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Research article

DHA- rich fish oil improves complex reaction time in female elite soccer players

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Abstract
Omega-3 fatty acids (n-3) has shown to improve neuromotor function. This study examined the effects of docosahexaenoic acid (DHA) on complex reaction time, precision and efficiency, in female elite soccer players. 24 players from two Spanish female soccer Super League teams were randomly selected and assigned to two experimental groups, then administered, in a double-blind manner, 3.5 g·day^{-1} of either DHA-rich fish oil (FO =12) or olive oil (OO = 12) over 4 weeks of training. Two measurements (pre- and post-treatment) of complex reaction time and precision were taken. Participants had to press different buttons and pedals with left and right hands and feet, or stop responding, according to visual and auditory stimuli. Multivariate analysis of variance displayed an interaction between supplement administration (pre/post) and experimental group (FO/OO) on complex reaction time (FO pre = 0.713 ± 0.142 ms, FO post = 0.623 ± 0.109 ms, OO pre = 0.682 ± 1.132 ms, OO post = 0.715 ± 0.159 ms; p = 0.004) and efficiency (FO pre = 40.88 ± 17.41, FO post = 57.12 ± 11.05, OO pre = 49.52 ± 14.63, OO post = 49.50 ± 11.01; p = 0.003). It was concluded that after 4 weeks of supplementation with FO, there was a significant improvement in the neuromotor function of female elite soccer players.

Key words: Fatty acids, omega 3, efficiency, decision-making.

Introduction

Docosahexaenoic acid (DHA) with 22 carbon and 6 double links is an example of a poly-unsaturated fatty acid of the omega-3 family. DHA is considered to be essential to health and vitality (Sears, 2002), due to its relation to the prevention and improvement of cancer and heart disease (Stillwell and Wassall, 2003), its psychological and emotional benefits (Fontani et al., 2005), its attention improvement (McNamara et al., 2010), and to its anti-inflammatory properties (Mori and Beilin, 2004).

In the sport and exercise context, long-chain omega-3 DHA and eicosapentaenoic acid (EPA), called "fish oils", have been analyzed in recent studies that attempted to demonstrate their benefits as ergogenic aids. Walser and Stebbins (2008) confirmed, with a sample of 21 healthy adults, the hypothesis that dietary supplementation of DHA (2 g·day^{-1}) + (EPA) (3 g·day^{-1}) over a 6-week period enhances an increase in stroke volume and cardiac output as well as a decrease in systemic vascular resistance during dynamic exercise. In another study, performed with a sample of 25 elite Australian Rules football players, Buckley et al. (2009) communicated that a 6 g·day^{-1} supplementation of DHA-rich fish oil over a period of 5 weeks improved cardiovascular function and reduced serum triglyceride concentrations and heart rate during submaximal exercise, but did not improve endurance performance or recovery. A supplementation of 3.2 g·day^{-1} EPA + 2.2 g·day^{-1} DHA over 3 weeks administered to a sample of 10 elite athletes was also related to a decline in the severity of exercise-induced bronchoconstriction (Mickleborough et al., 2003).Another study showed that a 2.2 g·day^{-1} EPA + 2.2 g·day^{-1} DHA supplementation over 6 weeks was related to lower levels of the inflammation biomarkers C-reactive protein (CRP) and tumor necrosis factor-alpha (TNF-α) in a sample of 14 exercise-trained men (Bloomer et al., 2009). Nevertheless, other studies did not find any evidence of DHA supplementation effects on physical performance or anti-inflammatory markers (Nieman et al. 2009; Raastad et al., 1997). These non-conclusive results suggest the necessity for further investigation to clarify the possible benefits of this fatty acid in sports.

A major part of this research on DHA and its benefit to sport has been focused on analyzing the benefits of decreasing or delaying fatigue and of reducing muscular oxidative stress. Nevertheless, there are other possible benefits derived from its possible effects on the nervous system that could enhance performance in sports. It is generally accepted that DHA accumulates rapidly in the brain during the last trimester of pregnancy and during the first 2 years of life. DHA levels then continue to increase in the cerebral cortex up to 18 years of age before declining thereafter. The concentration of DHA is especially high in the frontal cortex, the region of the brain where appropriate responses to internal and external stimuli are planned and complex perceptual information are integrated, developing the executive function (McNamara, 2010). However, little is known about whether dietary DHA can increase cortical DHA content, or whether changes in cortex neural activity are related to cortex DHA. McNamara et al. (2010) performed one study with 38 boys aged 8 to 10 years in which the experimental group consumed either 0.4 g·day^{-1} or 1.2 g·day^{-1} of DHA over 8 weeks while the control group was administered a corn oil placebo. An improvement of attention was found in healthy children after supplementation with DHA due to a higher activation of cerebral cortex. These results support the hypothesis that DHA could potentially improve performance in sports where perceptual-motor activity and decision-making are the keys to success (Overney et al., 2008).

Complex reaction time, also called decision-

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reaction time or discriminative reaction time (Link and Bonnet, 1998; Orellana, 2009), is different than simple reaction time because the perceptual fact requires a behavioral decision between several possibilities when stimuli are present (Pieron et al., 1972), reflecting both perceptual-motor and cognitive activity. Overney et al. (2008) proposed that that exercise and sport may increase some basic perceptual-motor skills. They reported that experienced tennis players had better accuracy in detecting parameters of movement, higher speed discrimination, and faster temporal processing than triathletes and non-athletes. Thus, if a sport is related to perceptual-motor skills, it could be hypothesized that the intervention (such as DHA supplementation) that led to a better perceptual-motor behavior could also improve the performance in sport.

It is hypothesized that DHA has a dual effect on improving complex reaction efficiency; DHA is thought to firstly delay fatigue, which has been related to the maintenance of perceptual-motor efficiency (Thomson et al., 2009), and secondly to improve the perceptual-motor processes that lead to lower complex reaction time and higher accuracy.

The aim of this study was to analyze the effects of DHA supplementation on perceptual-motor processes, such as complex reaction time, accuracy, and efficiency in elite female soccer players. The second objective was to analyze possible differences in DHA effects when supplementation is offered at the beginning versus the end of the soccer season.

Methods

Participants

The sample was composed of 34 elite professional female soccer players (M = 23.58, SD = 5.22), selected from two teams of the female soccer Spanish Super league. They were selected from Levante U.D. (n = 20), and Valencia C.F. (n = 14). All participants were in good health, not suffering from any chronic diseases, not receiving any medication that could affect physiological or biochemical responses, not consuming any food enriched with polyunsaturated fatty acids one month before and during the experiment. Each participant was informed of the program and the product characteristics and its possible side effects and signed the participation consent. The study was approved by the Ethical Committee of the University of Valencia (Spain). The protocol met all requirements established by the Conference of Helsinki for research on humans.

Procedure

A 4-week, double-blind study was performed. The participants were administered a supplementation of either DHA or a placebo. The Levante U.D players (n = 20) performed the study in the final period of the 2007-2008 season (June 2008), and the Valencia C.F. players (n = 14) at the start of the 2009-2010 season (October 2009). In each team, the participants were randomly assigned to the experimental and control groups.

Athletes from the experimental group received a 3.5 $g \cdot day^{-1}$ of DHA (Algatrium Plus, Brudy Technology, Barcelona) nutritional supplement, while participants from the control group received only the placebo (olive oil), which did not contain any Omega-3 fatty acids . Pills administered to both groups were similar, and in both cases participants ingested 5 units each day at breakfast without chewing. The World Health Organization (WHO) recommends a dosage of 150 $mg \cdot day^{-1}$, and the International Society for the Study of Fatty Acids and Lipids (ISSFAL) recommends 650 $mg \cdot day^{-1}$. In this study we hypothesized that elite athletes, with high levels of complex reaction efficiency and physiological erosion produced by training load, would need a higher quantity of DHA/day to experience benefits.

Over a period of 7 days, each participant had to complete a nutritional chart ("24 hours inventory") by registering all dietary intake (food and drink) during the 7 days. The data collected allowed the researchers to control the participants' diet (caloric intake and percentage of protein, fat and carbohydrate intake). All analyses were performed by the same trained person.

A questionnaire of daily routines and habits was administered as a control measure, as well as a measure of complex reaction efficiency (time and accuracy), which was applied at two points in time: basal (pre-test), and after 4 weeks (post-test).

Measure of complex reaction efficiency

To measure complex reaction efficiency we employed a computerized task named "multiple reaction times" that presented visual and auditory stimuli and registered responses accordingly. This instrument is part of the ASDE driver test (General ASDE, 2005; Monterde, 2005; Monterde et al., 1986), which is composed of a series of psychological tests developed to evaluate psychophysics and perceptual-motor abilities related to driving and the manipulation of complex machinery.

To perform the multiple reaction times task, participants were seated on a chair at a distance of one meter from the computer, with their hands and feet on the buttons and pedals provided and prepared to respond to the stimuli. The test presented 4 different visual stimuli (red circle, green circle, white cross, and white plus sign), and two auditory stimuli (high and low frequency sounds). After 4 stimuli (red circle, white cross, high frequency sound, and low frequency), participants had to answer as fast as possible by pressing the right or left button or pedal with the right hand, left hand, right foot, or left foot respectively. When the screen showed the green circle or the white plus sign participants were instructed to stop responding.

The task administration had three phases: learning-demonstration, essay and test. In the learning-demonstration phase, participants were instructed to respond to the stimuli while they had a key table on the computer screen with the answers and received feedback of performance and correction if necessary. In the essay phase, participants were asked to respond to the stimuli without the key table but they still received feedback and correction. Finally, in the test phase, participants responded to 36 stimuli without receiving any feedback. At the end of the task three results were displayed: successes, failures, and complex reaction time mean.

Statistical analysis

Multivariate analysis of variance was performed. It was carried out with one intra-subject factor, nutritional supplementation (pre test-post test), and two inter-subject factors, experimental group (DHA-placebo) and time of the season (beginning-ending). Three dependent variables where analyzed: complex reaction time, accuracy (successes - failures), and complex reaction efficiency, by means of a complex reaction efficiency index (CREI): (successes - failures) / reaction time.

Results

No significant differences were found between the nutritional intakes of the two teams. The average caloric intake was 3050 kcal·day^{-1} (SD =140; 16% protein, 44% fat and 40% carbohydrates). All the players were less than 2 SD away from the mean, thus none were excluded from the study.

Multivariate contrast analysis showed significant effects of nutritional supplementation ($F = 3.54$; λ Wilks= 0.73; $p = 0.027$; η^2 partial = 0.28; l-β= 0.72) and interaction between nutritional supplementation and experimental group ($F = 5.92$; λ Wilks= 0.61; $p = 0.003$; η^2 partial = 0.39; l-β= 0.92). No significant effects were found for the time of the season or interaction between the factors.

Univariate contrast analysis showed effects of nutritional supplementation on accuracy, efficiency and the interaction between the nutritional supplement and experimental group on complex reaction time and efficiency (Table 1). Results showed that with DHA supplementation complex reaction time and accuracy similarly decreased, and consequently complex reaction efficiency increased. On the other hand, by analyzing the interaction between the nutritional supplement and the experimental group, results showed that the complex reaction time of the control group slightly increased in post-treatment measure, while the experimental group decreased almost by a tenth of a second. Moreover, the control group efficiency did not change while the experimental group increased significantly.

Discussion

The results of this study support the idea that DHA supplementation produces benefits related to perceptual-motor behavior. An interaction between the supplement (pre-test-post-test) and the experimental group (DHA-placebo) showed that DHA supplementation produced significant improvements in not only the complex reaction time ($p = 0.004$), but also in the complex reaction efficiency ($p = 0.003$). This research also found that this effect did not vary when supplementation was offered at the start or at the end of the season. Thus, the possible cumulative fatigue did not produce significant changes in the DHA effects.

Regarding the mechanisms that could produce this improvement, some studies have proposed that DHA modulates the functional activity in cortical attention networks. In a study by McNamara et al. (2010) performed on 30 boys aged 8-10 years, the authors provided 8 weeks of DHA supplementation, which increased the erythrocyte membrane DHA composition, and was positively correlated with dorsolateral prefrontal cortex activation and inversely correlated with reaction time.

The reliability of the study was supported by the homogeneity of the sample. No differences in nutritional intake were found between the players of both teams, and the athletes, having been professional players, had similiar training loads and lifestyles (daily routines, leisure, etc.), as indicated by the questionnaires.

Nevertheless, some points may be considered. First, the athletes already had a good perceptual-motor performance in the pre-treatment measure (high CREI), thus it was important that DHA supplementation could lead to performance improvement. Second, complex reaction efficiency was measured under laboratory conditions and results did not necessarily indicate that an improvement will lead to an increase in individual or collective game performance. Nevertheless, these results suggest that an improvement in complex reaction efficiency could lead to a better selection and performance of technical and tactical variables. This hypothesis could be explored in subsequent studies. Third, in this study participants performed without fatigue. It would be interesting to see if DHA supplementation would increase or maintain perceptual-motor performance under fatigued conditions similar diet alterations (Pawlosky et al., 2003), however it would to that of a game, where it has been found that perceptual-motor efficiency decreases (Thomson et al., 2009). Finally, this research was performed on women because some studies suggest that females are more responsive to

Table 1. Results of the study.

Factor	Dependent variables	F	Sig.	η²partial	l-β	Pre-treatment Mean (SD)		Post-treatment Mean (SD)	
Supplementation	Reaction time	2.11	.157	.066	.289	.698 (.136)		.667 (.141)	
	Accuracy	6.13	**.019**	.170	.673	30.06 (8.61)		34.24 (2.30)	
	Efficiency	10.44	**.003**	.258	.878	44.95 (16.51)		53.54 (11.53)	
						Experimental	**Control**	**Experimental**	**Control**
Supplementation * Experimental group	Reaction time	9.83	**.004**	.247	.859	.713 (.142)	0.682 (1.132)	.623 (.109)	.715 (.159)
	Accuracy	1.89	.179	.059	.265	28.11 (10.50)	32.25 (5.31)	34.56 (2.55)	33.88 (2.00)
	Efficiency	10.46	**.003**	.258	.879	40.88 (17.41)	49.52 (14.63)	57.12 (11.05)	49.50 (11.01)
Supplementation * Team	Reaction time	.16	.692	.005	.067				
	Accuracy	.09	.771	.003	.059				
	Efficiency	.03	.862	.001	.053				
Supplementation * Experimental group * Team	Reaction time	2.63	.115	.081	.349				
	Accuracy	.69	.413	.022	.013				
	Efficiency	.02	.891	.001	.052				

be useful to perform this research on male participants in order to verify similar results. Moreover, it would be interesting to perform similar studies with other groups of healthy participants (Fontani, 2005) or groups with different levels of physical or psychological handicaps.

Conclusion

The results obtained from the study suggest that supplementation with DHA produced perceptual-motor benefits in female elite athletes, and that DHA could be a beneficial supplement in sports where decision making and reaction time efficiency are of importance. Moreover the necessity to perform similar studies under fatigue conditions with male and/or non-athlete samples is suggested.

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Key points

- The results obtained from the study suggest that supplementation with DHA produced perceptual-motor benefits in female elite athletes.
- DHA could be a beneficial supplement in sports where decision making and reaction time efficiency are of importance.

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