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# Decoding the elite soccer player's psychological profile

Leonardo Bonetti[a,b,c,d,1,2], Torbjörn Vestberg[e,1], Reza Jafari[e], Debora Seghezzi[d], Martin Ingvar[e], Morten L. Kringelbach[a,b,c], Alberto Filgueiras[f,g,1], and Predrag Petrovic[e,1]

Affiliations are included on p. 10.

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**Soccer is arguably the most widely followed sport worldwide, and many dream of becoming soccer players. However, only a few manage to achieve this dream, which has cast a significant spotlight on elite soccer players who possess exceptional skills to rise above the rest. Originally, such attention was focused on their great physical abilities. However, recently, a new perspective has emerged, suggesting that being an elite soccer player requires a deep understanding of the game, rapid information processing, and decision-making. This growing attention has led to several studies suggesting higher executive functions in soccer players compared to the general population. Unfortunately, these studies often had small and nonelite samples, focusing mainly on executive functions alone without employing advanced machine learning techniques. In this study, we used artificial neural networks to comprehensively investigate the personality traits and cognitive abilities of a sample of 328 participants, including 204 elite soccer players from the top teams in Brazil and Sweden. Our findings indicate that elite soccer players demonstrate heightened planning and memory capacities, enhanced executive functions, especially cognitive flexibility, elevated levels of conscientiousness, extraversion, and openness to experience, coupled with reduced neuroticism and agreeableness. This research provides insights into the psychology of elite soccer players, holding significance for talent identification, development strategies in soccer, and understanding the psychological traits and cognitive abilities linked to success.**

cognitive abilities | personality | soccer | football | artificial neural networks

Soccer is arguably the most widely followed sport worldwide (1, 2), and many dream of becoming soccer players. However, only a few manage to achieve this dream. This phenomenon has cast a huge spotlight on elite soccer players, who possess exceptional skills to rise above the rest and succeed.

Originally, such attention was focused on their exceptional physical abilities (3). For instance, the importance of soccer players' aerobic endurance and strength, including speed and power, has been well documented (4). Similarly, it has been shown that elite female soccer players possess above-average aerobic capacities and are generally taller and heavier compared to the average female population (5).

Over the past decade, a new perspective has emerged, suggesting that being an elite soccer player may not solely depend on athletic capacities. Instead, it may be crucial to have a deep understanding of the game, process information quickly, and make decisions faster than others (6). In other words, psychological aspects (7–9) have become essential for a comprehensive understanding of elite soccer players.

Initially, researchers attempted to study sport-specific cognitive abilities (10–14). However, these strategies have not elucidated how specific cognitive core capacities differ from those of the general population. As a development, executive functions, i.e. higher-order top–down regulatory mechanisms controlling low-level processes (15, 16), were hypothesized to be of great importance for success in ball sports as they make it possible to adapt and plan behavior in a quickly changing environment (17). In line with this idea, several studies have collectively suggested that soccer players exhibit higher executive functions compared to the general population. In pioneering research, Vestberg and colleagues (17) found that the overall capacity for executive functions, particularly cognitive flexibility, was higher in a few elite soccer players than in subelite players and the general population. Notably, the primary measure of cognitive flexibility, design fluency, predicted the number of goals and assists over the following 2.5 y. Subsequent studies have reported similar findings (18–25), although they mostly focused specifically on junior players (18, 20, 23, 25) or nonelite players not competing in the highest leagues (20–22, 24) and used tests lacking a universal norm. In a preliminary attempt to solve these limitations, Vestberg and colleagues (24) showed that the design fluency performance was higher among national team players (NTP) compared to Premier League players (PLP), with design fluency abilities correlating

## Significance

This study explores the psychological profiles of elite soccer players, revealing that success on the field goes beyond physical ability. By analyzing a sample of 328 participants, including 204 elite soccer players from the top teams in Brazil and Sweden, we found that elite players have exceptional cognitive abilities, including improved planning, memory, and decision-making skills. They also possess personality traits like high conscientiousness and openness to experience, along with reduced neuroticism. Using AI, we identified unique psychological patterns that could help in talent identification and development. These insights can be used to better understand the mental attributes that contribute to success in soccer and other high-performance fields.

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[1]L.B., T.V., A.F., and P.P. contributed equally to this work.

[2]To whom correspondence may be addressed. Email: leonardo.bonetti@psych.ox.ac.uk.

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with season-long assist tallies. This study also showed that coach-rated game intelligence—describing a player's ability to read the game, adapt quickly, and always be in the right place—was associated with design fluency scores. A similar relationship between executive functions and coach-rated game intelligence was suggested in another thorough study, which however focused on a youth academy's talent development program and included only a few professional elite players (25). Thus, taken together, while these studies provided valuable results, they were limited by their restricted samples of truly elite soccer players.

Furthermore, while executive functions are only part of the comprehensive psychological profile of individuals, only a couple of studies have simultaneously investigated additional psychological features in soccer players (26, 27). For example, Vaughan and Edwards (26) focused on both executive functions and personality traits, revealing that soccer players exhibited heightened levels of Extraversion, Openness, and Conscientiousness, alongside superior executive function scores. Conversely, nonathletes reported elevated levels of Neuroticism and Agreeableness.

In conclusion, while previous studies have provided relevant insights, they have mostly relied on small or nonelite samples and should therefore be considered preliminary in the context of cognition in elite soccer players. To date, no large-scale study on adult elite soccer players has investigated executive functions and their relationship to successful play. Even fewer studies, if any, have extended this investigation to other psychological traits. This limitation arises from the difficulty of collecting data from truly elite soccer players, who are largely inaccessible to researchers and the general public. Additionally, previous studies did not utilize the advanced machine learning techniques available today. Consequently, a comprehensive description of the psychological profile of elite soccer players has not yet been achieved.

In this study, we addressed these gaps by taking three key steps.

First, we recruited a large sample of elite soccer players. Specifically, out of the 328 participants described in this study, 204 were elite soccer players from the top teams in the first divisions of Brazil and Sweden. Notably, this sample also included elite female players, a group often previously neglected, thereby partially addressing the usual gender bias that undermines women in soccer.

Second, recognizing that soccer is a complex sport arguably requiring a broad spectrum of cognitive abilities and personality traits (6, 28), and not just the executive functions predominantly investigated in previous studies (17, 18, 21, 22, 24, 29), we expanded our investigation. We selected essential tests that effectively exemplify various aspects of the individual's psychological profile, including planning and problem-solving, memory, executive functions, and personality traits.

Third, we complemented traditional analyses which independently assess each psychological measure with artificial neural networks (ANNs) and support vector machine (SVM). This approach provides a multivariate, comprehensive understanding of the intricate connections between our measured psychological features and constructs a model of the ideal psychological profile of elite soccer players.

In brief, our results showed that elite soccer players demonstrate heightened planning, problem-solving, and memory capacities, alongside enhanced executive functions, especially cognitive flexibility. They also exhibit elevated levels of Conscientiousness, Extraversion, and Openness to experience, coupled with reduced Neuroticism and Agreeableness. Furthermore, the ANN and SVM decoding we implemented leveraged these features as well as their connections to build a model of the ideal psychological profile of an elite soccer player. This model successfully classified elite soccer players from matched controls with 97% accuracy.

## Results

**Overview of the Study.** In this study, we recruited 204 elite soccer players and 124 controls matched for social and educational background. To achieve a comprehensive yet parsimonious description of the elite soccer player's psychological profile, we selected an array of state-of-the-art psychological tests and questionnaires. These included measures for personality traits [Big Five Inventory (BFI)], planning and problem-solving abilities (accuracy and speed measures of the Tower of Hanoi), working memory skills (WM; Wechsler Adult Intelligence Scale-IV, forward and backward scales), and executive functions (Trail Making Test, Design Fluency, Color-Word Interference Test, 5-Point Test). Our analyses comprised two complementary methods (as graphically depicted in Fig. 1). First, we conducted independent analyses for each psychological feature considered in the study (i.e., personality, executive functions, planning and problem solving, and memory measures), contrasting the elite soccer players with the controls (or normative values of the tests, Fig. 2). Second, we performed multivariate analysis using machine learning to derive the ideal, comprehensive psychological profile of the elite soccer player (Fig. 3). Finally, by combining the measured psychological features, we predicted soccer-oriented achievements such as the number of goals, assists, and successful dribbles based on the psychological profile of individual soccer players.

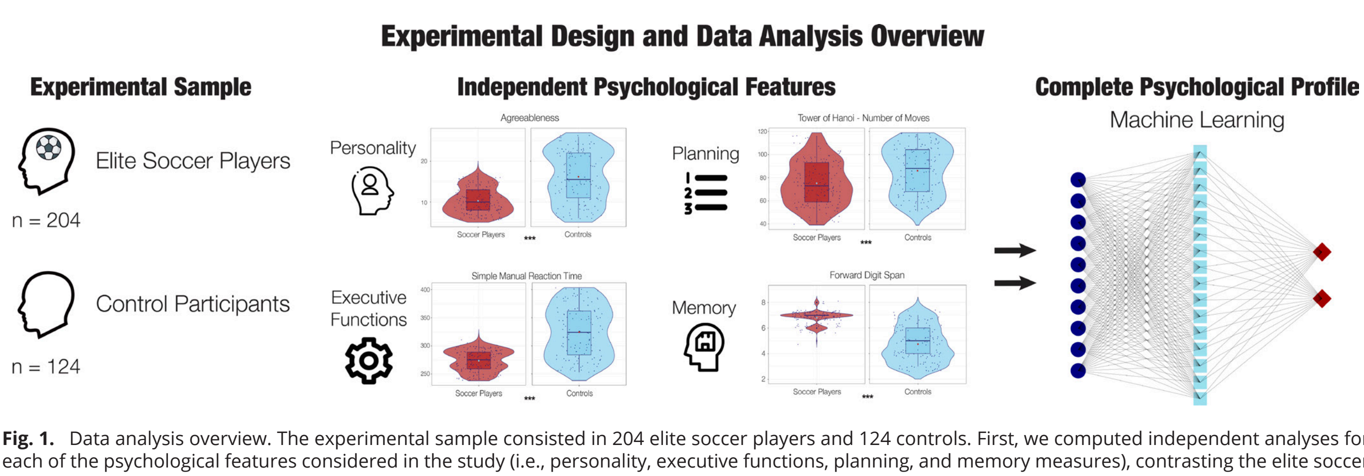


**Fig. 1.** Data analysis overview. The experimental sample consisted in 204 elite soccer players and 124 controls. First, we computed independent analyses for each of the psychological features considered in the study (i.e., personality, executive functions, planning, and memory measures), contrasting the elite soccer players versus the controls (or normative values of the tests). Second, we computed multivariate analysis by employing machine learning to obtain the ideal, complete psychological profile of the elite soccer player.

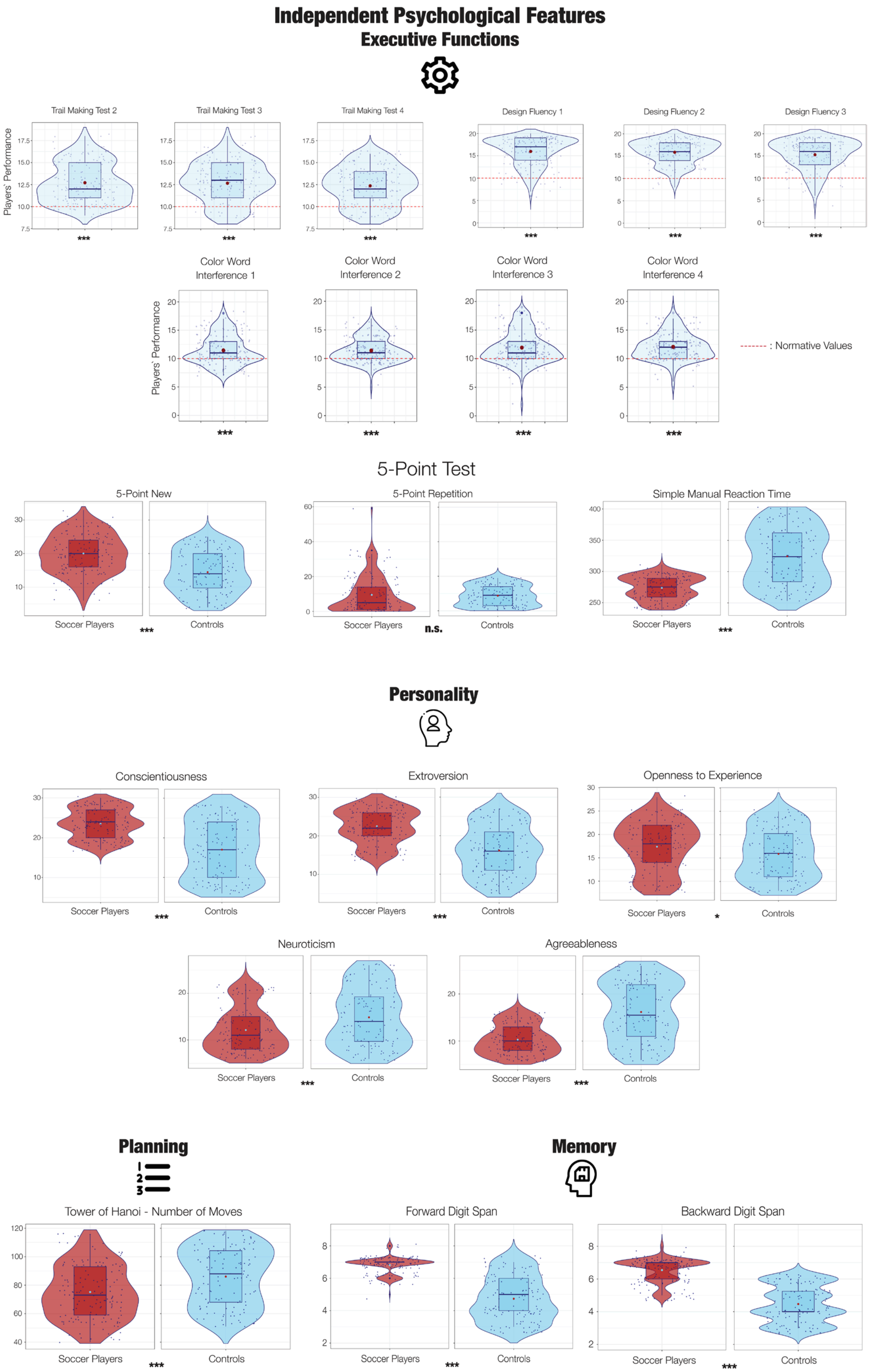


**Fig. 2.** Executive functions, personality, planning and problem-solving, and memory abilities of elite soccer players. In the top part of the figure the performance of soccer players (both Brazilian and Swedish, n = 174) compared to normative values of the standard age-matched population are shown along three tests indexing executive functions: Trail Making Test, Design Fluency, and Color Word Interference Test. The normative values are shown by red dash lines. The soccer players performance is displayed using violin plots, boxplots, and scatter plots (each blue dot represents a participant). The mean across the soccer players is indicated by a larger red dot. The difference across the performance was tested using two-sample *t* tests and Bonferroni corrected for multiple comparisons (*P*-values: * <0.05; ** <0.01; *** <0.001; n.s. = not significant). In the bottom part of the figure, we show planning and problem-solving, memory abilities, and personality scores of elite soccer players and controls matched for age and socioeconomic status using several tests: 5-Point Test, Tower of Hanoi, Working Memory Test, and the five dimensions of the Big Five Personality Inventory: Conscientiousness, Extroversion, Openness to Experience, Neuroticism, and Agreeableness. The cognitive and personality scores for the different tests are displayed using violin plots (red for soccer players and blue for controls), boxplots, and scatter plots (each dark blue dot represents a participant). The mean across the elite soccer players is indicated by a larger light blue dot, while the mean for the controls by a red dot. The difference across the cognitive and personality scores was tested using Wilcoxon tests and MANCOVA/ANCOVAs, respectively. Bonferroni correction was used to address multiple comparisons (*P*-values: * <0.05; ** <0.01; *** <0.001; n.s. = not significant).

**Cognitive and Personality Differences between Soccer Players and Controls.** To assess the performance of soccer players in Trail Making Test, Design Fluency Test and Color-Word Interference Test from the Delis–Kaplan Executive Function System (D-KEFS) test battery in comparison to standardized norms, we computed 10 two-sample *t* tests and corrected for multiple comparisons using Bonferroni correction. In this analysis, 123 Brazilian and 51 Swedish elite soccer players were included since both cohorts performed these tests. The results were highly significant, as reported in Table 1, highlighting that soccer players were characterized by better cognitive scores than controls. We also performed independent analysis of the Brazilian (n = 123) and Swedish (n = 51) cohorts of elite soccer players to control that the results were not driven by one specific cohort (*SI Appendix*, Table S1).

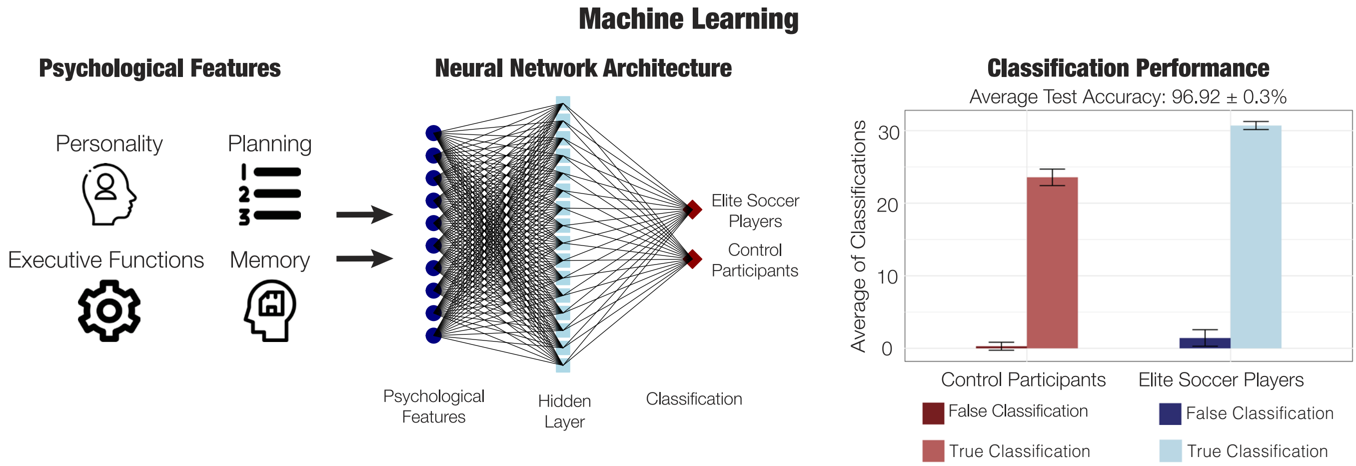


**Fig. 3.** The psychological profile of the elite soccer player. The personality, planning and problem-solving, executive functions, and memory scores of the elite soccer players and controls have been used to train and test a cross-validated (1,000 permutations) ANN algorithm aimed at classifying the elite players and the controls based solely on their combined psychological features. The classification performance of the algorithm reached almost an average 97% of accuracy in the 1,000 permutations, highlighting the ideal psychological profile of the elite soccer player.

To assess the differences between soccer players and matched controls on cognitive and personality scores, a series of MANCOVA and Wilcoxon tests were computed, and Bonferroni corrected for multiple comparisons (see *Materials and Methods* for details). The Brazilian cohorts were included in this analysis (153 elite soccer players and 124 controls) as the Swedish cohort only contained elite soccer players and only performed D-KEFS tests.

As shown by a MANCOVA, there was a statistically significant difference between the elite players and controls with regard to personality scores ($F$(1, 274) = 65.70, $P$ = <2.2e-16, partial η2 = 0.55). Follow-up ANCOVAs showed statistically significant differences between the participants for all personality variables. These analyses indicated that soccer players had higher scores in Extraversion ($F$(1, 274) = 96.12, $P$ < 2.2e-16, partial $\eta^2$ = 0.26; mean soccer players: 22.49 ± 4.38; mean controls: 16.14 ± 6.42), Openness to experience ($F$(1, 274) = 5.29, $P$ = 0.02, partial $\eta^2$ = 0.02; mean soccer players: 17.39 ± 5.27; mean controls: 15.90 ± 5.29), Conscientiousness ($F$(1, 274) = 97.15, $P$ < 2.2e-16, partial $\eta^2$ = 0.26; mean soccer players: 23.49 ± 3.70; mean controls: 17.01 ± 7.17) compared to controls. On the contrary, controls reported higher scores in Neuroticism ($F$(1, 274) = 17.76, $P$ = 3.4e-05, partial $\eta^2$ = 0.06; mean soccer players: 12.12 ± 4.74; mean controls: 14.89 ± 6.14) and Agreeableness ($F$(1, 274) = 100.05, $P$ < 2.2e-16, partial $\eta^2$ = 0.27; mean soccer players: 10.28 ± 3.11; mean controls: 16.18 ± 6.26) compared to soccer players.

In relation to the Five Point Test, we computed three independent Wilcoxon tests and Bonferroni corrected them for multiple comparisons. This allowed us to assess the difference between soccer players and controls across the scores recorded for each of the variables obtained from the Five Point Test: 5-point new, 5-point repetition and Simple Manual Reaction Time. The test for 5-point new was significant (W = 13,885, $P$ = 3.08e-11, effect size: 0.399, soccer players sample size: 153; mean: 20.03 ± 5.92, controls sample size: 124; mean: 14.47 ± 6.15). The test for 5-point repetition was not significant ($P$ = 0.17). The test for the Simple Manual Reaction Time was significant: W = 3,280, $P$ < 2.2e-16, effect size: 0.563, soccer players sample size: 153; mean: 273.60 ± 18.37, controls sample size: 124; mean: 324.60 ± 44.74.

With regard to WM, we computed two independent Wilcoxon tests and Bonferroni corrected them for multiple comparisons. The test for WM forward was significant: W = 16,990, $P$ < 2.2e-16, effect size: 0.722, soccer players sample size: 153; mean: 6.82 ± 0.51, controls sample size: 124; mean: 4.73 ± 1.36. The test for WM backward was also significant: W = 17,594, $P$ < 2.2e-16, effect size: 0.759, soccer players sample size: 153; mean: 6.54 ± 0.73, controls sample size: 124; mean: 4.47 ± 1.11.

In relation to the Tower of Hanoi Test, we computed two independent Wilcoxon tests (one for the seconds and one for the moved used to complete the task) and Bonferroni corrected them for multiple comparisons. The test for the number of seconds used to complete

**Table 1. Enhanced executive functions in soccer players**

| Test | Df | *t*-value | *P*-value | 95% CI low | 95% CI high | Mean | Norm |
|---|---|---|---|---|---|---|---|
| *TMT-1* | 173 | 15.83 | $<2.2 \times 10^{-16}$ | 12.37 | 13.05 | 12.71 | 10 |
| *TMT-2* | 173 | 14.07 | $<2.2 \times 10^{-16}$ | 12.29 | 13.03 | 12.66 | 10 |
| *TMT-3* | 173 | 14.36 | $<2.2 \times 10^{-16}$ | 12.04 | 12.69 | 12.36 | 10 |
| *DF-1* | 173 | 25.15 | $<2.2 \times 10^{-16}$ | 15.49 | 16.42 | 15.95 | 10 |
| *DF-2* | 173 | 29.16 | $<2.2 \times 10^{-16}$ | 15.47 | 16.26 | 15.86 | 10 |
| *DF-3* | 173 | 20.74 | $<2.2 \times 10^{-16}$ | 14.76 | 15.76 | 15.26 | 10 |
| *CWI -1* | 173 | 7.32 | $8.74 \times 10^{-12}$ | 11.06 | 11.84 | 11.45 | 10 |
| *CWI -2* | 173 | 8.60 | $4.71 \times 10^{-15}$ | 11.07 | 11.70 | 11.39 | 10 |
| *CWI -3* | 173 | 9.11 | $<2.2 \times 10^{-16}$ | 11.51 | 12.35 | 11.93 | 10 |
| *CWI -4* | 173 | 11.68 | $<2.2 \times 10^{-16}$ | 11.72 | 12.42 | 12.07 | 10 |

Results for the 10 independent two-sample *t* test used to assess whether the performance of soccer players in Trail Making Test (TMT), Design Fluency Test (DF) and Color-Word Interference Test (CWI) was different in comparison to standardized norms, indexing the score of the average population. The table shows the tests (and the relative subscales), degrees of freedom, *t*-value, *P*-value, 95% low and high CI, mean, and norm.

**Table 2. Psychological features predict soccer performance**

| | Dependent variables | | | | |
|---|---|---|---|---|---|
| | *GLM 1− Goal* | *GLM 2−Shot* | *GLM 3−Assist* | *GLM 4−Attempted dribbles* | *GLM 5−Successful dribbles* |
| **Model statistics** | Adj. $R^2$ = 0.22<br>*P* = 1.22e-06 | Adj. $R^2$ = 0.07<br>*P* = 0.03 | Adj. $R^2$ = 0.08<br>*P* = 0.02 | Adj. $R^2$ = 0.29<br>*P* = 3.25e-09 | Adj. $R^2$ = 0.31<br>*P* = 7.04e-10 |
| **Predictors** | | | | | |
| *Age* | *P* = 0.33 | *P* = 0.15 | *P* = 0.84 | *P* = 0.28 | *P* = 0.11 |
| *Neuroticism* | *P* = 0.25 | *P* = 0.07 | *P* = 0.06 | *P* = 0.02<br>β = −0.07 | ***P* = 0.009**<br>**β = −0.05** |
| *Extraversion* | *P* = 0.60 | *P* = 0.12 | *P* = 0.30 | *P* = 0.50 | *P* = 0.65 |
| *Openness* | ***P* = 0.003**<br>**β = 0.16** | *P* = 0.27 | ***P* = 0.008**<br>**β = 0.08** | ***P* = 2.03e-06**<br>**β = 0.17** | ***P* = 7.71e-07**<br>**β = 0.09** |
| *Agreeabl.* | *P* = 0.48 | *P* = 0.35 | *P* = 0.60 | *P* = 0.67 | *P* = 0.96 |
| *Conscient.* | ***P* = 0.04**<br>**β = −0.15** | *P* = 0.18 | *P* = 0.49 | *P* = 0.17 | *P* = 0.43 |
| *5-point new* | ***P* = 6.8e-07**<br>**β = 0.24** | ***P* = 0.01**<br>**β = 0.03** | *P* = 0.21 | *P* = 0.42 | *P* = 0.67 |
| *S Manual RT* | *P* = 0.44 | *P* = 0.71 | *P* = 0.68 | *P* = 0.84 | *P* = 0.78 |
| *WM* | *P* = 0.28 | *P* = 0.69 | *P* = 0.39 | ***P* = 0.002**<br>**β = 6.94** | ***P* = 0.005**<br>**β = 3.69** |
| *Hanoi* | *P* = 0.23 | *P* = 0.74 | *P* = 0.76 | ***P* = 0.02**<br>**β = 0.02** | ***P* = 0.0004**<br>**β = 0.02** |

Five GLMs assessing the predictive power of personality and cognitive scores on a selected array of soccer skills/objectives. The table reports the key statistics for each of the five models, as well as the *P*-values and coefficients (only if significant) for independent variables (predictors). Significant predictors from the GLMs are reported in bold.



the task was not significant ($P = 0.33$). The test regarding the number of moves was significant, indicating that soccer players needed a lower number of moves to complete the task: W = 6630.5, $P = 1.65\text{e-}05$, effect size: 0.259, soccer players sample size: 153; mean: 75.19 ± 18.90, controls sample size: 124; mean: 86.08 ± 20.29.

**Cognitive and Personality Profile of Soccer Players and Soccer Performance.** To investigate the relationship between personality traits, cognitive scores, and a selected array of specific soccer skills/objectives, five general linear model (GLM) analyses were conducted, and Bonferroni corrected for multiple comparisons. The independent variables for the five GLMs included the cognitive and personality scores which were significant in the previous tests, while the dependent variables, inserted separately in the five GLMs, were i) the number of goals scored by the players, ii) number of shots attempted per game, iii) number of assists per game, iv) average attempted dribbles v) and successful dribbles. The Brazilian cohort (n = 153) was included in this analysis since these data were not available for the Swedish cohort. The results are reported in Table 2.

**ANN Performance.** The neural network model, trained and evaluated using permutation-based (1,000 permutations) cross-validation, demonstrated robust predictive capabilities for assessing the relationship between personality traits, cognitive scores, and soccer membership. Average Test Loss: 0.14 ± 0.04; Average Test Accuracy: 96.92 ± 0.03%; Average Precision: 95.66 ± 0.03%; Average Recall: 99.06 ± 0.02%; Average F1 Score: 97.29 ± 0.02%. The average confusion matrix, summarizing the model's classification performance, is presented as follows and illustrated in Fig. 3. It includes the distribution of true positive (TP): 30.71 ± 0.55; true negative (TN): 23.57 ± 1.14; false positive (FP): 1.43 ± 1.14; and false negative (FN): 0.29 ± 0.55 predictions, providing a detailed insight into the model's performance across different classes. The model achieved a high level of precision, recall, and F1 score, indicative of its ability to effectively distinguish between soccer players and control subjects.

To further validate our findings, we employed a comparable approach, computing similar metrics (test accuracy, precision, recall, F1 score, and confusion matrix) for decoding classification through SVM. As for ANNs, the SVM was applied to differentiate elite soccer players from control subjects based on psychological traits and cognitive tests that only were performed in the Brazilian cohort. Although ANNs and SVMs produce similar outcomes and serve similar purposes, ANNs are generally considered a more recent and advanced algorithm. However, SVMs have the advantage of returning interpretable weights, allowing us to identify the psychological features that most significantly distinguish soccer players from controls—something ANNs cannot offer.

As for the ANNs described above, the SVM analysis was performed by using a permutation-based cross-validation approach with 1,000 permutations, yielding the following results: Average Test Accuracy: 97.61 ± 0.02%; Average Precision: 96.50 ± 0.03%; Average Recall: 99.37 ± 0.01%; Average F1 Score: 97.89 ± 0.02%. The average confusion matrix is reported as follows, including TP (correctly identified elite soccer players): 30.81 ± 0.42; TN (correctly identified controls): 23.86 ± 0.98; FP (noncorrectly identified elite soccer players): 1.15 ± 0.98; and FN (noncorrectly identified controls): 0.20 ± 0.42 predictions. These metrics illustrate the model's high precision, recall, and F1 score, demonstrating its robust capacity to differentiate between elite soccer players and controls.

Importantly, the interpretability provided by SVM also allowed for the identification of the psychological features most critical to this classification. In order of decreasing relevance, these features are Backward Digit Span, Forward Digit Span, Simple Manual Reaction Time, Agreeableness, 5-point scale (new), Conscientiousness, Extraversion, Tower of Hanoi (number of moves), Neuroticism, and Openness to Experience. These findings are graphically represented in Fig. 4.

Taken together, these results suggest that both the ANN model and the SVM reliably predicted elite soccer membership based on personality and cognitive factors.

## Discussion

Our investigation unveiled notable differences in the performance of elite soccer players versus matched controls and the norm across several cognitive tests and personality ratings. This allowed us to

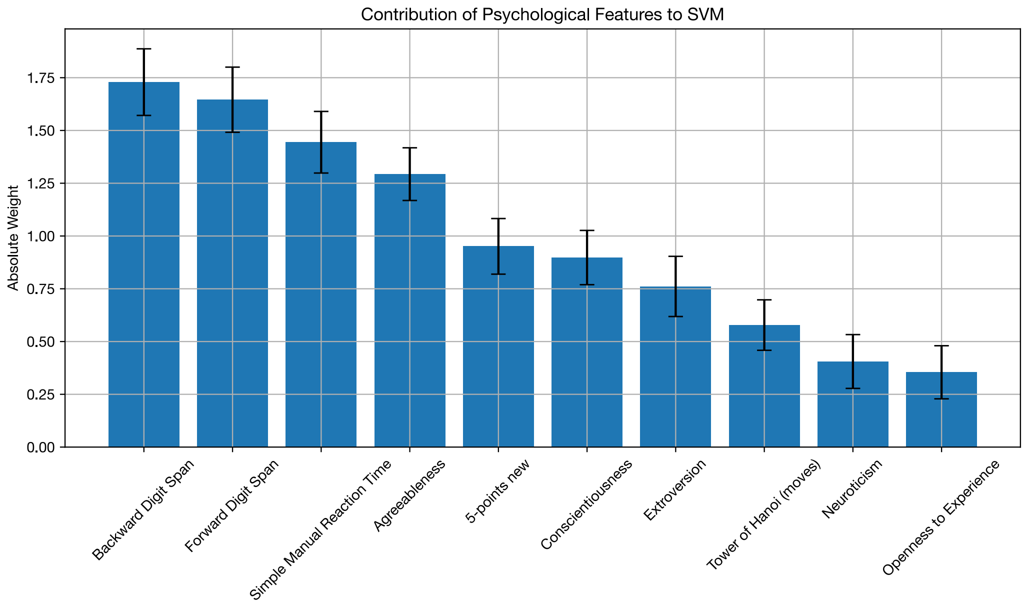


**Fig. 4.** SVM weights. This figure displays the average weights of the SVM algorithm, calculated over 1,000 permutations of the cross-validation procedure. The weights represent the relative contribution of each psychological feature to the model's ability to distinguish elite soccer players from controls. Error bars indicate the SD, illustrating a small variability across the permutations. The psychological features with the highest weights were the most influential in the classification task.

delineate the psychological profile of elite soccer players. These athletes displayed superior cognitive abilities, including higher levels of executive functions, memory, problem-solving, and planning. Additionally, their personality profile diverged with elevated scores in Extraversion, Openness to Experience, and Conscientiousness, alongside lower scores in Agreeableness and Neuroticism. The tests were also able to predict several successful soccer behaviors ranging from goals and assists to different types of dribbling. Finally, the decoding that we implemented using both ANN and SVM leveraged the measured psychological features as well as their connections to build models of the ideal psychological profile of an elite soccer player, successfully classifying elite soccer players from matched controls with 97% accuracy.

The psychological profile that emerged from our results of heightened executive functions in elite soccer players aligns with prior studies (17, 18, 21, 22, 24). Our findings expand on this by highlighting superior performance in cognitive flexibility and inhibition response within an extensively larger sample of elite soccer players compared to previous studies. Notably, while some earlier studies included a relatively large number of participants (21–23, 25), most of them were not adult nor elite players competing in a top league. Therefore, while previous results are valuable, yet arguably preliminary, the present findings are more conclusive. Interestingly, similar results have also been reported in other team sports, including volleyball (30) ice hockey (31), and basketball (32). Despite variations in the role of executive functions across different sports (33), these studies collectively suggest a consistent trend: Elite athletes generally outperform their less experienced counterparts in executive functions (34–37).

Notably, while previous studies have primarily focused on a limited set of executive functions, soccer proficiency encompasses a broader spectrum of abilities. This includes memory, visuo-spatial reasoning, and planning (6, 28). In our study, we demonstrate that elite soccer players significantly outperform matched controls in memory, problem-solving, and planning tasks. Previous research on these cognitive abilities within soccer is rather sparse but suggests that soccer players might be characterized by higher levels of WM compared to controls (see, for example, refs. 18 and 22). Our findings are consistent with and expand on these studies, underscoring the pivotal role of memory processes in soccer performance in a large sample of elite soccer players. Furthermore, the current research investigated strategic planning using the Tower of Hanoi as an essential assessment tool to obtain insights into participants' spatial reasoning and problem-solving abilities. Our results indicate that soccer players clearly outperformed controls, suggesting superior efficiency in analyzing situations and devising optimal strategies to achieve their goals in the same time frame. The ability to plan several steps ahead in order to reach a goal in a quickly changing environment may be one of the most crucial cognitive processes related to successful behavior in complex ball sports such as soccer.

In our study, we assessed personality traits and found that elite soccer players exhibit heightened levels of extraversion, openmindedness, self-discipline, and energy. These findings are consistent with prior research on personality traits in elite athletes in general (38) and a systematic review examining the relationship between personality and athletic performance (39). Our study expands on this body of research by specifically focusing on elite soccer players. Additionally, our study revealed lower levels of cooperativeness and a reduced propensity for negative emotions, as evidenced by lower scores in Neuroticism and Agreeableness. This contrasts with findings from previous studies on other sports, suggesting that soccer players' personality profiles may differ from those of different categories of athletes. Specifically, soccer players tend to score particularly low in Agreeableness. This trend may be attributed to the global popularity of soccer, which fosters intense competition at elite levels where being particularly agreeable could represent a disadvantage. In broader research on personality traits among athletes, other studies have employed different yet compatible measurement tools. For example, Gabrys and Wontorczyk (40) used temperamental and impulsivity scales in their study of short-track speed skating to achieve a more nuanced understanding of athlete profiles. They reveal that these athletes are characterized by high scores on temperamental scales such as persistence, harm avoidance, and novelty seeking, as well as character scales like cooperativeness. Additionally, they score high on impulsivity scales, including sensation seeking and positive urgency. Similarly, Kang et al. (41) explored temperamental factors to elucidate success among baseball players, suggesting that predictive temperamental factors for success in these athletes include traits such as novelty seeking and reward dependence. Future research could explore how those traits are related to elite soccer players.

An innovative aspect of our study is the application of ANN and SVM, which shows promise for future research. We applied this approach to differentiate between elite soccer players and controls based solely on cognitive and personality attributes. Our findings demonstrate the efficacy of this method in accurately predicting participants' membership in these groups. This suggests that the psychological profile of soccer players exhibits distinctive characteristics effectively captured by our models. Specifically, the confusion matrix of our classifier reveals near-perfect accuracy in predicting soccer players based on their psychological features. Among the few errors identified by our model, we observed that almost all were false positives, where individuals who were not athletes were incorrectly classified as athletes. This finding is particularly intriguing and logical, suggesting that successful soccer players possess a distinct psychological profile. Essentially, without this specific psychological profile, achieving success in soccer appears extremely improbable. Conversely, possessing the correct psychological profile does not guarantee success, as various factors such as personal choices, preferences, or physical limitations can still hinder one's soccer career. Moreover, the analysis of the SVM weights provided insight into which psychological features contributed most significantly to the decoding algorithm. While each feature made a meaningful contribution, our results indicated that cognitive tests, as a group, had a greater impact on the model's performance than personality traits. Notably, the WM score emerged as the strongest individual contributor.

A final interesting result delivered by our research lies in identifying specific abilities that serve as predictors of future performance outcomes. Our findings build upon previous studies by Vestberg and colleagues (17, 18, 24), which demonstrated significant correlations between WM and goals scored (18), as well as between design fluency capacity and assists provided (24) or goals/assists scored in subsequent seasons (17). In our study, utilizing different predictors and performance indicators, we identified additional significant relationships. Importantly, we considered both cognitive and personality factors as predictors and examined a diverse range of soccer abilities beyond goals and assists, such as successful dribbles.

Future research might build on these findings by exploring a wider array of psychological and soccer-related features. Additionally, moving beyond our cross-sectional design, future studies could also benefit from adopting longitudinal approaches, following previous successful examples in the context of behavioral and neuroscientific research (42–44). For instance, such designs would be particularly valuable for investigating how the psychological profiles of young players, assessed early in their careers, might causally predict their long-term success in elite soccer. Moreover, longitudinal studies might suggest whether executive functions and psychological features remain stable or change due to practice and use—a topic that has previously been fiercely debated in research (45–47). This approach could provide deeper insights into human psychology while offering practical implications for improving soccer and sports training practices. Furthermore, future research should explore other factors that might contribute to the differences between elite soccer players and controls. For instance, the observed lower levels of Neuroticism in elite players reported in the current study suggest that they might have a superior ability to perform under pressure or to remain unaffected by external disturbances while playing. Moreover, future research could also focus on additional soccer-related features such as the potential influence of coaching and management styles on the players' mental attributes. Investigating these aspects could provide an even more comprehensive understanding of the unique characteristics of elite soccer players.

Beyond elite soccer players and athletes in general, the findings of our study can also be viewed in the context of broader human success and psychology. While we have described the essential psychological traits for becoming an elite soccer player, an intriguing question arises: How do these results apply to other domains and predict success in those areas? Interestingly, our findings resonate beyond sports. For instance, research on chess has not only highlighted that higher-level players report superior chess-related skills compared to lower-level players (48), but also indicated that expert players exhibit higher cognitive abilities than nonplayers, suggesting a correlation between playing proficiency and overall intelligence (49). This parallels our observations, where elite soccer players competing at the highest levels exhibit exceptional cognitive abilities. Moreover, studies on professional gamers have similarly reported superior performance in cognitive assessments (50, 51) and enhanced cognitive flexibility (52), aligning with our findings in elite soccer athletes. These cognitive advantages are also evident in other domains of expertise; professional musicians, for instance, outperform controls in cognitive assessments (53–56). This suggests that expertise in music, similar to elite sports, is associated with heightened cognitive abilities. Personality traits have also been studied across various domains beyond sports, remaining crucial for achieving success in professional contexts. For example, our findings align with studies on professional politicians, which reported elevated levels of Energy and Agreeableness. Nettle (57) explored personality traits in professional actors compared to the general population, reporting a profile which is similar to the one described in the current study on elite soccer players, particularly in relation to higher levels of Extraversion and Openness to Experience. However, contrary to our results, Nettle found that professional actors also exhibited higher levels of Agreeableness, challenging the notion that top-level performance requires lower Agreeableness. Taken together, our results provide insights not only into elite soccer players but also contribute, alongside findings from previous literature, to a broader psychological profile associated with achieving success in the society.

In conclusion, this study delineated the psychological profile of elite soccer players through comprehensive analyses of cognitive and personality measures in a large sample. Our findings not only define this profile but also shed light on the broader psychological traits which might be crucial for success in society. Looking toward future perspectives, our results reignite the enduring debate of nature versus nurture. Are the psychological traits and cognitive abilities identified in this study innate or acquired? Furthermore, can deliberate interventions during their developmental stages shape the optimal psychological profile of elite soccer players? Addressing these questions through carefully designed longitudinal experiments represents a crucial objective for future research, building upon the current study to deepen our understanding of human behavior and provide insights into fostering excellence in professional soccer and other elite human activities.

## Materials and Methods

**Participants.** The sample consisted of three groups of participants.

The first cohort was composed of 153 Brazilian elite soccer players (0 females, 153 males, mean age: 26.14 ± 5.63 y, average years of formal education: 8.74 ± 1.83, age range: 18 to 35 y old) who played in the Brazilian top league at the time of the data collection. The second cohort was composed of 124 Brazilian control participants, matched for education, age, and biological sex (0 females, 124 males, mean age: 27.38 ± 5.25 y, average years of formal education: 8.01 ± 1.82, age range: 18 to 35 y old). The third cohort was composed of 51 elite Swedish soccer players (19 females, 32 males, mean age: 24.50 ± 4.60 y, age range 17 to 35 y; Men: 24.50 ± 4.70 y, age range 18 to 35 y; Females: 24.50 ± 4.60, age range 17 to 33 y). Within this group of 51 players, 28 individuals had not previously participated in any senior-level matches for a national team, designated as PLP. Meanwhile, the remaining 23 players, classified as NTP, had experience in playing at least one game for their respective senior national teams. Notably, these 23 NTPs had represented a total of 14 different national teams globally. While preliminary results from this third cohort have been previously presented (24), in the current study they were gathered with the first two larger cohorts to obtain an extensive global sample of adult elite soccer players, which allowed us to draw more solid and definitive conclusions. As a matter of fact, for certain analyses, a combined dataset of Swedish and Brazilian players was created and juxtaposed against norm values derived from general populations. In other analyses, the Brazilian elite soccer players were specifically contrasted with the control group. The project was approved by the following ethical committees: Regionala etikprövningsnämn–Stockholm; Dnr 2017/2453-31/5 (Swedish cohort) and Rio de Janeiro State University Ethical Committee under the consubstantiated report 2.990.037 (Brazilian cohorts). The experimental procedures complied with the Declaration of Helsinki–Ethical Principles for Medical Research. Participants' informed consent was obtained before starting the experiment.

**Psychological Tests and Procedure.** In our study, we employed multiple assessments to evaluate the personality and cognitive scores of the participants. This approach enabled us to derive a comprehensive understanding of the cognitive and personality profiles of elite soccer players in comparison to controls who were matched for age and education.

The study combined three international datasets in which participants were tested either in Sweden or in Brazil. Regardless of the place, the assessment of each participant occurred independently within a quiet and controlled environment. The study provided a dedicated room equipped with the necessary resources, where participants could complete the several tests we administered without external disturbances. An experimenter was present and readily available throughout the assessment sessions to address any queries or concerns that participants might have encountered. Participants were given standardized instructions and encouraged to respond honestly and to the best of their possibilities to each item of the tests. As follows, we provide detailed information on the tests used, specifying which samples of participants underwent specific assessments.

The BFI (58) questionnaire was used to assess participants' personality traits across five dimensions: Openness to Experience, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. The BFI is a widely employed self-report instrument that has demonstrated good reliability and validity in previous studies and has been widely used across various cultures and populations. The BFI was administered to the Brazilian cohorts (153 elite soccer players and 124 controls).

For the assessment of participants' cognitive abilities, we utilized a battery of tests aimed at constructing a thorough profile, particularly focusing on executive functions, visuo-spatial reasoning, memory, inhibition control, and the ability to follow traces. This comprehensive approach allowed us to investigate the nuanced aspects of cognitive functioning among soccer players, shedding light on specific domains that contribute to their cognitive profiles.

We employed three scales from the Delis–Kaplan Executive Function System (D-KEFS) (59): the Design Fluency Score, Color-Word Interference Test, and Trail Making Test. The D-KEFS is a comprehensive neuropsychological assessment tool designed to evaluate various aspects of executive functioning, such as cognitive flexibility, inhibition control, and problem-solving. The Design Fluency Score assesses participants' capacity for generating as many novel designs as possible within a set period, providing insights into creative thinking and mental flexibility. In our study, this score comprised three progressively challenging subscales. In the initial stage, participants were tasked with connecting provided black dots exclusively into novel four-line shapes (the test is mainly focusing on cognitive flexibility but also includes behavioral flow, convergent creativity, response inhibition, and WM). Subsequently, the difficulty increased as participants were required to connect white dots, disregarding the presence of black dots (this variant add a need for behavioral inhibition). The third and final stage introduced a more complex task, where participants alternated between connecting one black and one white dot in a sequential manner (this variant increases the need for cognitive flexibility). This nuanced progression in difficulty allowed us to capture a spectrum of cognitive abilities related to design fluency, ranging from basic pattern recognition to more complex cognitive flexibility.

The Color-Word Interference Test is a Stroop task and serves as a robust measure of inhibition control and cognitive flexibility. In our study, this test was administered through four consecutive short blocks, each presenting participants with tasks of a similar nature. These tasks required participants to inhibit automatic responses to conflicting stimuli (e.g., participants were requested to name the color of a color-word which was printed in a different, conflicting color). The task offers an evaluation of their ability to adapt and flexibly switch between cognitive processes.

Finally, the Trail Making Test was employed to gauge cognitive flexibility, visual attention, sequencing, and motor speed. In comparison to Design Fluency, the Trail Making Test does not involve creativity (i.e., there is only one possible solution). This test featured three distinct subscales: first, connecting numbers in ascending order; second, linking letters in alphabetical order; and third, alternating between connecting one number and one letter in sequence. The inclusion of these subscales allowed for a comprehensive evaluation of visual attention and cognitive processing speed, providing valuable insights into participants' abilities to navigate sequential tasks with varying complexity. The selection of these specific D-KEFS scales was deliberate, as they collectively offer a nuanced perspective on the executive functions essential for high-performance activities like elite soccer. These tests were administered to both the Brazilian (n = 123 elite soccer players out of the total n = 153 since 30 players did not complete the D-KEFS battery) and Swedish (n = 51 elite soccer players) cohorts.

We used another set of cognitive tests to compare elite soccer players with controls including The Five-Point Test, Forward and Backward Working Memory Tests, and Tower of Hanoi task. These cognitive tests were performed approximately three months after the D-KEFS tests to minimize learning effects. The Five-Point Test (60) is a structured and standardized assessment designed to measure figural fluency functions. In our study, we utilized three distinct measures to estimate participants' performance on this test: the 5-Point New, 5-Point Repetition, and Simple Manual Reaction Time. The 5-Point New involves participants generating unique designs in response to a set of specific criteria within a five-point framework. This measure assesses participants' ability to produce novel and varied figural patterns, offering insights into creative thinking and cognitive flexibility. On the other hand, the 5-Point Repetition measures the number of repeated or perseverative designs, which are considered as errors. Repetition errors reflect difficulties with cognitive control, specifically in set-shifting and inhibition, which are key aspects of executive functioning. Additionally, the Simple Manual Reaction Time measure evaluates participants' basic motor speed and reaction time during the 5-Point task by recording their response times to simple stimuli. Together, these three measures contribute to a comprehensive assessment of figural fluency functions, offering a nuanced understanding of participants' cognitive performance in this domain. The Brazilian cohorts performed this test (153 elite soccer players and 124 controls).

Furthermore, we incorporated two additional cognitive assessments to comprehensively evaluate participants' memory and planning abilities: the Forward and Backward Working Memory Tests from the Wechsler Adult Intelligence Scale-IV (61) and the Tower of Hanoi (62) task. The Forward and Backward Working Memory Tests are classic measures designed to assess the capacity to temporarily store and manipulate information in participants' mind. The Forward version involves participants recalling and reproducing a sequence of presented numbers in the same order, while the Backward version requires them to recall the sequence in reverse order, tapping into the cognitive process of mental manipulation. The Brazilian cohorts performed this test (153 elite soccer players and 124 controls).

Finally, the Tower of Hanoi task was utilized, employing both the time taken to complete the task and the number of moves required as performance metrics. This task is a well-established measure of executive functions, specifically problem-solving, planning, and spatial reasoning. Participants were tasked with moving a series of disks from one peg to another, adhering to specific rules. The duration and efficiency of task completion provide valuable insights into participants' cognitive processes related to strategic planning and problem-solving skills. The Brazilian cohorts performed this test (153 elite soccer players and 124 controls).

The comprehensive battery of cognitive assessments employed in our study was meticulously curated to yield a nuanced and thorough understanding of various facets of human cognition. By incorporating a diverse range of tests, including measures of executive functions, figural fluency, WM, and problem-solving, we aimed to capture the multifaceted nature of cognitive abilities in elite soccer players. The inclusion of well-established and standardized tests ensures the reliability and validity of our findings, providing a robust foundation for analyzing cognitive differences among participants.

**Cognitive and Personality Profile of Soccer Players Against Controls.** This study employed comparative analyses to investigate whether soccer players were characterized by a different cognitive and personality profile compared to controls. As described below, this was done either by comparing the soccer players' scores versus standardized values (using two-sample *t* tests) of the population or by contrasting the soccer players' scores against the ones of controls matched for age and socioeconomic background [using one-way multivariate analysis of covariance (MANCOVA) or Wilcoxon tests when the assumptions of normality for the MANCOVAs were not met]. Independent analyses were performed grouping families of cognitive and personality variables in the same statistical models. All the statistical analyses were computed using the R statistical software (R Core Team, 2022).

First, using a series of independent two-sample *t* tests, we assessed the performance of soccer players in Trail Making Test, Design Fluency Test and Color-Word Interference Test in comparison to standardized norms, indexing the score of the average population.

Specifically, 10 *t* tests were employed, corresponding to three scales for the Trail Making Test, three for the Design Fluency Test, and four for the Color-Word Interference Test. To address the issue of multiple comparisons, Bonferroni correction was applied, resulting in a revised threshold *P*-value of 0.005 (obtained by dividing 0.05 by the total number of tests, i.e., 10). Both Brazilian (n = 123 elite soccer players out of the total n = 153 since 30 players did not complete the D-KEFS battery) and Swedish (n = 51) elite soccer players (total n = 174) were included in this analysis, as they underwent the exact same set of tests.

Second, we computed five MANCOVAs [at $\alpha = 0.01$ after applying the Bonferroni correction (0.05 divided by 5)] to contrast several personality and cognitive scores of soccer players versus controls. This involved only the full Brazilian cohorts (soccer players n = 153, controls n = 124).

The five personality scores taken from the Big Five Questionnaire (Neuroticism, Extraversion, Openness to Experience, Agreeableness, Conscientiousness) were tested. Unlike the previous analysis that relied solely on norms of the general population, this investigation incorporated data not only for soccer players but also for matched controls. A one-way MANCOVA (Wilk's Lambda [$\Lambda$], adjusted $\alpha = 0.01$) was performed to compare the personality scores between the two groups while controlling for age. The independent variable was group (soccer players and controls), and the model included five dependent variables (Neuroticism, Extraversion, Openness to Experience, Agreeableness, Conscientiousness) along with one covariate (age). Afterwards, to determine the effects of the independent variable on each of the dependent variables inserted in the MANCOVA, five univariate analyses of covariance (ANCOVA) were computed. These were computed at $\alpha = 0.01$ after applying the Bonferroni correction (0.05 divided by the number of ANCOVAs conducted) as follow-up tests to the MANCOVA.

A second MANCOVA (Wilk's Lambda [$\Lambda$], adjusted $\alpha = 0.01$) was computed for the Five Point Test. In this analysis, the independent variable was group (soccer players and controls), and the dependent variables comprised three variables from the Five Point Test: 5-point new, 5-point repetition, and Simple Manual Reaction Time. Once again, age served as the covariate. Although the MANCOVA yielded statistical significance, the residuals were found to deviate from linearity. Consequently, three independent Wilcoxon tests were executed separately for each of the aforementioned variables (5-point new, 5-point repetition, and Simple Manual Reaction Time) to compare performance between soccer players and controls. To account for multiple comparisons, a Bonferroni correction was applied, resulting in an adjusted threshold *P*-value of 0.016 (obtained by dividing 0.05 by the number of independent Wilcoxon tests conducted, i.e., 3).

Subsequently, we computed a MANCOVA (Wilk's Lambda [$\Lambda$], adjusted $\alpha = 0.01$) for the WM test. Here, the independent variable was group (soccer players and controls), the dependent variables were forward digit span and backward digit span, and the covariate was the age of the participants. Once again, although the MANCOVA was significant, its residuals were not linearly distributed. Thus, we computed two independent Wilcoxon tests to compare, separately, each of the variables reported above (forward digit span and backward digit span) across soccer players and controls. Bonferroni correction for multiple comparisons was applied, obtaining a new thresholding *P*-value corresponding to 0.05/2 = 0.025.

A last MANCOVA (Wilk's Lambda [$\Lambda$], adjusted $\alpha = 0.01$) was computed for the Tower of Hanoi test. Here, the independent variable was group (soccer players and controls), the dependent variables were seconds (time) and number of moves used for the completion of the task, and the covariate was the age of the participants. As for the previous analysis, although the MANCOVA was significant, its residuals were not linearly distributed. Thus, we computed two independent Wilcoxon tests to compare, separately, each of the variables reported above (seconds and number of moves) across soccer players and controls. Bonferroni correction for multiple comparisons was applied, obtaining a new thresholding *P*-value corresponding to 0.05/2 = 0.025.

To be noted, as previously mentioned, Bonferroni correction was applied for adjusting the $\alpha$ level of the five MANCOVAs described. The adjusted $\alpha$ corresponded to 0.05/5 = 0.01. The effect size of each MANCOVA was calculated using partial eta squared (i.e., partial $\eta^2$), while the effect size for the Wilcoxon tests was computed by using Z statistic and dividing it by the square root of the sample size, as commonly done in the routines of the R statistical software (R Core Team, 2022).

**Cognitive and Personality Profile of Soccer Players in Relation to Soccer Performance.** To investigate the relationship between personality traits, cognitive scores, and a selected array of specific soccer skills/objectives, five GLM analyses were conducted using the R statistical software (R Core Team, 2022). The independent variables for the five GLMs included the cognitive and personality scores which were significant in the previous tests. Specifically, the independent variables were Neuroticism, Extroversion, Openness, Agreeableness, Conscientiousness, 5-points new and Simple Manual Reaction Times, WM (forward and backward combined), Tower of Hanoi (moves) and age.

We focused on five key soccer abilities/objectives, which were inserted as dependent variable, separately for the five GLMs that we computed. These skills/objectives corresponded to i) the number of goals scored by the players in 24 games on average in the 2021 season (including both Brazilian League 1st division [Brasileirao Serie A] and Libertadores da America or the South American Cup), ii) number of shots attempted per game, iii) number of assists in 24 games on average in the 2021 season (including both Brazilian League 1st division [Brasileirao Serie A] and Libertadores da America or the South American Cup), iv) average attempted and v) successful dribbles in 24 games on average in the 2021 season (including both Brazilian League 1st division [Brasileirao Serie A] and Libertadores da America or the South American Cup).

Since we computed five independent GLMs, we computed the Bonferroni correction for multiple comparisons, which set the significance level for hypothesis testing at *P* = 0.01. This analysis involved only the Brazilian cohort of elite soccer players (n = 153) since these data were not available for the Swedish cohort.

**ANNs and SVM.** ANNs (63) were used to decode soccer players from controls based on their cognitive and personality profile. The implementation of the ANNs was coupled with permutation-based cross-validation to prevent overfitting and ensure robustness of the results. The dataset included the same variables described for the previous analyses and involved personality traits (Neuroticism, Extroversion, Openness, Agreeableness, Conscientiousness) and cognitive scores (5-points new, Simple Manual Reaction Time, Forward Digit Span, Backward Digit Span, Tower of Hanoi moves). The dataset was divided into soccer player and control groups, and features were normalized by scaling them between zero and one. As mentioned above, to account for potential overfitting and ensure robust model evaluation, a permutation-based cross-validation strategy was employed. The data underwent 1,000 permutations, with the data randomly reassigned to either training or testing set, for each iteration. The ANN architecture was constructed using the TensorFlow and Keras frameworks in Python. The model comprised an input layer with the same number of neurons as input variables (10), followed by a hidden layer with 16 neurons and a ReLU activation function. The output layer consisted of a single neuron with a sigmoid activation function, which is suitable for binary classification tasks. The model was trained using the Adam optimizer and binary cross-entropy loss function. During training, the data were processed in batches of 32 samples for 20 epochs, as commonly done in ANN implementations. The evaluation of the model on the test set was performed separately after training. Here, for each permutation, various performance metrics were computed and stored, including test loss, test accuracy, precision, recall, F1 score, and confusion matrix.

The test loss is a measure of how well the model is performing in predicting whether an individual is a soccer player or a control. It quantifies the disparity between the model's predictions and the actual outcomes in the test dataset. Lower test loss values indicate a closer alignment between the predicted and actual values. Test accuracy provides a straightforward gauge of the model's correctness in classifying instances within the test set. It represents the proportion of correctly classified samples, showcasing the model's overall accuracy in distinguishing between soccer players and controls. Precision focuses on the accuracy of positive predictions. It assesses the ratio of correctly predicted soccer players to the total instances predicted as soccer players. A higher precision value signifies fewer instances where the model wrongly identified a control as a soccer player. Recall, also known as sensitivity or true positive rate, evaluates the model's ability to correctly identify actual soccer players. It measures the ratio of correctly predicted soccer players to the total actual soccer players, emphasizing the model's sensitivity in recognizing true positives. The F1 score combines precision and recall, providing a balanced metric that considers both false positives and false negatives. This harmonic mean is particularly useful when there is an imbalance in class distribution, offering a comprehensive assessment of the model's effectiveness. The confusion matrix is a representation of the model's classification performance. It delineates true positive, true negative, false positive, and false negative predictions. This matrix allows for a nuanced understanding of specific types of errors and correct classifications, aiding in the identification of areas for model improvement.

The results from the 1,000 permutations were aggregated to compute average values for the aforementioned performance metrics. This analysis involved only the Brazilian cohort of elite soccer players (n = 153) since it required participants with no missing scores across the personality and cognitive tests.

To further validate our findings, we applied a comparable approach, calculating the same metrics (test accuracy, precision, recall, F1 score, and confusion matrix) using a SVM algorithm to differentiate elite soccer players from controls based on their personality traits and cognitive abilities. In brief, SVM is a supervised machine learning algorithm used for both classification and regression tasks. It operates by identifying the optimal hyperplane that maximally separates data points of different classes. Essentially, the algorithm seeks to create the largest possible margin between the classes in a high-dimensional space. Although both ANNs and SVMs are used for classification, they differ in their mechanisms. While ANNs is generally considered able to capture more subtle, complex relationships within the data, SVMs provide interpretable weights. These weights highlighted which psychological features most significantly contributed to distinguishing elite soccer players from controls—a level of interpretability ANNs cannot offer. By reporting the results of both analyses (ANN and SVM), we provide a more comprehensive interpretation and strengthen the reliability and robustness of our findings.

**Data, Materials, and Software Availability.** The code used for the analyses and the anonymized data from the experiment are available in the following repository: https://github.com/leonardob92/Soccer_PsychologicalProfile.git (64).

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Author affiliations: [a]Center for Music in the Brain, Department of Clinical Medicine, Aarhus University & The Royal Academy of Music, Aarhus/Aalborg 8000, Denmark; [b]Centre for Eudaimonia and Human Flourishing, Department of Psychiatry, Linacre College, University of Oxford, Oxford OX39BX, United Kingdom; [c]Department of Psychiatry, University of Oxford, Oxford OX37JX, United Kingdom; [d]Department of Psychology, University of Bologna, Bologna 40127, Italy; [e]Center for Psychiatry Research and Center for Cognitive and Computational Neuropsychiatry, Department of Clinical Neuroscience, Karolinska Institutet, Stockholm 17177, Sweden; [f]College of Psychology, School of Health and Applied Sciences, Central Queensland University, Cairns 40939, Australia; and [g]Department of Psychology, School of Education and Social Sciences, Rio de Janeiro State University, Rio de Janeiro 24435-000, Brazil

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