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Research Notes

Dual-task cognitive-motor training and its impact on the sports and cognitive performance of young basketball players: a pilot study

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HIGHLIGHTS
- Both protocols showed targeted sports performance tasks improvements.
- No Go/No-Go changes, indicating no cognitive gains from the experimental protocol.
- The study combined sport-specific exercises with cognitive training, unlike others.

ABBREVIATIONS

BP	Bereitschaftspotential
CM-DT	Cognitive-motor dual-task
DRTs	Discrimination response tasks
EEG	Electroencephalogram
ERP	Event-related potentials
pN	Prefrontal negativity
RT	Response time
W	Effect size
χ^2	Chi-square

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BACKGROUND: In open-skill sports, athletes must divide attention across multiple variables during motor actions, presenting dual-task demand. Cognitive-motor dual-task (CM-DT) training, which integrates cognitive and motor components, shows greater benefits for cognitive functions than isolated training. However, functions like inhibition and anticipation still require further study.
AIM: This study investigated the effects of CM-DT on sports and cognitive performance in young basketball players.
METHODS: Six boys aged 14–18 years completed an eight-week basketball-specific training phase, followed by an eight-week wash-out, and then an eight-week CM-DT training phase. Assessments included the NBA Draft Combine dribbling tests (for motor performance) and the Go/No-Go Paradigm (for cognitive functions, including inhibition and anticipation). Statistical analyses were conducted in SPSS v.29 ($p < 0.05$). Normality was assessed with Shapiro–Wilk's test; as some distributions were non-normal and uncorrected by log transformation, data were reported using medians, interquartile ranges, and minimum–maximum values. Comparisons between conditions and time points were made using Friedman's two-way ANOVA by ranks, with Kendall's W used to report effect sizes: negligible (< 0.10), small (0.10–0.29), moderate (0.30–0.49), and large (≥ 0.50).
RESULTS: Changes were observed in specific variables, notably a large effect for "Time Double Crossover" and a moderate effect for "Time Between the Legs + Behind the Back," suggesting improvements despite no consistent statistical significance. Other variables showed negligible to small effects.
INTERPRETATION: CM-DT training led to improvements in specific motor tasks. Further research should explore protocol variations, long-term impacts, sample variability, training comparisons, and real-world applicability.

KEYWORDS: Athletic Performance | Cognitive Training | Basketball

INTRODUCTION

The incorporation of neuroscience methods into sports is gaining increasing interest, as it may lead to improvements in athletic performance [1,2]. For players of open-skill sports, such as basketball, it is important to divide attention between multiple simultaneous variables while performing motor actions [3]. In this way, cognitive-motor training, by combining motor and cognitive exercises, has proven to be more effective than solely motor training in improving both cognitive and motor performance. Moreover, dual-task cognitive-motor training (which means simultaneous cognitive-motor training), aimed at functionality, appears to be more beneficial for cognitive functions than sequential training and motor training alone [4].

Cognitive-motor training can be divided into two groups depending on the movement dynamics: sequential and simultaneous. In sequential training, athletes perform motor and cognitive exercises successively, either on the same day or on different days, in simultaneous training (dual-task), athletes perform motor and cognitive exercises simultaneously [5]. The cognitive functions typically worked on in cognitive-motor training include attention, concentration, reasoning, creative thinking, memory, and decision-making [4]. However, proactive cognitive functions [6], such as inhibition and anticipation, still need to be investigated. These functions are essential in open-skill sports, where athletes are frequently exposed to dynamic scenarios and are required to perform the best action at the right time [7]. This is particularly true for basketball, where players must often process visual information and make decisions while simultaneously executing motor actions, such as dribbling while scanning the court, deciding whether to pass, shoot, or reposition defensively, all under time and pressure constraints [8]. Additionally, basketball has been shown to affect cognition in areas such as attentional control, inhibition, and anticipation [9], particularly during free throw situations [10]. In this context, athletes use attentional control to coordinate their motor actions effectively, inhibition to filter out distracting visual, auditory, and sensory stimuli from the environment and focus on the rim, and anticipation to mentally project the trajectory of a successful shot, integrating these processes dynamically during execution.

Given these considerations about basketball, it is possible to observe brain electrophysiological methods and thus obtain information on the rapid and complex dynamics of neuronal processing that occurs during the execution of cognitive and motor tasks. In particular, electroencephalogram (EEG) methods and event-related potentials (ERP) allow for the precise measurement of neural dynamics in milliseconds, and due to this precision, they have been successfully used to identify the temporal course of cognitive processes, from task preparation to motor execution [11]. Recent literature using these shows that sports practice can affect the anticipatory components of the frontal ERP, which are related to the execution of complex sensorimotor cognitive tasks [12,13]. These studies use discrimination response tasks (DRTs), such as the Go/No-Go paradigm, which require strong involvement of anticipatory cognitive functions [14]. They identify strong involvement of pre-stimulus anticipatory ERP components, such as the Bereitschaftspotential (BP), which has been associated with neural activity involved in movement preparation and prefrontal negativity (pN), which has been associated with cognitive preparation processes, such as inhibition and anticipation and with task complexity, and is more prominent in complex tasks.

In DRTs, it has been shown that the amplitude of the BP is inversely related to response time, meaning that the larger the BP, the shorter the response time [11]. While the pN predicts response accuracy, meaning that the larger the pN, the lower the error rate [11]. While the BP is an anticipatory readiness potential reflecting the excitability of supplementary motor and cingulate areas and emerges before any voluntary action [15], the pN, originating from the inferior frontal gyrus, has been associated with proactive cognitive functions such as top-down attention and inhibition in the prefrontal cortex [12]. As in DRTs, the task requires responding as quickly and accurately as possible or withholding/inhibiting an inappropriate response with the same speed and accuracy, studies have shown that this task strongly stimulates cognitive and motor preparation [16,17], making its use suitable for its intended purpose. So, as previously reported, we do not have much information about the effects of Cognitive-Motor Dual-Task (CM-DT) on inhibitory and anticipatory functions, especially when we talk about BP and pN, we hypothesize that stimulating these capacities through a CM-DT can alter the amplitude of BP and pN in a positive way, thus improving the speed and quality of response to stimuli.

The main objective of this study is to analyze whether a CM-DT training, can improve the sports performance of young basketball players compared to traditional physical training. Furthermore, we aimed to investigate the effects of CM-DT training on behavioral performance during a cognitive DRT, as well as its impacts on anticipatory processes related to the BP and pN components before the stimulus. To this end, we developed a specific CM-DT training protocol for basketball, which uses tasks that stimulate specific cognitive functions, while physically training athletes with one of the fundamentals of the game: dribbling. Considering that both CM-DT and DRT require common cognitive functions, especially task anticipation, we expect that CM-DT reduces the response time (RT) in DRT (which is related to BP amplitude) and improves accuracy rates (which is related to an improved pN amplitude).

METHODS

Participants

The participants consisted of six male adolescents aged 14-18 years (mean age = 15.36 ± 2.22 years; mean weight = 71.65 ± 28.42 kg; mean height = 178.5 ± 5.00 cm) who have at least one-year of practice in basketball. The inclusion criteria were absence of any neurological or psychiatric disorders, no use of any medication during the experimental session, and normal or corrected-to-normal vision (with the use of corrective lenses), and the exclusion criteria included attending more than 75% of the classes and participating in all evaluations. The consent of parents or legal guardians was obtained through a free and informed consent form, provided at the time the individual joined the project. This study was approved by the Ethics Committee Ethics in Research with Human Subjects no 38855920.5.0000.8123.

Experimental design

The individuals formed a single group and were stimulated at three distinct time points: during the first phase, they received two weekly training sessions for eight weeks, with each session divided into 10 minutes of standard motor training and 50 minutes of standard basketball-specific training; the second phase was a Wash-Out period, during which the individuals received two weekly training sessions for eight weeks, with each session consisting of 50 minutes of standard basketball-specific training; the third phase consisted of another eight weeks, including two weekly training sessions, where each session was divided into 10 minutes of dual-task cognitive-motor training and 50 minutes of standard basketball-specific training. Data were collected before and after each intervention at four distinct time points, as shown in Figure 1:

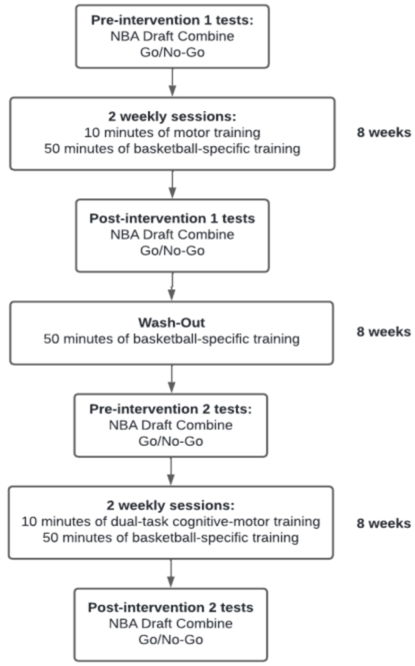

Figure 1. Visual representation of the study procedure.

The standard motor training sessions included a single 10-minute phase aligned with the basic principles of training, where the responsible instructors focused on the fundamentals of dribbling with various hand changes, speeds, and directions, ending with a basket finish. The exercises were organized into dribbling routines aimed at stimulating body movements with the ball, in harmony with the primary goal of creating and maintaining an advantage over the opponent by dribbling the ball. The training was conducted using one or two balls simultaneously.

The dual-task cognitive-motor training sessions consisted of a single 10-minute phase where participants were required to perform physical and cognitive exercises simultaneously, involving strong inhibitory control and attention, in order to disable any impulsive or distracting reactions during task performance. The task aimed to improve both functional and cognitive skills. The exercises were organized into short routines with the objective of simultaneously stimulating, in a coordinated manner, muscular power, static and dynamic balance, and different cognitive functions. For example, to promote inhibition of habitual responses and challenge working memory, participants performed task sequences by reversing or dispersing the learned order. They were also asked to learn different stimulus-response associations and then alternate between them according to external signal changes. The exercises were organized into dribbling routines with the goal of stimulating body movements with the ball, in harmony with the primary objective of creating and maintaining an advantage over the opponent by dribbling the ball. The balls used in both interventions were NBA and FIBA regulation size (#7), with circumferences ranging from 75 to 78 cm and weights ranging from 567 to 650 g.

Tests

The sports performance assessment consisted of five dribbling tests based on basketball fundamentals and adapted from the NBA Draft Combine to ensure standardized measurement. Each test required participants to dribble along a designated path as quickly as possible, switching hands five times every five meters (measured using a VONDER© 5-meter tape measure) and marked by orange cones (11×18 cm). The tasks were conducted across the full lateral area of a basketball court (as shown in Figure 2), and the time to complete each task was recorded using a cronometer (Incoterm© 62×19×79 milimeters) These tests aimed to evaluate basketball-specific sports performance by extracting execution speed, allowing comparison of average times across assessments. Data collection occurred at four time points: at the beginning and end of the first eight weeks, and at the beginning and end of the final eight weeks of the training program. The five tests were as follows:

(1) Crossover;
(2) Double Crossover;
(3) Between the Legs;
(4) Crossover + Between the Legs;
(5) Between the Legs + Behind the Back.

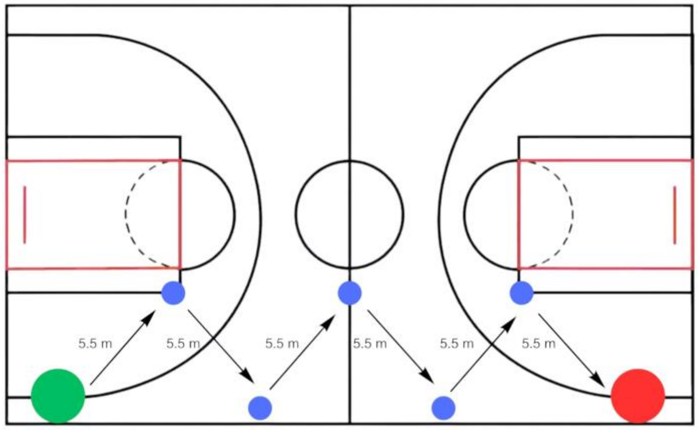

Figure 2. Representation of the path used in the sports performance tests. Green circle: start of the route; Red circle: end of the route; Blue circles: cones separated by five meters.

The Go/No-Go paradigm, a visuomotor task used to assess inhibitory control, was employed as the second test in this study. Participants were seated in a low-light, sound-reduced room, positioned approximately 114 cm from a computer screen (Multilaser© Ultra Intel Pentium Notebook, 14.1" HD screen, 4GB RAM, 120GB SSD, Windows 10). Their preferred hand—determined by observing which hand was used to perform the jumpshot—was placed palm-down on a designated key (the spacebar). During the task, 25 visual stimuli were presented in random order on the screen in green and red oval shapes. A green stimulus indicated that the participant should press the key as quickly as possible, whereas a red stimulus required the participant to withhold their response. The interval between stimuli was set at two seconds to prevent overlap between responses, as illustrated in Figure 3. The task was administered through the PsyToolkit online platform (www.psytoolkit.org/experiment-library/experiment_go-no-go.html) [18], which automatically recorded correct and incorrect responses as well as the reaction times. This test provides two outcome measures: the number of correct responses and the individual response times. However, in this study, only the mean response time was used for analysis. Each participant performed the test once per session. Data collection occurred at four distinct points: at the beginning and end of the first eight weeks and at the beginning and end of the final eight weeks.

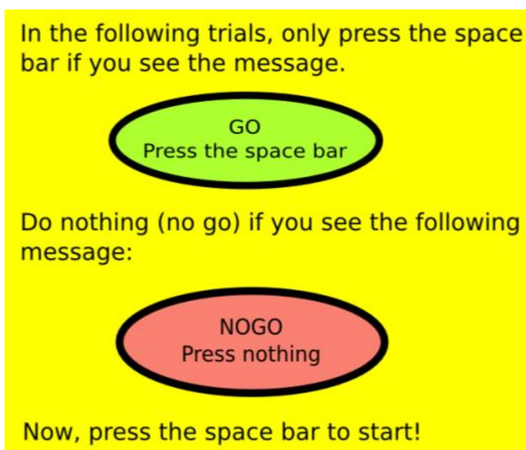

Figure 3. Representation of the Go/No-Go Paradigm test.

Statistical Analysis

All statistical inferences were performed using the IBM Statistical Package for the Social Sciences v.25 (IBM Corp. ©, Armonk – USA). Data normality was assessed using the Shapiro–Wilk test. As normal distribution was not confirmed for some variables and was not corrected by logarithmic transformation, all data are reported as median (interquartile range) and [minimum–maximum] values. Experimental conditions and assessment times (pre- and post-intervention) were compared using Friedman's two-way ANOVA by ranks. This nonparametric test provides a chi-square (χ^2) statistic and Kendall's W as a measure of effect size. Kendall's W was interpreted as negligible ($W < 0.10$), small (0.10–0.29), moderate (0.30–0.49), or large (≥ 0.50) [27].

RESULTS

The results presented in the table indicate variations in performance across experimental conditions before and after the interventions, with particular emphasis on the variable "Time Double Crossover", which showed a reduction in measured values in both conditions, accompanied by a large effect size (W = 0.611). Although no p-value was available, this effect size suggests a potentially meaningful change that warrants further investigation. The variable "Time Between the Legs + Behind the Back" also showed a decrease in values, with a moderate effect size (W = 0.489). It is important to note that these values should be interpreted with caution in the absence of statistical significance tests. The other variables, such as "Correct Answers Go/No-Go", "Time Go/No-Go", "Time Crossover", "Time Between the Legs", and "Time Crossover + Between the Legs" presented small or negligible effect sizes, which may indicate limited changes in performance across conditions, as shown in Table 1.

Table 1. Median (interquartile range) and [minimum–maximum] values of response time and accuracy in the Go/No-Go task and time in the NBA Draft Combine Dribbling Tests.

	Condition 1		Condition 2		Statistics
	Before	**After**	**Before**	**After**	**X^2; W [Classification]**
Correct Answers Go/No-Go	25 (0.0) [24 - 25]	25 (0.8) [24 - 25]	24 (0.8) [24 - 25]	25 (0.8) [24 - 25]	1.000; 0.056 [Negligible]
Time Go/No-Go (ms)	347.0 (57.0) [297.7 - 464.7]	393.6 (56.4) [293.4 - 432.7]	360.4 (41.7) [334.2 - 419.8]	377.0 (83.7) [289.1 - 440.6]	4.385; 0.244 [Small]
Time Crossover (s)	15.5 (2.1) [14.1 - 18.7]	14.6 (1.0) [12.5 - 15.9]	13.9 (2.3) [13.2 - 16.6]	13.5 (1.4) [12.7 - 17.9]	2.400; 0.133 [Small]
Time Double Crossover (s)	20.6 (3.4) [18.1 - 24.2]	17.5 (2.9) [15 - 21.4]	18.0 (2.6) [14.3 - 20]	16.0 (4.2) [14.1 - 22.3]	11.000; 0.611 [Large]*
Time Between the Legs (s)	18.4 (3.7) [15.1 - 21.2]	18.5 (5.7) [14.1 - 23.6]	15.5 (4.0) [14.6 - 22]	15.3 (3.3) [14.1 - 23.1]	1.800; 0.100 [Small]
Time Crossover + Between the Legs	22.3 (4.2) [19 - 25.4]	23.1 (4.1) [17.8 - 26.6]	23.1 (3.2) [18.6 - 24.2]	20.7 (7.2) [16.2 - 25.7]	2.600; 0.144 [Small]
Time Between the Legs + Behind the Back (s)	26.1 (4.5) [20.9 - 28.5]	21.9 (3.2) [16.9 - 24.9]	21.7 (1.6) [19.4 - 24.6]	20.4 (2.7) [17.1 - 25.7]	8.800; 0.489 [Moderate]*

DISCUSSION

This study aimed to examine whether CM-DT training enhances the sports performance of young basketball players compared to traditional physical training. Additionally, we investigated its effects on behavioral performance during a cognitive DRT and its impact on anticipatory processes related to the BP and pN components before stimulus onset. Given that both CM-DT and DRT rely on common cognitive functions, particularly task anticipation, we hypothesized that CM-DT would reduce response time (RT) in DRT (linked to BP amplitude) and improve accuracy rates (associated with enhanced pN amplitude). However, our results indicated that neither experimental intervention produced significant positive or negative effects on sports or cognitive performance, which does not support our initial hypothesis. Notably, only two sports performance tests following a standard motor training intervention showed moderate to large effect sizes, but no confirmed statistical significance.

The findings contrast with those of Lucia et al. [19], who conducted a similar study. However, the experimental group in their study trained for five weeks, seven times per week, with one day dedicated to a basketball match (two hours) and six days for standard group basketball training (three hours), with two sessions of 30 minutes of dual-task cognitive-motor training. When comparing the two studies, there is a conflict: Lucia et al. [19] used 20 hours of weekly standard basketball training plus one hour of weekly dual-task cognitive-motor training, whereas our study included one hour and 40 minutes of basketball plus 20 minutes of dual-task cognitive-motor training. This suggests that the duration of the intervention may have played a crucial role in the results, thus requiring further studies on the topic, addressing session length and weekly training hours.

These results also show that the accuracy performance in the cognitive test did not improve, contradicting Evans and Stanovich [20], who argue that the dual process required by the experimental task could stimulate higher cognitive functions, such as attention, thereby facilitating response accuracy. However, this requires a more in-depth analysis of the data, because specifically, the sample's average score in the first data collection was exactly 24.83 correct responses out of 25 attempts (99.32%), indicating that there was not much room for significant improvement in the statistical data. By the end of the first intervention, this average dropped to 24.66 (98.64%), and after the wash-out period, it further decreased to 24.33 (97.32%). By the end of the CM-DT intervention, the average returned to

24.66 (98.64%). This can be explained by the DRT (dual-response task) test protocol adopted in the study, which consisted of 25 visual stimuli with a two-second standardized interval between them. In contrast, the protocol used by Lucia et al. [19] consisted of 400 stimuli with a variable interval between one and two seconds. This suggests that, for a short period, attention, along with inhibitory and anticipatory processes, can operate at a high frequency, requiring the brain's machinery and the neural processes involved to be "fatigued" before a significant error rate is observed.

Regarding the times to complete the sports performance tests, an interesting phenomenon was observed when comparing the pre-intervention and post-first intervention moments. Although no statistically significant differences were confirmed, two subtests from the NBA Draft Combine dribbling test—Double Crossover and Between the Legs + Behind the Back—showed moderate to large effect sizes. This can be explained by the effects of task learning [21,22], and it aligns with the cognitive processes model suggested by Weigel and Wollny [23], which proposes that athletes in team sports are particularly trained to efficiently capture action-related information, enabling optimal tactical decision-making.

The main innovation of this study, compared to previous literature on dual-task cognitive-motor training, was the use of specific sports exercises alongside cognitive training. Other studies [24,25] used more general exercises, such as aerobic capacity training, strength, balance, flexibility, walking, progressive resistance, and functional balance, alongside general tasks stimulating executive functions, including working memory, attention, or calculation abilities. In this study, as well as in recent studies like Lucia et al. [19] with young basketball athletes and Fleddermann et al. [26] with volleyball athletes, the training was more specific to the study's objectives and the sample's characteristics.

However, several limitations should be acknowledged: the lack of a control group may have limited the ability to determine whether the observed effects were truly due to the intervention or to external factors; the small sample size, which reduces statistical power and increases the likelihood of Type II errors; the absence of randomization and counterbalancing of the training protocols may have introduced order or learning effects, potentially influencing the outcomes. This occurred because the training sessions were conducted in group settings, making individual randomization logistically unfeasible. The present study showed that the proposed cognitive-motor training protocol did not yield observable improvements in sports and cognitive performance in this sample within this period. To deepen the understanding of the cognitive-motor training protocol and its effectiveness, it will be interesting to conduct new studies addressing aspects such as sample variability, protocol diversification, longitudinality, evaluation methods, comparison with other methods, psychological impact, studies in real-world settings, and multidisciplinary interventions. It remains unclear whether the absence of observed effects was due to the short duration of the intervention, insufficient intensity, the washout period, or the small sample size, considering that all of which may have attenuated or obscured potential effects of the training.

CONCLUSION

The present study demonstrated that the proposed cognitive-motor training protocol was not effective in improving sports or cognitive performance. Although these results contradict previous positive findings, they should be interpreted with caution due to the study's limitations, particularly the small sample size. Rather than supporting immediate practical application, these findings offer a valuable perspective for future studies aiming to explore how cognitive training might be effectively integrated with technical-motor training in team or group settings.

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