



Evaluating the Effects of Cognitive Training on Task Switching and Working Memory

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ABSTRACT

Background: Cognitive abilities, including task switching and working memory, are essential for sports performance, especially in athletes who require swift decision-making and adaptation. This study examined how male collegiate athletes' working memory and task switching were affected by a three-week cognitive training program. **Materials and Methods:** Fourteen male athletes, aged 18 to 23 years, were allocated at random to either an experimental group (n=7) or a waitlist control group (n=7). The experimental group participated in cognitive training program that integrated light physical exercises with cognitively challenging tasks aimed at enhancing working memory and task switching for 15 minutes each day over a span of 21 consecutive days. Both groups were evaluated pre- and post-intervention utilising the Trail Making Test (TMT-B) for task switching and the Digit Span Test for working memory assessment. Nonparametric statistical tests (Wilcoxon Signed-Rank and Mann-Whitney U) were employed to assess intra- and inter-group differences, with significance established at $p < 0.05$. **Results:** The experimental group exhibited substantial enhancements in task switching ($Z = -2.375, p = .018$) and working memory ($Z = -2.530, p = .011$) following the intervention, but the



control group displayed no significant change. Comparisons between groups did not show statistically significant differences, possibly attributable to the limited sample size and elevated baseline cognitive ability of the participants. **Conclusion:** A three-week cognitive training program can significantly improve task switching and working memory in physically active young athletes. Implementing this kind of cognitive training into sports training plans/schedules might help boost executive functioning and decision-making abilities that are necessary for success in sports.

INTRODUCTION

Over the past few decades, cognitive research has grown significantly due to a greater understanding of its applicability to daily life, which has been largely fuelled by scientific advances in cognitive psychology (Fathirezaie et al., 2014). Now, scientists can study not only the functional structure of brain networks but also how genetic variations influence how each person uses these networks to learn and perform (Fathirezaie et al., 2015). In order to improve performance in one or more particular cognitive areas, cognitive training comprises of organised programs that let participants practise standardised cognitive activities under supervision (Martin et al., 2011).

Numerous RCTs (randomised controlled studies) shows that mental training/cognitive training helps to improve cognitive performance, improvements do not always outperform those seen in inactive control settings (Reijnders et al., 2012). Many diverse sets of cognitive training methods have been used in the recent past and they also have shown improvements in the aspect of working memory and task switching. These methods include integrative body-mind training, mindfulness training, attention state training, physical cognition training, brain gym training, cognitive training using specific software's and equipment's (cognifit, cogmed, neurotracker, Vienna test system etc.).

Cognitive training programs primarily focuses on the basic functions of the brain that support cognition, in particular attention, working memory, executive functions etc. (Karch et al., 2013). The fact that cognitive decline is common as people become older (Kim et al., 2012; Plassman et al., 2008) and that the population is getting older faster makes it clear that we need to develop ways to improve or keep cognitive function later in life (Kelly et al, 2014). Increasing number of evidences suggests that cognitive interventions are effective. The efficacy of interventions can be evaluated by looking at how well



participants perform on specific cognitive tasks, how long those improvements last, whether or not the training benefits can be transferred to other tasks in the same or different cognitive domains and whether or not the effects can be generalised to day-to-day functioning (Klingberg, 2010; Martin et al., 2011).

Cognitive processes, like working memory and task switching, are extremely significant in our daily lives because they help us hold, manipulate, and switch between different pieces of information and mental tasks. Cognition is basically about the mental processes we use to gain knowledge and understand things through our experiences, thoughts, and perceptions (Uk & Ki, 2022). Working memory is a cognitive ability with limited capacity that is responsible for storing and manipulating information for brief periods of time (Miyake & Shah, 1999). Reasoning, decision-making, and conduct are all guided by the capacity of one's working memory (Diamond, 2013) and task switching is shifting one's attention between one task to the other unconsciously (Yerys et al., 2009). Task switching enables an individual to adapt quickly and efficiently to new situations and is often an intuitive matter for cognitive and experimental psychologists. In simple words task switching ability allows individuals to switch their attention from one task to the other in an effortless manner barring other stressors which create diversion. Working memory and task switching play a big part in every person's life, from doing their daily chores to more complicated sports and games.

It's no longer out of our reach to boost cognitive performance or speed up the learning process with brain augmentation systems thanks to recent advancements in neurotechnology and advances in the knowledge of brains cognitive functions (Taya et al., 2015). Many fMRI-based studies have shown that changes in brain activity associated with specific cognitive functions, which is linked to improvements in behavioural performance (Claros-Salinas et al., 2014; Hempel et al., 2004). Olesen et al. and Hempel et al. both reported that cognitive training interventions made parts of the brain that are linked to working memory more active (Hempel et al., 2004; Olesen et al., 2003). Cognitive training has also been shown to increase blood flow to the prefrontal cortex (Reuter-Lorenz & Cappell, 2008).

Cognitive Training's Neural Adaptations

Recent advancements in mathematical techniques and neuroimaging technologies have enhanced our understanding of cerebral function (Taya et al., 2015). fMRI (functional magnetic resonance imaging) studies have demonstrated that cognitive training enhanced behavioural capabilities and altered brain activations associated with cognitive ability (Hempel et al., 2004). Hempel et al. observed an increase in activations following two weeks of practice on a working memory task, followed by a drop after four weeks, indicating the presence of two distinct pathways (Hempel et al., 2004). Olesen et al. conducted a



study that revealed an enhancement in brain activity in regions associated with working memory following five weeks of practice with working memory tasks (Olesen et al., 2004). Numerous studies have identified the activation of various brain regions, including the Wernicke's area, temporal lobe, frontal lobe, occipital lobe, parietal lobe, and Broca's area (McKendrick et al., 2014; Anguera et al., 2013; Prakesh et al., 2012; Maclin et al., 2011; Jolles et al., 2010; Dahlin et al., 2008; Olesen et al., 2004; Hempel et al., 2004).

MATERIALS AND METHODS

A total of 14 male subjects (n=14) were randomly selected from a men's hostel in Trivandrum district; their age ranged between 18-23 years, the subject selection was based on certain criterion, i.e., should be involved in regular physical activities (all the subjects were inter-collegiate athletes) and should not have any undiagnosed and pertaining physical or mental discomfort or injuries. So, after screening 31 subjects, 20 subjects were shortlisted, but the post-test was data was collected from 14 subjects only, as three participants withdrew the experimental group, while a few others from the control group did not attend the final testing session. Other than the author one additional trainer (qualified physical education teacher) was also recruited and the details regarding the nature of the study and the methodology were thoroughly explained to him, additionally a practical session was also conducted to train the trainer. The data pertaining their injuries and health were collected from the subjects using a self-administered open-ended questionnaire. The subjects were briefed about the nature of the training and its importance in detail prior to the commencement of the training. The participants were randomly assigned to two groups: Group I (experimental group, n = 7) and Group II (waitlist control group, n = 7). The study used a randomised controlled trial design with pre- and post-test assessments.

Intervention

The Experimental group (group-I) participated in cognitive training program that incorporated light movement activities along with cognitively challenging tasks aimed at enhancing the cognitive domain, specifically focusing on working memory and task switching. The training took place for 15 minutes each session over a period of 3 weeks (21 consecutive days), following suggestions from earlier research (Al-Thaqib et al., 2018; Nouchi et al., 2012). The cognitive training program is specifically designed to target the working memory and task-switching abilities of the human brain. The training involves simple physical activities like walking, throwing, and tapping the ball, which are straightforward to implement and manageable. It also includes cognitively challenging tasks such as remembering and cancelling numbers, which are similarly easy to administer and perform.



The three-week Cognitive training plan was adapted from Uk & Ki, (2024):

The training session included a 6-minutes progressive tennis ball exercise paired with memorising numbers displayed on the wall, followed by a 3-minutes rest; the participants then next performed a 6-minutes number cancellation task while walking within the designated area. Finally, Finally, participants were asked to recall and reproduce the sequence of numbers learnt during the initial ball exercise.

Weekly plan:

Week1- The participant has to tap one tennis ball on the ground using their both hands while looking at the large font numbers on the wall. When the trainer calls out a number, the participants throw the ball to that number (using their preferred hand) and then catch it back. Then they have to start tapping the tennis ball on the ground again with both hands. The subject has to walk slowly (in the desired area) and cancel out the numbers (in large font size). Finally, they have to write down the seven numbers that the trainer told them to throw the ball in the first activity in the same order that the trainer did (Uk & Ki, 2024).

Week2- The participant will tap a single tennis ball on the ground with both hands while simultaneously reading the numbers displayed on the wall, which will be in large font and will increase in quantity of the numbers pasted will be increased compared to that of the 1st week. Upon the trainer calling out a number, the subject must throw the ball at that specific number using their preferred hand, catch it, and resume tapping the ball on the ground with both hands. The subject will then engage in slow walking within a designated area predetermined by the trainer, simultaneously performing number cancellation tasks in medium font size. Finally, the subject must write down the nine words that the trainer instructed them to target with the ball in the initial activity, maintaining the same sequence as provided by the trainer (Uk & Ki, 2024).

Week3- The participant taps two tennis balls on the ground with both hands while reading numbers displayed on the wall in medium font. Upon the trainer calling out a number, the subject must throw one ball at that specific number using their preferred hand, catch it, and resume tapping both balls. Subsequently, the subject briskly walks within a designated area predetermined by the trainer while engaging in number cancellation tasks in small font size. Finally, the subject is required to write down the eleven words that the trainer instructed them to target with the ball in the initial activity, maintaining the same sequence as presented by the trainer (Uk & Ki, 2024).



Note: Each session's number cancellation activity involved the trainer reading aloud numbers from a printed sheet that the participants had also received. Participants had to find and strike out each number on the same sheet as it was called (Uk & Ki, 2024).

Evaluation

All subjects in both groups were tested identically in the beginning and at the end of training. The testing session lasted for 15-30 minutes per subject. Task switching was measured using Trail Marking Test (TMT trial-B). TMT is a neuropsychological examination of task switching, and visual attention; it elicits data on task switching, executive functioning, mental flexibility, processing speed, scanning, and visual search speed. It comprises of two sections (Arnett and Seth, 1995). The test was invented by Ralph Reitan in 1944; the participants have to connect a sequence of 25 consecutive numbers/alphabets on the TMT test sheet; the participants must connect the dots in a sequence alternating between numbers and alphabets (e.g. 1-A, 2-B, 3-C, etc.), and the total time required to complete the test is recorded (Tombaugh, 2004).

Working memory (WM) was assessed with the Digit Span Test. It is a simple assessment tool of working memory ability. Each participant is shown with a sequence of numbers on the laptop screen, one sequence at a time (e.g., 73, 734, 7349, etc.) (Uk & Ki, 2024). The exam comprises two variations: the forward digit span test and the backward digit span test. This study employed the forward version, requiring the subject to recall and input the digits in the sequence presented on the screen. In each successive trial sequence, the quantity of digits displayed rises by one. The quantity of available digits for the subsequent trial remains unchanged regardless of any missing digits or incorrect sequencing after a failed attempt (Uk & Ki, 2024). The task concludes when the participant incorrectly answers two consecutive questions within a certain digit span. The ultimate score is determined by the total number of consecutively recalled digits that are correct. The exam was initially conducted verbally; however, in this study, it is delivered using a 13-inch laptop, positioned 35 cm from the subject, utilising the PsyToolkit application (PsyToolkit.org, Psychological software application for running experiments and assessments in cognitive psychology, Stoet, 2010, 2017) based on the recommendations of other authors (Lee et al, 2020; Stoet, 2017).

Raw data's normality was established using the Shapiro-Wilk test, indicating an approximate normal distribution. Due to the restricted sample size ($n = 7$ per group), nonparametric tests were used to ensure the reliability of the results. Comparisons within-groups was analysed using Wilcoxon Signed-Rank tests,

and comparisons between groups was analysed using Mann-Whitney U tests. SPSS version 21.0 was the statistical software used for analysis, with a significance level of $p < .05$.

RESULT

Table 1

Between-Group and Within-Group Comparisons of Task Switching and Working Memory

Measure	Group/Comparison (Control Group-CG, Experimental Group- EG)	N	Mann- Whitney U	p (2- tailed)	Wilcoxon Signed Ranks Z	p (2- tailed)
Task Switching	CG (pre vs post)	7	-	-	-0.507	.612
	EG (Pre vs Post)	7	-	-	-2.375	.018*
	Pre-test (CG vs EG)	14	18.00	.406	-	-
	Post-test (CG vs EG)	14	17.00	.338	-	-
Working Memory	CG (pre vs post)	7	-	-	-1.000	.317
	EG (Pre vs Post)	7	-	-	-2.530	.011*
	Pre-test (CG vs EG)	14	18.50	.421	-	-
	Post-test (CG vs EG)	14	18.50	.417	-	-

Note: Task switching is measured in seconds, with lower values signifying enhancement. Working memory scores denote the number of correct responses, with higher scores indicating enhancement. $p < 0.05$.

Task Switching

Mann-Whitney U tests indicated no statistically significant changes in task switching performance between the control group and experimental groups at the pre-intervention stage ($U = 18.00$, $p = .406$) or post-intervention ($U = 17.00$, $p = .338$).

The within-group analysis using the Wilcoxon signed-rank test indicated that the control group exhibited no significant variation from pre-test to post-test, $Z = -0.507$, $p = .612$. The experimental group showed a



statistically significant enhancement in task switching, $Z = -2.375$, $p = .018$, indicating that the intervention significantly improved executive function in this area.

Working Memory

Working Memory Between-group analyses using the Mann-Whitney U test revealed no significant differences in working memory scores between the control and experimental groups at pretest ($U = 18.50$, $p = .421$) or post-test ($U = 18.50$, $p = .417$).

The Wilcoxon signed-rank test results indicated that the control group had no significant enhancement in working memory, $Z = -1.000$, $p = .317$. The experimental group exhibited a notable enhancement from pre-test to post-test, $Z = -2.530$, $p = .011$.

Discussion

This study investigated the impact of a 21-day cognitive training program on task switching and working memory in collegiate male athletes. Participants were between the ages of 18 to 23 years and were engaged in regular sports training at the inter-collegiate level. Following screening, 14 healthy athletes were allocated randomly to an experimental group or a waitlist-control group. All participants engaged in a structured intervention facilitated by the researcher and a qualified physical education instructor. The research employed a randomised controlled trial design with pre-test and post-test assessments.

The results indicated that participants in the experimental group exhibited enhancements in task switching and working memory after the intervention. The findings indicate that short-term, structured cognitive training may effectively enhance executive functioning in high-performing individuals, including trained athletes. The control group, which did not receive the intervention during the same period, exhibited no observable changes in either cognitive domain.

Although no significant differences were found between the groups post-training, the improvements noted in the experimental group suggest that the intervention had a substantial impact. The lack of differences between groups may result from various factors. The small sample size may have restricted the detection of subtle differences at the group level. Secondly, given that all participants were already cognitively and physically active, their baseline cognitive abilities may have been relatively elevated, resulting in limited potential for significant improvements. The intervention duration was limited to three weeks, potentially insufficient to produce significant differences between the groups.



Despite these limitations, the observed within-group improvements are significant and indicate that cognitive training may provide additional advantages for athletes who are already physically and mentally involved. Improving task switching may facilitate quicker decision-making and greater adaptability in gameplay, whereas enhancements in working memory could aid in strategy retention, motor learning, and in-game adjustments.

Practical Implications

The results of this study support the incorporation of cognitive training into sports training programs/schedules. Sporting activities requiring prompt decision-making, memory retention, and flexibility in handling multiple cues may particularly benefit by adding this cognitive training method mentioned in this study, which is short and targeted in nature. Coaches, athletes, and trainers may contemplate this cognitive training method along with their physical training program to enhance these cognitive abilities, which will in turn enhance their sporting performance (Lucia et al., 2022).

Limitation and Recommendations

This study had some limitations, including a small sample size and a short training duration, which might have made it harder to identify wider or longer-lasting effects. Also, all the participants were male athletes from the same area and background, which might restrict how broadly the results can be applied. Future research needs to include bigger and more varied samples, increase the training duration, and look into long-term cognitive results. Adding neurocognitive assessments or actual game performance metrics might help confirm how this training affects athletic success.

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