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General Executive Functions and Cognitive–Motor Integration in Soccer Players of Different Competitive Levels

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Research Article

Keywords: soccer players, executive function, cognitive–motor integration, task context

Posted Date: September 21st, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10939666/v1

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Additional Declarations: No competing interests reported.

Abstract

Background

Soccer performance requires the integration of cognitive processing with sport-specific actions. This study compared general executive functions and sport-specific cognitive–motor integration between soccer players of different competitive levels and examined whether competitive-level differences varied across task contexts.

Methods

Thirty-eight male soccer players were classified into an elite group (n = 22) and a non-elite group (n = 16). Inhibitory control, cognitive flexibility, and working memory were assessed using standardized laboratory tasks (Flanker, More-Odd shifting, and 2-back) and corresponding soccer-specific field tasks. Laboratory outcomes included accuracy and reaction time, whereas field outcomes included cognitive judgment accuracy, foot-selection accuracy, and passing success rate. Between-group differences were analyzed using independent-samples *t* tests or Mann–Whitney *U* tests, as appropriate.

Results

In laboratory tasks, between-group differences were limited. No significant differences were observed in Flanker accuracy or reaction time. For cognitive flexibility, a significant difference was found only in repeat-condition accuracy. In the 2-back task, accuracy did not differ between groups, whereas the elite group showed longer reaction times. In contrast, field tasks revealed broader differences. The elite group showed higher foot-selection accuracy and passing success in the inhibitory-control task, superior performance on most cognitive judgment, foot-selection, and passing measures in the cognitive-flexibility task, and higher accuracy in the working-memory task.

Conclusions

Competitive-level differences were not consistently evident in general executive functions but became more pronounced when cognitive demands were integrated with soccer-specific actions. Elite players' advantages were more apparent in sport-specific cognitive–motor performance involving cognitive judgment, action selection, and technical execution. These findings highlight the context-dependent nature of cognitive performance in soccer and support combining standardized cognitive measures with sport-specific cognitive–motor assessments.

1. Background

Soccer is an open-skill sport characterized by dynamic and unpredictable environments in which players must rapidly perceive relevant information, make decisions, and execute appropriate actions as possession, spatial configurations, and offensive–defensive situations change. Effective performance therefore depends not only on physical and technical abilities but also on the coordination of information processing, cognitive judgment, action selection, and technical execution [1, 2]. Accordingly, cognition in soccer is increasingly conceptualized as a continuous perception–action process in which players interpret evolving situations, select appropriate actions, and adjust subsequent behavior based on action outcomes [3].

Executive function provides cognitive control for goal-directed behavior and is commonly conceptualized as comprising inhibitory control, cognitive flexibility, and working memory [4, 5]. These functions are relevant to soccer because players must suppress inappropriate responses, adapt actions to changing situations, and maintain and update task-relevant information [6]. Previous studies have reported associations between executive functions and soccer performance, with elite players showing advantages in some measures of inhibitory control, cognitive flexibility, and other executive functions [7–11]. However, these advantages have not been consistently observed across cognitive components or task paradigms, suggesting that general executive-function performance does not correspond directly to competitive level [12–15].

One possible explanation concerns how executive functions are assessed. Most studies have used standardized laboratory paradigms, such as the Flanker, task-switching, and N-back tasks, which typically involve abstract stimuli and button-press responses [16, 17]. Although these paradigms allow specific cognitive processes to be examined under controlled conditions, their informational and action demands differ substantially from those encountered in soccer. Methodological concerns regarding construct definition, task selection, and measurement reliability further limit inferences from individual laboratory tasks [15, 18, 19]. Consistent with these concerns, a meta-analysis of 142 studies found that although high-level athletes generally demonstrated cognitive advantages, between-group differences were larger in sport-specific decision-making tasks than in general cognitive tasks and were more apparent when sport-specific stimuli were used [17, 20]. Thus, expertise-related cognitive differences appear to depend partly on task context and specificity.

Sport cognition research has therefore increasingly focused on information processing and decision-making within sport-specific contexts. High-level athletes are generally more effective at extracting task-relevant information and selecting appropriate actions under time constraints [1, 2]. In soccer, however, cognitive abilities and technical skills have often been assessed separately, making it difficult to determine how cognitive processing is translated into sport-specific actions [21]. Recent studies have attempted to address this limitation by incorporating soccer-specific information and motor responses into cognitive assessments [22–24]. For example, Musculus et al. [24] adapted Flanker and task-switching paradigms by replacing button presses with soccer passing actions. Nevertheless, increasing task specificity involves more than substituting a motor response: soccer performance requires

cognitive judgments to guide action selection and technical execution within an integrated perception–action process [25–27].

This distinction is also reflected in recent theoretical and empirical work. The General Model of Cognition in Elite Soccer Players conceptualizes soccer cognition as a continuous perception–action cycle involving executive control, attention, anticipation, decision-making, action selection, and execution [3]. Recent reviews similarly emphasize the remaining gap between laboratory-based cognitive assessments and actual sport behavior [28]. Importantly, however, greater task specificity does not necessarily provide a better measure of competitive level. Whether expertise-related differences emerge may depend on whether the task captures relevant information processing, action selection, and technical execution. Few studies have directly compared standardized laboratory tasks with soccer-specific field tasks targeting corresponding cognitive components in players of different competitive levels [29]. It therefore remains unclear whether competitive-level differences are consistently evident in general executive functions and whether these differences become more pronounced when comparable cognitive demands are integrated with soccer-specific actions.

Accordingly, the present study assessed inhibitory control, cognitive flexibility, and working memory using both standardized laboratory tasks and corresponding soccer-specific field tasks. Performance on the laboratory tasks was operationalized as general executive functions, whereas integrated performance involving cognitive processing, action selection, and technical execution in the field tasks was defined as sport-specific cognitive–motor integration. We hypothesized that differences between elite and non-elite players would be limited and inconsistent across general executive-function measures but would become more evident when cognitive demands were integrated with soccer-specific actions. By comparing performance across these two task contexts, this study aimed to clarify the context-dependent characteristics of cognitive performance associated with competitive level in soccer. The findings may contribute to a better understanding of how soccer expertise is expressed across different task contexts and provide a basis for developing more ecologically relevant cognitive assessment and training approaches in soccer.

2. Methods

2.1 Participants

This study adopted an elite–non-elite comparative design and recruited 38 male soccer players aged 18–22 years, with a mean age of 19.34 ± 1.02 years. All participants had received systematic soccer-specific training. Following the expert–novice paradigm, participants were divided into elite and non-elite groups according to China's national athlete classification standards. The elite group consisted of 22 nationally certified Level-1 soccer players, whereas the non-elite group consisted of 16 soccer players without an official athlete classification. No significant difference in age was observed between the two groups ($p > 0.05$). In terms of educational background, all participants were undergraduate students, resulting in a relatively homogeneous level of education and thereby reducing, to some extent, the

potential influence of educational background on executive-function measures. All participants volunteered to take part in the study. Before testing, they were fully informed of the experimental procedures, task requirements, and relevant precautions, after which written informed consent was obtained. The experimental protocol was approved by the Ethics Committee of Beijing Sport University.

With respect to training experience, participants in the elite group had 9–14 years of soccer training, with a mean training duration of 11.50 ± 1.14 years, whereas the non-elite group had a mean training duration of 6.62 ± 2.39 years. The difference between groups was statistically significant ($p < 0.05$). Differences in training duration and competitive classification reflected clear differences in sport-specific training experience and competitive level between the two groups, consistent with the basic grouping principles of the elite–non-elite comparative design. Participants represented the major playing positions, including forwards, midfielders, and defenders. Overall, the two groups were comparable in basic demographic characteristics such as age and educational background, while showing clear differences in competitive classification and soccer-specific training experience. This grouping therefore provided an appropriate basis for comparing general executive functions and sport-specific cognitive–motor integration between soccer players of different competitive levels. Participant characteristics are presented in Table 1.

Table 1
Participant characteristics

Variable	Elite group (n = 22)	Non-elite group (n = 16)
Number of participants	22	16
Age (years)	19.09 ± 0.92	19.69 ± 1.09
Educational background	Undergraduate level	Undergraduate level
Training experience (years)	11.50 ± 1.14	6.62 ± 2.39
Competitive classification	National Level-1 athlete	No official classification
Playing position	Forward, midfielder, defender	Forward, midfielder, defender

2.2 Study Design and Testing Procedures

A cross-sectional comparative design was adopted, with competitive level (elite vs. non-elite) as the between-subject factor. The study examined differences in general executive functions and sport-specific cognitive–motor integration between soccer players of different competitive levels. Testing consisted of two components: soccer-specific field testing and laboratory-based standardized cognitive testing. The field tasks were designed primarily to assess integrated cognitive processing and action execution in soccer-specific contexts, whereas the laboratory-based cognitive tasks were used to assess general executive functions under relatively decontextualized conditions [24, 30].

The field testing comprised three task domains corresponding to inhibitory control, cognitive flexibility, and working memory: conflict inhibition and action selection, rule switching and action adjustment, and working-memory updating, respectively. During these tasks, players were required to interpret presented

information, make an appropriate judgment, select the corresponding foot, and execute a soccer-specific technical action. These tasks were therefore intended to capture performance integrating cognitive processing and action execution in a sport-specific context. The laboratory component employed the Flanker task, More-Odd shifting task, and 2-back task to assess inhibitory control, cognitive flexibility, and working memory, respectively [31–33]. Similar executive-function paradigms have been widely used in cognitive assessments of athletes, particularly soccer players [16, 30, 34].

All participants completed the assessments according to a standardized testing procedure. Because laboratory-based cognitive tasks may induce cognitive fatigue and potentially produce priming or transfer effects on subsequent sport-specific tasks, all participants completed the field tests before the laboratory tests. Within both testing components, tasks were administered in the same order: inhibitory control, cognitive flexibility, and working memory, thereby ensuring consistency across participants.

Before formal testing, all participants received standardized instructions regarding task rules and completed familiarization trials. A technical baseline test was also conducted. The baseline test used the same ball-delivery parameters and testing environment as the formal field tasks but required only basic soccer technical actions without any additional cognitive judgment demands. This procedure was used to assess participants' baseline technical execution and to provide a reference for interpreting performance in the sport-specific cognitive–motor integration tasks.

Stimulus parameters for the field tasks were standardized based on pilot testing. Globus EuroGoal 1000 ball-launching machine was used, with ball speed set at 50% of the machine's capacity, corresponding to approximately 50 km/h, and a delivery distance of 10 m. Under these conditions, participants were able to complete the required technical actions while also identifying stimulus information and responding within a limited time. The task therefore imposed meaningful temporal pressure and soccer-specific demands while maintaining standardized experimental conditions and a degree of ecological validity.

Throughout formal testing, the ball-delivery interval, experimental environment, task procedures, and instructions were kept constant. All field tasks were recorded in their entirety using video equipment. After testing, cognitive judgments, action selections, and technical execution outcomes were checked and coded through video replay to ensure completeness and consistency of data recording.

2.3 Field Tests

The field tests were designed primarily to assess sport-specific cognitive–motor integration in soccer players. Compared with the laboratory-based standardized cognitive tasks, the field tasks incorporated soccer-specific stimuli and action demands, requiring participants not only to make cognitive judgments but also to select an appropriate action and complete a technical execution. This design was intended to strengthen the connection between the assessment and soccer-specific task contexts. Separate field tasks were developed for inhibitory control, cognitive flexibility, and working memory, allowing performance to be examined under conditions in which cognitive processing and action execution were integrated. All field tests were conducted on an artificial-turf soccer field, as illustrated in Fig. 1.

2.3.1 Soccer-Specific Inhibitory Control Task

The soccer-specific inhibitory control task was designed to assess players' ability to suppress interfering information during soccer actions and to complete target judgment, action selection, and technical execution according to predefined task rules [24, 35]. The test was conducted within a designated area of a standard soccer training field. Participants stood 10 m in front of the ball-launching machine. Two small target goals, each 2 m wide and 1 m high, were positioned diagonally to the left and right of the participant. The center of each target goal was located 2.5 m from the participant. A visual display screen was used to present task stimuli.

During the test, the ball-launching machine delivered balls continuously at a fixed interval of 2 s, while arrow stimuli combining different colors and directions were randomly presented on the visual display. Participants were required to determine the target goal according to predefined stimulus-response rules. When a blue arrow was presented, participants selected the target goal corresponding to the direction indicated by the arrow. When a red arrow was presented, arrow direction served as interfering information; participants were required to inhibit the directional cue and select the target goal according to the color-based rule.

After receiving the ball, participants were required to execute a one-touch pass directly toward the selected goal. Ball control or a second adjustment was not permitted. Passes toward the left target goal were performed with the right foot, whereas passes toward the right target goal were performed with the left foot. Each participant completed two blocks of 30 trials, with a 5-min rest interval between blocks. The primary outcome measures were stimulus judgment accuracy, foot-selection accuracy, and passing success rate, reflecting information processing, action selection, and technical execution, respectively.

2.3.2 Soccer-Specific Cognitive Flexibility Task

The soccer-specific cognitive flexibility task was designed to assess players' ability to adapt their behavior in response to changing rules and to complete information integration, target selection, and technical execution within a soccer-specific context. The testing setup was broadly similar to that used in the soccer-specific inhibitory control task. Participants stood approximately 10 m in front of the ball-launching machine. Four small target goals, each 2 m wide and 1 m high, were positioned in four directions around the participant. The center of each goal was located approximately 2.5 m from the participant.

During the task, the ball-launching machine delivered balls continuously at a fixed interval of 3 s. Visual arrow stimuli were presented simultaneously with auditory rule cues. Arrow direction could be either left or right, and arrows were displayed in either blue or red, with these features providing different target-related information. The auditory cues consisted of two rules: “same side” and “opposite side.” Participants were required to integrate the current visual information and auditory rule cue to determine the appropriate target, receive the ball, and then perform one controlled touch followed by a pass toward the selected target direction. Repeated adjustments were not permitted.

By requiring participants to continuously modify previously established stimulus–response relationships according to changing rules and to complete the corresponding technical action within a limited time, the task was designed to assess cognitive flexibility and sport-specific cognitive–motor integration. Each participant completed two blocks of 30 trials, for a total of 60 trials, with a 5-min rest interval between blocks. The primary outcome measures were cognitive judgment accuracy, foot-selection accuracy, and passing success rate, representing rule-based cognitive judgment, action selection, and technical execution, respectively.

2.3.3 Soccer-Specific Working-Memory Task

The soccer-specific working-memory task was designed to assess players' ability to maintain, update, and retrieve information during continuous soccer actions and to use that information to guide sport-specific technical execution [36, 37]. The task was conducted within a standardized 8 m × 8 m area. Four rebound boards, each corresponding to a specific number, were positioned in front of, behind, and to the left and right of the participant. According to the task requirements, participants were required to pass the ball toward the rebound board corresponding to the relevant numerical stimulus.

The task was adapted from the 2-back paradigm. Auditory numerical stimuli were presented continuously at 3-s intervals. The first two stimuli served as a preparatory phase, during which participants passed the ball according to the currently presented number. Beginning with the third stimulus, participants were required to maintain the current numerical information while retrieving the number presented two trials earlier and then, according to the 2-back rule, pass the ball toward the corresponding target area.

Throughout the task, participants were required to continuously maintain and update numerical information while performing soccer actions and to translate working-memory processing into sport-specific passing behavior. Each participant completed two blocks of 22 passes, including 20 valid judgment trials per block, with a 5-min rest interval between blocks. The primary outcome measure was cognitive judgment accuracy, reflecting the accuracy with which participants maintained, updated, and retrieved information while performing sport-specific actions.

2.4 Laboratory-based Tests

The laboratory-based tests were used to assess general executive functions in soccer players under standardized conditions and were designed to correspond conceptually to the sport-specific cognitive–motor integration tasks used in the field. Testing was conducted in a quiet laboratory with appropriate lighting. Standardized cognitive tasks were presented on a computer to assess inhibitory control, cognitive flexibility, and working memory. Specifically, inhibitory control was measured using the Flanker task, cognitive flexibility using the More-Odd shifting task, and working memory using the 2-back task.

All experimental programs were developed and administered using E-Prime software. The testing computer was equipped with a standard monitor with a resolution of 1920 × 1080 pixels, and participants were seated approximately 60 cm from the screen. Before formal testing, the experimenter

provided standardized instructions regarding the task rules and response requirements, followed by practice trials to ensure that participants fully understood each task. During formal testing, the computer automatically recorded reaction time and accuracy. The data were subsequently organized in a standardized manner for statistical analysis. The experimental procedures for the three laboratory-based cognitive tasks are illustrated in Fig. 2.

2.4.1 Assessment of Inhibitory Control: Flanker Task

Inhibitory control was assessed using the Flanker task. Each trial began with a fixation cross presented for 500 ms, followed by the stimulus display for 1000 ms. The interstimulus interval was 2 s. The task included congruent and incongruent conditions. In the congruent condition, the central target stimulus and the flanking distractors pointed in the same direction, whereas in the incongruent condition they pointed in opposite directions. Participants were instructed to identify the direction of the central target as quickly and accurately as possible and respond by pressing a key: the “F” key for “left-foot shot” and the “L” key for “right-foot shot.”

Participants completed 12 practice trials before formal testing. The formal task consisted of two blocks of 48 trials each. Congruent and incongruent trials were presented randomly with equal probability. The primary outcome measures were reaction time, accuracy, and the conflict effect. The conflict effect was calculated by subtracting the mean reaction time in the congruent condition from that in the incongruent condition, with smaller values indicating greater efficiency in interference inhibition.

2.4.2 Assessment of Cognitive Flexibility: More-Odd Shifting Task

Cognitive flexibility was assessed using the More-Odd shifting task. Digits from 1 to 9, excluding 5, were presented sequentially at the center of the screen. Each stimulus was displayed for 2000 ms, with an interstimulus interval of 3 s. The task included magnitude judgment, parity judgment, and switching conditions. For red digits, participants judged numerical magnitude: numbers smaller than 5 required an “F” key response, whereas numbers greater than 5 required an “L” key response. For blue digits, participants judged parity: odd numbers required an “F” key response, whereas even numbers required an “L” key response. In the switching condition, participants were required to alternate between the magnitude and parity rules according to digit color.

The formal task consisted of six blocks administered in an ABCCBA sequence. Blocks A and B represented single-rule conditions, and each contained 16 trials. Blocks C represented the switching condition, and each contained 32 trials, including 16 switch trials. Before the first A or B block, participants completed eight practice trials, whereas 16 practice trials were completed before the first C block. The primary outcome measures were reaction time, accuracy, and switch cost. Switch cost was calculated by subtracting the mean reaction time under the non-switch condition from the mean reaction time under the switch condition. Smaller values indicated greater task-switching efficiency.

2.4.3 Assessment of Working Memory: 2-Back Task

Working memory was assessed using a spatial 2-back task. The stimulus consisted of a small ball presented randomly in one of nine positions within a 3 × 3 grid. Each stimulus was displayed for 1 s, with an interstimulus interval of 3 s. Participants were required to continuously maintain and update the spatial location of the ball and determine whether the current location matched the location presented two trials earlier. When the positions were identical, participants pressed the “L” key; when they differed, participants pressed the “J” key.

Participants completed 12 practice trials before formal testing to ensure that they understood the task rules. The formal task consisted of two blocks of 25 trials each. The primary outcome measures were mean reaction time and accuracy. Provided that a high level of accuracy was maintained, shorter reaction times were interpreted as indicating greater efficiency in the maintenance and updating of working-memory information.

2.5 Statistical Analysis

Data processing and statistical analyses were performed using SPSS. Raw data were first screened, and invalid trials and clearly anomalous values were excluded. Descriptive statistics were then calculated for all outcome measures. Continuous variables were presented as mean ± standard deviation (M ± SD). Before inferential analyses, the main outcome variables were examined for normality and homogeneity of variance, and statistical procedures were selected accordingly. Because data were missing for a small number of participants in certain tasks, each analysis was conducted using the valid data available for the corresponding task. Consequently, the actual sample size and degrees of freedom for independent-samples comparisons varied across tasks.

Competitive level was treated as the between-group factor, and performance was compared between the elite and non-elite groups for both laboratory-based general executive-function tasks and soccer-specific field tasks. For the field tasks, the main outcome measures included cognitive judgment accuracy, foot-selection accuracy, and passing success rate across the three sport-specific tasks. For the laboratory-based tasks, the main measures included reaction time, accuracy, and conflict effect for the Flanker task; reaction time, accuracy, and switch cost for the More-Odd shifting task; and reaction time and accuracy for the 2-back task. For continuous variables that met the assumptions of normality and homogeneity of variance, between-group differences were examined using independent-samples t tests. Variables that did not satisfy the assumptions for parametric testing were analyzed using the Mann–Whitney *U* test. All statistical tests were two-tailed, and the level of statistical significance was set at $p < 0.05$.

3. Results

3.1 Inhibitory Control

3.1.1 Field Test Results

For the incongruent condition, independent-samples t tests showed no significant between-group differences in cognitive judgment accuracy ($t(30) = 0.777$, $p = 0.444$) or foot-selection accuracy ($t(30) = 1.160$, $p = 0.255$). However, the elite group achieved significantly higher passing success rates than the non-elite group ($t(30) = 5.707$, $p < 0.001$).

For the congruent condition, cognitive judgment accuracy remained non-significant between groups ($t(30) = 1.225$, $p = 0.230$), whereas significant differences were observed in foot-selection accuracy ($t(30) = 2.711$, $p = 0.011$) and passing success rate ($t(30) = 5.281$, $p < 0.001$).

Overall, group differences in the soccer-specific inhibitory control task were mainly observed during action selection and technical execution rather than cognitive judgment. The detailed results of the soccer-specific inhibitory control field task are presented in Table 2.

Table 2
Results of the soccer-specific inhibitory control field task

Measure	Elite group	Non-elite group
Congruent cognitive judgment accuracy	0.82 ± 0.18	0.74 ± 0.20
Congruent foot-selection accuracy	0.72 ± 0.21	0.48 ± 0.28
Congruent passing success rate	0.66 ± 0.23	0.30 ± 0.15
Incongruent cognitive judgment accuracy	0.72 ± 0.19	0.66 ± 0.22
Incongruent foot-selection accuracy	0.56 ± 0.16	0.49 ± 0.17
Incongruent passing success rate	0.57 ± 0.14	0.26 ± 0.16

3.1.2 Laboratory-Based Test Results

No significant between-group differences were observed in accuracy or reaction time under either congruent or incongruent conditions (all $p > 0.05$). Detailed results of the laboratory-based inhibitory control task are presented in Table 3.

Table 3
Results of the laboratory-based inhibitory control task

Measure	Elite group	Non-elite group
Congruent reaction time (ms)	467.50 ± 44.49	455.86 ± 107.17
Congruent accuracy	0.94 ± 0.07	0.85 ± 0.25
Incongruent reaction time (ms)	473.06 ± 52.10	462.50 ± 109.98
Incongruent accuracy	0.94 ± 0.06	0.87 ± 0.22

3.2 Cognitive Flexibility

3.2.1 Field Test Results

Under color-cue conditions, the elite group showed significantly higher performance in repeat-condition cognitive judgment accuracy ($t(35) = 2.268$, $p = 0.030$) and foot-selection accuracy ($t(35) = 4.809$, $p < 0.001$). The difference in repeat-condition passing success rate approached significance ($t(35) = 2.029$, $p = 0.050$). Under switch conditions, significant differences were observed in cognitive judgment accuracy ($t(35) = 2.309$, $p = 0.027$), foot-selection accuracy ($t(35) = 5.013$, $p < 0.001$) and passing success rate ($t(35) = 2.288$, $p = 0.028$).

Under auditory-cue conditions, significant between-group differences were found in cognitive judgment accuracy, foot-selection accuracy, and passing success rate under both repeat and switch conditions (all $p < 0.05$).

These results indicate that competitive-level differences in cognitive flexibility were consistently expressed across cognitive judgment, action selection, and technical execution when cognitive demands were integrated with soccer-specific actions. Detailed results of the soccer-specific cognitive flexibility field task are presented in Table 4.

Table 4
Results of the soccer-specific cognitive flexibility field task

Measure	Elite group	Non-elite group
Repeat trials: color-cue cognitive judgment accuracy	0.68 ± 0.16	0.54 ± 0.22
Repeat trials: color-cue foot-selection accuracy	0.50 ± 0.17	0.25 ± 0.14
Repeat trials: color-cue passing success rate	0.58 ± 0.15	0.47 ± 0.19
Switch trials: color-cue cognitive judgment accuracy	0.71 ± 0.17	0.59 ± 0.13
Switch trials: color-cue foot-selection accuracy	0.52 ± 0.15	0.26 ± 0.16
Switch trials: color-cue passing success rate	0.59 ± 0.11	0.48 ± 0.16
Repeat trials: auditory-cue cognitive judgment accuracy	0.70 ± 0.14	0.56 ± 0.21
Repeat trials: auditory-cue foot-selection accuracy	0.54 ± 0.15	0.28 ± 0.15
Repeat trials: auditory-cue passing success rate	0.59 ± 0.13	0.45 ± 0.19
Switch trials: auditory-cue cognitive judgment accuracy	0.69 ± 0.14	0.55 ± 0.14
Switch trials: auditory-cue foot-selection accuracy	0.51 ± 0.15	0.24 ± 0.15
Switch trials: auditory-cue passing success rate	0.58 ± 0.14	0.47 ± 0.15

3.2.2 Laboratory-Based Test Results

In the laboratory task, the elite group showed higher accuracy under the repeat condition ($t(36) = 2.310$, $p = 0.027$). However, no significant differences were observed in switch-condition accuracy or reaction times under either condition (all $p > 0.05$). Detailed results of the laboratory-based cognitive flexibility task are presented in Table 5.

Table 5
Results of the laboratory-based cognitive flexibility task

Measure	Elite group	Non-elite group
Repeat-condition accuracy	0.92 ± 0.08	0.84 ± 0.12
Switch-condition accuracy	0.88 ± 0.10	0.84 ± 0.15
Repeat-condition reaction time (ms)	700.56 ± 109.10	645.01 ± 197.78
Switch-condition reaction time (ms)	794.83 ± 128.95	725.49 ± 242.27

3.3 Working Memory

3.3.1 Field Test Results

Independent-samples t tests showed a significant between-group difference in accuracy on the soccer-specific field working-memory task, $t(32) = 2.859$, $p = 0.007$. The elite group demonstrated higher accuracy than the non-elite group, indicating a significant difference in working-memory performance when cognitive processing was integrated with sport-specific actions.

3.3.2 Laboratory-Based Test Results

Independent-samples t tests showed no significant between-group difference in accuracy on the 2-back task, $t(34) = -0.758$, $p = 0.454$. However, a significant between-group difference was observed in reaction time, $t(34) = 3.202$, $p = 0.003$. Specifically, the elite group exhibited longer reaction times than the non-elite group. Thus, the between-group difference in the laboratory-based working-memory task was evident in reaction time rather than accuracy. Detailed results of the working-memory assessments are presented in Table 6.

Table 6
Results of the working-memory assessments

Measure	Elite group	Non-elite group
Field-task accuracy	0.87 ± 0.17	0.69 ± 0.21
Laboratory-task accuracy	0.79 ± 0.27	0.85 ± 0.13
Laboratory-task reaction time (ms)	774.99 ± 140.03	616.39 ± 156.80

4. Discussion

The present study examined general executive functions and sport-specific cognitive–motor integration in soccer players of different competitive levels using both laboratory-based cognitive tasks and soccer-specific field tasks. Overall, competitive-level differences were limited in laboratory tasks but became more evident when cognitive demands were integrated with soccer-specific actions. Specifically, inhibitory control differences were mainly observed in action selection and passing execution, cognitive flexibility showed consistent differences across multiple sport-specific outcomes, and working memory demonstrated different patterns between laboratory and field conditions.

Previous research indicates that expertise-related cognitive advantages are not consistently observed across all executive-function components or task paradigms. Task specificity and behavioral demands influence whether differences between athletes of different levels emerge [17, 38]. Therefore, laboratory-based executive-function performance should not be directly interpreted as an indicator of sport-specific expertise [15, 18]. The present findings further support the importance of examining cognitive performance within appropriate task contexts.

4.1 Competitive-level Differences in Inhibitory Control

In the laboratory-based Flanker task, no significant differences were observed between groups, suggesting that elite players did not demonstrate a general advantage in inhibitory control under decontextualized conditions. This is consistent with previous findings showing that executive-function advantages among athletes are not uniformly evident across cognitive components or tasks [15, 34, 38].

In contrast, differences emerged in the soccer-specific inhibitory control task. Although groups showed similar cognitive judgment accuracy, elite players achieved higher passing success, and under the congruent condition also demonstrated superior foot-selection accuracy. These results suggest that competitive-level differences became apparent when cognitive judgments were required to guide sport-specific actions.

Thus, elite players' advantage may not primarily reflect superior inhibitory control itself but rather a greater ability to translate cognitive decisions into effective actions under time constraints [39]. Because passing performance is influenced by technical ability, these findings should be interpreted as differences in cognitive–motor integration rather than isolated inhibitory control.

4.2 Competitive-level Differences in Cognitive Flexibility

Cognitive flexibility showed the most consistent differences in the sport-specific tasks. In the laboratory-based More-Odd shifting task, group differences were limited to repeat-condition accuracy, with no differences in switching performance or reaction time.

However, in the field task, elite players outperformed non-elite players across cognitive judgment, foot selection, and technical execution under both visual and auditory cue conditions. These findings suggest that expertise-related differences in cognitive flexibility may be expressed less through abstract rule switching and more through the ability to adjust actions according to changing task demands [40].

In soccer, effective flexibility requires not only detecting changes in the environment but also reorganizing subsequent actions. Therefore, sport-specific cognitive flexibility may reflect the coordination between cognitive updating and action adjustment rather than switching ability alone.

4.3 Competitive-level Differences in Working Memory

Working memory showed a distinct pattern across task contexts. In the laboratory-based 2-back task, accuracy did not differ between groups, whereas reaction time differed significantly, with elite players showing longer reaction times. Therefore, the present results do not indicate a general working-memory advantage under standardized conditions, particularly because reaction time should be interpreted together with accuracy.

Conversely, elite players achieved higher accuracy in the soccer-specific working-memory task. Unlike the laboratory task, the field task required players to maintain and update information while simultaneously performing soccer actions [41]. Therefore, the observed advantage may reflect more effective integration of working-memory processes with ongoing motor execution rather than superior isolated working-memory capacity.

4.4 Contextual Differences between General Executive Functions and Sport-specific Cognitive–motor Integration

The main finding of this study is that cognitive differences associated with soccer expertise are context dependent rather than characterized by a general advantage in executive functions. Laboratory tasks revealed limited group differences, whereas sport-specific tasks showed broader differences when cognitive processing was coupled with action selection and technical execution.

This finding is consistent with previous research showing that expertise-related advantages are typically stronger in sport-specific decision-making than in general cognitive tasks [17]. General executive functions may provide cognitive resources for soccer performance, but they cannot fully explain sport-specific behavior without considering task demands and action requirements [6].

The contribution of the present study lies in directly comparing corresponding laboratory and field tasks across the same cognitive domains. By separating cognitive judgment, action selection, and technical execution, the study demonstrates that competitive-level differences do not emerge uniformly across the behavioral process but become more apparent when cognitive processing must be translated into sport-specific actions.

Laboratory and field tasks therefore provide complementary information rather than representing different levels of validity. Laboratory tasks assess relatively isolated cognitive processes, whereas field tasks reveal how these processes are expressed during soccer-specific behavior [42]. Future assessments of soccer cognition should integrate both approaches to better characterize cognitive performance associated with expertise.

4.5 Limitations and Future Directions

Several limitations should be considered. First, the sample was limited to young male soccer players, and the relatively small sample size may restrict generalizability. Second, elite and non-elite groups differed in training experience; therefore, the cross-sectional design does not allow causal conclusions regarding the effects of training or competitive level on cognitive–motor integration. Third, although the field tasks incorporated soccer-specific actions and temporal constraints, they remained controlled experimental tasks and did not fully reproduce match situations involving opponents, teammates, dynamic environments, and physical interactions. In addition, technical ability may have influenced field-task performance, and the reliability and validity of the newly developed tasks require further investigation.

Future studies should include larger and more diverse samples, control for technical ability, and incorporate more realistic interactive environments. Longitudinal and intervention studies are also needed to clarify how executive functions and sport-specific cognitive–motor integration contribute to soccer performance development.

5. Conclusions

The present study showed that differences between soccer players of different competitive levels were not consistently reflected in general executive functions measured by laboratory-based tasks. Instead, more extensive differences emerged when cognitive demands were integrated with soccer-specific actions.

Specifically, inhibitory control differences were mainly observed in action selection and passing execution rather than cognitive judgment alone. Cognitive flexibility showed the most consistent sport-specific differences, with elite players demonstrating better performance across cognitive judgment, action selection, and technical execution. Working memory showed different patterns across task contexts, with elite players achieving higher accuracy in the soccer-specific working-memory task.

These findings highlight the context-dependent nature of cognitive performance associated with soccer expertise. Combining standardized cognitive assessments with sport-specific cognitive–motor tasks may provide a more comprehensive evaluation of soccer players' cognitive abilities.

Declarations

Ethics approval and consent to participate: The study protocol was approved by the Ethics Committee of Beijing Sport University (No. 2026379H). The study was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants before participation.

Consent for publication: Not applicable.

Availability of data and materials: The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

Funding: This study was supported by the Fujian Provincial Natural Science Foundation–Chuangqing Program entitled “Brain–Knee Coupling Mechanisms and Cognitive Control Training for Knee Injuries in Athletes” (Grant No. 2026J008200); and the Major Science and Technology Innovation Program of the General Administration of Sport of China entitled “Application Research on the Construction of Competitive Ability Evaluation and Selection Model for National Team Football Players Based on Artificial Intelligence” (Grant No. ZBZJ25-11).

Authors’ contributions: YC conceived the study, led the study conceptualization and experimental design, conducted the experiments and data collection, performed the statistical analysis, and drafted the original manuscript. FW and XD participated in participant recruitment and assisted with experimental testing and data curation. DR and QZ contributed to methodology refinement, supervised the project, and critically revised the manuscript. All authors read and approved the final manuscript.

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Figures

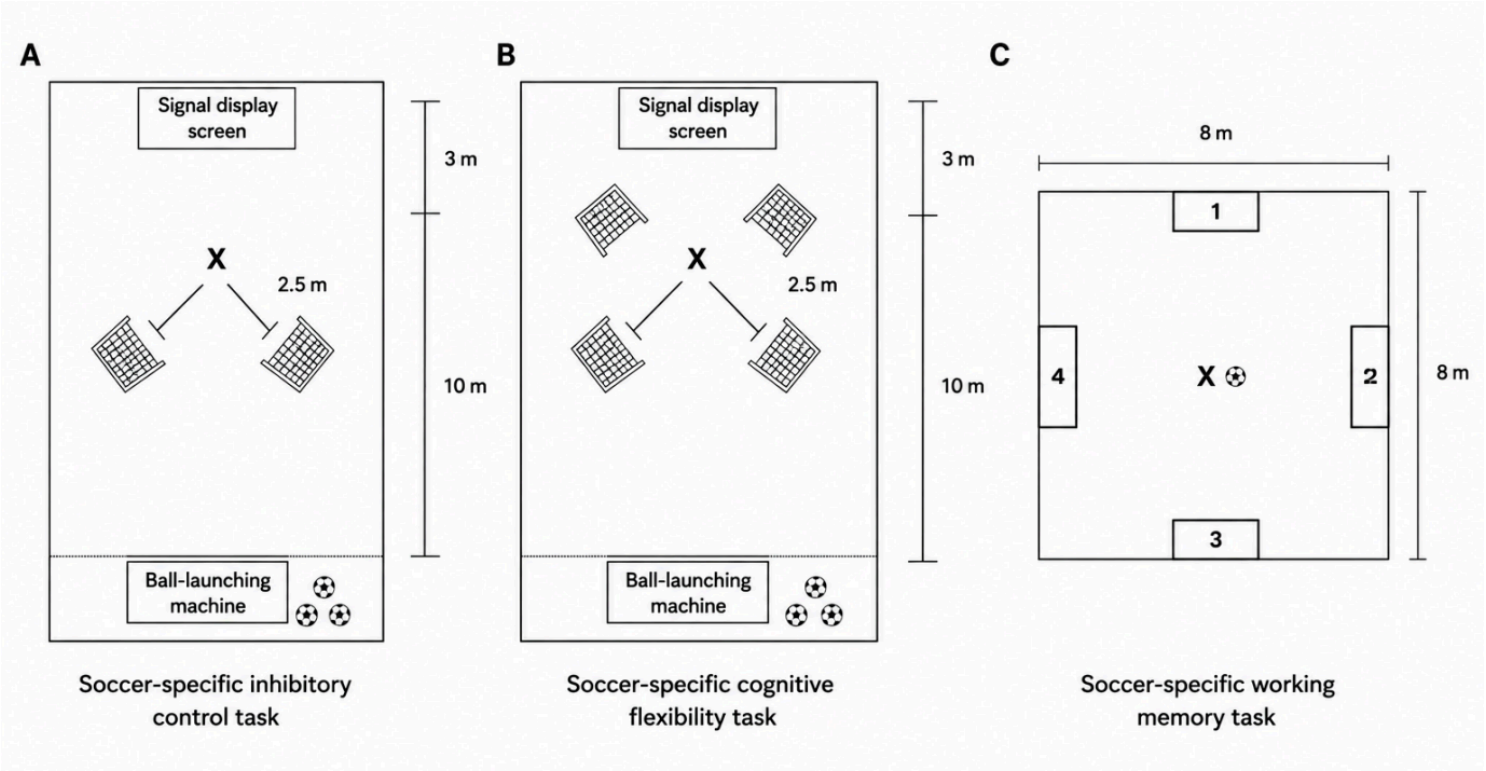


Figure 1

Schematic representation of the field-testing tasks

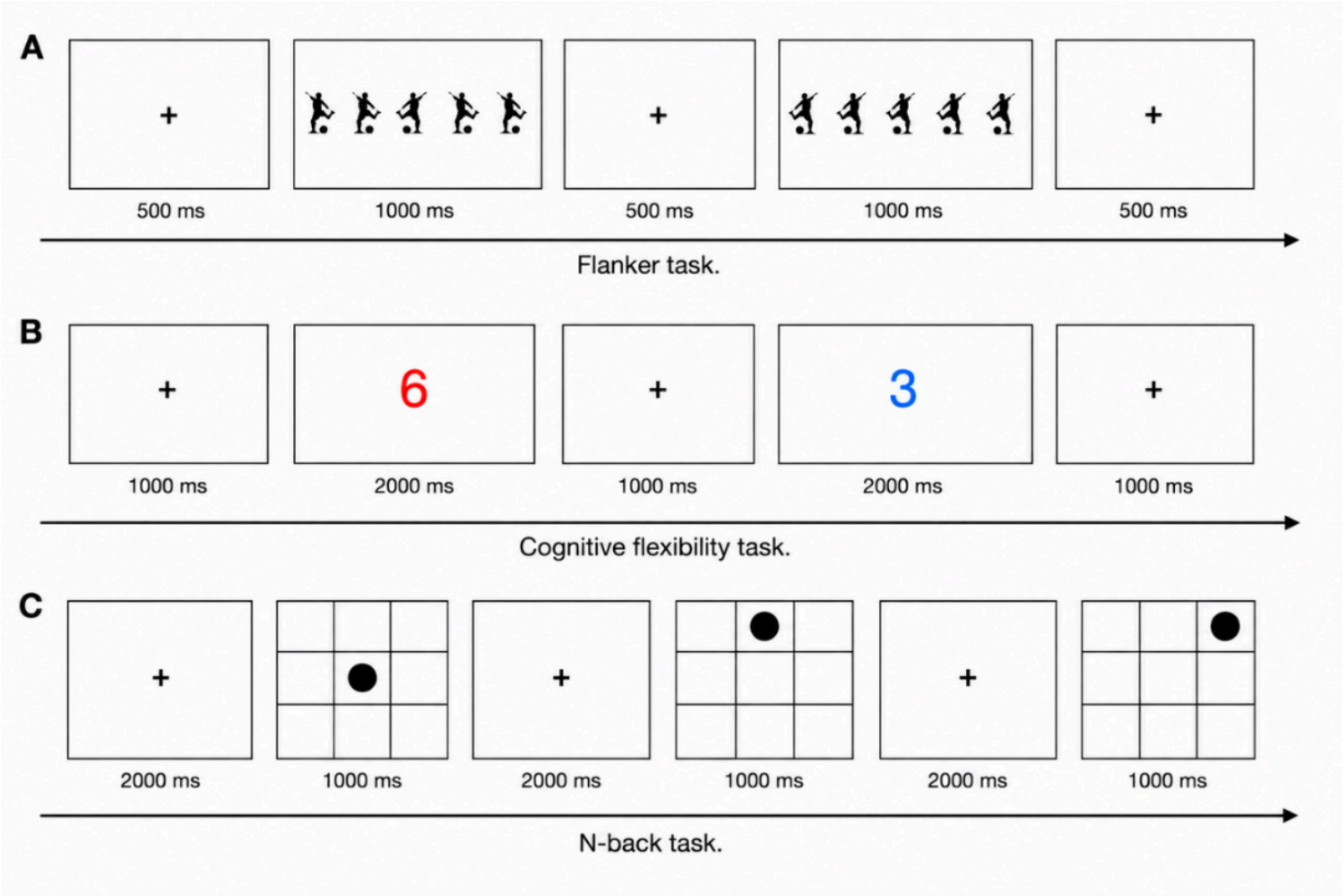


Figure 2

Laboratory-based cognitive tasks