral podem não prever diretamente o sucesso no futebol de elite juvenil. No entanto, os jogadores Sub-17 demonstraram tempos de reação e resposta mais rápidos em várias tarefas cognitivas, refletindo melhorias relacionadas com a idade na velocidade de processamento sem perda de precisão. Estes resultados destacam a progressão do desenvolvimento das funções executivas durante a adolescência e enfatizam a importância de incorporar avaliações cognitivas específicas e ecologicamente válidas no contexto desportivo em futuras investigações.

Palavras-chave: Cognição, Desempenho Desportivo, Funções Executivas, Funcionamento Cognitivo, Futebol Juvenil

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State of the Art

Scientific research in sports aims to validate evidence that supports strategies, theories, and approaches for maximizing athletic performance and understanding the contributing factors. Institutions responsible and interested in developing professional athletes of every kind of sport are giving more importance to the capacities that influence and predict future talent.

Football is one of the most practiced sports and, in contemporary society, a business that mobilizes lots of money and people. Beyond the technical, tactical, physiological, and motor domains (Sarmento et al., 2018), the cognitive dimension has gained significant prominence within the scientific community. While human cognition is a broad and multifaceted field of study, it can be explored in greater detail through specific definitions that help to understand its various dimensions and applications.

Cognitive abilities are the capacity to identify and process contextual information and integrate it with previously acquired knowledge (Marteniuk, 1976, as cited in Scharfen & Memmert, 2019b). Such capacity enables individuals to generate responses to specific situations. Given the excess of information to which athletes, particularly in team sports, are exposed, often resulting in mental overload or psychological pressure, cognitive capacity plays a pivotal role in this process (Scharfen & Memmert, 2019b). Football is a team-play sport with a challenging, dynamic and fast-paced environment where the actions of the opponents, the colleagues and an amount of external information need to be perceived and processed by the player to decide and act efficiently (Habekost et al., 2024).

Within the cognitive dimension, under non-controlled and non-routine environments like football games, which demand behavior flexibility and adaptability, the executive functions are critical for understanding the processes regulating thoughts and subsequent actions (Friedman et al., 2006). These functions are divided into two distinct groups: central executive functions, such as working memory, cognitive flexibility, and inhibitory control, that are fully developed during adolescence; and higher-level functions, such as rationality, problem-solving, and planning, which continue to mature into adulthood (Diamond, 2013). In football, the specific sport under study, the literature highlights the importance of both groups for athletic success in adolescents, with greater emphasis on central executive functions (Vestberg et al., 2017).

One of the most recent studies on cognition's role in sports (Scharfen & Memmert, 2019a) conducted a meta-analysis focusing on the influence of age and expertise level on cognitive performance. This meta-analysis included 29 studies and examined the relationship between cognitive functions and

athletic performance, adopting the cognitive skills approach, a framework which emphasizes the importance of mental processes such as attention, memory, and decision-making in sports contexts and that will be further elaborated later. The results revealed that high-performance athletes exhibit superior cognitive functions compared to their lower-performing counterparts, particularly in tasks requiring attention, working memory, and processing speed. However, the statistical power of the included studies was relatively low, suggesting the need for further research with larger sample sizes and more robust methodologies to confirm these findings.

This evidence was later corroborated by Kálen et al. (2021), who reported that athletes with advanced skills - defined as those with higher ability for sports practice - tend to perform better in cognitive functioning tests than lower-skilled athletes. This differentiation is more pronounced in decision-making skills tests than those evaluating central or higher cognitive functions.

Extending on the findings of the aforementioned studies, further research has placed more emphasis on core executive functions, revealing a similar pattern when athletes were compared to members of the general population without sports experience. Athletes demonstrated superior executive functions, particularly in inhibitory control and working memory, when compared to general population(Ren et al., 2025). Moreover, open-skill athletes - including football players - also outperformed others in cognitive flexibility, similar to the advantage observed among elite athletes relative to non-athletes. These observed differences in cognitive performance have prompted researchers to explore various theoretical frameworks to better understand the mechanisms underlying these findings.

The Long-Term Working Memory Theory and the Specific Processing Hypothesis (Ericsson & Delaney, 1999; Chabris & Simons, 2010, as cited in Glavaš, 2020) are two theories that provide a perspective on the relationship between expertise and cognitive abilities. According to these frameworks, this difference is attributed to mechanisms acquired through deliberate practice, which optimize cognitive processes relevant to athletic performance. Consequently, cognitive abilities are not viewed as an innate competitive advantage but rather as a result of adaptation and evolution through sports practice. These perspectives suggest that cognitive abilities in skilled athletes are higher result from sport-specific adaptations, driven by factors such as intensity, quantity, and quality of deliberate practice.

However, it is possible to argue that the threshold hypothesis may apply to developing executive functions in their relationship with football skills. This effect suggests a limit beyond which further improvements do not translate into enhanced performance. In other words, once a certain level of executive

functioning is reached, additional gains may not contribute meaningfully to football-specific performance outcomes and vice versa (Beavan et al., 2020).

Contrary to the idea that executive functioning skills are primarily developed through deliberate practice, studies conducted outside the sports domain argue that genetic and hereditary factors are 99% responsible for these cognitive abilities play a predominant role in determining cognitive abilities. For instance, a trivial percentage is attributed to the influence of the environment (Friedman et al., 2008). This perspective considers that innate predispositions, such as genetic makeup, may set the foundation for cognitive potential, including abilities like.

Supporting this perspective, research by Huijgen et al. (2015) found that, even when controlling for training volume, elite youth football players demonstrated superior performance in specific executive functions like inhibitory control, cognitive flexibility, and meta-cognition compared to their sub-elite counterparts. Although the genetic explanation provides a contrasting view by downplaying the role of training, it is important to consider the potential interaction between genetic predispositions and the training environment in shaping cognitive abilities. The development of executive functions, particularly in the context of sports, is a complex process that needs a more integrative and comprehensive approach to understanding these mechanisms.

The existing literature also explored the relationship between cognitive abilities and sports performance. A study by Scharfen and Memmert (2019b), aimed at identifying the relationship between cognitive functions and specific motor skills in young elite football players, found a partial association between working memory and attention span with specific core motor skills. This finding supports the predictive capacity of working memory for attention control and the likelihood of failure under pressure in sports contexts (Wood et al., 2016).

An example of this relationship in a different team sport is a basketball study demonstrating that players with better working memory scores are more effective in maintaining attention during decision-making tasks in laboratory settings, successfully blocking distractions and irrelevant stimuli (P. A. Furley & Memmert, 2012). However, these findings require replication in real-world sports contexts, limiting the certainty of their application in competitive environments. Thus, athletes with superior working memory capacity may only benefit from situational advantages in particular game scenarios requiring enhanced attention control.

Game intelligence has also been studied in football, with findings indicating a low-to-moderate correlation with certain executive cognitive functions, particularly working memory and cognitive flexibility (Scharfen & Memmert, 2021). This reinforces the significance of cognitive abilities, especially working

memory, in indicators of sports success. These findings are consistent across age groups, suggesting no significant effect of age on the correlations.

In a different direction, a study adopting a more ecologically valid methodology employed a perceptual-cognitive task within a dynamic 360° environment to better approximate the demands of an actual football game (Ehmann et al., 2022). This approach emphasizes the importance of approximate experimental setting to the complex and dynamic nature of a football match.

The study aimed to explore the integration of perception, decision-making, and motor execution in a way that traditional laboratory-based tasks often are not capable to fulfil. A positive relationship between performance in perceptual-cognitive tasks involving visuospatial attention and working memory and sports performance in football was identified. This relationship was particularly evident in passing accuracy and defensive actions during small-sided games. The findings, which are considered more representative of real-world performance contexts, also revealed significant differences between elite and sub-elite youth players, with the most pronounced advantages observed among the highest-age groups.

A study examining the association between core executive functioning and performance outcomes found a positive correlation between working memory and sports success, measured by goals scored, in youth football players (Vestberg et al., 2017). However, assessing football success solely through the number of goals may be limited, as it overlooks important mediating variables such as positional characteristics and role-specific contributions to team performance. Moreover, the maturation of core executive functions during adolescence can further influence findings in studies with young footballers, highlighting the need to account for the developmental stage when interpreting results.

A general model of the cognitive processes of elite football players (Habekost et al., 2024) suggests a three-stage cycle of perception-action to understand the phenomenon. The first is mainly connected to visual perception and other attentional functions to inform players about the game situation. The second stage evaluates the data collected during the situation to provide the best action possible. The game's high speed makes that selection and execution automatic, and it is produced by the unconscious domain influenced by executive functioning. The third stage is related to evaluating the outcome and the possible changes according to the feedback. Once again, the literature considers executive functions an important part of the cognitive abilities of a football player.

Two distinct theoretical approaches support the symbiotic relationship between sports and cognition. The first, the Specialized Performance Approach, studies athletes in a specific, ecologically valid

sports context (Ericsson, 2003; Singer, 2000, as cited in Voss et al., 2010). This perspective focuses on evaluating parameters that represent direct interactions between an athlete and their specific environment. Studies conducted within this framework have shown superior performance by experts in tests involving domain-specific contexts, such as declarative memory, attention distribution, perception and information gathering, anticipation, decision-making, and memory (Mann et al., 2007). According to these authors, the type of sport, stimuli, and research paradigm significantly influence study outcomes and conclusions from this line of inquiry. For example, the author asserts that athletes in sports require frequent and demanding coordination of body-object relations in competitive settings, such as football and tennis, and respond more rapidly in visual recognition, decision-making, anticipation, and visual memory tests than in self-paced sports like swimming. Voss et al. (2010) identify a major limitation of this approach: the inability to compare cognitive performance evaluations across different sports and expertise levels.

The second approach, the Cognitive Skills Approach, focuses on the relationship between sports expertise levels and performance on standardized cognitive tests considered essential for competitive sports (Nougier, Stein, and Bonnel, 1991, as cited in Voss et al., 2010). This approach investigates how athletes at different expertise levels perform differently on standardized cognitive tasks that measure fundamental processes such as attention, working memory, inhibition, processing speed, and decision-making.

Researchers adopting this approach apply laboratory-based tasks, such as reaction time paradigms, Go/No-Go tasks, and multiple-object tracking, to quantify domain-general cognitive capacities and compare results across groups of participants with different expertise levels. This model reflects general cognitive efficiency as important as physical skill acquisition or sport-specific knowledge in sports performance. The assumption is that cognitive skills are transferable across contexts, meaning that individuals who perform well on generic cognitive tests are more likely to succeed in sport-specific situations.

The standardization of tests proposed by this approach enables identifying and categorizing fundamental cognitive abilities for competitive performance in each sport. It emphasizes evaluating the central executive functions. However, one of the criticisms of this perspective is the lack of contextualization and specificity of these tests in relation to the sport under study.

To fulfil the lack of literature, this study, based on the Cognitive Skills Approach, will evaluate the difference between cognitive abilities, focusing more on executive functioning, in youth elite football players.

There is no evidence to establish patterns and relations between cognitive functioning and football performance in youth-elite football players. To achieve that and simultaneously create a database that will

allow them to get some inference on the prospective development of those young players, this study will establish comparisons between elite football players of a similar level and different ages. As mentioned above, some evidence shows that high-level executive tests are positively related to performance in football. However, the proper relation between executive functions and performance is still limited because of the absence of naturalistic research designs (Habekost et al., 2024).

Methods

Participants

The participants were male elite youth football players from a professional club academy. A total of 50 players were included: 24 outfield players born in 2008, 22 born in 2010, 1 born in 2011, and 3 goalkeepers born in 2010. Players were grouped into two age categories: under-15 (U15) and under-17 (U17) according to the *Federação Portuguesa de Futebol*. Four players were excluded due to scheduling constraints that prevented them from attending the testing sessions.

Prior to participation, written informed consent was obtained from the players' legal guardians. The study was conducted in accordance with the principles of the Declaration of Helsinki for research with human participants.

Materials

An open-source cognitive test battery was applied to assess the cognitive capacities of the players (Adolphe et al., 2022). The tasks compounding the battery were:

1) Multiple Object Tracking Task - a task in which the participant must follow several objects moving simultaneously and locate them among distracting objects, assessing dynamic visual attention as well as visuospatial tracking ability in that way. Besides the execution time, the main measure extracted was the accuracy rate across different speed conditions (low, medium, and high velocity).

2) Go-no-Go Task - to measure the ability to distinguish information by its relevance (inhibitory control), the participant must press a key whenever the target situation is presented on the screen. This task also provides response monitoring. Participants' performance was evaluated through accuracy (precision) and reaction time to target stimuli.

3) Enumeration Task - this task requires participants to be able to count a certain number of objects presented very quickly (in milliseconds). This measures the perceptual abilities associated with information processing speed. The outcome variables were the number of correct responses and the total value of correctly enumerated items.

4) Working Memory Spatial Task (Corsi Block Task)- in order to measure visuospatial working memory capacity, the Corsi Block Task consists of the rapid presentation of a sequence of block signals that

the participant must be able to replicate in the same order. The measures extracted included the number of correctly reproduced sequences and the total span length achieved.

Procedure

The study was conducted in two phases. In the first phase, participants completed the cognitive test battery described above. Given the length of the battery, testing was divided into two sessions, with each participant completing two tasks per session. Due to the equipment available, participants were ideally organized into groups of six per session (maximum). However, adjustments were made to accommodate their academic schedules.

After a five-minute explanation of the presented tasks to reduce the influence of the language proficiency, since the instructions were in English, the participants were told to start the experiment simultaneously. The first session included the Multiple Object Tracking task and the Go-no-go Task, which took around 35 to 40 minutes to complete, depending on each participant's pace. The second session lasts 30 to 35 minutes and assesses the Enumeration and Working Memory Tasks.

The allocation of computers and seating was partially randomized to ensure that players did not repeat the same workstation across sessions to reduce the potential influence of the equipment, since the computers had different specifications. Task order was counterbalanced across participants to minimize potential order effects. Each computer had a specific and constant task order defined, and the researcher distributed the participants through different computers from one session to another.

The second phase was conducted after the end of the national championships, the main competitions where the teams involved took part. Performance statistics were collected for each player. These included number of call-ups, total minutes played, average minutes per call-up, minutes per game, national team call-ups, national team matches, and minutes in national team matches. Only official national competitions were considered like the national championship and the national team matches.

To evaluate the performance of participants across various metrics, a scoring system was implemented. Based on these metrics, performance rating was constructed to classify and differentiate players according to their sport performance rating.

This system assigned the highest score to the best-performing individual within each metric, while the lowest score was attributed to the least-performing individual. Scores for the remaining participants were distributed proportionally, with higher scores reflecting better performance. For example, in the case of the number of call-ups, the participant with the highest number of call-ups received the maximum score, which progressively decreased along the ranking until the participant with the lowest number of call-ups received the minimum score. This scoring methodology was applied to each performance metric, and the cumulative sum of all scores across the metrics constituted the Sports Performance Rating for each participant.

A similar approach was used to construct ratings for the Cognitive Dimension. Specifically, performance variables associated with each cognitive task (e.g. percentage of accuracy) were used to generate individual task ratings. These task-specific ratings were then added to obtain an overall Cognitive Performance Rating for each participant. This approach was necessary to enable the comparison between cognitive and sports performance through the application of statistical correlation measures and difference tests conducted using JASP software.

Results

First, in order to compute comparative analyses such as correlations between cognitive ratings, the normality state of the data must be assessed. The ratings for each task were computed by attributing a value to the player's performance compared to the other participants of his age. The player with the best performance received the maximum score, decreasing incrementally down to the minimum score for the worst-performing player.

Table 1 - *Descriptive Analysis and normality tests for cognitive and sport performance ratings (U15 and U17)*

	MOT RATING V1		**MOT RATING V4**		**MOT RATING V8**		**GNG RATING**		**ENU RATING**		**WM RATING**		**COGNITIVE RATING**		**SPORT RATING**	
	U15	U17	U15	U17	U15	U17	U15	U17	U15	U17	U15	U17	U15	U17	U15	U17
n	27	24	27	24	27	24	27	24	27	24	27	24	27	24	27	24
W	.943	.943	.955	.953	.951	.947	.704	.693	.959	.959	.957	.959	.959	.955	.950	.954
p	.145	.187	.282	.314	.228	.238	< .001	< .001	.347	.416	.309	.416	.356	.340	.215	.332
Min	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	34.00	23.00	8.000	5.000
Max	25.00	23.00	27.00	24.00	27.00	24.00	12.00	10.00	27.00	24.00	27.00	24.00	137.0	121.0	142.0	114.0

Table 1 presents the descriptive statistics for all cognitive tasks and the sport performance rating for both groups of participants.

For the Multiple Object Tracking (MOT) task, each participant received a rating corresponding to their accuracy rate at each tracking speed - percentage of correct responses for each stimulus velocity. The ratings ranged from 1 (lowest performer) to a maximum of 24–27 (highest performer). Shapiro–Wilk tests indicated that all MOT ratings were approximately normally distributed ($p > .05$), supporting the use of parametric methods for all the analyses concerning these results.

For the Go-No-Go (GNG) task, each participant received a rating based on their accuracy rate across trials, with higher ratings reflecting greater precision. Shapiro–Wilk tests indicated that the distributions for both groups deviated significantly from normality ($p < .001$), suggesting that non-parametric statistics provide a more robust approach for subsequent analyses.

For the Enumeration (ENU), participants received a rating for the total number of correctly identified items across all trials. Parametric methods can be applied since the Shapiro–Wilk tests showed no deviation from normality ($p > .05$).

For the Working Memory (WM) task, participants received a rating equal to the total number of blocks correctly recalled across trials, with both distributions being approximately normal ($p > .05$).

Cognitive Rating represents the standardized sum of all cognitive task ratings, reflecting global cognitive functioning across attentional control, inhibitory control, visuospatial processing, and working memory. Ratings ranged from 34 to 137 in U15 and 23 to 121 in U17, with normal distributions ($p > .05$).

Finally, the Sport Performance Rating, derived from match participation metrics (calls, minutes played, minutes per call, and national team selections), ranged from 8 to 142 and 5 to 114 across the two groups. The reported values present a normal distribution ($p > .05$).

Cognitive Ratings

Pearson's correlations were computed separately for the U15 and U17 groups to examine the relationships between cognitive task ratings that showed a normal distribution (see Table 2).

For the U15 players, small-to-moderate positive associations (Cohen, 1988) were observed across tasks. However, most of them were not statistically significant ($p < .05$). MOT V1 showed a moderate correlation with MOT V4, $r(25) = .35$, $p = .076$. Enumeration Rating correlated positively with MOT V4, $r(25) = .432$, $p = .025$, suggesting that participants with higher attentional tracking under moderate speed also tended to perform better in rapid visual enumeration. Working Memory showed moderate positive correlations with other cognitive tasks, especially with MOT V4, $r(25) = .339$ and ENU, $r(25) = .329$, though these did not reach significance ($p > .05$). The pattern of correlations suggests convergence between attentional tracking and tasks requiring rapid processing and memory, but the relationships were not statistically robust.

For the U17 players, stronger and statistically significant associations were observed between multiple tasks. MOT V1 correlated strongly with MOT V4, $r(22) = .700$, $p < .001$, indicating that performance at lower and moderate speed stimuli was highly consistent – a participant who performs better at lower speed tends to repeat it in moderate speed. The same effect was observed between MOT V4 and MOT V8, showing a positive moderate correlation, $r(22) = .589$, $p = .002$.

Enumeration Rating correlated strongly with MOT V4, $r(22) = .639$, $p < .001$, and moderately with MOT V1, $r(22) = .543$, $p = .007$, indicating that players with higher tracking ability at lower and moderate speed also performed better in rapid enumeration. Working Memory Rating was significantly correlated with MOT V1, $r(22) = .650$, $p < .001$, and MOT V4, $r(22) = .680$, $p < .001$, as well as with Enumeration Rating, $r(22) = .571$, $p = .004$. These results suggest a close and positive association between visuospatial memory capacity, attentional tracking (low and moderate speed), and rapid visual processing.

Table 2 – *Parametric Correlations between Cognitive Ratings*

	MOT RATING V1		MOT RATING V4		MOT RATING V8		ENU RATING		WM RATING	
	U15	U17	U15	U17	U15	U17	U15	U17	U15	U17
MOT RATING V1	-	-	-	-	-	-	-	-	-	-
MOT RATING V4	.347	.700***	-	-	-	-	-	-	-	-
MOT RATING V8	.169	.265	.297	.589**	-	-	-	-	-	-
ENU RATING	.285	.543**	.432*	.639***	.290	.261	-	-	-	-
WM RATING	.296	.650***	.339	.680***	.299	.298	.329	.571**	-	-

** p < .05, ** p < .01, *** p < .001*

The association between Go-No-Go (GNG) performance and the ratings of the other cognitive tasks was examined using Spearman's rank-order correlation, given the non-normal distribution of GNG data. Table 3 presents the associations between inhibitory control and the other cognitive abilities, reported separately for the U15 and U17 groups.

For the U15 players, none of the correlations between GNG and the other tasks reached statistical significance (all $p > .05$). The coefficients were small in magnitude, ranging from weakly negative to weakly positive, suggesting minimal performance overlap between inhibitory control and the remaining cognitive measures at this age group.

For the U17 players, a moderate positive and statistically significant correlation was observed between GNG and MOT V1, $\rho(22) = .438$, $p < .05$. This indicates that players with higher inhibitory control accuracy also tended to perform better in attentional tracking under the lowest speed condition. Positive but non-significant correlations were also observed between GNG and MOT V4 ($\rho = .37$) and MOT V8 ($\rho = .37$), suggesting a consistent pattern of association, although not reaching statistical significance.

Overall, the U17 group tended toward more positive associations between GNG and other cognitive tasks compared to U15, even though most correlations remained small and non-significant. The significant association between GNG and MOT V1 in U17 may indicate that inhibitory control becomes increasingly linked to attentional tracking performance with age or playing experience.

Table 3 - *Non-parametric Correlations between Cognitive Ratings*

	MOT RATING V1		MOT RATING V4		MOT RATING V8		ENU RATING		WM RATING		GNG RATING	
	U15	U17	U15	U17	U15	U17	U15	U17	U15	U17	U15	U17
GNG RATING	.087	.438*	-.062	.368	.069	.373	-.226	.081	-.104	.362	-	-

Correlation between Cognition and Sports Performance

The correlations between Sport Performance Rating and individual cognitive task ratings were computed using Pearson's product–moment correlation, given that the data met parametric assumptions. No statistically significant correlations were observed between sport performance and any cognitive tasks in either age group (all $p > .05$). All associations were weak, with most r values close to zero. The two highest correlations pointed in opposite directions: for U15 players, MOT V8 was weakly and positively correlated with sport performance, $r(25) = .27$, $p > .05$, whereas for U17 players, MOT V4 was weakly and negatively correlated with sport performance, $r(22) = -.21$, $p > .05$.

Table 4 - *Parametric Correlation between Sport Rating and Cognitive Tasks Rating*

	MOT RATING V1		MOT RATING V4		MOT RATING V8		ENU RATING		WM RATING		SPORT RATING	
	U15	U17	U15	U17	U15	U17	U15	U17	U15	U17	U15	U17
SPORT RATING	.137	-.045	.023	-.205	.267	-.008	-.034	.101	.195	-.032	-	-

The association between Sport Performance Rating and the Go-No-Go (GNG) task rating was examined using Spearman's rho, due to the non-normal distribution of GNG scores. No significant correlations were found for either age group (all $p > .05$). Similar to the Pearson results for MOT, the correlations were weak and pointed in opposite directions: for U15 players, GNG was weakly and positively correlated with sport performance, $\rho(25) = .18$, $p > .05$, while for U17 players, GNG was weakly and negatively correlated, $\rho(22) = -.22$, $p > .05$.

Table 5 - *Non-Parametric Correlation Between Sport Rating and GNG Task*

	SPORT RATING	
	U15	U17
GNG RATING	.177	-.217

The association between Cognitive Rating and Sport Performance Rating was examined using Pearson's correlation (see Table 6).

For U15 players, a weak positive correlation was observed between cognitive and sport ratings, $r(25) = .200$, $p > .05$, indicating that players with slightly higher overall cognitive performance tended to have somewhat higher sport performance scores, although the relationship was not statistically significant.

For U17 players, the association was weakly negative and non-significant, $r(22) = -.072$, $p > .05$, suggesting no meaningful linear relationship between overall cognitive ability and sport performance in this group.

Table 6 - *Correlation between Cognitive and Sport Ratings*

	SPORT RATING	
	U15	U17
COGNITIVE RATING	.200	-.072

Descriptive analyses of cognitive performance per position

Table 7 presents the descriptive statistics for Cognitive Rating separated by playing position (forwards, midfielders, defenders, and goalkeepers) and age group (U15, U17).

Table 7 - *Descriptive Analyses of Cognitive Rating considering positions*

	COGNITIVE RATING							
	FORWARDS		MIDFIELDERS		DEFENDERS		GOALKEEPERS	
	U15	U17	U15	U17	U15	U17	U15	U17
N	8	9	6	6	10	9	3	-
M	76.25	61.78	97.33	75.83	65.70	72.22	85.33	-
SD	21.11	27.96	38.94	29.67	17.08	31.96	8.083	-
MIN	46.00	25.00	44.00	46.00	34.00	23.00	78.00	-
MAX	116.0	115.0	137.0	121.0	86.00	117.0	94.00	-

For U15 players, the highest mean cognitive rating was observed among midfielders (M = 97.33, SD = 38.94), followed by goalkeepers (M = 85.33, SD = 8.08) and forwards (M = 76.25, SD = 21.11). Defenders showed the lowest mean cognitive rating (M = 65.70, SD = 17.08).

For U17 players, midfielders again showed the highest mean cognitive rating (M = 75.83, SD = 29.67), followed closely by defenders (M = 72.22, SD = 31.96) and forwards (M = 61.78, SD = 27.96). Data for goalkeepers was not available in this age group.

Overall, the descriptive statistics suggest that midfielders consistently presented the highest average cognitive ratings across both age groups. However, these results are descriptive and should be interpreted cautiously due to the small sample sizes within each position.

Correlation between Cognition and Sports Performance per position

Considering the small sample size for each position, statistical significance for correlations between Cognitive Rating and Sport Rating was not computed. Among U15 players, a strong positive association was observed for forwards (r = .81), suggesting that players with higher overall cognitive performance also tended to have higher sport participation scores. Positive associations were also observed for defenders (r = .39) and goalkeepers (r = .68). In contrast, midfielders showed a small positive relationship (r = .13). These findings, although not tested for statistical significance due to small subgroup sample sizes, indicate a consistent positive trend across positions, particularly pronounced among forwards and goalkeepers.

For U17 players, the associations were generally weak. Forwards showed a moderate negative correlation (r = −.44), suggesting an inverse trend between cognitive performance and sport participation, whereas midfielders (r = .30) and defenders (r = −.04) presented small and near-zero associations. Given the limited number of players per position, these results should be interpreted cautiously.

The results indicate that the relationship between overall cognitive performance and sport participation appears to vary according to playing position and age group. Due to the small sample sizes within positions, these results should be considered exploratory and descriptive rather than inferential.

Table 8 - *Correlation between Cognition and Sport Performance per position*

	SPORT RATING							
	FORWARDS		MIDFIELDERS		DEFENDERS		GOALKEEPERS	
	U15	U17	U15	U17	U15	U17	U15	U17
COGNITIVE RATING	.808	-.435	.129	.297	.392	-.040	.679	-

Differences between age groups

To explore differences between age groups, a descriptive analysis was conducted first to evaluate whether the data collected corresponded to normality standards. Then, a difference test according to the normality of the data.

Multiple Object Tracking

Table 9 - *Multiple Object Tracking Descriptive Statistics*

	MOT RT		MOT V1		MOT V4		MOT V8		MOT HIT RATE	
	U15	U17	U15	U17	U15	U17	U15	U17	U15	U17
N	27	24	27	24	27	24	27	24	27	24
M	6141	4210	0.904	0.909	0.695	0.703	0.583	0.569	0.727	0.727
SD	1677	901	0.060	0.051	0.076	0.082	0.048	0.061	0.048	0.054
W	.905		.955		.982		.974		.980	
p	*<.001*		.054		.618		.332		.545	

MOT ET measures the execution time of each task stimulus. U15 players demonstrated substantially slower execution times (M = 614 ms, SD = 1677) compared to U17 players (M = 4210 ms, SD = 901). The Shapiro–Wilk test indicated that MOT ET deviated from normality (W = 0.905, p < .001). Considering that, the Mann-Whitney U Test was applied. An independent samples test revealed a statistically significant difference between groups, U = 578.00, p < .001, with a large effect size (r = –0.78). These results indicate that U17 players responded significantly faster on average than U15 players.

MOT V1, V4 and V8 indicate the accuracy of the task's response for each stimulus speed. For V1, mean accuracy was very similar between U15 (M = 0.904, SD = 0.060) and U17 (M = 0.909, SD = 0.051), with no statistically significant difference, t(49) = –0.37, p = .715. Same statistical insignificance was observed for V4, accuracy was slightly higher in U17 (M = 0.703) compared to U15 (M = 0.695), but the difference was not significant, t(49) = –0.36, p = .719., and V8, U15 players showed marginally higher accuracy (M = 0.583) than U17 players (M = 0.569), t(49) = 0.87, p = .388.

Mean hit rate (MOT HIT RATE) evaluates the participants' accuracy without discriminating the stimuli's velocity. It was identical between U15 and U17 players (M = 0.727 for both groups) and showed no group difference, t(49) = –0.01, p = .991.

Table 10 - *Multiple Object Tracking Age-Group Differences*

	Test	Statistic	*df*	*p*	Effect Size
MOT ET	Mann–Whitney *U* test	578.000		*< .001*	-0.784
MOT V1	Student's *t* test	-0.367	49	.715	-0.103
MOT V4	Student's *t* test	-0.362	49	.719	-0.101
MOT V8	Student's *t* test	0.870	49	.388	0.244
MOT HIT RATE	Student's *t* test	-0.012	49	.991	-0.003

Note. For the Student t-test, the effect size is given by Cohen's d. For the Mann-Whitney test, the rank biserial correlation provides the effect size.

GO-NO-GO

Table 11- *Go-No-Go Descriptive Statistics*

	GNG RT		GNG ACCURACY	
	U15	U17	U15	U17
N	27	24	27	24
M	558	552	0.982	0.971
SD	82	89	0.033	0.067
W	.973		.557	
p	.294		*< .001*	

Go-no-Go reaction time means were similar between U15 (M = 558 ms, SD = 82) and U17 players (M = 552 ms, SD = 89). Shapiro–Wilk tests indicated that RT values did not deviate significantly from normality (W = 0.973, p = .294), supporting a parametric test. An independent-samples t-test

revealed no significant difference between groups, $t(49) = 0.77$, $p = .444$, corresponding to a small effect size (Cohen's $d = 0.22$). These results suggest that inhibitory control speed was comparable between U15 and U17 players.

GNG mean accuracy was slightly higher for U15 ($M = 0.982$, $SD = 0.033$) than for U17 players ($M = 0.971$, $SD = 0.067$), but this difference was not statistically meaningful. The values differed significantly from normality ($W = 0.557$, $p < .001$); therefore, the non-parametric Mann-Whitney U test was used. Results indicated no significant difference between age groups, $U = 307.00$, $p = .758$, with a negligible effect size ($r = 0.05$).

Table 12 - *Go-No-Go Age-Group Differences*

	Test	Statistic	*df*	*p*	Effect Size
GNG ACCURACY	Mann–Whitney *U* test	307.000	-	.758	0.052
GNG RT	Student's *t* test	0.771	49	.444	0.216

Note. For the Student t-test, the effect size is given by Cohen's d. For the Mann-Whitney test, the rank biserial correlation provides the effect size.

ENUMERATION

Table 13 - *Enumeration Descriptive Statistics*

	ENU ET		ENU HIT VALUE		ENU HITS	
	U15	U17	U15	U17	U15	U17
N	27	24	27	24	27	24
M	4220	3201	317.41	340.25	48.81	51.83
SD	1377	765	83.31	109.12	12.44	16.35
W	.870		.973		.963	
p	*< .001*		.285		.115	

Table 14 presents the descriptive statistics and inferential analyses for Enumeration Task performance, including total executing time for each stimulus (ENU ET), total value of correctly enumerated stimuli (ENU HIT VALUE), and number of correct responses (ENU HITS).

U15 players spent significantly more time completing the task (M = 4220 ms, SD = 1377.73) than U17 players (M = 3201 ms, SD = 765.09). Since ENU ET was not normally distributed (W = 0.870, p < .001), the Mann–Whitney U test was applied. Results indicated a statistically significant difference, U = 498.00, p < .001, with a large negative effect size (r = −0.54), suggesting that U17 players completed the task faster.

Although U17 players had a slightly higher mean score of Hit Value (M = 340.25, SD = 109.12) than U15 players (M = 317.41, SD = 83.31), the difference was not statistically significant, $t(49)$ = −0.85, p = .402, with a small-to-moderate effect size (Cohen's d = −0.24).

Similarly, U17 players showed a marginally higher number of correct responses (M = 51.83, SD = 16.35) compared to U15 players (M = 48.81, SD = 12.44), but this difference did not reach significance, $t(49)$ = −0.75, p = .459, Cohen's d = −0.21.

Table 14 - *Enumeration Age-Group Differences*

	Test	Statistic	df	*p*	Effect Size
ENU ET	Mann–Whitney *U* test	498.000	-	*< .001*	- 0.537
ENU HIT VALUE	Student's *t* test	-0.846	49	.402	- 0.237
ENU HITS	Student's *t* test	-0.747	49	.459	- 0.210

Note. For the Student t-test, the effect size is given by Cohen's d. For the Mann-Whitney test, the rank biserial correlation provides the effect size.

WORKING MEMORY

Table 15 - *Working Memory Descriptive Statistics*

	WM ET		WM HIT VALUE		WM HITS	
	U15	U17	U15	U17	U15	U17
N	27	24	27	24	27	24
M	6818	4784	129.19	143.13	25.37	27.42
SD	1675	888	46.090	63.385	7.840	10.810
W	.823		.982		.986	
p	< .001		.619		.808	

In the same way as the Enumeration task, Working Memory Task performance includes execution time (WM ET), total value of correct responses (WM HIT VALUE), and number of correct responses (WM HITS).

U15 players spent significantly more time completing the WM task (M = 6818 ms, SD = 1675) than U17 players (M = 4784 ms, SD = 888). Since normality was not verified (W = 0.823, p < .001), a Mann–Whitney U test was performed. Results showed a statistically significant difference between groups, U = 581.00, p < .001, with a large negative effect size (r = −0.79). This indicates that U17 players performed the task considerably faster.

Although U17 players obtained a higher mean score of the total value of correct responses (*M* = 143.13, *SD* = 63.39) compared to U15 players (*M* = 129.19, *SD* = 46.09), the independent-samples t-test revealed that the difference was not statistically significant, *t*(49) = −0.91, *p* = .370, with a small-to-moderate effect size (Cohen's *d* = −0.25). Similarly, U17 players showed a slightly higher number of correct responses (*M* = 27.42, *SD* = 10.81) compared to U15 (*M* = 25.37, *SD* = 7.84), but this difference was also non-significant, *t*(49) = −0.78, *p* = .439, Cohen's *d* = −0.22.

Across all cognitive tasks, U17 players consistently demonstrated faster processing speed than U15 players, particularly in the reaction time of Multiple Object Tracking and execution time in Enumeration and Working Memory. Despite these speed advantages, no meaningful differences were observed in accuracy-related measures across any task, including MOT accuracy at different speeds, Go-No-Go accuracy, total enumeration hits, or working memory hits.

Table 16 - *Working Memory Age-Group Differences*

	Test	Statistic	df	*p*	Effect Size
WM ET	Mann–Whitney *U* test	581.000	-	*< .001*	- 0.793
WM HIT VALUE	Student's *t* test	-0.905	49	.370	- 0.254
WM HITS	Student's *t* test	-0.780	49	.439	- 0.219

Note. For the Student t-test, the effect size is given by Cohen's d. For the Mann-Whitney test, the rank biserial correlation provides the effect size.

Discussion

The present study had the intention to explore the relationship between cognitive functioning and sport performance in young elite football players. This study conducted comparisons between players of the same age group and from two different developmental stages (U15 and U17). Cognitive performance was assessed through an open-source test battery comprising attention, inhibitory control, processing speed, and working memory tasks. Sports performance was computed based on statistical data related to the players' appearances in club and national teams.

Contrary to expectations, there was no statistical significance or consistent trend indicating a relationship between cognitive skills and sport performance. This lack of correlation was observed when considering global cognitive ratings and individual task scores. The absence of correlation indicates that higher cognitive test performance does not necessarily translate to greater participation or success in sports competitive contexts and general cognitive abilities may not directly predict competitive performance among already elite youth players. This finding aligns with previous research suggesting that the link between executive functioning and sport success is not linear (Vestberg et al., 2017; Scharfen & Memmert, 2019).

The study was conducted according to the Cognitive Skills Approach (Nougier, Stein, & Bonnel, 1991, as cited in Voss et al., 2010), which proposes that general cognitive abilities such as attention, working memory, and inhibition can be assessed through standardized cognitive tests to evaluate their contribution to sport performance. In line with this model, in previous studies, elite athletes have been found to outperform non-athletes in domain-general cognitive tasks (Kalén et al., 2021; Scharfen & Memmert, 2019a). However, the current findings contradict this tendency. The absence of significant differences and correlations between cognitive tasks performance with sport performance suggests that general cognitive efficiency alone is not enough to fully explain competitive success in youth football and other factors, such as physicality, technical and tactical qualities, competitive context, training exposure, coaching strategies, and motivational factors should be considered.

Previous literature focused on spotting the differences between expert and non-expert football players, with more sport-specific methodologies and instruments, showed a relation between cognitive capacities and sports performance. For example, Ehmann et al. (2022) showed that elite youth players outperformed sub-elite ones in a 360° perceptual-cognitive task that simulated in-game contexts, highlighting the importance of ecological validity. Similarly, Huijgen et al. (2015) found that elite players

demonstrated superior inhibitory control and cognitive flexibility compared to sub-elite players when controlling training volume.

The present study used standardized cognitive tasks, which can explain the lack of significant correlations mentioned previously. These findings enhance the criticism against the Cognitive Skills Approach, pointing laboratory-based measures as incomplete methods to evaluate specific context cognitive capacities such as anticipation, pattern recognition and decision-making, that are influenced by a competitive, dynamic and fast-paced environment. As an alternative, the Specialized Performance Approach (Ericsson, 2003; Singer, 2000, as cited in Voss et al., 2010), highlights sport-specific perceptual and decision-making adaptations closely linked to the context of play rather than domain-general cognition. To sum up, the results do not contradict the Cognitive Skills Approach but suggest that its predictive power may lack ecological fidelity in the tasks.

From a different interpretative point of view, the study participants were selected by a professional club scouting department based on their demonstrated abilities and perceived potential, defining them as an elite performance group. Therefore, if the players have a similar level (elite), the threshold hypothesis can also explain the absence of statistically significant results. This effect assumes that once a certain level of cognitive capacities is reached, additional gains may not contribute meaningfully to football-specific performance outcomes and vice versa (Beavan et al., 2020). In this sense, the current findings may reflect that all players have well-developed executive functions measured by general cognitive tasks, leaving little space for these abilities to further distinguish performance within an elite group. These findings drive in the same direction as a previous study (P. Furley & Wood, 2016), suggesting that executive functions may indirectly moderate learning and adaptation rather than directly determining performance outcomes.

Despite the lack of statistical significance in most results, small trends were observed when the analysis was computed, comparing only players from the same pitch position. A few directional trends appeared, but these should be interpreted cautiously due to the small subsample sizes. Descriptive statistics suggest that midfielders in both age groups had the highest average cognitive ratings.

When considering midfielders' central position on the field, surrounded by teammates and opponents, the results may reflect the specific demands of their role. This position requires constant spatial awareness, anticipation, and rapid decision-making under high cognitive and informational load, placing significant demands on their perception-action cycle (Habekost et al., 2024). These findings align with the expected skill set for midfielders, who must possess exceptional spatial awareness, perception,

working memory, and attention span to anticipate, react, and make quick decisions effectively. From this perspective, their superior cognitive scores could reflect functional adaptations developed through extensive experience in cognitively demanding contexts. However, it is important to interpret these results with caution, as they are descriptive and based on a relatively small sample size. In small samples, individual variability can influence group means, especially when participants differ in maturity or experience, so these results can also represent statistical noise. Therefore, even though the pattern observed is consistent with what would be expected from the cognitive demands of the midfielder's role, more studies with larger samples are needed to determine whether these differences truly reflect position-specific cognitive characteristics or are simply the result of sample limitations. Even though the U15 group forwards and goalkeepers showed a positive relationship between cognitive and sport ratings, these patterns are not observed in the U17 group, which does not allow for the inference of trends from this data.

Focusing more closely on the comparison between age groups allows for a deeper understanding of how cognitive abilities develop throughout adolescence. The comparison between the two different age groups indicates that U17 players exhibited faster performance in cognitive tasks, specifically in the Multiple Object Tracking (MOT), Enumeration (ENU), and Working Memory (WM) tasks. Although there were no performance differences in the accuracy measures. The consistent pattern of faster reaction and execution times in U17 players compared to the U15 aligns with previous research on younger ages, supporting executive function development during adolescence (Diamond, 2013). In essence, U17 players showed greater processing speed than U15 players, achieving quicker responses without a decline in accuracy, suggesting increased cognitive efficiency with age. So, the differences found can be explained by the maturation of core executive functions as previewed in previous literature (Vestberg et al., 2017). The fact that accuracy-specific measures of cognitive tasks did not differ significantly between age groups suggests that younger players can achieve similar outcomes but require more time to process information. In practical terms, this emphasizes the importance of youth development training sessions and programs promote a focus on information processing speed. That can improve visual-perceptual capacities and situational awareness, especially in younger players still developing executive functioning skills.

In the opposite direction of the other tasks, the Go-no-Go task did not register any difference between age groups, not even on reaction time, which can suggest that inhibitory control might reach a high development stage at the age of fifteen.

The interpretation of the results from the conducted study must consider certain methodological aspects. The small sample size within age and positional subgroups limited the statistical power to detect the desired effects. This limitation may not only explain the lack of significant correlations but also mean that the findings should be considered exploratory, and generalizations cannot be reliably made based on them.

As discussed earlier, the methodological approach measured attention, inhibition, processing speed, and working memory in a controlled and laboratory environment. The tasks used lacked ecological validity and did not simulate a football match's dynamic and fast-paced specific environment. Consequently, the cognitive skills measured may not fully represent the context-dependent processes underlying real match performance such as anticipation, pattern recognition and fast-decision making. This limitation highlights the gap between controlled experimental tasks and the complexity and context-specific demands of a football match. Future studies should look for insights that can predict differences between elite football players integrating immersive and game-based paradigms, assessing football-specific cognitive, perceptual and decision-making processes using a design based on Specialized Performance Approach.

Additionally, the sports performance data analyzed was based solely on each player's playing time and calls, which are often influenced by coaching strategies, game plans, and subjective assessments made by the technical staff. To better control these variables, future research should prioritize using more objective and quantitative data related to players' actions during matches or training sessions. Metrics such as pass accuracy rate, expected goals, and duel success rate, among others, would capture the perceptual-motor decision demands that the metrics used in this study cannot. Furthermore, incorporating AI tools to calculate player ratings based on these metrics could enhance the accuracy and reliability of the analysis.

The existing literature lacks a longitudinal approach, which could provide a more accurate framework for assessing the relationship between cognitive abilities and future sports success. Adopting such an approach would allow researchers to track sports development over time and identify which specific cognitive skills are most valuable in predicting future performance. This, in turn, could serve as a valuable and helpful tool for enhancing talent identification strategies and achieving more effective outcomes.

Despite these limitations, the results indicate increased processing speed without a loss of accuracy in older age groups, suggesting that cognitive efficiency tends to develop with age and

experience. From a practical perspective, this developmental pattern highlights the importance for coaches and youth performance staff to design training sessions and promote competitive environments that stimulate rapid information processing and decision-making under time pressure. Incorporating exercises that require quick visual scanning, anticipation of opponents' movements, and continuous updating of spatial information like small-sided games may help young players develop greater cognitive adaptability. Promoting competitive game scenarios, adequate to both team and individual levels, can also enhance game intensity and cognitive engagement. By exposing players early to time-pressure and challenging situations, coaches can facilitate the integration of perceptual, attentional, and executive control processes that are critical for advanced tactical performance in football.

In conclusion, this study has made a valuable contribution to the exploratory research on cognitive functioning in youth football players and its impact on sports performance. Although there was no direct relationship between cognitive abilities and sports performance, the findings revealed that age-related differences in elite young footballers are evident in the processing speed of different executive functions. Future research integrating developmental, cognitive, and sport-specific methodological approaches would provide a more comprehensive understanding of how cognitive skills can predict future success in elite players. Ultimately, while cognitive abilities are important, our findings suggest they cannot be isolated from physical, tactical, and environmental factors when predicting football success. The challenge for future research is to bridge laboratory tasks with ecologically valid football scenarios.

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Annex I

Ethics Committee Approval

Universidade do Minho

Conselho de Ética

Comissão de Ética para a Investigação em Ciências Sociais e Humanas (CEICSH)

Identificação do documento: CEICSH 166/2024

Título do projeto: *O desempenho cognitivo e o desportivo: uma relação de influência*

Equipa de Investigação: Gonçalo Costa Santos (IR), Mestrado em Cognição Humana, Escola de Psicologia da Universidade do Minho; Pedro B Albuquerque (orientador), Escola de Psicologia, Universidade do Minho.

PARECER

A Comissão de Ética para a Investigação em Ciências Sociais e Humanas (CEICSH) analisou o processo relativo ao projeto de investigação acima identificado, intitulado *O desempenho cognitivo e o desportivo: uma relação de influência.*

Os documentos apresentados revelam que o projeto obedece aos requisitos exigidos para as boas práticas na investigação com humanos, em conformidade com as normas nacionais e internacionais que regulam a investigação em Ciências Sociais e Humanas.

Face ao exposto, a Comissão de Ética para a Investigação em Ciências Sociais e Humanas (CEICSH) nada tem a opor à realização do projeto nos termos apresentados no Formulário de Identificação e Caracterização do Projeto, que se anexa, emitindo o seu parecer favorável, que foi aprovado por unanimidade pelos seus membros.

Braga, 23 de outubro de 2024.

A Vice-Presidente da CEICSH

CRISTINA MARIA MOREIRA FLORES

Digitally signed by CRISTINA MARIA MOREIRA FLORES
Date: 2024.10.25 00:34:20 Z

(Cristina Maria Moreira Flores)

Anexo: Formulário de identificação e caracterização do projeto