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A new injury prevention program 'FUNBALL' improves cognitive performance of young football (soccer) players: A cluster randomized controlled trial

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ABSTRACT

The youth football injury prevention program 'FUNBALL' contains exercises requiring high cognitive demands, which are performed concurrently to the training of the respective motor task. This study evaluates whether the program increases cognitive performances of young football players.

1253 football players (aged 13–19 years old) were randomly assigned to either a control (CON) or an intervention (INT) group. The INT group performed the 'FUNBALL' program at least twice per week in their training sessions for one season (9 months). The CON group continued their training routine. From the total sample, the cognitive performance of 304 players (n = 135 CON; n = 169 INT) was assessed at the beginning and the end of the season using the Cogstate® Brief Battery, with the following subtests: One Back test (accuracy), Two Back test (accuracy), One Card Learning test (accuracy), Chase Test (correct moves per second), Set Shifting (accuracy), Identification test (speed), Detection test (speed), Groton Maze Learning Test (accuracy), and Groton Maze Learning Test Delayed Recall (accuracy).

A multivariate analysis of variance (MANOVA) on the cognitive performance improvements from pre-to posttest showed that the INT group improved their performances more strongly than the CON group for all cognitive tests, namely for working memory, visual learning, visual motor control, attention, psychomotor function, memory, and executive function.

The present study indicates that the exercise-based injury prevention program 'FUNBALL' may improve the cognitive performance of young football players. Future research should include an active control group, and should investigate whether the improvement in cognition also has beneficial effects on in-game performance.

Trial registration number: AsPredicted (https://aspredicted.org/2kb3b.pdf).

1. Introduction

Cognition may contribute to success in soccer, since the game puts high demands on inhibition, executive control, and speeded decision-making (Ballester et al., 2018; Huijgen et al., 2015; Prien et al., 2018; Verburgh, Scherder, et al., 2014; Vestberg et al., 2017). Intervention studies using cognitive training regimes have often reported considerable performance improvements in the trained tasks, but limited transfer to untrained tasks. According to Fransen (2022), near transfer refers to improvements in skills that are strongly related to the training activities, while far transfer refers to improvements in domains that are only weakly or not at all related to the trained skills. A meta-analysis on cognitive training regimes conducted by Gobet and Sala (2023) documented that near transfer is considerably more evident than far transfer in different cognitive training situations (see also Owen et al., 2010; Sala & Gobet, 2020). Studies conducted by Romeas et al. (2016) and Hirao and Masaki (2018) showed improvements in decision-making and reaction speed after cognitive training among athletes, which may reflect far-transfer effects. However, this research field has been criticized previously (Fransen, 2022; Harris et al., 2018; Renshaw et al., 2019; Walton et al., 2018), since most studies show limited transfer to tasks that have not been trained directly. There is also some evidence that

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physical training regimes and exercise can improve cognitive functions (Best, 2010; Etnier et al., 2006; Ludyga et al., 2020; Sibley & Etnier, 2003), but reviews and meta-analyses show that effect sizes for "pure" physical training on cognition tend to be small or even non-existent (Ciria et al., 2023; Singh et al., 2019; Verburgh, Königs, et al., 2014).

Some studies propose that an enrichment of physical exercises with cognitive challenges may elicit stronger cognitive benefits (Diamond, 2015; Diamond et al., 2007; Moreau & Conway, 2013; Pesce, 2012; Pesce et al., 2013, 2016; Staiano et al., 2022). The framework proposed by Tomporowski and Pesce (2019) explicitly states that "instructional methods that optimize physical and mental challenges provide the conditions necessary to produce long-term changes in the way individuals process information, make decisions, select movements, and experience the consequences of actions" (page 929). In a similar vein, Renshaw et al. (2019) and Walton et al. (2018) suggest that in order to maximize the benefits of training and its' transfer to real-world performance, cognitive training should be designed to closely resemble actual sports circumstances (see also Travassos et al., 2013). These authors argue that cognitive training approaches should integrate cognitive, perceptual, and motor functions. In highly dynamic team sports like football, athletes often perform a motor skill while concurrently facing cognitive challenges. For example, they sprint to a position on the field while keeping an eye on several opponent players, or they anticipate the trajectory of a ball flying towards them while preparing to execute a kick. Recent studies on cognitive-motor dual-tasking in sports have shown that high-level tennis or table tennis players show less pronounced dual-task costs in cognition and motor performance compared to lesser-skilled players (Amico & Schaefer, 2022; Schaefer & Amico, 2022; Schaefer & Scornaienchi, 2019). While there are several studies showing that motor-cognitive dual-task training regimes can improve cognitive and motor performances in participants from different age groups (Herold et al., 2018; Johann et al., 2016; Schmidt et al., 2015; Schmidt et al., 2020; van der Niet et al., 2016; Wollesen et al., 2022), evidence for sport-related motor skills appears to be limited (for an overview, see Moreira et al., 2021). A recent cognitive-motor dual-task intervention study by Lucia et. al. (2023) asked semi-elite basketball players to perform dribbling exercises while concurrently working on cognitive tasks using interactive devices located around the athlete on the basketball court. Participants in the intervention group increased their decision-making processes and basketball-specific performances. This indicates that an enrichment of motor skill training with additional cognitive challenges may be particularly beneficial for athletes in open-skill sports (Wang et al., 2013; Heilmann, Weinberg, & Wollny, 2022).

Recently, a new multi-component exercise-based injury prevention program ('FUNBALL') was developed (Obërtinca et al., 2024), aiming to reduce the incidence of football-related injuries. The 'FUNBALL' program targets youth football players aged 13–19 years. Cognitive challenges are part of the physical exercises in advanced difficulty levels. The program includes exercises requiring mental calculation, updating, inhibition and switching, reaction speed, memory and recall of information. The cognitive challenges are integrated into the physical demands of the underlying motor task, in a dual-task like fashion. For example, participants have to touch a specific location with one foot while balancing on the other foot (easiest level). With increasing proficiency, task-difficulty is increased by adding inhibition or mental calculation tasks, by reducing visual input, or by introducing a competition against an opponent.

When initially planning the 'FUNBALL' program, cognitive challenges were included for two reasons: Firstly, the aim was to increase the variety of the original exercises in order to improve the attractiveness of the training regime and as a consequence the (long-term) adherence to the program. By flexibly adding cognitive challenges to the exercises, coaches were able to increase task-difficulties in an adaptive manner over the course of the program. Secondly, the inclusion of cognitive tasks added to the complexity of the exercises. While playing soccer, simultaneous cognitive and physical tasks need to be fulfilled. Aspects addressed in the injury prevention program, such as core and leg axis stability, have to be executed automatically while at the same time passing the ball or observing/anticipating the behavior of teammates/opponents, etc. By adding cognitive demands, the hope was to increase the efficacy of the program with regards to injury prevention, as it closer resembles reality.

A reported positive "side-effect" of the injury prevention program was an improvement in athletic performance, which is often deemed more important to coaches and players alike. It is "directly" assessable e.g., by the players' running speed, playing performance, etc. Improving performance lies in their immediate focus whereas injuries "lurk in the background". This performance aspect increases adherence to the program, as it offers an "additional benefit" and makes the extra time spent for the injury prevention somehow "worthwhile". Please note that the control group of the current study continued their usual training regime (passive control group).

The effect of previous injury prevention programs on cognitive performance has not been examined yet. The vast majority of exercises included in the existing programs require only limited cognitive demands. Consequently, it would be highly advantageous if injury prevention measures would not only effectively reduce the incidence of injuries, but also directly enhance athletic as well as cognitive performance, thereby presenting a triple benefit to footballers.

The current study does not train cognition with standardized laboratory tasks in order to generate performance advantages in sports. The 'FUNBALL' program represents a different approach: The program consists of a soccer-specific physical training regime including cognitive challenges (FUNBALL; Obërtinca et al., 2024), and cognition at pre- and posttest is assessed with a standardized battery of cognitive tasks (Cogstate® Brief Battery). In order to assess whether the program improves overall cognitive performance in many different domains, a standardized cognitive battery was utilized. For cognitive training regimes, meta-analyses indicate that far transfer is rare to non-existent (Gobet & Sala, 2023; von Bastian et al., 2022), despite occasional positive results of individual training studies (Dahlin et al., 2008; Jaeggi et al., 2008; Karbach & Kray, 2009; Zimmermann et al., 2016). As suggested by Tomporowski and Pesce (2019), the optimization of physical and mental challenges by combining motor and cognitive tasks during training may elicit improvements in information processing and decision-making. We argue that potential positive effects of the 'FUNBALL' program on the standardized battery of cognitive tasks represent far transfer effects for most of the cognitive tasks.

The FUNBALL program was designed and later implemented in a real-world football context/environment. The 'FUNBALL' exercises involve a gradual increase in the complexity of tasks to maintain engagement and to challenge players appropriately, including social and competitive elements to enhance motivation and ensure active participation. This should optimize cognitive load and induce a prolonged mismatch between environmental demands and available processing resources, leading to plastic changes in the cognitive system (Lövdén et al., 2010). The current study evaluates the "FUNBALL" programs' effects on cognitive performance in 13- to 19-year old footballers. We hypothesize that the program will enhance the cognitive capacity and efficacy of targeted abilities, and maximize the possibility of occurrence of near and far transfer.

2. Methods

2.1. Study design

The design of the study was a two-armed, cluster randomized controlled trial. It was developed in the framework of a larger project, related to cognition and injury prevention in football (Obërtinca et al., 2024). The study has been preregistered in AsPredicted (https://aspredicted.org/2kb3b.pdf). The ethics committee of Faculty of Philosophy, within the University of Prishtina "Hasan Prishtina", Kosovo approved the study.

2.2. Sample size estimation and participants

A statistical power analysis was performed for sample size estimation (GPower 3.; Faul et al., 2007). Previous studies on intervention effects of motor training regimes that aimed to improve cognition mainly report small effect sizes (Hillman et al., 2014; Lind et al., 2017), and some authors argue that effects are reduced to zero when controlling for publication bias (Ciria et al., 2023). However, adding cognitive challenges to motor training regimes may enhance chances to find positive effects (Diamond, 2015; Schmidt et al., 2015; Staiano et al., 2022; Tomporowski & Pesce, 2019). Given the lack of studies that used a cognitive-motor training regime to increase performance on standardized cognitive tests, we used the effects of previous motor training regimes for our power analysis. To detect a small interaction effect (f = .10) for 2 groups and 2 measurements (pre and post; correlation among repeated measures of r = .5) with an *alpha* = .05 and a *power* = .95, the projected sample size was N = 328. Since we did not know how many teams would be willing to participate in the pre- and posttest cognitive performance assessment, we decided to offer that possibility to the entire sample recruited for the injury prevention program ‘FUNBALL’. Please note that samples sizes in the Preregistration of the current study (https://aspredicted.org/2kb3b.pdf) are based on the targeted 1200 participants that we asked to participate in the overall injury prevention study (Obërtinca et al., 2024).

The study included male football players (13–19 years old) of the Under 15, Under 17, and Under 19 age groups. Players competed in the Regional and the Super League of Kosovo, in their respective age group leagues. The eligibility criteria for the clubs to be included in the study was to be officially enrolled for the participation in the cRCT that investigated the efficacy of the injury prevention program ‘FUNBALL’ on injury risk (Obërtinca et al., 2024). We excluded the teams that dropped out from the intervention (see Figure 1). All the clubs that enrolled for the current study were previously randomized into an intervention (INT) or control group (CON). Teams from one club were randomized to the same treatment arm to reduce contamination between the groups. During the football season (August 2021–May 2022), players of the INT group implemented the multi-component exercise-based injury prevention program ‘FUNBALL’ (manual of the program) in their training sessions. The program took about 15–20 min to complete after familiarization and was used in 72.2 % of all training sessions, on average 2.2 times per week (Obërtinca et al., 2024).

The program contained six categories of mandatory exercises and one optional game. The exercise categories included: balance, core stability, hamstring eccentrics, glute activation, plyometrics, and running/sprinting. All those categories included two different exercises. This decision was made to provide more variability, allowing the coach the freedom to choose between the two options for each training session. All exercises were organized in five or six progressive levels with increasing difficulty, physically and cognitively. The optional ’games’ category included three games and was added with the intention of increasing the attractiveness of the program. In addition to the physical demands of the exercises, most exercises included cognitive challenges. Players had to react to a target stimulus instructed by the coach. The stimulus could be a specific color or number, each attached to a specific task to be executed. For example, in the Y-Balance test (see page 10 of the “FUNBALL manual for coaches”), players had to touch a colored cone with their foot as quickly as possible. In the easiest condition, the coach named the color (e.g., “blue”). In the next level, each color was replaced by a specific number (e.g., “blue” → 1; “red” → 2; “yellow” → 3). To increase the difficulty of the cognitive task further, players had to do a mental calculation to reach the target number (e.g., “9–7” → = 2 → red). In other exercises, players had to memorize cones and partner positions while reaching the target with eyes closed, or they had to inhibit interference while reacting to specific commands, by touching a cone that has a different color than the one that is instructed. Exercises were often performed with a partner, who competes for the correct solution. This leads to time-pressure for solving the cognitive and motor

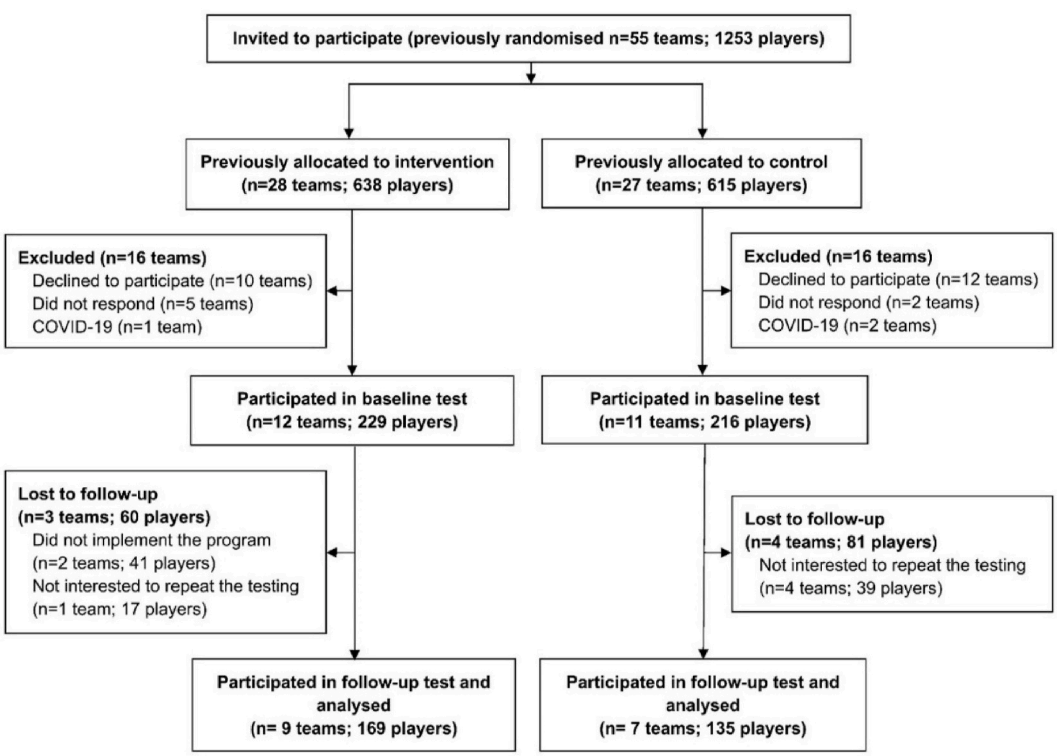

Figure 1. Flowchart of the study.

tasks. All players started on the first level and proceeded to the next one when exercises were performed with good technique as assessed by the coach. A more detailed description of the participants, randomization and the intervention is provided in the Obërtinca et al. (2024) paper.

2.3. Outcome measures

The main outcome of this study was the difference in cognitive performance changes between the INT and CON group. More specifically, the following cognitive functions were analysed, based in their assumed relevance for football-specific performance: attention, executive functioning, visual memory, visual motor control, working memory, psychomotor functioning, and visual learning.

2.4. Testing battery and administration

The cognitive performance of footballers was measured with the English version of the Cogstate® Brief Battery. The nonverbal subtests of the Cogstate battery were used. The reliability and stability of the CogState battery provides validity for its use as a research and screening tool (Collie et al., 2003). It consists of several validated subtests that can be used in specific research situations (Dingwall et al., 2009). The assessment of the cognitive functions was completed before the start of the 2021/22 season. Prior to cognitive testing, all participants filled in a demographic information questionnaire, which assessed demographic data (age and grade-point-average (GPA)) and physical activity data (days and hours of sport participation, playing position and amount of leisure activities other than football). The cognitive test battery was completed in small groups (up to 10 persons) in classrooms with laptops connected to headsets and internet. The overall testing time was about 60–80 min. Test instructions were given in the participants' native language (Albanian), and practice trials were administered for each test. The test administration team consisted of the project leader (RM) and four master students of the Psychology department which have been helped by four bachelor students. The administration team had been trained in the implementation of the cognitive tests according to the manual of the CogState battery. The team was not blinded to the group allocation of the players. The decision not to blind the team was reached through consensus, as the results were obtained using computerized methods, eliminating any possibility of interference by the testers. During the testing, the administration team offered verbal encouragement and positive feedback, and ensured that the testing environment had adequate lighting, minimal distractions, and suitable seating. Teams were asked to refrain from any physical activity on the day of testing. We measured the cognitive functions following the original test protocol (see also Dingwall et al., 2009; Fredrickson et al., 2010; Maruff et al., 2009). Tests were always assessed in the following order: visual motor control (Chase Test), executive function (Groton Maze Learning Test), psychomotor function (Detection Test), attention (Identification Test), visual learning (One Card Learning Test), working memory (One back test and two back test), set shifting (Set Shifting Test), and visual memory (Groton Maze Learning Test Delayed Recall).

2.5. Cognitive measures

2.5.1. Psychomotor function

The Detection test (DET) uses a simple reaction time paradigm to measure psychomotor function. The on-screen command asks: "Has the card turned over?". In the center of the screen, a playing card is initially presented in face-down position. The card turns over, so it is face up. The participant must press "Yes" as soon as the card turns over on the face up position. The outcome measure for this test is the mean of the log10 transformed reaction times for correct responses (Cogstate, 2023).

2.5.2. Attention

The Identification test (IDN) uses a choice reaction time paradigm to measure attention. In the center of the screen a playing card is initially presented in face down position. The card turns over, so it is face up. As soon as it turns over, the participant will have to decide whether the card is red or not. The participant must press "Yes" if it is red and "No" if it is another color. The outcome measure for this test is the speed of performance of the mean of the log10 transformed reaction times for correct responses (Cogstate, 2023).

2.5.3. Executive function

The Groton Maze Learning Test (GML) uses a maze learning paradigm to measure executive function. A 10×10 grid of tiles is shown to the participant on the screen. A 28-step pathway is hidden among these tiles, starting from the top left corner, and ending on the bottom right corner of the grid. The blue tile at the top-left corner indicates the start and a tile with red circles at the bottom-right corner indicates the finish. They move one step at a time from the beginning toward the end by pressing a tile next to their current location. If the move is correct, a green checkmark appears, and if the move is incorrect, a red cross appears. Once finished, participants are returned to the start location and asked to repeat the same pathway test once. The participants must try to remember the same pathway they have just completed. The outcome measure for this test is the total number of errors made while trying to learn the same hidden pathway on five consecutive trials (Cogstate, 2023).

The Set-Shifting (SETS) test uses a set shifting paradigm to measure executive function. In the center of the screen a playing card is presented. The participant must guess whether the card contains a target stimulus, which is either a color or a number. An audible signal indicates when the response is incorrect. The next stimulus is not presented until a correct response has been made. That way, the participant is taught the target card which could vary from one color to the other color (intra-dimensional shift), or from color to number (extra-dimensional shift). Since the card dimension changes after a while, the new rule must be learnt to proceed (Nordenswan et al., 2020). The task terminates after 120 correct responses. The outcome measure for this test is the arcsine transformation of the square root of the proportion of correct responses (Cogstate, 2023).

2.5.4. Working memory

The One Back test uses a n-back paradigm to measure working memory. The on-screen command asks: "Is the previous card the same?". A playing card is presented face up in the center of the screen and the participant has to decide whether the card is identical to the previous card. If the card is the same the participant must press "Yes", and if it is not the same the participant must press "No". The task terminates after 32 correct responses. The outcome measure for this test is the arcsine transformation of the square root of the proportion of correct responses (Cogstate, 2023).

The Two Back test uses a n-back paradigm to measure working memory. The on-screen command asks: "Is the card the same as that shown two cards ago?". A playing card is presented face up in the center of the screen and the participant has to decide whether the card is identical to the card shown two cards previously. If the card is the same the participant must press "Yes", and if it is not the same the participant must press "No". The outcome measure for this test is the arcsine transformation of the square root of the proportion of correct responses (Cogstate, 2023).

2.5.5. Visual memory

Groton Maze Learning Test Delayed Recall (GMR) uses the same maze learning paradigm as at GML to measure visual memory, while this time participants must complete the paradigm relying on what they have memorized from the path passed previously. The outcome measure for this test is the total number of errors made when remembering the maze pathway after approximately 30 min (Cogstate, 2023).

2.5.6. Visual learning

The One Card Learning test uses a pattern separation paradigm to measure visual memory. The on-screen command asks: “Have you seen this card before in this test?“. A playing card is presented face up in the center of the screen and the participants have to decide whether they have seen the card before. The participants are instructed to work as quickly as they can and be as accurate as possible. The outcome measure for this test is the accuracy of performance of the arcsine transformation of the square root of the proportion of correct responses (Cogstate, 2023).

2.5.7. Visual motor control

The Chase test (GMCT) uses a “chase the target” paradigm to measure visual motor control. The Chase test uses the same size grid as the Groton Maze Learning Test (e.g., a 10 × 10 grid of tiles). A red target is presented in the top left tile; the participant will have to select this target to begin the test. The target will move randomly from tile to tile throughout the grid and the participant must chase it by clicking on the target tiles one at a time. If the correct move is made, a green checkmark appears briefly and if the move is incorrect, a red cross appears briefly. As soon as the current target has been clicked on, the next target appears. The outcome measure for this test is the number of correct moves per second chasing the target (Cogstate, 2023).

2.6. Statistical analysis

The statistical analysis was conducted using IBM SPSS Statistics 25. Descriptive statistics are reported for baseline characteristics (see Table 1). Continuous variables (age and GPA) are reported as mean and standard deviation (*SD*). First, we checked for normality by inspecting QQplots for the raw data of each variable. Homogeneity of variances was assessed with Levene tests. To investigate changes in cognitive performance before and after the intervention period, we calculated a score for the posttest performance taking individual differences in the pre-test into account, by using the following formula: post/(pre + post) (see also suggestions by Liu et al, 2016). For the multivariate pattern of performances across all cognitive tasks, a multivariate analysis of variance (MANOVA) with group (2: INT vs CON) as between-subjects factor was conducted, followed by univariate analyses for individual subscales. Statistical significance was set at $p < .05$.

3. Results

3.1. Participants

In the ‘FUNBALL’ injury prevention study (Obërtinca et al., 2024), 1253 football players were randomized into the intervention group (INT) and control group (CON). Coaches were asked if their teams would be willing to participate in cognitive testing as well. Based on the coaches’ responses, we were able to conduct cognitive testing on 445 players. These players (229 in the INT and 216 in the CON) completed the baseline testing of cognitive performance. From this sample, 304 players (169 INT and 135 CON) completed the follow-up testing as well. The drop-out rate was higher in the CON group compared to the INT group (37.5 % v 26.2 %) (see Figure 1). Demographic characteristics are presented in Table 1. When checking the normality assumptions for the pre- and posttest performances of each test, we excluded 31 cases who showed extreme values or instruction non-compliance in specific tests, resulting in a final sample size for the MANOVA analysis of $n = 150$ participants in the intervention group, and $n = 123$ participants in the control group.

3.2. Cognitive performance results

The change scores from pre-to posttest for each group and each test are presented in Table 2. Scores are higher than .5 if posttest performances were better than pre-test performances. Multivariate analyses of variance (MANOVA) with group (2: INT vs CON) as between-subjects factor on the multivariate pattern of the change scores revealed a significant effect of group, $F(10, 262) = 15.431$, $p < .001$; *Wilk's lambda* = .629, $\eta^2 p = .279$, indicating that groups differed in performance changes from pre-to posttest. The univariate tests for each dependent variable are reported in Table 3, and Figures 2 to 4 present the pattern of findings graphically. We find significant group effects for each univariate test. Subjects in the intervention group improved their cognitive performances from pre-to posttest more strongly than subjects in the control group.

4. Discussion

4.1. Main findings

The primary finding of this study is the improvement of cognitive

Table 2
Means and standard deviations for change scores from pre-to posttest for individual tests of the Cogstate test battery by group.

Variable	Intervention group (*M, SD*)	Control group (*M, SD*)
GMR	.662 (.221)	.532 (.206)
IDN	.504 (.008)	.496 (.009)
DET	.505 (.013)	.495 (.014)
GMCT	.687 (.151)	.618 (.153)
GML	.682 (.115)	.592 (.103)
OCL	.553 (.040)	.531 (.036)
ONB (accuracy)	.525 (.054)	.508 (.048)
ONB (speed)	.516 (.010)	.503 (.010)
SETS	.538 (.027)	.514 (.029)
TWOB (accuracy)	.528 (.050)	.501 (.047)

Note. Values higher than .5 indicate a performance improvement from pre-to posttest.

Table 1
Demographic characteristics of the participants included in the study.

	Intervention group				Control group			
	n	%	*M*	*SD*	*n*	%	*M*	*SD*
Group	150	55			123	45		
Age			15	1.54			15.62	1.42
GPA			4.0	.69			3.81	.69
Sport participation (time per week)			4.26	.96			4.35	1.42
Leisure activity (time per week)			3.71	1.36			3.18	.92
Playing position								
Goalkeeper	16	10.7			12	9.9		
Defender	52	34.7			41	33.3		
Midfielder	43	28.7			37	30.1		
Offensive	39	26			33	26.3		

Note. GPA = grade point average (maximum = 5).

Table 3
Main effects of group for the individual tests of the Cogstate test battery: Univariate tests of the overall MANOVA.

Variable	*dfeffect*	*dferror*	*F-value*	*p*	$\eta^2 p$	*Cohen's d*
GMR	1	271	24.835	<.001	.084	.303
IDN	1	271	58.042	<.001	.176	.462
DET	1	271	45.008	<.001	.142	.407
GMCT	1	271	13.521	<.001	.048	.225
GML	1	271	45.756	<.001	.144	.401
OCL	1	271	22.601	<.001	.077	.289
ONB (accuracy)	1	271	7.385	.007	.027	.167
ONB (speed)	1	271	100.765	<.001	.271	.610
SETS	1	271	52.021	<.001	.161	.438
TWOB (accuracy)	1	271	20.760	<.001	.071	.276

Note. GMR = Groton Maze Learning Recall test; IDN = Identification test; DET = Detection test; GMCT = Chase test; GML = Groton Maze Learning test; OCL = One Card Learning test; ONB = One Back test; SETS = Set-shifting test; TWOB = Two Back test. df = degrees of freedom; $\eta^2 p$ = eta-squared partial. Note that the *p*-values for the univariate tests have been corrected for multiple comparisons.

performance of young male football players after participation in the 'FUNBALL' program. The improvement relates to various cognitive functions, such as working memory, executive functions, attention and alertness, psychomotor functions, memory, visual memory, visual learning, and visual motor control. The control group shows lesser or no improvements, and in some tasks (i.e., psychomotor function, attention) even a decline of performance over time. However, the absence of an active control group could mean that factors other than the injury prevention program influenced cognitive performances.

4.2. Efficacy of the investigated program

To the best of our knowledge, this is the first study to investigate the efficacy of an injury prevention program on cognitive performance in young male football players. The 'FUNBALL' program includes highly demanding cognitive exercises that challenge a variety of cognitive domains. The program exercises target multiple aspects of executive functioning, including response inhibition and interference control, as well as working memory and cognitive flexibility. The exercises also demand sustained attention, self-control, selective attention, and visual memory. The program further involves psychomotor function and visual motor control, with exercises that require hand-eye coordination and precise motor responses. Note that physical and cognitive challenges were combined when increasing the difficulty of the tasks. For example, reaching distances in a balance task were increased, while at the same time introducing a response-inhibition component to the reaction-time task.

Research on cognitive training has indicated that cognitive performance can be enhanced in both younger and older adults through the acquisition of knowledge or the improvement of task-relevant processing efficiency (Ball et al., 2002; Noack et al., 2009; Zelinski, 2009), and also through the enhanced capacity of trained cognitive abilities (Dahlin et al., 2008; Jaeggi et al., 2008; Lövdén et al., 2010). Therefore, the cognitive demands of the 'FUNBALL' tasks—such as updating, mental calculation, switching and response inhibition, memory, and reaction speed and accuracy—possibly have led to the development of specific strategies, more efficient cognitive processes and enhanced capacities of the underlying cognitive abilities. Furthermore, the task-specific strategies acquired during the program implementation may have caused transfer to other paradigms or abilities.

For example, 'FUNBALL' exercises including working memory demands require players to update and maintain new information, to

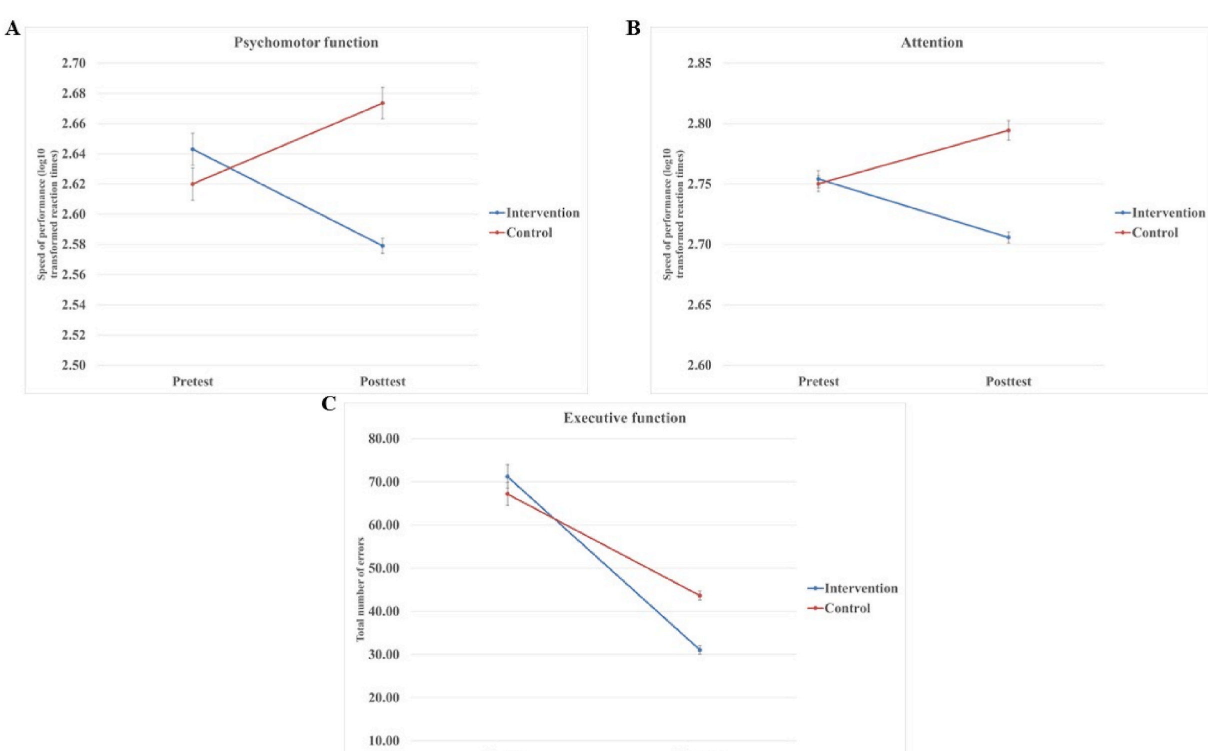

Figure 2. Pre- and posttest performance in psychomotor function (Detection Test = DET, A), attention (Identification Test = IDN, B), executive function (Groton Maze Learning Test = GML, C) for intervention and control group. Errors bars = Standard Error (SE) mean.

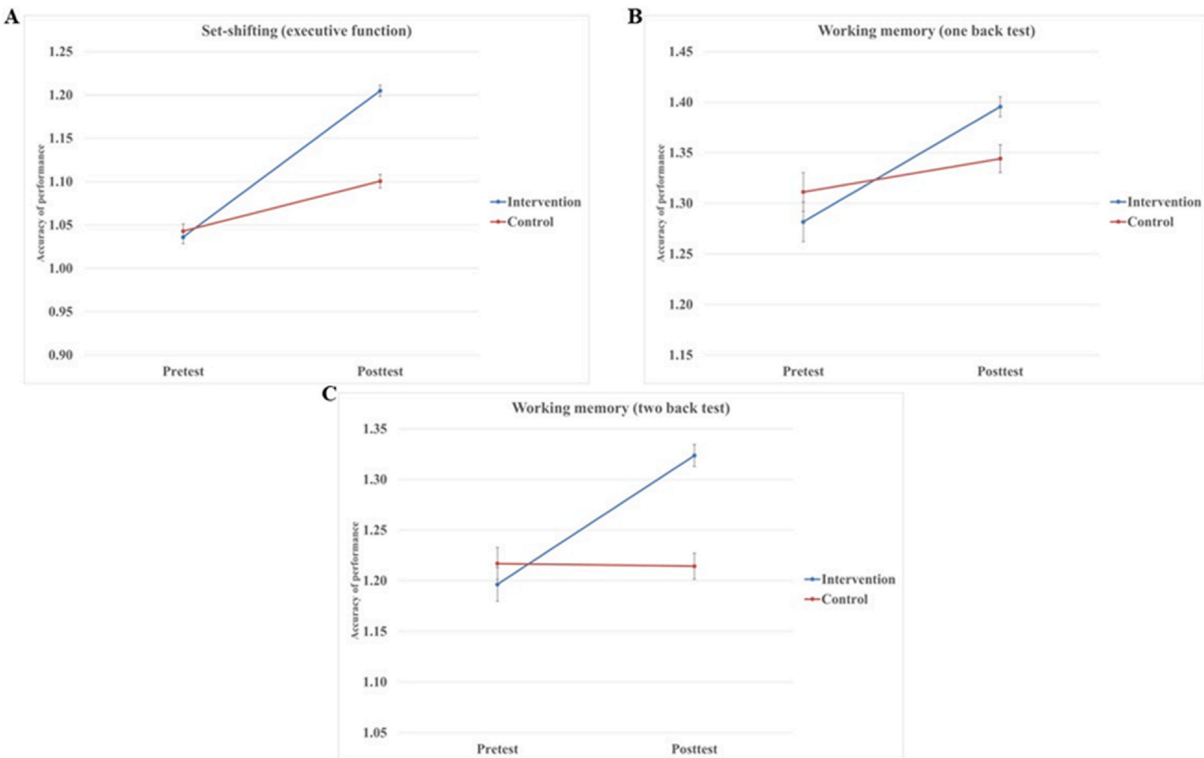

Figure 3. Pre- and posttest performance in set-shifting (Set-Shifting = SETS, A), working memory (One Back Test = ONB, B) and working memory (Two Back Test = TWOB, C) for intervention and control group. Errors bars = Standard Error (SE) mean.

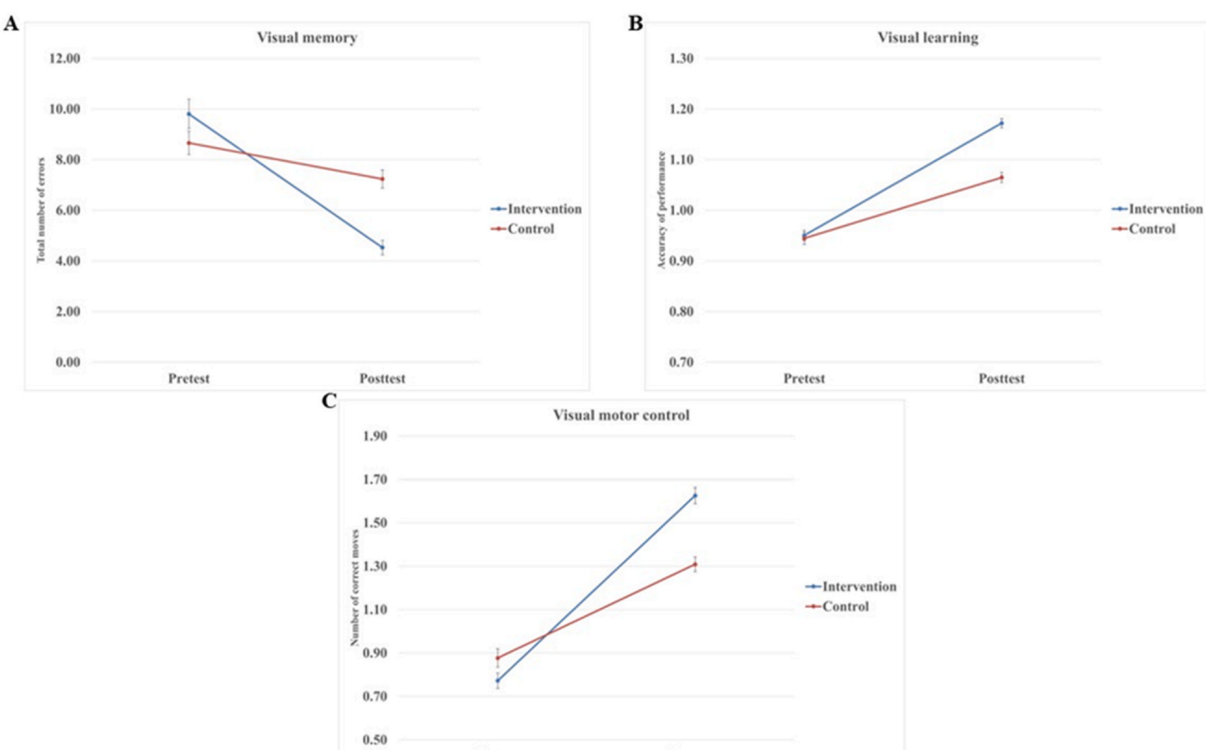

Figure 4. Pre- and posttest performance in visual memory (Groton Maze Learning Test Delayed Recall = GMR, A), visual learning (One Card Learning test = OCL, B) and visual motor control (Chase test = GMCT, C) for intervention and control group. Errors bars = Standard Error (SE) mean.

change the target of the movement, and to manipulate information by using mental calculation. As a result, near transfer could be observed in posttest tasks measuring visual memory, attention, and executive functioning, while far transfer occurred in the tests on psychomotor function and visual motor control. In addition, many of the exercises of the 'FUNBALL' program, especially in the advanced training stages, involve a combination of cognitive and motor tasks. For example, participants have to hold a specific postural position (a plank to train core stability), and are asked to concurrently react to color words by quickly touching a cone. Cognitive task-difficulty is increased further by introducing inhibitory demands (reacting to the other color) or additional processing steps (using numbers instead of the colors). Tasks are performed under time-pressure and in a competitive setting, and coaches are free to increase task-difficulties over the course of the program. These dual-tasks and training conditions may have generated significant potential for far transfer effects. Similarly, von Bastian et al.'s review (2022) reported that dual-task training enhances coordination efficiency, leading to greater improvements in both trained and untrained dual tasks.

A recent review by Moreira et. al. (2021) indicated that dual task training in athletes is likely to increase working memory capacity and attentional control. We argue that the cognitive-motor challenges of the FUNBALL program are an important prerequisite for the cognitive benefits that were observed (see also Diamond, 2015; Staiano et al., 2022; Tomporowski & Pesce, 2019). However, further research is needed to fully understand the mechanisms underlying cognitive plasticity and the likelihood of eliciting near and far transfer to untrained tasks (Lövdén et al., 2010). In the 'FUNBALL' program, the coaches had a lot of freedom in deciding which exact tasks to use in each training session, and when to implement an increase in task-difficulty level for specific tasks (see manual for details). It is possible that coaches differ in the extent to which they prioritize increases in physical fitness over increases in cognitive performances in their athletes. This may add to variance in training outcomes between different intervention teams.

The 'FUNBALL' program led to considerable performance increases in standardized cognitive tasks, with effect sizes that are higher than in many "pure" physical fitness interventions (for reviews, see Ciria et al., 2023; Singh et al., 2019; Verburgh, Königs, et al., 2014). However, the current study does not allow for conclusions concerning the practical relevance of cognitive performance improvements in applied settings, for example in academic performance. Since this is a study on football players, the question whether the 'FUNBALL' training regime also improves soccer abilities is even more important. The addition of soccer-specific tasks in the pre- and posttest would be an important target for future research. We argue that an improvement in soccer-specific tasks can be considered "near transfer" in the context of the 'FUNBALL' program, and would be highly relevant in applied settings.

5. Strengths and limitations

The present study has several strengths. The study was designed as a large cRCT and includes a high number of participants and a long duration of the intervention (nine months). The teams were cluster-randomized to avoid contamination between the control and intervention groups. In-season, the intervention group was regularly monitored for the program implementation (without previous announcements), with the vast majority of the teams administering the program according to the program manual. Moreover, cognitive performance was measured with a research-validated battery of cognitive tests, and the measurement was performed in small groups of players.

The study also has some limitations. We lacked involving an active control group in our study. The decision was implied by the "umbrella" study that investigated the efficacy of the 'FUNBALL' program in reducing the incidence of football-related injuries (Obërtinca et al., 2024). That study included only two groups, so it was impossible to expand the number of groups. The absence of an active control group introduces a potential limitation in discerning the true effects of the intervention from other factors, such as expectation effects (Denkinger et al., 2021; Foroughi et al., 2016; Parong et al., 2022; Wager & Jung, 2022). It is possible that players expected their cognitive performance to improve from the cognitive challenges that were part of their 'FUNBALL' training regime. In addition, coaches in the intervention teams may have emphasized the cognitive challenges of the program to different extents, and may have also communicated the importance of cognitive improvements to their players. Consequently, attributing observed effects solely to the intervention may be confounded by participants' expectations or other unaccounted variables. Note, however, that the 'FUNBALL' was primarily labeled as an injury prevention program, and may have been perceived as such by most participants. We suggest that an active control group for future research should be confronted with the physical exercises of the 'FUNBALL' training regime, without adding any of the cognitive challenges, or a group for which the cognitive challenge is low and kept constant throughout the physical training regime. Outcome measures should assess injuries, changes in standardized cognitive tests (far transfer) as well as soccer-related abilities (near-transfer).

The current study found a decrease in cognitive performance over time in two tests in the control group: in the Detection Test (DET) measuring psychomotor function, and in the Identification Test (IDN) measuring attention. Participants usually improve their performances in a second administration of a test, so this pattern in surprising. It is possible that participants in the control groups were bored when taking these tests for a second time, and that factors like low cognitive workload and decreased arousal decreased their performances in the posttest (Jackson et al., 2014).

Another limitation is participant attrition. In the first step, many teams who had agreed to participate in the intervention itself were not willing to invest the extra time for cognitive testing at pre- and posttest (see flowchart in Figure 1), resulting in only 23 out of 55 teams that provided cognitive pre-test measures. In addition, a considerable number of participants did not perform the second cognitive measurement. Some teams were not interested to repeat the measurement, and a high number of players changed teams during the season. As such, the final sample is smaller than the number of participants who signed up at baseline at the start of the season. This also meant that our sample was not equally balanced between the two groups. Additionally, four coaches in the intervention teams pulled out from the program implementation due to their heavy training workload. Finally, during the season, the levels of difficulty of exercises progressed with the decision of the coach without any guidance from the study assistants or research staff. In some cases, we detected a big difference between the clubs, some of them made very high progress moving to the most advanced levels in the first weeks of the study, while other clubs were still at the initial levels. Future research should carefully document each team's progression through the different stages, and also consider providing coaches with stricter rules concerning when to proceed to the next level.

6. Conclusions

This study provides initial evidence that the 'FUNBALL' program may improve the cognitive performance of young football players. Our findings point toward effective changes in working memory, visual learning, visual motor control, attention, psychomotor function, memory, and executive function in the intervention group compared to the control group. The 'FUNBALL' program has not been investigated with other age groups and the female gender yet. This calls for future studies on its efficacy, especially among even younger footballers. Moreover, future research should investigate whether the improvement in cognition also has beneficial effects on football-related tasks and on in-game performance. Cognitive performance has been related to football-abilities (Huijgen et al., 2015; Prien et al., 2018; Verburgh, Scherder, et al., 2014, 2016), but systematic empirical studies are needed to prove that cognitive or cognitive-motor interventions actually elicit beneficial effects on footballer-abilities. In terms of study design, researchers may apply higher control measures to mitigate attrition, include an active control group, and ensure high-powered studies that support the statistical measurement of changes over time.

Ethics approval and informed consent

The study was approved by the ethics committee of Faculty of Philosophy, within University of Prishtina "Hasan Prishtina", Kosovo. All players or in case of underage players their parents gave individual written informed consent.

Data availability statement

Requests for access to data from the study should be sent to the corresponding author (sabine.schaefer@uni-saarland.de). All proposals requesting data access will need to specify how the data will be used, and all proposals will need approval of the trial co-investigator team before data release.

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CRediT authorship contribution statement

Rina Meha: Writing – original draft, Visualization, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Rilind Obërtinca:** Writing – review & editing, Project administration, Conceptualization. **Karen aus der Fünten:** Writing – review & editing, Conceptualization. **Kai Leisge:** Writing – review & editing, Formal analysis. **Sabine Schaefer:** Writing – review & editing, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.psychsport.2024.102743.

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