Effects of training and competition on performance in execution time and decision-making in technical-tactical actions in football (passing and driving) in laboratory situations

Efectos del entrenamiento y la competencia sobre el rendimiento en el tiempo de ejecución y la toma de decisiones en acciones técnico -tácticas en fútbol (pase y conducción) en situación de laboratorio

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Abstract

Introduction: the effects of training on decision-making have been evaluated in sport to demonstrate improvements in tactical performance.
Objective: analyze the effects of a training macrocycle on decision-making and its delay time, using technical-tactical actions (passing and driving) in football carried out under laboratory situations.
Methodology: quantitative quasi-experimental, longitudinal, intra-subject pre-test/post-test study. A group (n=16) of young footballers were evaluated at two points (pre-test/post-test).
Results: there were no statistically significant differences for the decision-making variable (DMA) (p>.05; d=0.32; 1-B=0.22) but there were statistically significant differences for the execution time (ET) variables (p<.05; d=1,522; 1-B = 0.99) and total index (TI) (p<.05; d=1.303; 1-B=0.99).
Discussion: the results of this research regarding the decision-making variable differed from the results reported in other studies. Decision-making did not improve with the intervention; however, training and competition did decrease the time it takes to choose an option.
Conclusions: in open motor skill sports it is not enough to make a good decision, it is also necessary to decide in the shortest possible time. For that reason, this test analyzes the variables decision making (DMA) and execution time (ET) through a total index (TI), which is directly proportional to the performance of the football players in the test. The test is sensitive to neuroplastic changes generated by a three-month macro-cycle of training.

Keywords

Sensivity test, neuroplasticity, training, cognitive functions, football.

Resumen

Introducción: los efectos del entrenamiento sobre la toma de decisiones han sido evaluados en el deporte para demostrar mejoras en el rendimiento táctico.
Objetivo: analizar los efectos de un macrociclo de entrenamiento sobre la toma de decisiones y su tiempo de demora, utilizando acciones técnico – tácticas (pase y conducción) en fútbol realizadas en condiciones de laboratorio.
Metodología: estudio cuantitativo cuasiexperimental, longitudinal, pretest/postest intrasujeto. Un grupo (n=16) de jóvenes futbolistas fueron evaluados en dos momentos (pretest/postest).
Resultados: no hubo diferencias estadísticamente significativas para la variable toma de decisiones (DMA) (p>.05; d=0.32; 1-B = 0.22) pero si para las variables tiempo de ejecución (ET) (p<.05; d=1.522; 1-B = 0.99) e índice total (TI) (p<.05; d=1.303; 1-B=0.99).
Discusión: los resultados de esta investigación respecto a la variable toma de decisiones difieren de los resultados de otros estudios. La toma de decisiones no mejoró con la intervención; sin embargo, el entrenamiento y la competencia redujeron el tiempo que demora elegir una opción.
Conclusiones: en los deportes de habilidades motrices abiertas no es suficiente con tomar una buena decisión, también hay que decidir en el menor tiempo posible, por eso, esta prueba, analiza las variables toma de decisiones (DMA) y tiempo de ejecución (ET) a través del índice total (TI), el cual es directamente proporcional al rendimiento del futbolista en la prueba. La prueba es sensible a los cambios neuroplásticos generados por un macrociclo de entrenamiento de tres meses.

Palabras clave

Sensibilidad del test, neuroplasticidad, entrenamiento, funciones cognitivas, fútbol.

Introduction

Sports can be differentiated into open-skill and closed-skill sports (Sakamoto et al., 2018). Open-skill sports are characterized by changing and unpredictable situations (Sakamoto et al., 2018; Schumacher et al., 2018), where uncertainty, dynamism, and high levels of disorder demand significant cognitive activity (attention, perception, decision-making, and response) to obtain specific and useful information from the context in order to inform motor responses (Herrero, 2017; Benavides et al., 2018). In interactive sports (team/ball games), in addition to technique, physical attributes, and equipment, cognitive skills are also essential for achieving results (Herman et al., 2015; Zentgraf, 2017). For example, in football, to achieve high performance requires all the components (physical, technical, tactical) implicit in this sport (Sakamoto et al., 2018; Verburgh et al., 2014).

In sports, quick and precise execution increases the likelihood of errors (Benavides et al., 2018). Therefore, athletes must perceive, anticipate, and process situations to choose and execute the most effective action from all possible options within a short timeframe (Huijgen et al., 2015). Football players must quickly evaluate the information they have acquired before choosing the appropriate action. (Williams, 2000). In other words, they need to make quick decisions accompanied by inhibitory control to change their plan when they perceive that an opponent is hindering their action (Wilke & Vogel, 2020). Footballers must make the right decisions quickly in a changing environment to achieve results. (Sakamoto et al., 2018). Hence, cognitive functions, primarily executive functions, are necessary for high performance in sports (Vestberg et al., 2017; Aktop et al., 2017; Sakamoto et al., 2018). Cognitive functions are necessary for athletic performance because they are associated with tactical performance. (García et al., 2011; Lex et al., 2015).

To understand that the correct decision associated with the tactical component must be made quickly, it is necessary to explain that visual reaction time lasts between 360 and 500 ms. The first period is the time it takes for saccadic eye movements to detect the stimulus (180–300 ms), and the second period corresponds to the duration of the nerve impulse from the sensory organ to the motor endplate (180–200 ms) (Bonnet, 1994). Similarly, another factor to consider is the decision time, which depends on the characteristics of the stimulus. In other words, the more complex the stimulus, the longer the decision time and, consequently, the reaction time (Calle-Jaramillo et al., 2023).

It is also important to recognize that decision-making associated with working memory is a product of adaptive neural mechanisms based on motor control and stimulated by an environment that provides information related to real game situations in sports (Davids et al., 2006). These adaptive mechanisms require a creative process where athletes use their knowledge of a current situation, choosing the appropriate decision based on their perceived ability to execute a specific motor skill related to the context (Causer & Ford, 2014).

From this sporting perspective, the ability to make the right decision during complex game situations under pressure and time constraints is the key element in athletic performance (Höner et al., 2020). Thus, decision-making is an important skill that differentiates the level of performance (Lorains et al., 2013; Woods, 2016).

In this sense, we can say that there are two scientific approaches that study decision-making in sports. The first studies the differences between expert and novice players (Griffin et al., 2001), while the second relates to the effect of training on athletic performance (MacPhail, Kirk, & Griffin, 2008). Regarding the first approach, in a previous study, we found differences in athletic performance when comparing expert vs. novice players (Calle-Jaramillo et al., 2024); however, we see the need to use the same test (Calle-Jaramillo et al., 2023) to study the second approach.

In both approaches, structural, functional, cognitive, and motor changes occur as a result of training. That is, to achieve a level of expertise or improve performance through training, the neuroplasticity phenomena that occur in the cerebral cortex and the underlying behavior are a product of environmental stimuli. Thus, new information during the explicit learning of spatiotemporal events (episodic and spatial memory) travels from the cerebral cortex (prefrontal and parieto-occipitotemporal association areas) to the hippocampus to be stored as short-term memory, and subsequently, through a reverse process, this information migrates from the temporal lobe to other areas of the cerebral cortex to be consolidated as long-term memory (Buffalo et al., 2006; Loubon and Franco, 2010; Redolar, 2014). Also, information from spatial navigation based on objects that serve as a guide first reaches the anterior hippocampus and then the posterior hippocampus to be stored as spatial memory (Maguire et al., 2000).

When the environment and the athlete are successfully integrated with the task, a functional coordination pattern is generated, which can be improved with experience through the subject's trainability (Benavides et al., 2018). There are teaching models from a comprehensive perspective, where tactics take precedence over technique, in order to increase the athlete's performance by improving decision-making (Contreras, García-López, and Cervelló, 2005).

For example, Mesquita, Farias & Hastie (2012) studied the effects of teaching using a cognitive model to improve sports decision-making and tactical skills in children; Turner & Martinek (1999) worked in hockey, basing their training on cognitive aspects and tactical awareness, observing improvements in player performance in the decision-making component; and Praxedes-Pizarro et al. (2017) carried out interventions based on decision-making, linking technical actions of passing and dribbling. Vickers (2007) points out that decision-making skills are improved by applying cognitive models in varied contexts.

This study not only evaluates correct decision-making, but also the time it takes to choose and execute an action, which increases with the complexity of the stimulus. It is considered that players, after training and competing for a period of 12 weeks, demonstrate better decision-making and shorter decision times, as they are able to mitigate the conflicts, disturbances, and interferences inherent in the paradigms used (Calle-Jaramillo et al., 2023).

Therefore, using the STFT (Calle-Jaramillo et al., 2023), the objective of this research was to analyze the effects of training and competition on ET and DMA in technical-tactical actions (passing and driving) in football performed under laboratory situations. We hypothesized that there would be statistically significant differences between the pre-test and post-test with respect to the test variables (DMA, ET, and TI) after 12 weeks of training and competition.

Method

Design

This was a quantitative, quasi-experimental, or pre-experimental, longitudinal, pre-test/post-test within-subjects study (Manterola & Otzen, 2015; Baños et al., 2019). A group of football players were assessed twice using the STFT (Calle-Jaramillo et al., 2023) at two different time points. The first assessment (pre-test) was conducted, and the second, after the intervention (12 weeks of training and competition), was a post-test.

Variables

Independent variables: training and competition; dependent variables: TI, DMA, ET.

Participants

Sixteen footballers from the under-20 category belonging to the Envigado Fútbol Club participated in this study. The characteristics of the sample (mean ± SD) were as follows: age (18.55 ± 1.30 years), height (175.86 ± 5.27 cm), weight (65.14 ± 4.83 kg) and length of stay at the club: (8.81 ± 1.03 years).

Procedure

The STFT evaluates DMA and ET during technical–tactical football actions (passing and driving), providing a measure of motor–cognitive performance through the TI (Calle-Jaramillo et al., 2023). This test was administered during both the pre-test and post-test assessments to compare performance across time.

A twelve-week period separated the pre-test from the post-test. During this time, players completed 108 training sessions (nine sessions per week) and participated in twelve official matches from the Antioquia Football League competition schedule. Training sessions were conducted twice daily, with afternoon sessions emphasizing technical–tactical development (sixty sessions across the twelve-week period), while morning sessions focused on conditional capacities (Table 1).

Table 1. Planning a week of training.

(day +1)	(day +2)	(day +3)	(day -3)	(day -2)	(day -1)	(match day)
Rest	Morning: Active rest. Mobility and flexibility exercises.	Morning: Strength and power training. Plyometric exercises.	Morning: Session of speed and agility. Exercises for changes of pace and acceleration.	Morning: Rest.	Morning: Resistance training.	Morning: Warm-up and preparation for the match.
Rest	Afternoon: Technical training: Control, passing, driving. Position-specific training.	Afternoon: Tactical training: Positioning, pressure, transitions. Mock games	Afternoon: Friendly match or reduced football training.	Afternoon: Technical-tactical training: Combining technical skills with game strategies. Video analysis.	Afternoon: Tactical training: Specific strategies for the upcoming match. Technical talk.	Afternoon: Official match

Both tests were held during the competition season at the same time of the day, 48 hours after the competition. Before the execution of the tests, the participants warmed up based on typical football actions and similar to the STFT to check their understanding of it.

Environmental characteristics

The test was carried out between 8:00 and 10:00 am at a temperature between 18 and 25 degrees Celsius on football fields with synthetic turf. An official FIFA Golty® ball was used.

Inclusion criteria

Signing informed consent; completion of both tests (pre-test and post-test) and having attended all training sessions in the immediately preceding weekly cycle.

Exclusion Criteria

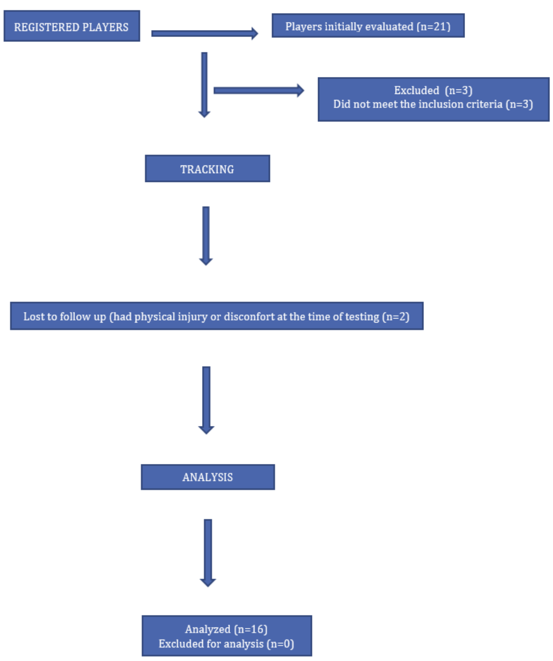
Consumption of caffeine or any other stimulant substance that day; diagnosis of any psychiatric or neurological problems and physical injury or discomfort at the time of the test.

A total of sixteen players participated in the study, three players did not meet the inclusion criteria, and two players were excluded (Figure 1).

Ethical considerations

We refer to the ethical provisions of the Declaration of Helsinki.

Figure 1. Flowchart: inclusion/exclusion criteria to obtain the sample.

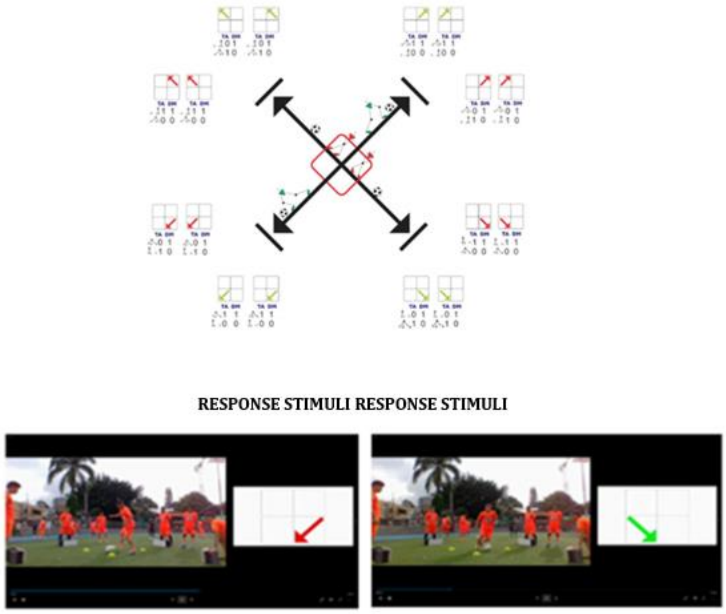


Design of the tests to evaluate the groups

The STFT assesses decision-making based on the sub-variables of type of action (TA) and direction of movement (DM), and also evaluates reaction time based on the execution time (ET) variable. In this test, the football player responds to visual stimuli (red and green arrows pointing in different directions), where red arrows indicate passing and green arrows indicate driving. Regarding movement direction (MD), the response must correspond to the direction of the arrow and not to the location.

The number of correct answers is equivalent to correct decision making (DMA) and is divided by the execution time (ET), to finally obtain the total index (TI). TA + DM = DMA; DMA/ET = TI (Calle-Jaramillo et al., 2023) (Figure 2). The duration of the test was calculated in decimal minute, for example; 50 seconds equals 0.83min, and 70 seconds equals 1.16min.

Figure 2. STFT rating. Evaluation of trials with their respective stimuli and responses.



Finally, the STFT data (Calle-Jaramillo et al., 2023) were exported to an Excel spreadsheet and subsequently analyzed in the IBM SPSS Statistical Software version 29®.

Results

To begin with the analysis of the results, the normality of the variables (DMA, ET and TI) was evaluated by comparing the data of the intragroup subjects (pre-test/post-test) from the Shapiro – Wilk test. The results indicated that the DMA variable in the pretest-posttest presented a non-normal distribution (p<.05), however, the ET and TI variables presented a normal distribution (p>.05) at both times (pre-test/post-test) (Table 2).

Table 2. Normality of variables.

Group		Shapiro-Wilk		
		Statistical	gl	*p*
Pre-test Post-test DMA	Experimental	.811	15	.004
Pre-test Post-test ET	Experimental	.961	15	.687
Pre-test Post-test TI	Experimental	.941	15	.356

Decision making (DMA); Execution Time (ET); Total Index (TI)

Later, the two groups were compared after the intervention was applied (twelve-week combining training and competitions), where the behavior of the dependent variable DMA was similar and without statistically significant differences ($p>.05$) between the pre-test and the post-test (Table 3). In the case of the ET variable, the statistical difference between the pre-test (M=1.111; SD=0.135) and post-test (M=0.968; SD=0.116) was statistically significant ($p<.01$; d=1.522; 1-B=0.99), likewise, the TI variable also showed differences between the pre-test (M=54.592; SD=9,841 and post-test (M=63,793; SD=8.598) statistically significant ($p<.01$; d=-1.303; 1-B=0.99) (Table 4).

Table 3. Comparison between the pre-test / post-test variable DMA

Variable	Group	Md	IR	Wilcoxon	*p*	*d*	1-β
DMA	Experimental (n = 16) Pre-test Post-test	61.00 62.00	5 5	55.00	.220	0.320	0.220

gl=15
Decision making (DMA); Md (median); IR (interquartile range); *d* (effect size); 1-*B* (statistical power)

Table 4. Comparison between the pre-test / post-test variables ET and TI

Variable	Group	M	SD	t	*p*	Mean differences	CI95 LL LS	*d*	1-β
ET	Experimental (n=16) Pre-test Post-test	1.111 0.968	0.135 0.116	-6.09	.001	0.143	-2.239 -0.781	1.522	0.990
TI	Experimental (n=16) Pre-test Post-test	54.592 63.793	9.841 8.598	5.21	.001	.201	0.618 1.965	1.303	0.990

gl=15
Execution Time (ET); Total Index (TI); M (Mean); SD (Standard Deviation); LL (Lower Limit); UL (Upper Limit); *d* (effect size); 1-*B* (statistical power).

Discussion

The aim of this study was to analyze the effect of a twelve-week period of training and competition on ET and DMA in technical–tactical actions in football, assessed under controlled laboratory situations. For this purpose, the Stroop Task Football Test (STFT) (Calle-Jaramillo et al., 2023) was administered before (pre-test) and after the intervention (post-test) to a group of young football players. This approach allowed us to determine whether systematic exposure to training and competitive play could modify the cognitive and motor processes involved in decision making and execution speed during football-specific tasks.

Previous studies, such as the one conducted by Práxedes Pizarro, A.P. et al., 2017, evaluated decision-making in nine male soccer players in the under-12 category with three to six years of experience in organized soccer. All players belonged to the same team and the same training group. After a 15-week intervention (a quasi-experimental, pretest-posttest, within-subjects study), improvements in decision-making were observed during 12 matches after 22 training sessions. The results showed statistically significant differences between the pre-test and post-test.

In another study, Turner and Martinek (1999) also demonstrated that decision-making in hockey players (71 sixth- and seventh-grade students: 32 boys and 39 girls) improved with the intervention when comparing the results among three groups (a control group that received softball lessons, an experimental group focused on hockey technique training, and an experimental group focused on game understanding). The game-comprehension approach, by emphasizing the development of tactical awareness and decision-making in confined spaces, produced statistically significant differences in decision-making regarding ball control and passing; however, no statistically significant differences were observed in decision-making regarding dribbling and shooting.

Finally, in the study conducted by Contreras et al. (2005), the transfer of generic invasion game instruction to floorball was examined in two groups of 18 children (12 boys and 6 girls in each group) between 10 and 11 years of age. The experimental group received generic invasion game instruction (14 lessons of 50 minutes each), while the control group received dance instruction. The experimental group showed statistically significant improvements in dribbling and passing decision-making after the intervention.

The aforementioned studies show an effect on the decision-making variable due to specific interventions resulting from training and competition, as well as generic interventions stemming from the influence of invasion sports. Similarly, we can say that the environments of invasion sports, being influenced by external stimuli that affect cognitive behavior, share tactical similarities. Therefore, the results obtained can be extrapolated to other sports with similar behavioral characteristics.

In contrast, the results of this research regarding the decision-making variable differed from those reported in other studies. Decision-making did not improve with the intervention; however, training and competition did decrease decision-making time (the time it takes to choose an option). This time is influenced by simple cognitive functions (attention, perception, proprioception, spatial navigation, memory) responsible for receiving, extracting, interpreting, and storing information from the environment, and by complex cognitive functions or executive functions (working memory, decision-making, inhibitory control, cognitive flexibility) responsible for recalling, processing, and selecting stored information to monitor and predict the future consequences of selected cognitive and motor responses. In this sense, sports games require and demand making good decisions in the shortest possible time. For this reason, we considered it necessary to compare decision-making and execution time between the pre-test and post-test to analyze whether there were differences in the athletes' performance.

On the other hand, there are also negative effects on decision-making after an intervention that induces fatigue (Frybort et al., 2016; Bian et al., 2022; Gantois et al., 2020; Smith et al., 2016). Furthermore, the test used in this study (Calle-Jaramillo, Guillermo Andrés et al., 2023) also evaluated decision-making and execution time after an intervention that induces fatigue by applying the RAST (anaerobic running sprint test), showing similar results to those obtained here. That is, neither fatigue (negative effect) nor training and competition (positive effect) generated statistically significant changes or differences in the decision-making variable (DMA), but they did generate statistically significant changes and differences in the execution time variable (ET). In other words, with fatigue, ET increased, and with the training macrocycle, ET decreased.

In summary, our results are consistent with recent literature suggesting that soccer training in dynamic environments promotes neuroplastic adaptations associated with improvements in executive functions (attention, working memory, and processing speed). In a recent systematic review and meta-analysis, Mao et al. (2024) reported moderate to significant effects of soccer training on executive functions in young players, indicating that continuous exposure to information-rich sporting environments improves both cognitive and motor efficiency. Additionally, recent findings in high-level football players show that executive function performance is not only shaped by training experience but also influenced by psycho-cognitive characteristics such as personality traits, which modulate the ability to perform under pressure (Spielmann et al., 2023).

In the intervention conducted between the pre-test and post-test, we mentioned that over the twelve weeks, the players trained their physical abilities (strength, speed, and endurance) and their individual and collective tactical skills in both defensive and offensive phases through exercises in confined spaces, simulations of real game situations, and training and competitive matches. These scenarios, which stimulate the neuroplastic phenomena underlying explicit learning and memory (cognitive component) and procedural learning and memory (motor component), are responsible for the decrease in decision-making latency and, consequently, the reduction in execution time. The decrease in execution time after twelve weeks of cognitive stimulation increases the overall index, which is directly proportional to the player's improvement in the individual tactical component.

It is important to recognize that the test initially validated by Calle-Jaramillo et al., 2023, is designed based on paradigms used in cognitive neuroscience, which generate conflicts, interferences, and disturbances when decision-making is accompanied by other executive functions (working memory, inhibitory control, and cognitive flexibility). This study demonstrated that training and competition mitigate these conflicts, thereby facilitating quick decision-making.

It is suggested that future research involve experimental studies, including different interventions with cognitive stimuli and tactical work, in order to compare the effects of different training methodologies on decision-making in sports.

Conclusions

The tactical training and cognitive stimuli carried out in a twelve-week macrocycle did not change the success of the decision-making, but they did change the decision-making time and therefore the execution time, thus increasing the total rate of the test, which is directly proportional to the individual tactical performance of the player.

The STFT is sensitive to neuroplastic changes resulting from the stimuli received by young football players during training and competition.

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