COGNITIVE ABILITIES ASSESSMENT AND ENHANCEMENT OF BASKETBALL PLAYERS

A Dissertation submitted in fulfillment of the requirements for the Degree of

MASTER OF ENGINEERING

in

Electronic Instrumentation & Control Engineering

Submitted by

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DECLARATION

I hereby certify that the work which is presented in dissertation entitled, "Cognitive Abilities Assessment and Enhancement of Basketball Players", in partial fulfillment of the requirements for the award of the degree of Master of Engineering in Electronic Instrumentation and Control Engineering, submitted to Electrical & Instrumentation Engineering Department of Thapar University, Patiala is an authentic record of my own work carried under the supervision of Dr. Ravinder Agarwal. It refers others researcher's work which are duly listed in the reference section. The matter contained in this dissertation has not been submitted, neither in part nor in full to any other degree to any other university or institute except as reported in text and references.

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NOMENCLATURE

BCI	Brain-Computer Interface
BSS	Blind Source Separation
EEG	Electroencephalography
EI	Emotional Intelligence
ICA	Independent Component Analysis
MATLAB	Matrix Laboratory
MOT	Multiple Object Tracking
PMR	Progressive Muscle Relaxation
PSD	Power Spectral Density
TMT	Trail Making Test

ABSTRACT

Development of the mental skills is important for an athlete along with the improvement of the physical skills, to achieve the desired performance in the competitions. The purpose of the present study is to improve the cognitive skills such as selective attention, working memory and mental toughness in the university basketball players. Twenty players participated in the study, out of which, ten players are given the interventions (experiment group), while the remaining ten players are not given any interventions (control group). Computer-based games are used as interventions for selective attention and working memory skills. A power point presentation (ppt.) on mental toughness and Progressive Muscle Relaxation (PMR) techniques are used as interventions for mental toughness skill. The physiological evaluation of these players included acquiring their electroencephalogram (EEG) data. The psychological evaluation required the 20 players to complete the d2 Test of Attention to assess selective attention, Trail Making Test Part B to assess working memory and Mental Toughness Questionnaire to assess mental toughness. The psycho-physiological results show that most of the players who received the interventions, are able to improve their aforesaid cognitive skills, than the control group players. The test-retest reliability of the psycho-physiological tests has been measured by Pearson correlation coefficient. The Pearson correlation coefficient values between the pre-test and post-test results show the effect of the above mentioned interventions in improving the cognitive skills. Furthermore, Cronbach's alpha coefficient values (> 0.70) show high internal consistency for the overall scores obtained for the Mental Toughness Questionnaire.

Keywords: basketball; mental toughness; Progressive Muscle Relaxation; psycho-physiological; selective attention; working memory

CHAPTER 1
INTRODUCTION

The athletes should possess various kinds of skills to excel in sports. The competition in sports is steadily increasing. Different sports place different demands on athletes. Therefore, an athlete should always try to improve the skillset, to keep pace with the dynamic sports environment. The coaches and sport psychologists can help the players in their skill development. A player undergoes physical training to improve the performance, but, there should be an equal emphasis on the mental training as well. There have been numerous instances where players have been unable to perform well due to match-pressure, anxiety and lack of emotion control. The qualitative evaluation [1] of the factors behind performance decline in the players in team sports has been performed. This information can be used by the coaches and sport psychologists to enhance the psychological skills of the athletes. The effect of various psychological interventions on mental toughness dimensions of table-tennis players has been studied [2]. It was found that the combination of different interventions was more beneficial for the players than the individual interventions.

Cognition means the process of acquiring, understanding and processing the information acquired by an individual. There are a number of cognitive skills such as selective attention, sustained attention, decision making, reaction time and mental toughness. These skills are important in improving the performance of players in different sports. In a dynamic sports environment, a player needs to focus only on the game and should be able to effectively block all the distractions. The player should make quick decisions in the game. Basketball is one of the most widely followed sports in the world. It is a team sport. It is played by two teams of five players each on a rectangular court. The players should be able to coordinate, focus, control emotions, stay calm and perform their best in the competitions. The cognitive components related to basketball performance have been studied [36]. In a study [38], the basketball skills are found to be related with the specific mental skills of the junior basketball players. In many cases, the difference between the winning and losing players is due to the psychological factors. The physical skills difference between them is minor, but, the mental skills difference is vast. Therefore, mental skills training should be incorporated in the training schedule of the players, along with the physical skills training.

Cognitive enhancement means the strengthening of the cognitive skills of the individuals by exposing them to various interventions. Our aim is to enhance the cognitive skills naturally. It is not ethical to choose the pharmaceutical drugs and surgical techniques for performance

enhancement in sports competitions. There are different kinds of interventions such as computer-based games, relaxation, imagery, neurofeedback, yoga, music and odor for cognitive enhancement naturally. The relationship of imagery with mental toughness [3] has been found. Through imagery, an athlete can feel confident, in control of the performance and reduce the competitive anxiety. The yoga intervention has been provided to the young subjects [4] and its effect has been assessed through the measurement of various physiological parameters. Yoga has been found to improve the cognitive functions. Similarly, neurofeedback intervention is increasingly being used by executives and athletes to achieve peak performance state [5]. Neurofeedback can be used to improve the cognitive functioning in the people suffering from learning disabilities, stroke and depression. The imagery intervention has been found to improve athletic performance [6]. It can be combined with other interventions to get more beneficial results. It has been found that perceptual-cognitive training can effectively lower the age-related effects in old persons. The old persons can develop the skills to process multiple information in a complex environment through appropriate training [39].

Chapter 1 presents the introduction to the present work. The importance of the study is mentioned. The research objective is stated.

Chapter 2 provides the background of the present study in the form of literature review.

Chapter 3 gives the description about the psycho-physiological parameters and the various interventions used for the cognitive skills.

Chapter 4 provides the methodology followed in the present work. The psycho-physiological test measures are explained. The calculation of physiological and psychological results is discussed. The statistical analysis is also presented.

Chapter 5 presents the physiological, psychological and statistical results obtained in this work. The discussion concerning the results obtained in this study is also provided.

Chapter 6 includes the conclusion made. The future suggestions are provided after the conclusion.

1.1 Problem Definition

The importance of mental training for the athletes has been understood. The present work focuses on the psycho-physiological assessment and enhancement of cognitive skills of the university basketball players. The cognitive skills considered in this study are selective attention, working memory and mental toughness. The physiological assessment comprises of acquiring the

electroencephalogram (EEG) data of the players. The psychological test measures include the d2 Test of Attention for assessing selective attention, Trail Making Test Part B for assessing working memory and Mental Toughness Questionnaire for assessing mental toughness. All the players are divided into the experiment group (exposed to the interventions) and the control group (not exposed to the interventions). The computer-based game intervention is used for selective attention and working memory skills. A power point presentation (ppt.) on mental toughness and Progressive Muscle Relaxation (PMR) techniques are used as interventions for the mental toughness skill. It is assumed that after undergoing the interventions' sessions, the experiment group players will be able to enhance their cognitive skills than the control group players. The physiological results consist of evaluating the theta/beta power ratio for the selective attention skill at the AF3 and AF4 locations and the theta power for the working memory skill at the F3 and F4 locations. The test-retest reliability of the psycho-physiological test measures has been evaluated through Pearson correlation coefficient. To check the internal consistency of the overall mental toughness score in the Mental Toughness Questionnaire, Cronbach's alpha coefficient has been calculated.

Graham Jones, 2010, has investigated the mental toughness skill of the elite sportspersons. There have been different definitions of mental toughness since a long time. The study addresses the issues of defining mental toughness as well as defining the qualities required to become a mentally tough player. Qualitative approach has been adopted in the study. Ten international performers have been taken. The study is based on personal construct theory. Purposive sampling is used in this work to select the study participants. The procedure for the study is divided into three main stages of focus group, individual interviews and individual rating of definition and ranking of mental toughness attributes. After evaluation, a definition of mental toughness is found. Accordingly, mental toughness is the process of developing the psychological edge that enables a person to cope better than one's opponents with the competition, training, lifestyle and be more consistent in remaining determined, focused, confident and in control under match-pressure. Twelve mental toughness attributes have been determined. The small sample size and using only one focus group are some of the limitations of the study. Future research should include sport psychologists and involve the physiological measurements [24].

Miguel Humara, 1999, discusses the relationship between anxiety and performance from a cognitive-behavioral viewpoint. The ability to deal with anxiety in competitions is of great importance, particularly, for elite athletes. The main problem with the research done till now relating anxiety and performance, is that researchers have not clearly defined the operational definitions like anxiety, stress and arousal, but these definitions have been clearly defined in this paper. Within the context of sports, those individuals who are low trait anxious and experience high state anxiety will find it facilitative to peak athletic performance, but, those individuals who are high trait anxious and experience state anxiety will find it debilitative to athletic performance. Self-confidence (a separate cognitive component) has been found to possess a positive linear relationship with performance. The author exhorts future researchers to focus on the development of manualized treatments within the athletic environment. However, this should be done with a consideration for the athlete's needs if the interventions by sport psychologists are to have their maximum impact [25].

Brunelle *et al.*, 1999, have examined the efficiency of anger awareness training (by self-monitoring) and role-playing (by behavioral rehearsal) in decreasing subjects' angry behavior and angry feelings. Fifty seven male soccer players are randomly given a role-playing, an anger awareness or a control group. The results show that the role-playing intervention is a more effective method. The results of maintaining or increasing athletic performance through anger control are important. Many players are unable to control their anger in the competitions and fight with the opposite team players and disregard the match referees. Such kind of behavior is unacceptable in a healthy competition. The players should understand the negative consequences of anger and learn to improve the performance by controlling their angry feelings. By decreasing bursts of anger, role-play training may not only improve the athletic performance but it may increase the health, the pleasure and the fair spirit of competitive sport [26].

Hyvärinen and Oja, 1999, have described the basic theory and applications of Independent Component Analysis (ICA) technique. The cocktail party problem has been explained. Two equations have been given by them as $x1(t) = a11s1 + a12s2;\ x2(t) = a21s1 + a22s2$. Here, the two original speech signals s1(t) and s2(t) are estimated, using only the recorded signals x1(t) and x2(t). The parameters a11, a12, a21, a22 depend on the distances of the microphones from the speakers. ICA is very closely related to the Blind Source Separation (BSS) method. ICA can reveal interesting information about EEG data. ICA can be used for feature extraction in digital signal processing. It can be used to reduce noise in natural images. It can also be used in biomedical signal processing, telecommunications, audio processing and econometrics [27].

Makeig *et al.*, 1996, explain that the ICA algorithm separates the problem of source identification from that of source localization. The various artifacts get mixed with the cerebral data of interest. ICA can be used to separate artifacts in EEG data. ICA can separate coinciding EEG phenomena, including alpha and theta bursts and spatially separable ERP components, to separate ICA channels. The problem in understanding the output of ICA is finding the proper dimension of input channels and the psychophysiological importance of the derived ICA source channels. ICA appears to be a good method for human EEG research analysis [28].

Cutton and Hearon, 2013, have identified attention cognitive skill as important for the athletes of all sports. There are many sources of information and the athletes should know which things need focusing and when they need to focus. With practice, athletes can learn to be attentive at the appropriate time and improve their performance. This information is useful for the coaches who can help their players in improving their attentional skills. During a match, a noisy environment prevails. The players and crowd make noise and it becomes difficult for some players to focus on their game. Coaches can create a noisy environment in the training, to help their players learn to cope with it. The coaches should understand and determine the solutions for the problems faced by the athletes in focusing. They should understand the athletes' needs and help them in improving their performance [29].

Pineschi and Pietro, 2013, have studied the effect of relaxation techniques in controlling anxiety. The result of the game and the rewards associated with it, lead to the anxiety in athletes. If they are unable to reduce it, their performance declines. With the help of relaxation techniques, an individual can learn to reduce the muscle and mental tension by own choice. By practicing relaxation techniques, an athlete learns to lower the anxiety in the matches and relax the mind as well as body to achieve peak performance. Through relaxation training, an athlete can learn to save the energy for appropriate time and lead a successful life. This information is useful for the sports practitioners and coaches working with the athletes, to include the relaxation methods in the training schedule of the players [30].

Gevins and Smith, 2000, discuss that the working memory mental skill is related with the reasoning, planning and comprehension abilities of a person. Working memory function is an indicator of general cognitive ability of a person. In this study, subjects' performance on various tasks is assessed and the individual differences in mental ability and cognitive style are found. The subjects with the higher cognitive ability were able to stay attentive for a long time [31].

Daly *et al.,* 2015, have identified a bidirectional relationship between physical activity and executive function in a large sample of older adults. In older adults, cognitive decline occurs which affects their mental, social and economic well-being. Regular physical activity has a beneficial effect on the cognitive functioning of an individual. The executive functions mean the higher level

cognitive processes which help in coordinating the fundamental processes central to leading a healthy life. The executive functions include planning, selective attention, sustained attention and the ability to deal effectively with situations. Similarly, a better executive functioning is responsible for the promotion and long-term compliance of performing physical activity. This information can be helpful in designing efficient interventions to assist old adults in healthy aging [32].

Stough *et al.*, 2009, have investigated the relationship between emotional intelligence (EI) and sport. Those athletes who are able to manage their emotions can direct them to produce motivation for a better performance. Therefore, it is important for the athletes to recognize and express their emotions appropriately. In team sports, the ability of a player to understand the teammates' feelings and communicate effectively holds significance. EI describes different ways to improve the athletes' ability in dealing efficiently with their own and others' emotions. Various interventions can also be designed to improve EI of athletes, keeping their psychological needs in mind. EI is helpful in the progress and training of players' for post-sport careers [33].

Baker *et al.*, 2003, have examined the sport-related practice and the development of competence in decision making skill in team sports such as field hockey, netball and basketball. The development of expertise in sports is not easy. Decision making means the ability to acquire the information from the environment, understand it and appropriately selecting the response to it. Good decisions can win the game and bad decisions can result in defeat in the game. Therefore, the skill of decision making should be practiced and the athletes should try to achieve prowess in it [34].

Teplan, 2002, has provided the basic understanding of EEG theory and measurement. EEG is the recording of the electrical activity of the brain. Different electrodes are placed on the scalp of an individual and these electrodes pick the electrical signals and EEG is recorded. EEG is used to monitor alertness, brain areas damaged after head injuries, stroke, tumor, cognitive skills level, brain physiology and sleep disorders. The surface position of cerebral cortex results in electrical activity which greatly affects EEG. EEG signal consists of different frequency waves such as delta,

theta, alpha and beta bands. Different characteristics of brain can be studied using these frequency waves. EEG studies are widely being used in medical and research areas [35].

CHAPTER 3

PHYSIOLOGICAL AND PSYCHOLOGICAL STUDY

3.1 Physiological Study

A brief information about the various physiological concepts is presented as follows.

3.1.1 The Human Brain

The brain is one of the most complex and magnificent organs in the human body. Our brain gives us awareness of ourselves and of our environment, processing a constant stream of sensory data. It controls our muscle movements, the secretions of our glands and even our breathing and internal temperature. Every creative thought, feeling and plan is developed by our brain. The brain's neurons record the memory of every event in our lives. Since many years, scientists and philosophers have been trying to understand the processes underlying the functioning of the human brain. Due to the advancements in neurological and behavioral science research around the world, the complex brain mechanisms are slowly being revealed. The study of the human brain is done for various purposes. In some cases, one wants to understand the cognitive functions underlying the skilled performance of great athletes, academicians, musicians and executives. While, in other cases, one wants to understand the mental processes responsible for the learning disabilities, depression and cognitive decline in the individuals, so as to help them to lead a better life. An understanding of the human brain is essential in order to correctly explain the various factors responsible for the behavior of the individuals.

The human brain can primarily be divided into three parts: cerebrum, cerebellum and the brain stem [7]. The cerebrum is the largest part and is in the front portion. It is composed of the right and left hemispheres. Its main functions include initiation of movement, coordination of movement, sensing temperature, touch, vision, hearing, judgment, reasoning, problem solving, emotions and learning. This is the most famous part of the human brain. The smaller part of the brain, located at the back is called cerebellum. Its purpose is to coordinate voluntary muscle movements and to maintain posture, balance and equilibrium. The brain stem is the midline or middle of brain. It includes the midbrain, the pons and the medulla. This part is responsible for movement of the eyes and mouth, relaying sensory messages like temperature, voice pain etc. It also controls hunger, respiration, consciousness, body temperature and involuntary muscle movements that include sneezing, coughing, vomiting and swallowing. The spinal cord is large

bundle of nerve fibres located in the back of the brain and carries messages to and from the brain and the rest of the body.

The cerebrum can further be divided into four lobes. These are frontal lobe, parietal lobe, occipital lobe and temporal lobe. The frontal lobe is the largest section of the brain located in the front of the head and is concerned with the personality characteristics and movement. The parietal lobe is the middle part of the brain and it helps a person in identifying the objects in space with respect to the body. The occipital lobe is the back part of the cerebrum and is primarily involved with vision. The temporal lobe is situated at the sides of the brain and is involved in memory, speech, and sense of smell. The different parts of the human brain are shown in Fig. 1.

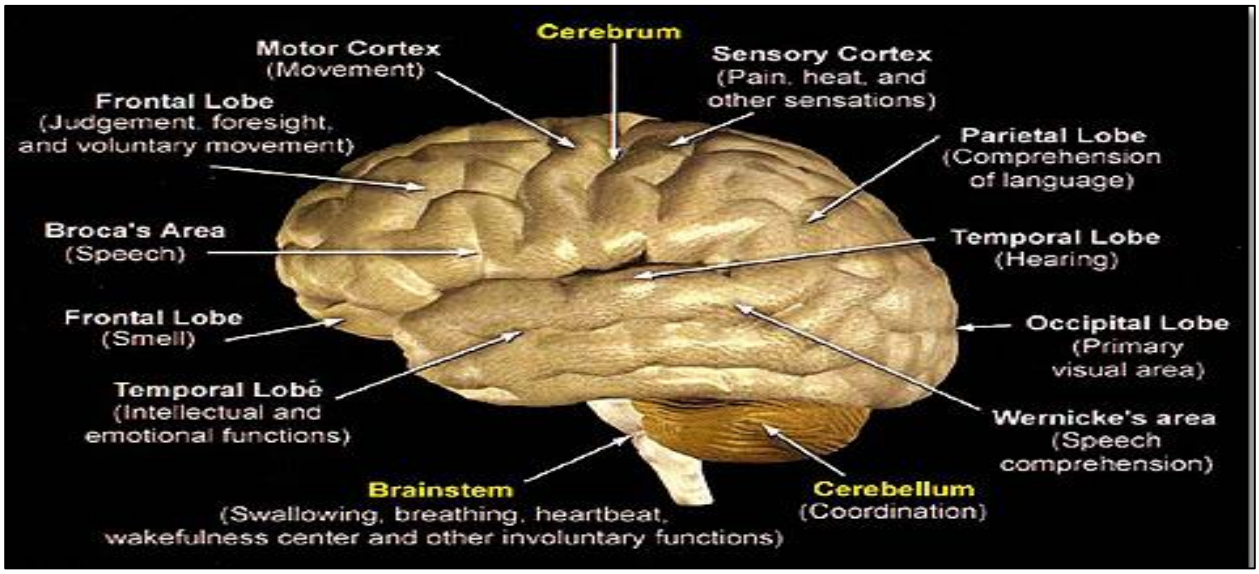

Fig. 1. Parts of human brain

3.1.2 Electroencephalography (EEG)

Electroencephalography (EEG) is the recording of the electrical activity of brain. This electrical activity is on account of firing of millions of neurons within the brain and the resultant electrical signals are picked from multiple electrodes placed on the scalp. This activity is usually recorded over a small period of time. The main application of EEG is in diagnosing epilepsy. EEG is used to diagnose various disorders of brain on account of injury or illness. EEG signals are also being used in the design of Brain-Computer Interfaces (BCI) and have applications in controlling machines through thought processes. There are observable strong correlations between changes in EEG brain wave activity and the degree of focus being produced in high performance sporting

action. EEG provides a non-invasive method of recording the electrical brain activity and therefore, it is widely being used in sports sciences research [8].

The frequency bands of interest of the human EEG waves are depicted in Fig. 2.

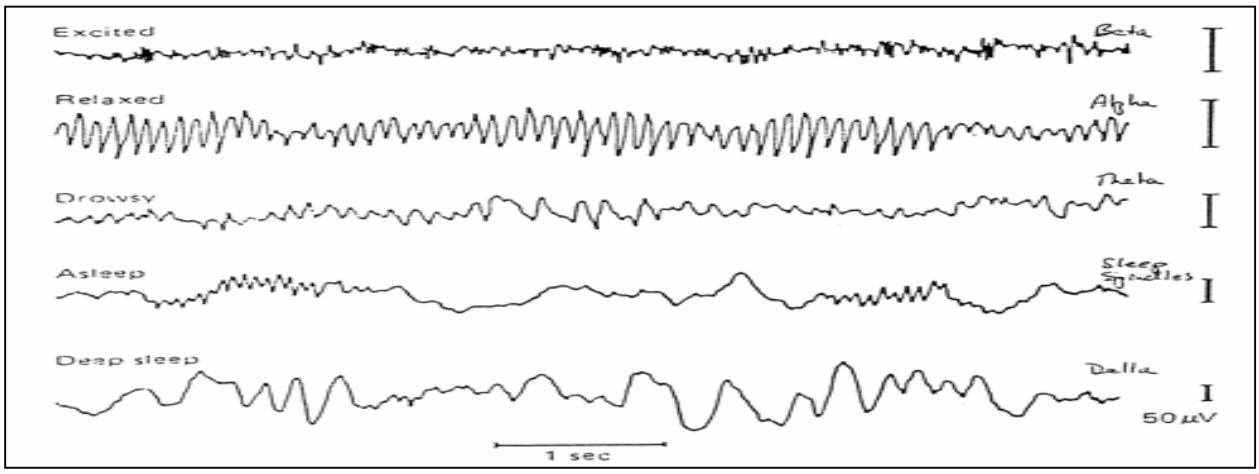

Fig. 2. Frequency bands of EEG wave

The main frequency bands of the EEG signal are explained as follows:

Delta: The delta band has frequency range of 0.1-4 Hz. These waves are the slowest waves and tend to be the highest in amplitude. This wave is normally observed in sleeping infants of the age up to one year.

Theta: The theta band has frequency range of 4-8 Hz and is classified as slow activity wave. It is perfectly normal in children up to 13 years of age and during sleep, but abnormal in awakened adults. This wave is found normally in waking adults who are in the state of deep meditation or in the relaxed and creative state of mind.

Alpha: The alpha band has frequency range of 8-13 Hz. This wave appears when closing the eyes and relaxing and disappears when opening the eyes or alerting by any mechanism like thinking or calculating. It is the major rhythm seen in normal relaxed adults.

Beta: The beta band has frequency range of 13-30 Hz. It represents fast activity. It is generally regarded as a normal rhythm. It is the dominant rhythm in persons who are alert, anxious or have their eyes open.

3.1.3 10-20 System of Electrode Placement

The 10-20 system is an internationally recognized method of electrode placement on the scalp of a person to record EEG. This method was developed to ensure standardized repetition so that a subject's EEG data could be compared over time. The subject's EEG data can also be compared with another subject's EEG data to know the factors behind their performance differences. The 10-20 system is based on the relation between the location of an electrode and the underlying area of cerebral cortex. The "10" and "20" indicate that the actual distances between adjacent electrodes are either 10% or 20% of the total front-back or right-left distance of the skull.

Every position has a letter to identify the lobe and a number to recognize the hemisphere position. The letters F, T, C, P and O mean the frontal, temporal, central, parietal and occipital lobes, respectively. Fp electrodes stand for Frontal pole electrodes. A "z" (zero) refers to an electrode placed on the midline. Even numbers (2, 4, 6, 8) cite the electrode positions on the right hemisphere, whereas odd numbers (1, 3, 5, 7) cite the electrode positions on the left hemisphere, as seen in Fig. 3. Two anatomical positions are used for the required positioning of the EEG electrodes, one of them, the nasion, which is the distinctly depressed area between the eyes just above the bridge of the nose and the second of them, the inion, which is the lowest point of the skull from the back of the head and is normally indicated by an eminent bump.

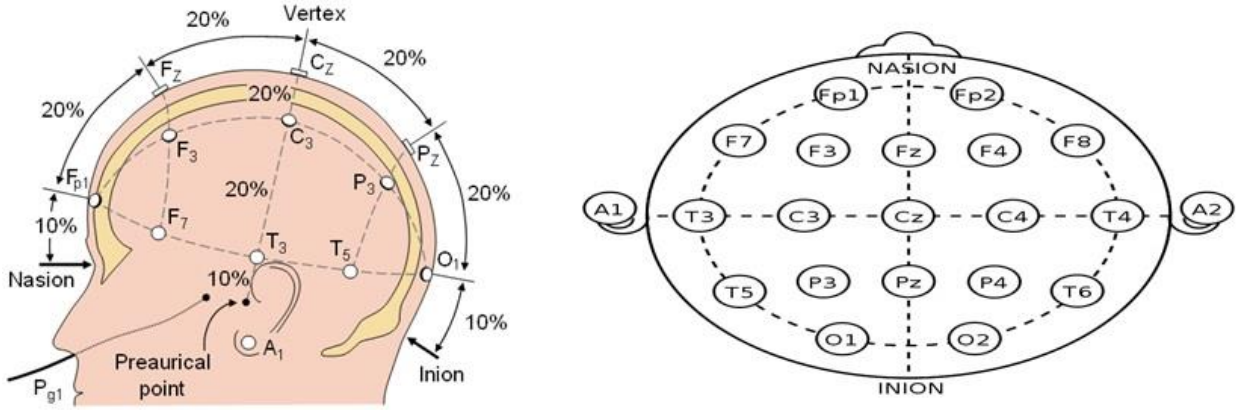

Fig. 3. 10-20 system of electrode placement

3.2 Psychological Study

In this section, the cognitive skills and the interventions considered in the present study are explained.

3.2.1 Selective Attention

Selective attention is an important cognitive skill in the sport of basketball. It means the ability to focus on a particular task only, while ignoring all other irrelevant information. Many things are occurring in the environment, but, a person should be selectively attentive to the task at hand. The ability of selective attention may vary depending upon the skill of a person. It is important to note that selective attention may be a conscious effort, but can occur subconsciously as well. In basketball, a player should be able to focus on the match strategy, while ignoring the opponents' tactics and the noisy crowd. This is very important for achieving success in the competitions.

3.2.2 Working Memory

Working memory is an important cognitive skill in the game of basketball. It means the ability to store and process multiple information for a comparatively short time. The mathematical abilities, problem solving ability, reasoning and understanding language are all thought to depend on working memory. Working memory is involved in the selection, initiation and termination of information-processing functions such as encoding, storing and retrieving data. The psychological skills are important [37] in the improvement of sports performance. Psychological training helps an athlete in understanding the reasons behind the weak performance. In basketball, a player should be able to remember the recent ball positions, teammates' and opponents' positions and the game strategy at the instant, for taking efficient decisions for the success of the team.

3.2.3 Mental Toughness

Mental Toughness is an important cognitive skill to be strengthened to achieve success in life. It is the psychological ability that enables an individual to be more consistent and better than the opponents in remaining determined, confident, focused, resilient and in control while facing tough life circumstances. Some of the key traits of mentally tough elite athletes are self-belief, focus, motivation, positive thinking and ability to handle pressure. The performance of many players declines under match-pressure. The occasional failures should be seen as opportunities to learn lessons and move forward. Young athletes should be exposed gradually to the demanding situations in training and competitions to develop mental toughness [9]. In this way, they can develop independent problem-solving and personal responsibility in a testing yet encouraging learning environment.

3.2.4 Interventions

Interventions are provided to the basketball players to enhance their cognitive skills. The experiment group players are given the interventions while the control group players are not given any interventions. In the present study, Multiple Object Tracking (MOT) task based computer game is used as an intervention for selective attention skill and Memory Trainer named computer-based game is used as an intervention for working memory skill. A power point presentation (ppt.) based on mental toughness and Progressive Muscle Relaxation (PMR) techniques are used as interventions for mental toughness skill. These interventions are explained in the following sections.

3.2.4.1 Computer-Based Games

Different cognitive tasks based computer games can be used as an intervention for the cognitive skills. Multiple Object Tracking (MOT) task develops the ability of an individual to keep attentional focus on multiple things in a dynamic environment. Perceptual-cognitive training [10] has been found to reduce age-related effects and improve tracking speed in a dynamic environment in the older individuals. In this study, MOT task based computer game is used as an intervention for enhancing the selective attention skill of the basketball players. A level of the MOT task based computer game is presented in Fig. 4.

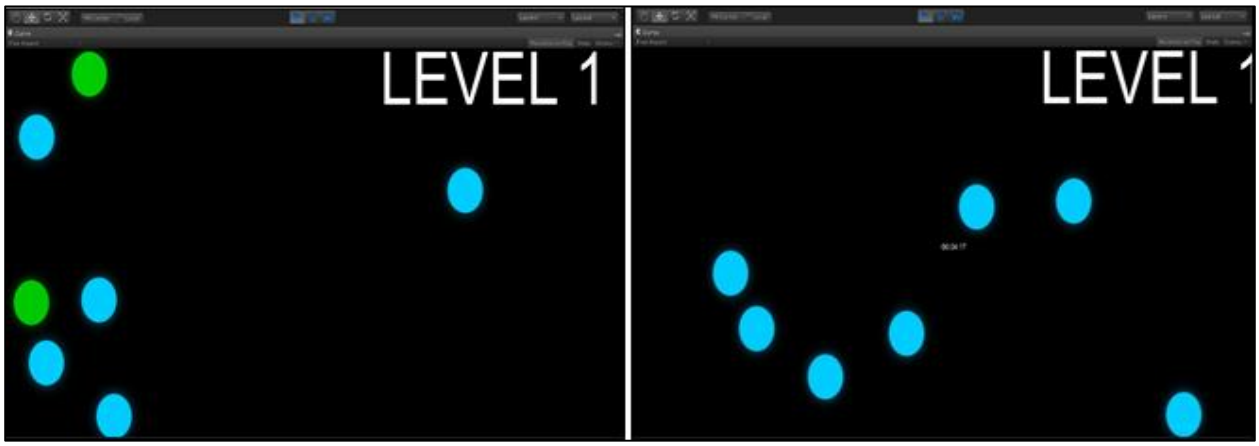

Fig. 4. MOT task based computer game

Initially, the ball(s) to be tracked in a group of balls are shown for a few seconds on the screen. Then, all the balls start moving and colliding with each other. After a brief period, all the balls stop and the player has to identify the ball(s), initially shown to be tracked. If the player correctly identifies the ball(s), next level of the game is presented on the screen, otherwise the player has to

repeat the same level of the game. MOT task based computer game is played by the experiment group players for 15 minutes each day for 8 sessions.

Similarly, Memory Trainer named computer game is used as an intervention for enhancing the working memory skill of the basketball players. Doing regular memory strengthening exercises like Memory Trainer helps strengthen our brain, but to really benefit from its effects, one should have a healthy diet, a regular exercise routine and reduce the stress as much as possible [11]. Memory Trainer game helps in improving the spatial memory, focus and concentration skills, which further can improve the problem solving skills. Memory Trainer helps us remember the people names by training our imagery mnemonic abilities. Training our memory has many benefits. It lowers the risk of Alzheimer's disease. Memory Trainer exercises keep our mind active, tone the mental muscles and keep the brain healthy. Memory Trainer game is depicted briefly in Fig. 5.

Fig. 5. Memory Trainer named computer game

Memory Trainer game consists of 20 sessions with increasing order of difficulty, with different exercises on each level. Memory Trainer's Numberz exercise helps in learning to break long strings of information into short strings of information, making it easy to remember complex information. Memory Trainer's TileFlip exercise involves showing images on tiles for a few seconds. Then, the tiles flip and different images on tiles are presented. The player has to identify the image on tile which was not shown earlier. Another exercise named Sequencer helps in improving the visualization, focus and concentration of the player. Memory Trainer game is played for 15 minutes each day by the experiment group players. This intervention is provided for 8 sessions.

3.2.4.2 Mental Toughness Skill Interventions

Most elite athletes report that psychological factors play an important role in the superior athletic performance. Mental toughness includes self-confidence, attentiveness, minimizing negative energy, increasing positive energy, maintaining motivation levels and attitude control. An investigation of the different components of mental toughness in sport has been done [12]. Research shows that mental toughness is an ongoing developing process. The relationship between emotional intelligence, competitive anxiety before a game and mental toughness has been evaluated [13] and the findings suggest that programs based on emotional intelligence are likely to benefit the athletes. Although, individual interventions are effective for mental toughness skill, various interventions should be used in conjunction with each other to get more beneficial effects. In the present study, Progressive Muscle Relaxation (PMR) techniques along with a ppt. on mental toughness, are used as interventions for the mental toughness skill.

A ppt. was prepared on mental toughness, to be provided as an intervention for experiment group players. The contents of the presentation included the definition of mental toughness, the characteristics of mentally tough players and the ways to achieve mental toughness. The ppt. motivated the players to become mentally tough and achieve success in life. This intervention is provided for 8 sessions of 5 minutes each. One of the slides of the ppt. is shown in Fig. 6.

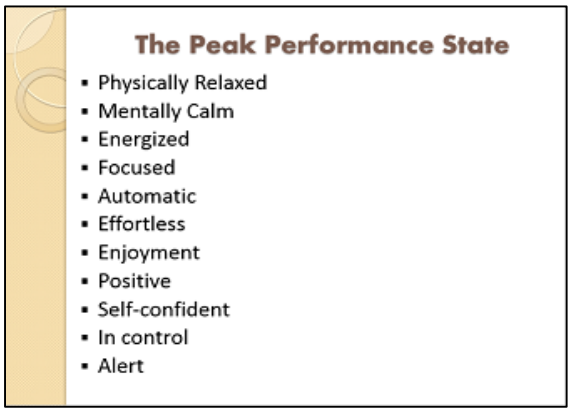

Fig. 6. A slide of ppt.

One of the body's reactions to fear and anxiety is muscle tension. This can lead to muscle ache and exhaustion. One method of reducing muscle tension, that people have found helpful, is through a technique called Progressive Muscle Relaxation (PMR). PMR technique is used to achieve deep relaxation as well as reduce stress and anxiety. In PMR exercises, the subject was instructed to tense specific muscle groups for a few seconds and then, relax the muscle groups completely. This

procedure was repeated for different muscle groups of the body. By continuous practice of this intervention, a participant learns to distinguish between tension and relaxation of muscles in the body. It is also found that the relaxation procedure is effective against a number of ailments including ulcers, insomnia and hypertension. Positive effects of relaxation interventions on depression and anxiety in older adults [14] have been found and relaxation techniques can be incorporated in the standard care of the older adults by the health care providers. In the present work, PMR intervention is practiced by the experiment group players for 8 sessions of 15 minutes each.

CHAPTER 4
METHODOLOGY

First, pre-testing of the cognitive skills is performed in the basketball players. Then, interventions are provided to the experiment group players and no interventions are provided to the control group players. Then, post-testing of the cognitive skills is done in the players. The pre and post-testing consists of physiological testing and psychological testing. The complete evaluation procedure of the cognitive skills and calculation process is explained in the subsequent sections.

4.1 Subject Selection

Twenty healthy university basketball players (Male=14, Female=6), aged 17-25 years, participated in the study. None of the players suffered from mental illness, diseases and all of them were injury free. A signed consent form was obtained from the subjects in accordance with the instructions of the University Ethics Committee, before conducting the study.

4.2 Data Collection

The 20 university basketball players are selected randomly. Out of the total 20 players, 10 are kept in experiment group and 10 are kept in control group, depending on the inclination of the players to join the interventions' sessions. The experiment group subjects are provided the interventions to improve their cognitive skills, whereas, no interventions are given to the control group subjects. In the pre-testing and post-testing, physiological as well as the psychological assessment of all the players is performed. In the present research work, two sets of pre and post-test data of the same 20 players have been acquired over a period of time. The first time, the entire procedure of pre-testing, interventions sessions and the post-testing is completed in two months. After a gap of two months, the same procedure is repeated i.e. the pre-testing, interventions sessions and the post-testing is completed again in two months.

4.3 Testing Measures

4.3.1 Physiological Testing

Tests designed to measure a specific physiological function, having an effect on the human performance are known as physiological tests. The physiological measurement of electroencephalogram (EEG) is made with Emotiv EPOC headset (Emotiv, Inc., California, USA), a 14 channel device measuring EEG at the locations AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4, having a sampling rate of 128 samples per second. The Emotiv EPOC is a high

resolution, wireless portable device designed for research applications. The various electrode positions of the Emotiv EPOC headset are represented in Fig. 7.

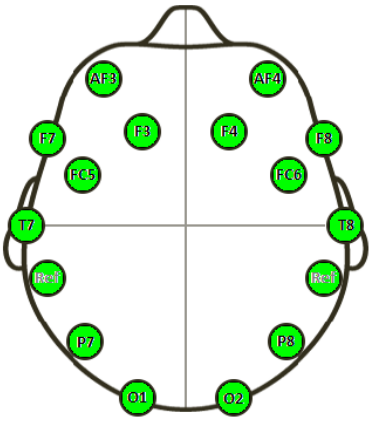

Fig. 7. Emotiv EPOC electrodes position

The colors of the electrodes' positions signify the quality of contact of the electrodes with the scalp positions. The various colors meaning is explained as follows.

Black color: No signal

Red color: Bad signal

Orange color: Poor signal

Yellow color: Fair signal

Green color: Good signal

The contact quality of the electrodes should be good to obtain reliable physiological data. In this study, each player was asked to sit in front of a laptop and the baseline reading of each player was taken, one minute with eyes closed condition and one minute with eyes open condition. Then, the player was given the instructions to play the MOT task based game on the laptop for a duration of 15 minutes by attentively focusing on the multiple balls. While the player played the game, simultaneously the player's EEG was acquired on another laptop kept nearby. In this way, EEG measurement for the selective attention skill is done. The selective attention is calculated for the channels AF3 and AF4 of the headset. One of the basketball player's EEG data being acquired is shown in Fig. 8.

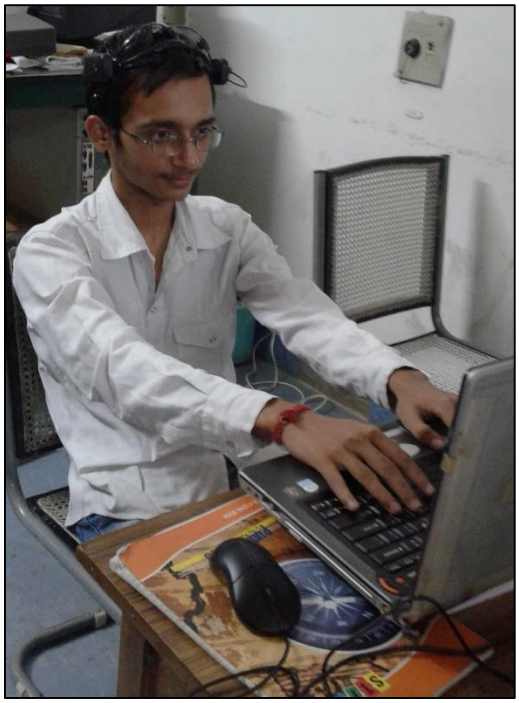

Fig. 8. EEG data acquisition of a player

In the similar manner, after completing the physiological measurement for selective attention skill, the player was given the instructions to play Memory Trainer named game on the laptop for a period of 15 minutes. Again, the player's EEG was acquired simultaneously on another laptop placed nearby, while playing the game. In this manner, EEG measurement for the working memory skill is made. The working memory is calculated for the locations F3 and F4 of the headset. The relationship between working memory and frontal theta activity has already been considered from stress perspective [15]. The information about frontal theta activity can be useful for the treatment of stress disorders and performance monitoring in challenging working environments. The differences in the frontal midline theta power have been studied during the aiming period between successful and unsuccessful basketball free throws by skilled basketball players [16]. It is suggested in the study that a constant amount of attention to the task before motor execution may help in better athletic performance.

4.3.2 Psychological Testing

A psychological test is an objective and standardized measure of an individual's performance on various tasks designed for the purpose of testing. A score on a well-constructed test is believed to

reflect the psychological factors such as cognitive ability, aptitude, emotional functioning and personality.

4.3.2.1 Mental Toughness Questionnaire

Mental Toughness is an important cognitive skill to be enhanced. In a study [18], the relationship between mental toughness and college basketball performance has been investigated considering the variables of gender and starting status. This information can be useful for the practitioners working with the teams. In the present study, Mental Toughness Questionnaire designed by Dr. Alan Goldberg [17] is used for evaluating the mental toughness level of the basketball players. The questionnaire is provided in the paper format to the players. The questionnaire consists of a total of 30 questions, measuring various parameters forming the overall mental toughness, like reboundability, ability to handle pressure, concentration, confidence level and motivation. The response of one of the players in Mental Toughness Questionnaire is presented in Fig. 9.

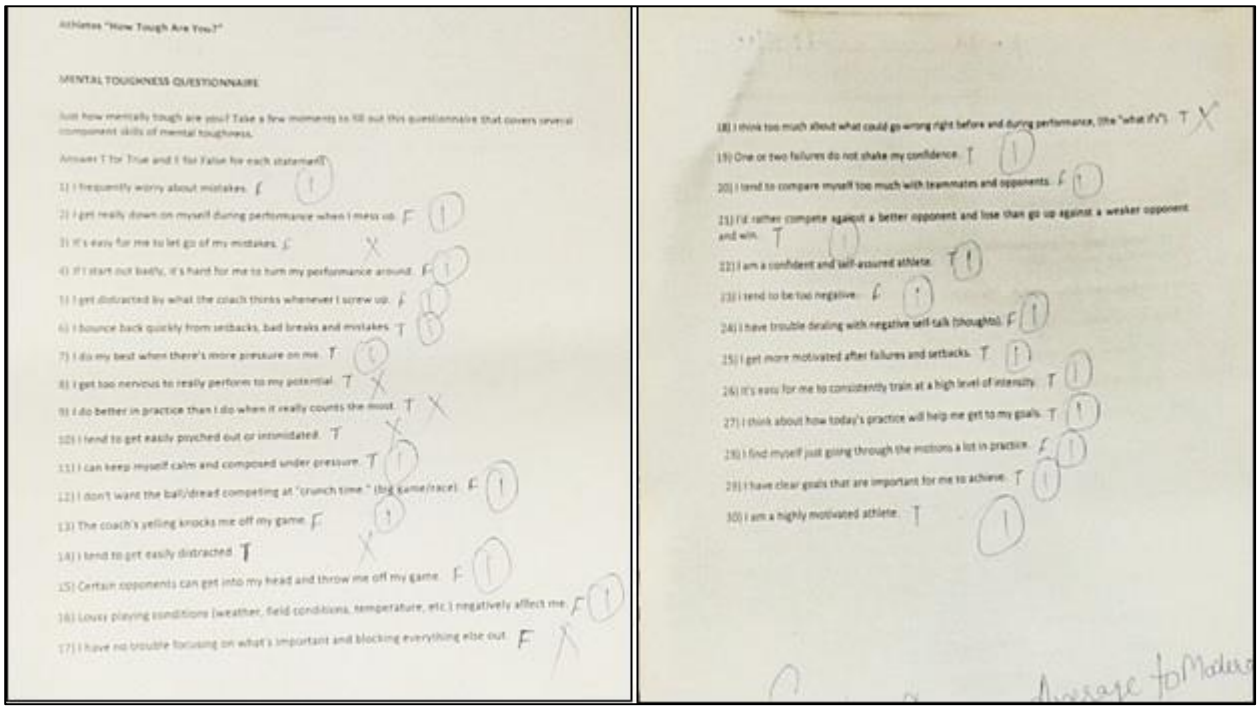

Fig. 9. Response of a player on Mental Toughness Questionnaire

The players were asked to answer the questions as either true or false. According to the scoring key, 1 point was assigned for the correct response and 0 point was assigned for the incorrect response. At last, all the points were summed to determine the overall score for mental toughness. Higher overall scores showed good mental toughness, whereas, medium overall scores showed

average to moderate mental toughness. Lower overall scores revealed weak mental toughness and revealed the need for the player to provide more time for mental toughness training.

4.3.2.2 d2 Test of Attention

The d2 Test of Attention is a neuropsychological measure of selective attention and concentration. It is suitable for the measurement of visual attention in people of almost all ages. In this work, the d2 Test of Attention is performed to measure the selective attention skill of the basketball players. It is performed in the present study in paper format. The test comprises of 14 lines with 47 characters in each line. Each character consists of a letter “d” or “p” marked with one, two, three or four small dashes. The player is instructed to go through the lines, moving from left to right in each line and cross out all the occurrences of the letter “d” with two dashes, while ignoring all other characters. The time required to complete the test is 5 minutes. The response of one of the subjects is shown in Fig. 10.

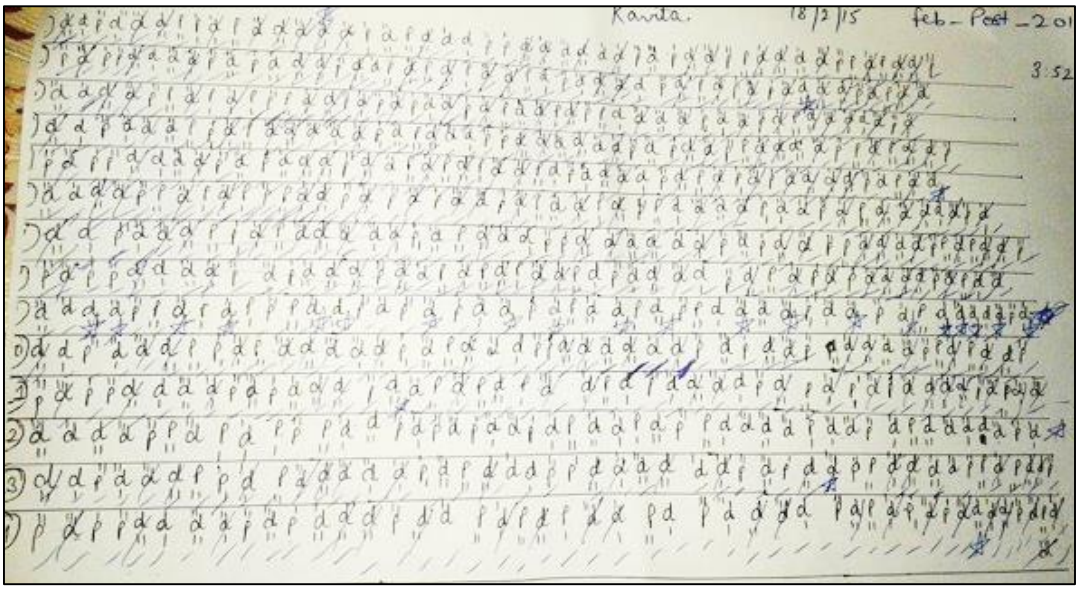

Fig. 10. Response of a player on d2 Test of Attention

The high number of correctly crossed out characters shows good selective attention skill, whereas, incorrectly crossed out characters give rise to errors in the performance. The higher the errors made, more time is needed to undergo the intervention designed for this cognitive skill.

4.3.2.3 Trail Making Test Part B

The Trail Making Test (TMT) is a commonly used neuropsychological measure to assess the cognitive processing speed and executive functioning. The test has two parts, A and B. The cognitive mechanisms underlying the direct and derived scores of the TMT Part A and B have

been examined [19]. It was found that TMT Part B reviews mainly working memory. In the present study, only the TMT Part B is used, to measure the working memory skill of the basketball players. The TMT Part B is provided in the paper format. The test consists of 25 circles distributed on a sheet of paper. The circles include numbers (1-13) and letters (A-L). The player had to connect the circles in an ascending order, by alternating between the numbers and letters like 1-A-2-B-3-C, etc. The player was asked to connect the circles quickly without lifting the pen or pencil from the sheet of paper. The amount of time taken to complete the test represented the direct score for the test. The time required to complete the test is 3 minutes. Lesser the time taken by a player, the stronger the working memory skill. If more time is taken and errors are made while connecting the circles, there is a need to strengthen this skill by regularly participating in the intervention sessions designed for the skill. The response of one of the players in TMT Part B is represented in Fig. 11.

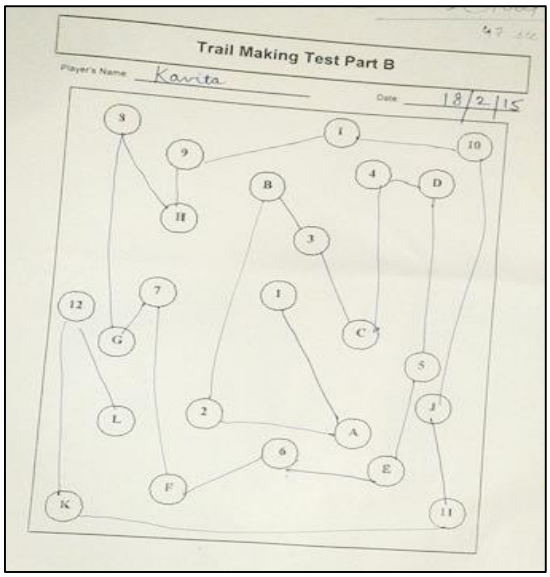

Fig. 11. Response of a player on TMT Part B

4.4 EEG Data Analysis

After the physiological testing of the cognitive skills of the basketball players, the acquired EEG data has to be examined. EEG data analysis is carried out in MATLAB software along with the EEGLAB toolbox [20]. MATLAB stands for Matrix Laboratory. MATLAB is a high-level language and provides an interactive user environment. Numeric calculation, data assessment and visualization, programming code development and designing of custom applications are some of the capabilities of this software. A basic MATLAB interface is shown in Fig. 12. The cerebral data of interest is often contaminated with the artifacts. Some of the artifacts can be due to the muscle

movements, eye movements, eye blinks, electrode movement and electrical noise. In the present work, the EEGLAB toolbox is used for artifacts and noise removal using the Independent Component Analysis (ICA) method. A basic window in EEGLAB is shown in Fig. 13. ICA method is commonly used to separate the mixed signal sources and remove the artifacts and line noise [21]. ICA method can be used in the areas of audio processing, image processing, telecommunications and biomedical signal processing.

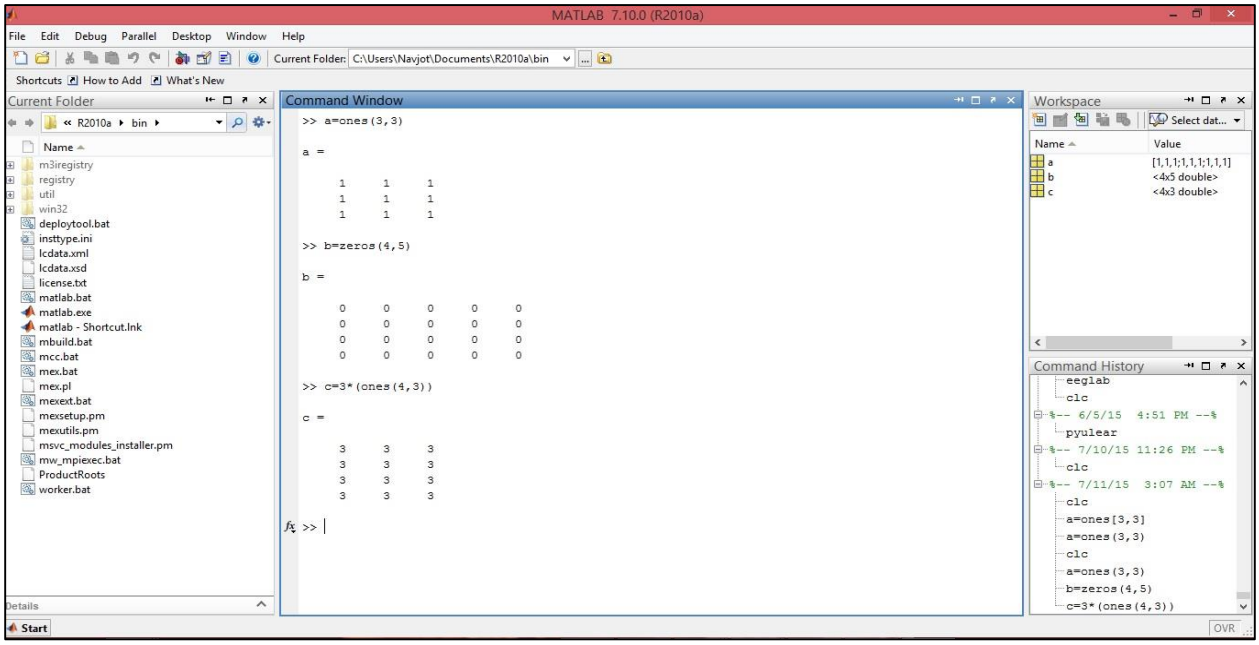

Fig. 12. Basic MATLAB interface

In the first step, the acquired EEG data is pre-processed. The acquired EEG data of one of the participants is shown in Fig. 14. The EEG data is filtered using a Windowed sinc FIR bandpass filter, with cutoff frequencies in the range 0.1-40 Hz. Hamming Window is applied to the data. The ICA algorithm is then applied to the filtered data over the 14 channels. After the application of algorithm, the artifact components are rejected and removed to obtain the clean EEG data. The artifacts rejection in EEGLAB is shown in Fig. 15. The EEG data before and after artifact rejection is depicted in Fig. 16.

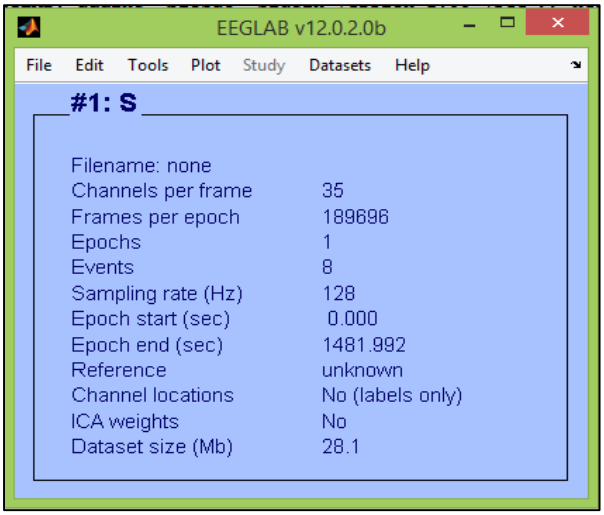

Fig. 13. Basic EEGLAB window

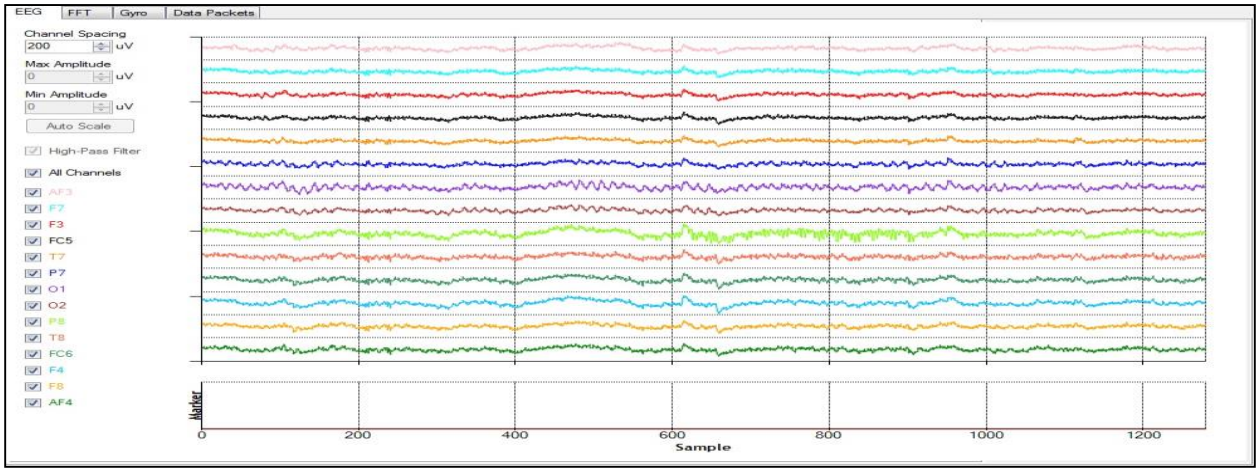

Fig. 14. Acquired EEG data of a player

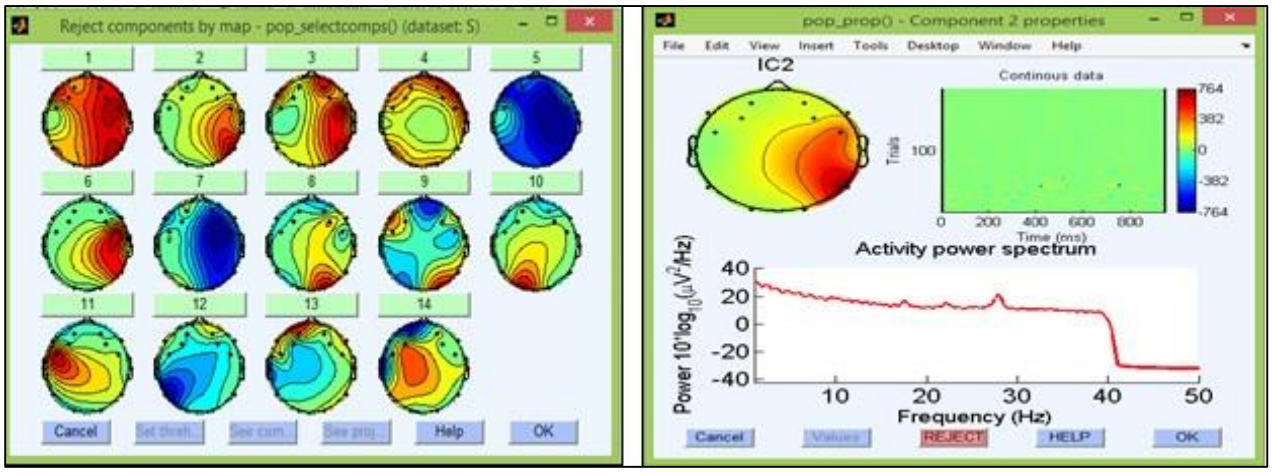

Fig. 15. Artifacts rejection in EEGLAB

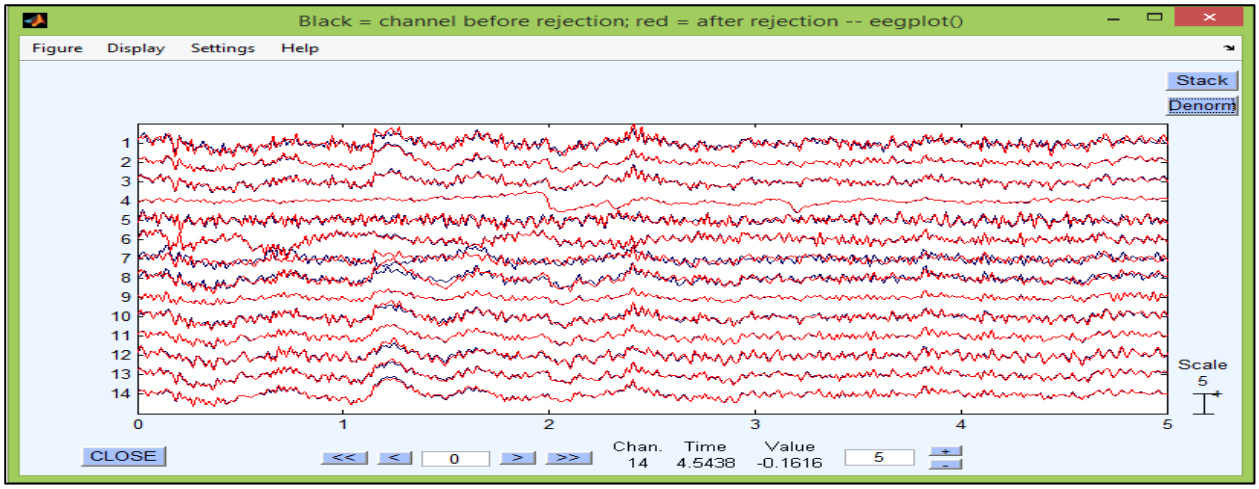

Fig. 16. EEG data before and after artifacts rejection

Secondly, features have to be extracted from the EEG data. Hence, an interval of 30 seconds artifact-free EEG data is extracted in MATLAB and wavelet decomposition is applied to it. Wavelets are mathematical functions which can be used to study frequency sub-bands and analyze the signals with discontinuities and sharp spikes. Wavelet decomposition is applied to the fifth level using db4 wavelet (Daubechies wavelet family), to obtain the delta (0.1-4 Hz), theta (4-8 Hz), alpha (8-13 Hz) and beta (13-30 Hz) frequency bands. Then, frequency domain parameters such as Energy, Shannon Entropy and Power Spectral Density (PSD) are calculated in the aforesaid four frequency bands, for AF3, AF4 channels for selective attention skill and F3, F4 channels for working memory skill. Entropy is a measure of disorder of the signal. PSD represents the distribution of signal power over the range of frequency. The frequency domain parameters calculated for the different channels in the four EEG frequency bands are shown in Fig. 17.

e	Channel AF3 SELECTIVE ATTENTION							
	DELTA		THETA		ALPHA		BETA	
	PRE	POST	PRE	POST	PRE	POST	PRE	POST
ENERGY	56.2472	52.429	18.4151	15.0323	10.8241	6.3852	6.661	7.9563
ENTROPY	-1.58E+06	-6.70E+06	-4.69E+05	-1.68E+06	-2.65E+05	-6.23E+05	-1.48E+05	-8.17E+05
MAX PSD	3.21E+03	6.68E+03	6.76E+02	1.97E+03	2.69E+02	4.88E+02	8.63E+01	326.0404

Channel AF4 SELECTIVE ATTENTION							
DELTA		THETA		ALPHA		BETA	
PRE	POST	PRE	POST	PRE	POST	PRE	POST
56.9568	50.5197	20.5794	15.2185	12.4355	6.0378	5.1767	8.4885
-1.39E+06	-1.92E+07	-5.10E+05	-5.21E+06	-3.11E+05	-1.84E+06	-1.05E+05	-2.74E+06
4.56E+03	1.83E+04	7.17E+02	5.21E+03	3.00E+02	1.17E+03	6.54E+01	9.22E+02

Channel F3 WORKING MEMORY							
DELTA		THETA		ALPHA		BETA	
PRE	POST	PRE	POST	PRE	POST	PRE	POST
47.0322	29.4958	15.1043	6.4156	14.8931	7.7732	8.1145	12.1595
-3.35E+05	-3.23E+05	-1.05E+05	-4.81E+04	-1.10E+05	-7.17E+04	-4.09E+04	-1.18E+05
6.59E+02	8.67E+02	228.0551	1.08E+02	112.9421	78.2853	30.528	71.3852

Channel F4 WORKING MEMORY							
DELTA		THETA		ALPHA		BETA	
PRE	POST	PRE	POST	PRE	POST	PRE	POST
49.054	23.8005	18.0941	7.064	14.9275	8.47	7.2644	12.8282
-3.59E+05	-2.33E+06	-1.40E+05	-4.69E+05	-1.23E+05	-6.53E+05	-3.71E+04	-1.02E+06
7.15E+02	3.34E+03	267.4382	6.48E+02	119.472	474.7345	29.3565	416.117

Fig. 17. Frequency domain parameters calculated in four EEG frequency bands for different channels

The Energy and Shannon Entropy are calculated using wavelet decomposition, in the four EEG frequency bands. The PSD is calculated using Yule-Walker autoregressive method. The maximum

value of PSD in each of the four frequency bands is calculated, which represent the four spectral band powers respectively.

In the third step, delta, theta, alpha and beta band powers are log-transformed, to obtain explainable results. The theta/beta band power ratio is calculated as a measure of selective attention for AF3 and AF4 channels. The theta band power is calculated as a measure of working memory for F3 and F4 channels. The aforesaid results are calculated for both pre-testing and post-testing data. It has been shown that theta oscillations produced in the frontal brain regions [22], are associated with memory maintenance. It has been studied that the brain activity in the theta frequency band is related to working memory functions.

4.5 Statistical Analysis

The statistical analysis is performed to validate the psycho-physiological results. The analysis is done using SPSS i.e. Statistical Package for the Social Science. SPSS can perform highly complex calculations easily with simple instructions. It is designed for evaluation of data. SPSS can take any type of data as input and produces charts and tabulated reports. Some of the applications of SPSS are in data examination, descriptive statistics, reliability tests, correlation analysis, regression analysis and data transformation. Correlation analysis is generally performed between outcome measurements in longitudinal studies [23]. The correlation analysis in SPSS is presented in Fig. 18.

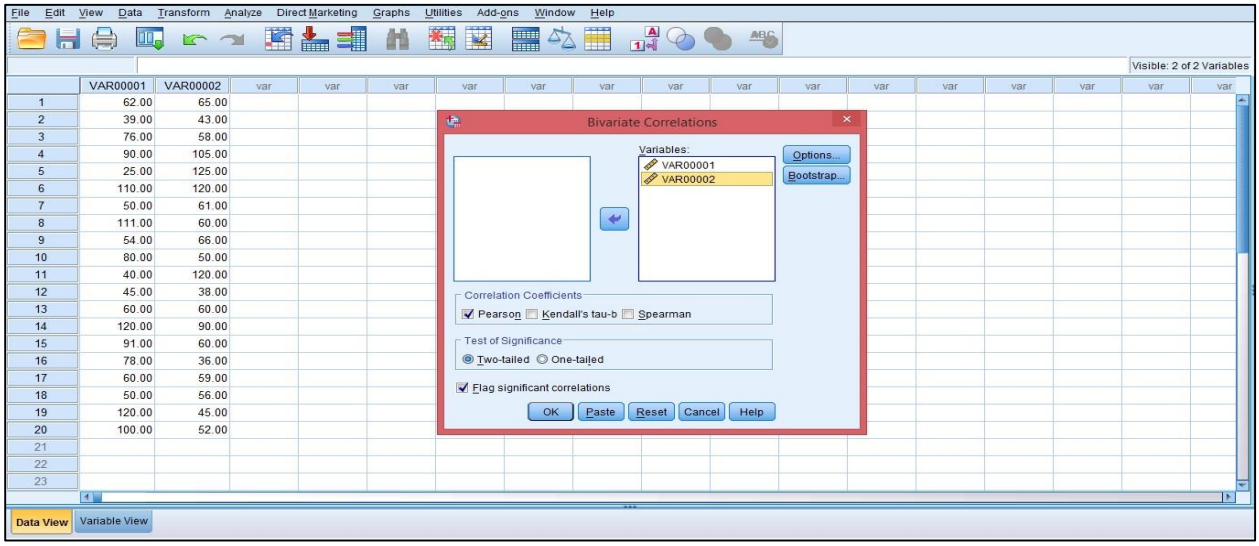

Fig. 18. Correlation analysis in SPSS

When measurements are repeated on the same persons over a period of time, it is expected that these measurements may be correlated. Therefore, correlation must be taken into consideration for effective parameter estimation and efficient study design.

In this study, the test-retest reliability between pre-test and post-test results has been calculated using Pearson correlation coefficient, for the two sets of psycho-physiological data acquired. The test-retest reliability of a test measures the stability of the results of the test over time. Pearson correlation shows the linear association between the two sets of data. The values of the coefficient can be between -1 and 1. The value of 1 signifies perfect positive correlation, value of -1 signifies perfect negative correlation and value of 0 signifies no correlation. The internal consistency of a psychological construct is usually measured with Cronbach's alpha coefficient. It measures the cohesiveness of all the items or a set of items in measuring a single aspect representing the outcome. Here, Cronbach's alpha coefficient has been calculated for checking the internal consistency of the overall mental toughness score of the Mental Toughness Questionnaire.

CHAPTER 5
RESULTS AND DISCUSSION

5.1 Psychophysiological Results

The psycho-physiological results for the two sets of data acquired over the period of the study are presented in the subsequent sections.

5.1.1 Results - 1st Set of Data

All the results are shown for the experiment and control group basketball players. The following Fig. 19 and 20 show the pre and post physiological test results for the selective attention and working memory cognitive skills respectively. The theta and beta band powers are calculated in units of power per radians per sample. Afterwards, the theta/beta power ratio values are individually calculated for the 20 players.

Fig. 21 shows the pre and post psychological test results for the d2 Test of Attention, related to selective attention and Trail Making Test Part B, related to working memory. In the d2 Test of Attention, the errors (in percentage) made by the 20 players while completing the test in the required time are indicated. Total errors comprise of the errors made as a result of crossing the wrong letters and errors made as a result of omission of the crossing of desired characters. A player may cross the wrong character due to less attentiveness in the test. Similarly, if the player misses out crossing the targeted character, it means that the player is unable to focus during the duration of the test. The player's problems in focusing at the task at hand should be understood by the coaches and a solution should be provided to them.

The formula to calculate Error % is:

Error % = (Total errors made / Total number of items processed) * 100

In the above formula, total number of items processed means the total number of characters crossed out, correctly or incorrectly, by the subject in the requisite time. If a player is unable to complete the test in the set time, the incomplete test is evaluated, but no extra time is allotted. The values of error % of the experiment and control group players reveal the effectiveness of the interventions used for selective attention skill.

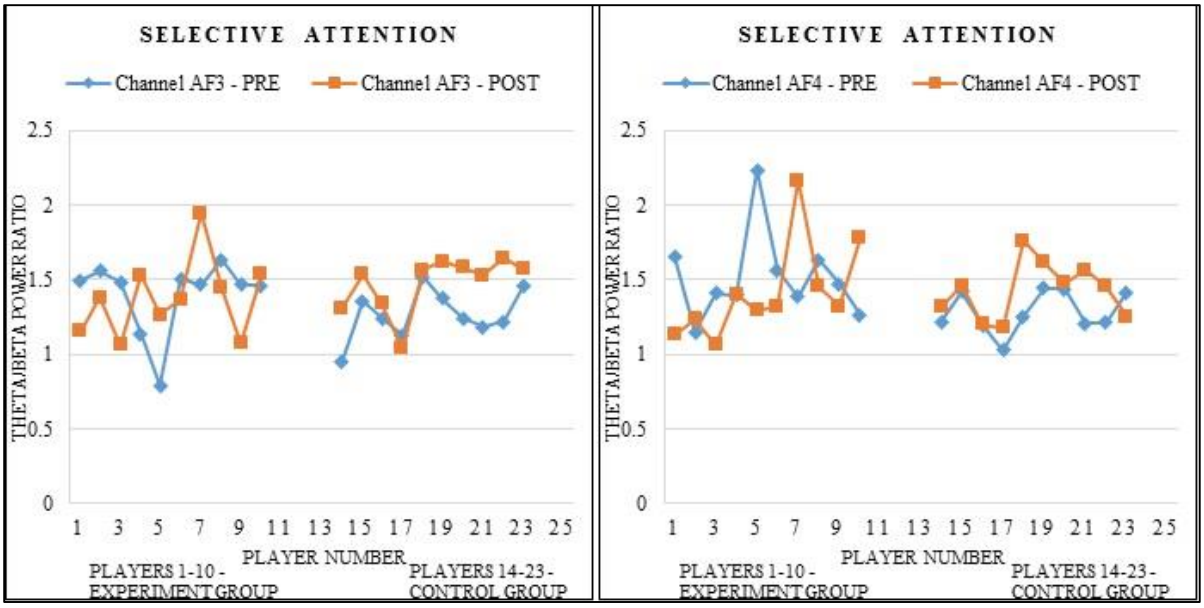

Fig. 19. Theta/Beta power ratio values of the 20 players at channels AF3 and AF4

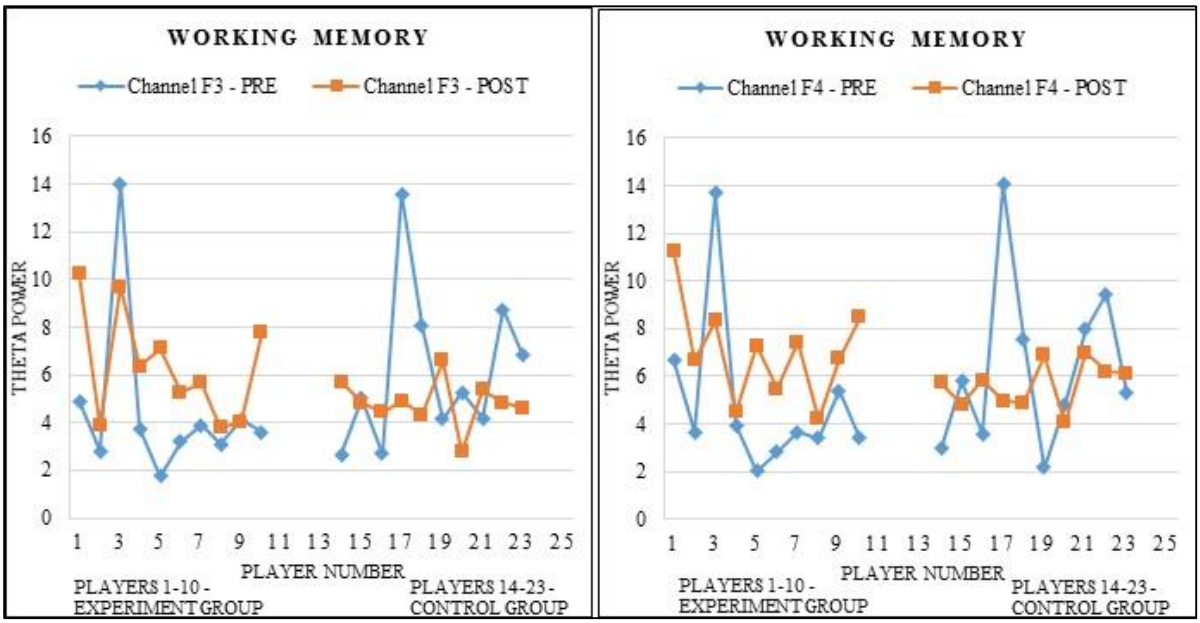

Fig. 20. Theta power (power per radians per sample) values at channels F3 and F4

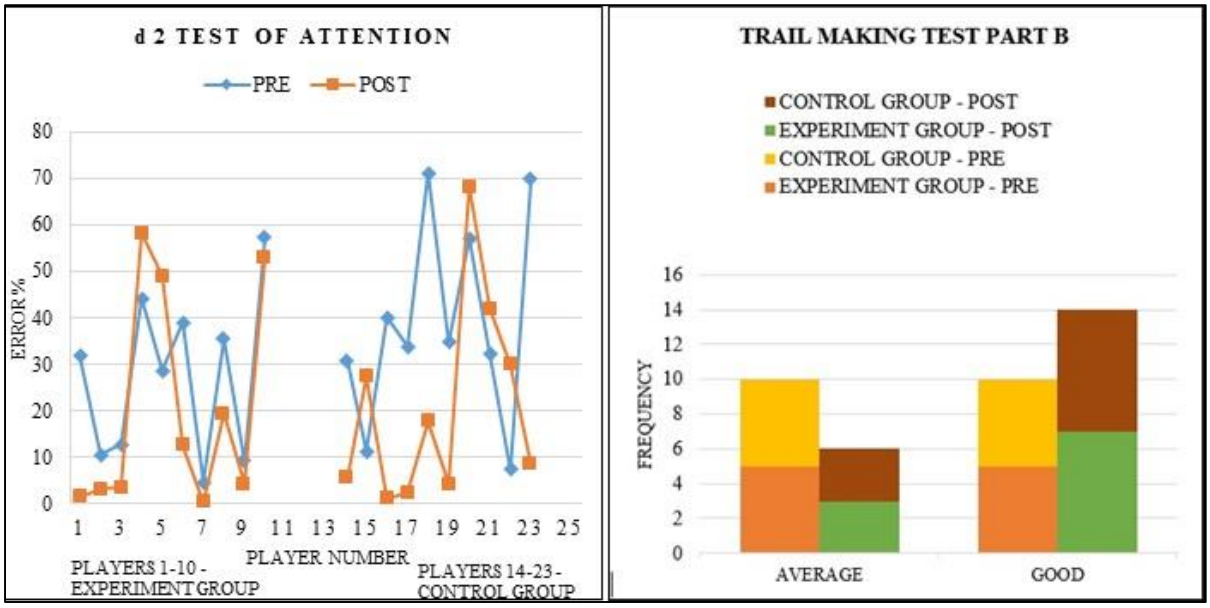

Fig. 21. d2 Test of Attention and TMT Part B results

In the Trail Making Test Part B, the players have to complete the test in 3 minutes. The players are required to finish the test as early as possible. If a player is unable to complete the test in the said time, no extra time is given. The frequency in TMT Part B results represents the number of players having average and good working memory skills. None of the players demonstrated weak working memory skills. If the player connects the circles incorrectly, it is considered in the evaluation of the test. Many players were able to complete the test quickly.

Fig. 22 depicts the Mental Toughness Questionnaire results. The frequency defines the number of players having weak, average to moderate and good mental toughness scores. The players answered the questions based on the understanding of their game. The pre and post-test results for the experiment and control group players are presented. Mental toughness is an important skill to enhance in order to achieve a successful and healthy life. It comprises of a number of components and a player's psychological needs should be considered before providing interventions related with mental toughness.

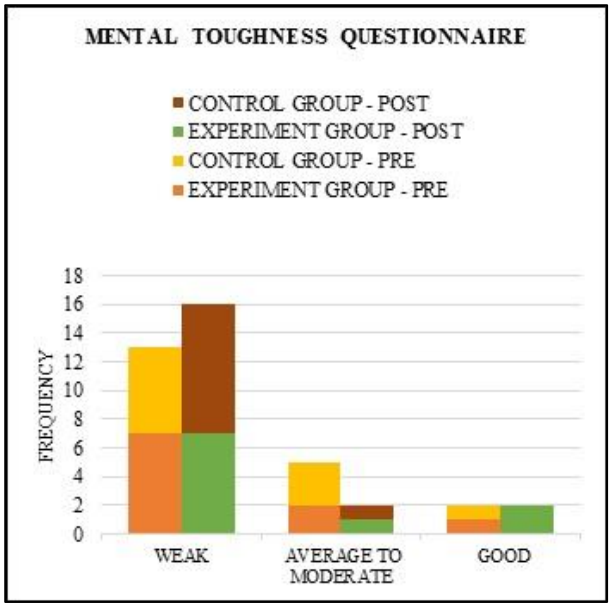

Fig. 22. Mental Toughness Questionnaire results

The aforementioned psycho-physiological results in the graphical form for the 1st set of data are depicted numerically in the tabular form as follows.

Table 1
Selective attention, Channel AF3 – Theta/Beta power ratio values

	PRE	POST
Player 1^{E}	1.4975	1.1590
Player 2^{E}	1.5627	1.3822
Player 3^{E}	1.4838	1.0616
Player 4^{E}	1.1380	1.5311
Player 5^{E}	0.7916	1.2639
Player 6^{E}	1.5096	1.3720
Player 7^{E}	1.4667	1.9461
Player 8^{E}	1.6338	1.4432
Player 9^{E}	1.4702	1.0765
Player 10^{E}	1.4653	1.5369
Player 11^{C}	0.9541	1.3102
Player 12^{C}	1.3586	1.5377
Player 13^{C}	1.2435	1.3403
Player 14^{C}	1.1256	1.0424
Player 15^{C}	1.5176	1.5651
Player 16^{C}	1.3778	1.6234
Player 17^{C}	1.2416	1.5814
Player 18^{C}	1.1869	1.5341
Player 19^{C}	1.2184	1.6462
Player 20^{C}	1.4565	1.5698

Note: ^{E} = Experiment Group, ^{C} = Control Group

Table 2
Selective attention, Channel AF4 – Theta/Beta power ratio values

	PRE	POST
Player 1^{E}	1.6612	1.1344
Player 2^{E}	1.1521	1.2351
Player 3^{E}	1.4105	1.0618
Player 4^{E}	1.4014	1.4060
Player 5^{E}	2.2384	1.2962
Player 6^{E}	1.5657	1.3256
Player 7^{E}	1.3860	2.1689
Player 8^{E}	1.6343	1.4549
Player 9^{E}	1.4760	1.3261
Player 10^{E}	1.2678	1.7773
Player 11^{C}	1.2188	1.3188
Player 12^{C}	1.4224	1.4640
Player 13^{C}	1.1947	1.2042
Player 14^{C}	1.0271	1.1794
Player 15^{C}	1.2523	1.7602
Player 16^{C}	1.4462	1.6180
Player 17^{C}	1.4392	1.4806
Player 18^{C}	1.2080	1.5686
Player 19^{C}	1.2159	1.4556
Player 20^{C}	1.4155	1.2534

Note: ^{E} = Experiment Group, ^{C} = Control Group

Table 3
Working memory, Channel F3 – Theta power (power per radians per sample) values

	PRE	POST
Player 1[E]	4.9090	10.2110
Player 2[E]	2.7980	3.9012
Player 3[E]	14.0386	9.6740
Player 4[E]	3.7328	6.3424
Player 5[E]	1.7422	7.1066
Player 6[E]	3.2013	5.2611
Player 7[E]	3.8836	5.6802
Player 8[E]	3.0784	3.7815
Player 9[E]	4.1255	4.0500
Player 10[E]	3.6121	7.7493
Player 11[C]	2.6497	5.7011
Player 12[C]	5.0178	4.8365
Player 13[C]	2.6810	4.4272
Player 14[C]	13.5722	4.9053
Player 15[C]	8.0488	4.3281
Player 16[C]	4.1271	6.6080
Player 17[C]	5.2679	2.7850
Player 18[C]	4.1701	5.3602
Player 19[C]	8.7258	4.8385
Player 20[C]	6.8669	4.6151

Note: [E] = Experiment Group, [C] = Control Group

Table 4
Working memory, Channel F4 – Theta power (power per radians per sample) values

	PRE	POST
Player 1[E]	6.6530	11.2186
Player 2[E]	3.6518	6.6773
Player 3[E]	13.6967	8.3284
Player 4[E]	3.9421	4.4957
Player 5[E]	2.0281	7.2654
Player 6[E]	2.8418	5.4665
Player 7[E]	3.6481	7.4325
Player 8[E]	3.4196	4.2036
Player 9[E]	5.3845	6.7310
Player 10[E]	3.3898	8.4764
Player 11[C]	2.9828	5.7259
Player 12[C]	5.8116	4.8257
Player 13[C]	3.5751	5.8201
Player 14[C]	14.0701	4.9488
Player 15[C]	7.5704	4.9053
Player 16[C]	2.1668	6.8987
Player 17[C]	4.8203	4.0758
Player 18[C]	7.9759	6.9847
Player 19[C]	9.4494	6.2118
Player 20[C]	5.2983	6.1203

Note: [E] = Experiment Group, [C] = Control Group

Table 5
Error % values of the 20 players in completing the d2 Test of Attention

	PRE	POST
Player 1[E]	31.82	1.36
Player 2[E]	10.41	3.08
Player 3[E]	12.64	3.44
Player 4[E]	44.14	58.20
Player 5[E]	28.67	49
Player 6[E]	38.89	12.45
Player 7[E]	4.59	0.34
Player 8[E]	35.45	19.43
Player 9[E]	9.12	4.14
Player 10[E]	57.51	53.06
Player 11[C]	30.83	5.55
Player 12[C]	11.28	27.31
Player 13[C]	40	1.01
Player 14[C]	33.76	2.40
Player 15[C]	71.19	17.71
Player 16[C]	34.62	4.21
Player 17[C]	57.07	68.18
Player 18[C]	32.17	41.98
Player 19[C]	7.42	29.83
Player 20[C]	69.83	8.42

Note: [E] = Experiment Group, [C] = Control Group

Table 6
Time taken to complete the Trail Making Test Part B in seconds

	PRE	POST
Player 1[E]	39	43
Player 2[E]	90	105
Player 3[E]	25	125
Player 4[E]	110	120
Player 5[E]	111	60
Player 6[E]	54	66
Player 7[E]	80	50
Player 8[E]	45	38
Player 9[E]	78	36
Player 10[E]	50	56
Player 11[C]	62	65
Player 12[C]	76	58
Player 13[C]	50	61
Player 14[C]	40	120
Player 15[C]	60	60
Player 16[C]	120	90
Player 17[C]	91	60
Player 18[C]	60	59
Player 19[C]	120	45
Player 20[C]	100	52

Note: [E] = Experiment Group, [C] = Control Group

Table 7
Overall scores (out of 30) of Mental Toughness Questionnaire

	PRE	POST
Player 1^{E}	24	26
Player 2^{E}	17	21
Player 3^{E}	15	15
Player 4^{E}	21	21
Player 5^{E}	23	12
Player 6^{E}	17	13
Player 7^{E}	18	15
Player 8^{E}	28	28
Player 9^{E}	13	23
Player 10^{E}	19	17
Player 11^{C}	3	21
Player 12^{C}	23	22
Player 13^{C}	17	9
Player 14^{C}	24	19
Player 15^{C}	15	20
Player 16^{C}	21	20
Player 17^{C}	26	23
Player 18^{C}	25	18
Player 19^{C}	20	15
Player 20^{C}	14	16

Note: ^{E} = Experiment Group, ^{C} = Control Group

5.1.2 Results - 2nd Set of Data

All the results are shown for the experiment and control group basketball players. For the 2nd set of data acquired, the following Fig. 23 and 24 show the pre and post physiological test results for the selective attention and working memory cognitive skills respectively. The theta and beta band powers are calculated in units of power per radians per sample. Afterwards, the theta/beta power ratio values are independently evaluated for the 20 players.

Fig. 25 shows the pre and post psychological test results for the d2 Test of Attention, related to selective attention and Trail Making Test Part B, related to working memory. In the d2 Test of Attention, the errors (in percentage) made by the 20 players while completing the test in the required time are indicated. Total errors comprise of the errors made as a result of crossing the wrong letters and errors made as a result of omission of the crossing of desired characters. A player may cross the wrong character due to less attentiveness in the test. Similarly, if the player misses out crossing the targeted character, it means that the player is unable to focus during the duration of the test. The player's problems in focusing at the task at hand should be understood by the coaches and a solution should be provided to them.

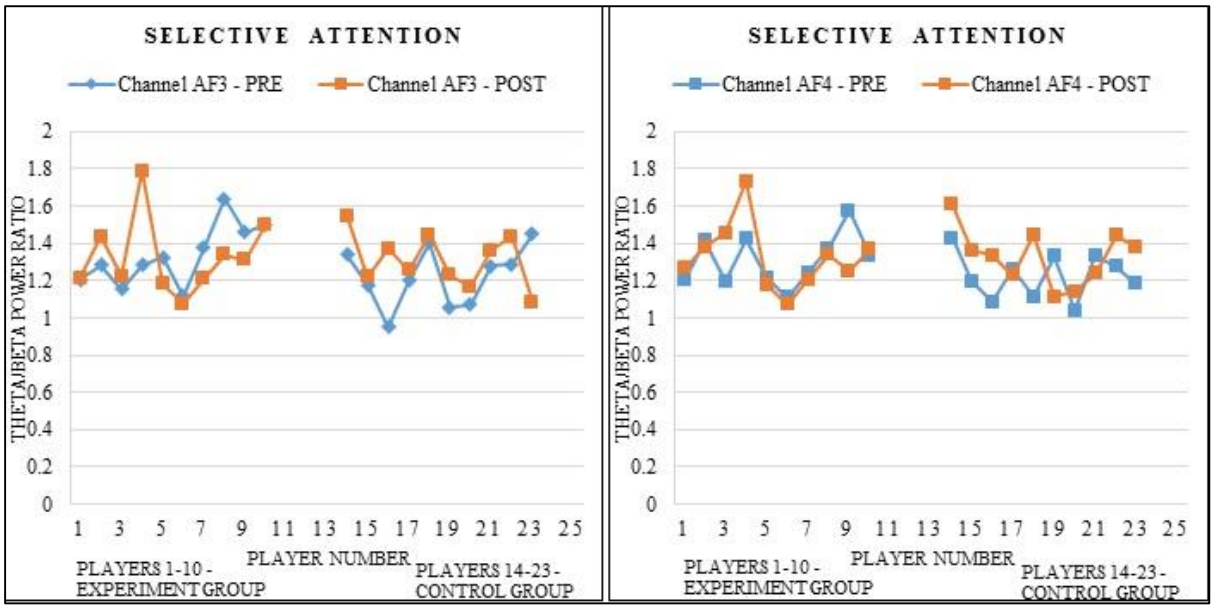

Fig. 23. Theta/Beta power ratio values of the 20 players at channels AF3 and AF4

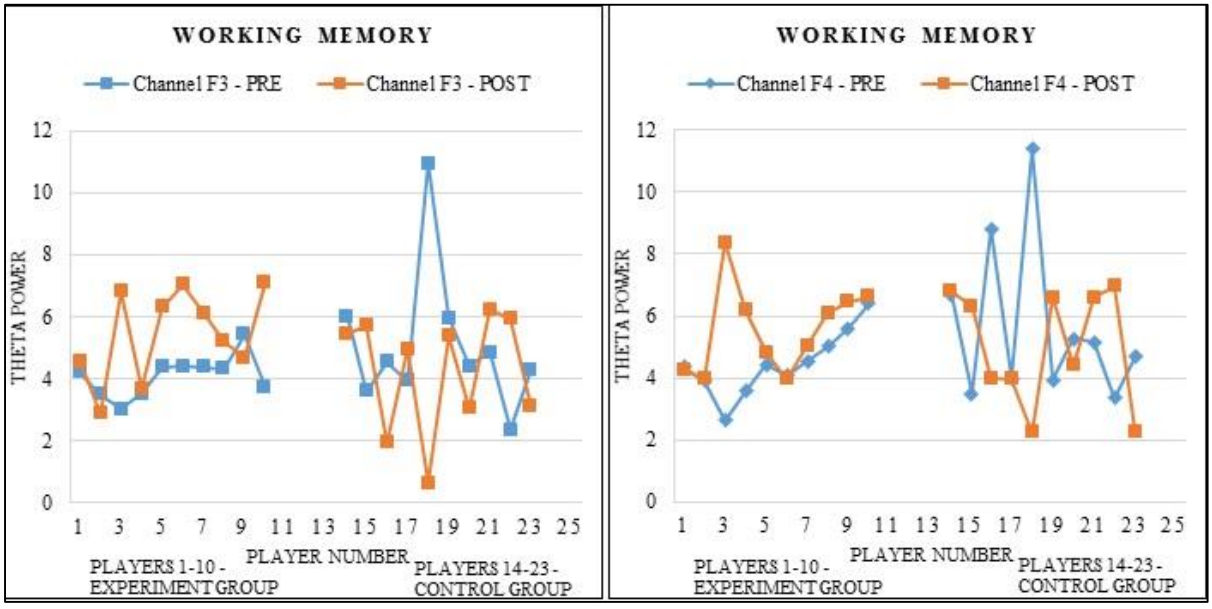

Fig. 24. Theta power (power per radians per sample) values at channels F3 and F4

The formula to calculate Error % is:

Error % = (Total errors made / Total number of items processed) * 100

In the above formula, total number of items processed means the total number of characters crossed out, correctly or incorrectly, by the subject in the requisite time. If a player is unable to complete the test in the set time, the incomplete test is evaluated, but no extra time is allotted. The values of error % of the experiment and control group players reveal the effectiveness of the interventions used for selective attention skill.

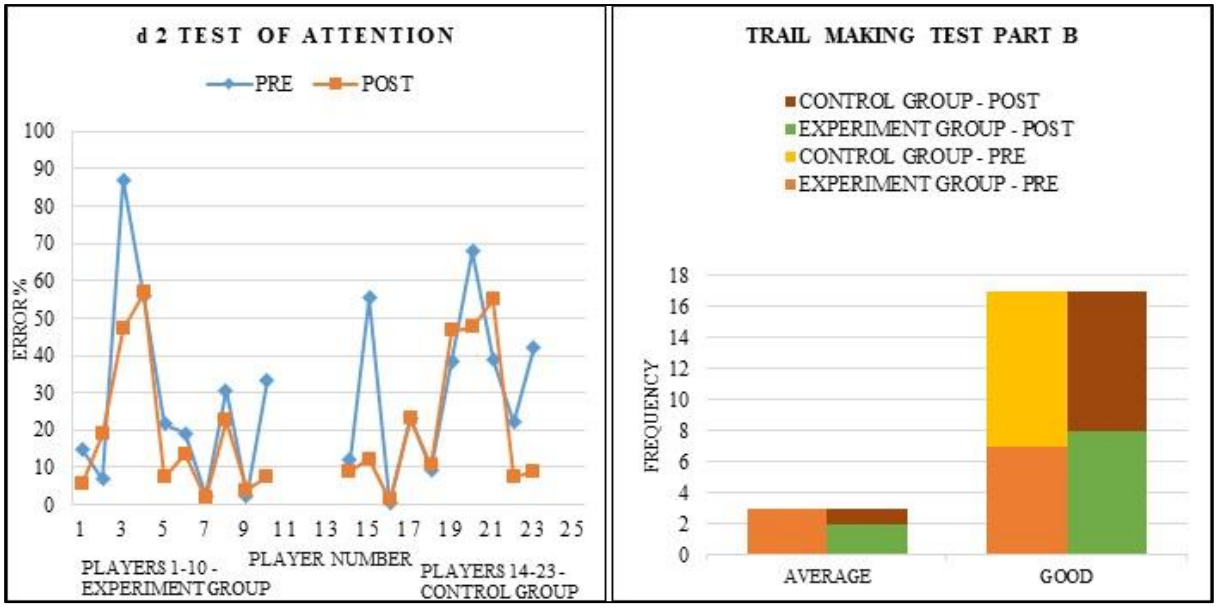

Fig. 25. d2 Test of Attention and TMT Part B results

In the Trail Making Test Part B, the players have to complete the test in 3 minutes. The players are required to finish the test as early as possible. If a player is unable to complete the test in the said time, no extra time is given. The frequency in TMT Part B results represents the number of players having average and good working memory skills. None of the players demonstrated weak working memory skills. If the player connects the circles incorrectly, it is considered in the evaluation of the test. Many players were able to complete the test quickly.

Fig. 26 depicts the pre and post-test results in the Mental Toughness Questionnaire of the 20 basketball players. The frequency defines the number of players having weak, average to moderate and good mental toughness scores. The scores of each player are calculated out of 30. The players answered the questions based on the understanding of their game. The pre and post-test results for the experiment and control group players are presented. Mental toughness is an important skill to

enhance in order to achieve a successful and healthy life. It comprises of a number of components and a player's psychological needs should be considered before providing interventions related with mental toughness.

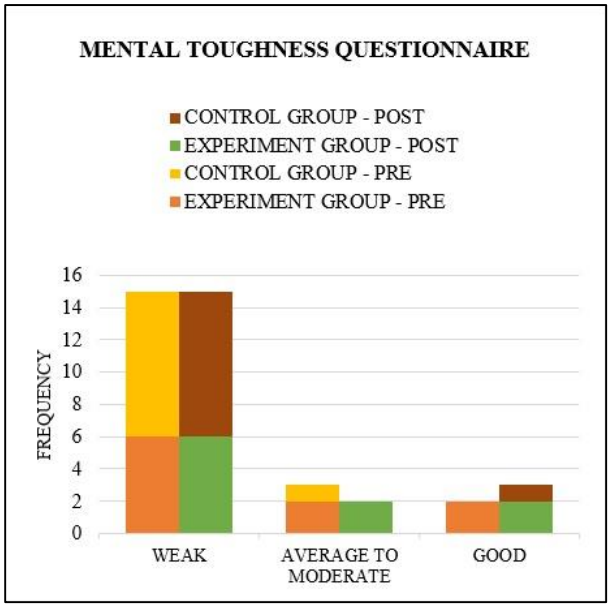

Fig. 26. Mental Toughness Questionnaire results

The above mentioned psycho-physiological results in the graphical form for the 2nd set of data are depicted numerically in the tabular form as follows.

Table 8
Selective attention, Channel AF3 – Theta/Beta power ratio values

	PRE	POST
Player 1^{E}	1.2037	1.2165
Player 2^{E}	1.2848	1.4359
Player 3^{E}	1.1521	1.2227
Player 4^{E}	1.2851	1.7899
Player 5^{E}	1.3250	1.1829
Player 6^{E}	1.1161	1.0774
Player 7^{E}	1.3773	1.2093
Player 8^{E}	1.6384	1.3412
Player 9^{E}	1.4618	1.3108
Player 10^{E}	1.5015	1.5005
Player 11^{C}	1.3399	1.5470
Player 12^{C}	1.1779	1.2196
Player 13^{C}	0.9514	1.3704
Player 14^{C}	1.2005	1.2567
Player 15^{C}	1.4027	1.4464
Player 16^{C}	1.0582	1.2274
Player 17^{C}	1.0716	1.1681
Player 18^{C}	1.2799	1.3640
Player 19^{C}	1.2865	1.4351
Player 20^{C}	1.4512	1.0869

Note: ^{E} = Experiment Group, ^{C} = Control Group

Table 9
Selective attention, Channel AF4 – Theta/Beta power ratio values

	PRE	POST
Player 1^{E}	1.1991	1.2657
Player 2^{E}	1.4114	1.3812
Player 3^{E}	1.1947	1.4566
Player 4^{E}	1.4244	1.7313
Player 5^{E}	1.2148	1.1792
Player 6^{E}	1.1103	1.0731
Player 7^{E}	1.2409	1.2058
Player 8^{E}	1.3715	1.3384
Player 9^{E}	1.5728	1.2537
Player 10^{E}	1.3351	1.3671
Player 11^{C}	1.4250	1.6057
Player 12^{C}	1.1969	1.3611
Player 13^{C}	1.0843	1.3346
Player 14^{C}	1.2609	1.2272
Player 15^{C}	1.1150	1.4455
Player 16^{C}	1.3309	1.1121
Player 17^{C}	1.0410	1.1417
Player 18^{C}	1.3330	1.2396
Player 19^{C}	1.2751	1.4414
Player 20^{C}	1.1834	1.3788

Note: ^{E} = Experiment Group, ^{C} = Control Group

Table 10
Working memory, Channel F3 – Theta power (power per radians per sample) values

	PRE	POST
Player 1^{E}	4.2002	4.5695
Player 2^{E}	3.4811	2.8792
Player 3^{E}	3.0153	6.8233
Player 4^{E}	3.5086	3.6738
Player 5^{E}	4.3698	6.3040
Player 6^{E}	4.4016	7.0300
Player 7^{E}	4.3618	6.1225
Player 8^{E}	4.3220	5.2149
Player 9^{E}	5.4296	4.6821
Player 10^{E}	3.7386	7.0901
Player 11^{C}	6.0154	5.4510
Player 12^{C}	3.6077	5.6964
Player 13^{C}	4.5470	1.9344
Player 14^{C}	3.9413	4.9546
Player 15^{C}	10.9367	0.6419
Player 16^{C}	5.9597	5.3706
Player 17^{C}	4.3987	3.0301
Player 18^{C}	4.8491	6.2303
Player 19^{C}	2.3493	5.9269
Player 20^{C}	4.2828	3.0865

Note: ^{E} = Experiment Group, ^{C} = Control Group

Table 11
Working memory, Channel F4 – Theta power (power per radians per sample) values

	PRE	POST
Player 1^{E}	4.3413	4.2794
Player 2^{E}	3.9155	3.9684
Player 3^{E}	2.6308	8.3756
Player 4^{E}	3.5855	6.1800
Player 5^{E}	4.4429	4.8252
Player 6^{E}	4.0655	3.9722
Player 7^{E}	4.5373	5.0385
Player 8^{E}	5.0090	6.1048
Player 9^{E}	5.5889	6.4739
Player 10^{E}	6.3909	6.6360
Player 11^{C}	6.7184	6.8057
Player 12^{C}	3.4861	6.3275
Player 13^{C}	8.8069	3.9927
Player 14^{C}	3.9905	3.9703
Player 15^{C}	11.4065	2.2534
Player 16^{C}	3.9441	6.5876
Player 17^{C}	5.2672	4.3969
Player 18^{C}	5.1675	6.6118
Player 19^{C}	3.3531	6.9565
Player 20^{C}	4.6736	2.2607

Note: ^{E} = Experiment Group, ^{C} = Control Group

Table 12
Error % values of the 20 players in completing the d2 Test of Attention

	PRE	POST
Player 1^{E}	15.06	5.36
Player 2^{E}	6.79	18.80
Player 3^{E}	87.04	47.06
Player 4^{E}	55.79	56.84
Player 5^{E}	21.74	7.42
Player 6^{E}	19.14	13.46
Player 7^{E}	2.42	1.71
Player 8^{E}	30.57	22.63
Player 9^{E}	2.49	3.77
Player 10^{E}	33.33	7.57
Player 11^{C}	11.93	8.94
Player 12^{C}	55.32	12.08
Player 13^{C}	0.34	1.37
Player 14^{C}	23.20	22.95
Player 15^{C}	9.42	10.62
Player 16^{C}	38.61	46.57
Player 17^{C}	67.98	47.55
Player 18^{C}	39.05	54.97
Player 19^{C}	22.08	7.59
Player 20^{C}	42.23	8.62

Note: ^{E} = Experiment Group, ^{C} = Control Group

Table 13
Time taken to complete the Trail Making Test Part B in seconds

	PRE	POST
Player 1^{E}	42	28
Player 2^{E}	103	47
Player 3^{E}	102	85
Player 4^{E}	63	51
Player 5^{E}	48	46
Player 6^{E}	36	53
Player 7^{E}	50	45
Player 8^{E}	38	43
Player 9^{E}	33	34
Player 10^{E}	52	60
Player 11^{C}	52	51
Player 12^{C}	48	45
Player 13^{C}	34	34
Player 14^{C}	57	60
Player 15^{C}	65	35
Player 16^{C}	40	82
Player 17^{C}	48	52
Player 18^{C}	122	90
Player 19^{C}	51	54
Player 20^{C}	50	55

Note: ^{E} = Experiment Group, ^{C} = Control Group

Table 14
Overall scores (out of 30) of Mental Toughness Questionnaire

	PRE	POST
Player 1^{E}	26	27
Player 2^{E}	23	23
Player 3^{E}	15	16
Player 4^{E}	23	21
Player 5^{E}	11	14
Player 6^{E}	15	13
Player 7^{E}	18	19
Player 8^{E}	29	29
Player 9^{E}	17	18
Player 10^{E}	22	19
Player 11^{C}	16	17
Player 12^{C}	21	19
Player 13^{C}	15	14
Player 14^{C}	19	19
Player 15^{C}	15	13
Player 16^{C}	18	22
Player 17^{C}	24	26
Player 18^{C}	19	24
Player 19^{C}	20	18
Player 20^{C}	9	10

Note: ^{E} = Experiment Group, ^{C} = Control Group

5.2 Statistical Results

The statistical analysis is performed to validate the psycho-physiological analysis of the two sets of data acquired. The various parameters of the statistical analysis are described in the forthcoming sections.

5.2.1 Correlation Analysis Results

The test-retest reliability of the physiological and psychological test measures has been evaluated by the Pearson correlation coefficient, r.

Table 15 and 16 represent the correlation between the pre and post-test results of the physiological and psychological tests for the selective attention, working memory and mental toughness cognitive skills in the 20 (n=20) basketball players.

Table 15
Pearson correlation coefficient, r, results for the 1st & 2nd sets of pre and post-test physiological data

Skill	Channel	r_1	r_2
Selective Attention	AF3	0.128	0.242
Selective Attention	AF4	-0.104	0.337
Working Memory	F3	0.188	-0.507
Working Memory	F4	0.081	-0.433

Note: r_1 : Pearson correlation coefficient for 1st set of data, r_2 : Pearson correlation coefficient for 2nd set of data

Table 16
Pearson correlation coefficient, r, results for the 1st & 2nd sets of pre and post-test psychological data

Skill	Test	r_1	r_2
Selective Attention	d2 Test of Attention	0.335	0.719
Working Memory	Trail Making Test Part B	-0.047	0.584
Mental Toughness	Mental Toughness Questionnaire	0.248	0.907

Note: r_1 : Pearson correlation coefficient for 1st set of data, r_2 : Pearson correlation coefficient for 2nd set of data

5.2.2 Internal Consistency Evaluation Results

The internal consistency of the overall mental toughness score in the Mental Toughness Questionnaire, during the pre and post-testing in both the sets of psychological data, has been evaluated with Cronbach's alpha coefficient. The internal consistency of a psychological measure is assessed to find whether several items of the measure combine well to measure the desired construct. In this study, the results (values > 0.70) show high internal consistency. The following Table 17 shows the Cronbach's alpha coefficient values after checking the internal consistency of the overall score of mental toughness, in the 20 basketball players.

Table 17
Cronbach's alpha values, checking the internal consistency of the overall score of Mental Toughness Questionnaire

	No. of questions	Cronbach's alpha
PRE_1	30	0.835
$POST_1$	30	0.753
PRE_2	30	0.767
$POST_2$	30	0.785

Note: PRE_1 , $POST_1$: pre and post-test for 1st set of data, PRE_2 , $POST_2$: pre and post-test for 2nd set of data

The present study is aimed at enhancing the cognitive skills such as selective attention, working memory and mental toughness in the university basketball players. Initially, it was assumed that the theta/beta band power ratio will decrease after enhancement of the selective attention skill in the experiment group players. This assumption finds support from the results obtained for the selective attention skill in the experiment and control group players. Table 1 and Fig. 23 show that most of the experiment group players are able to decrease their theta/beta band power ratio, whereas, most of the control group players are unable to decrease this ratio. Table 12 shows that most of the experiment group players are able to decrease their error (%) values in the d2 Test of Attention. The complete physiological and psychological results for the selective attention skill show similar outcome. These results are coherent with our assumption that the computer-based

game intervention is effective in enhancing the selective attention skill of the subjects. Similarly, it was assumed initially that the theta band power will increase after enhancement of the working memory skill in the experiment group players. Again, this assumption finds support from the findings of the working memory skill in the experiment and control group players. Table 3 and Fig. 24 present that most of the experiment group players are able to increase their theta band power, whereas, many control group players are unable to do so. Table 13 shows that most of the experiment group players are able to reduce the time taken to complete the Trail Making Test Part B. The complete physiological and psychological results for the working memory skill show similar outcome. These results are consistent with our assumption that the computer-based game intervention is effective in enhancing the working memory skill of the participants.

Additionally, the experiment group and control group players' physiological results are similar to their psychological results for the selective attention and working memory skills. Moreover, it is evident from the psychological results for the mental toughness skill that the mental toughness skill needs to be strengthened in most of the players. Future investigations should increase the intervention sessions for enhancing the mental toughness skill. Mental toughness is an important skill to be improved, to lead a fruitful life. Additionally, based on each subject's psychological needs, the interventions for different cognitive skills should be designed.

The test-retest reliability of the physiological and psychological tests has been computed by the Pearson correlation coefficient. The test-retest reliability coefficient checks for the stability of the results of a test over time. In the present study, there is a low correlation between the pre-test and post-test physiological results for the selective attention skill. A possible reasoning behind the low correlation is the effect of computer-based game intervention in enhancing the selective attention skill in the experiment group players. Most of these players are able to decrease their theta/beta band power ratio after the intervention. In the psychological results for the selective attention skill, there is a medium correlation between the pre-test and post-test results in the first set of data and a high correlation in the second set of data. The reason can be the players' improvement in d2 Test of Attention test performance over time. Similarly, there is a low correlation between the pre-test and post-test physiological results for the working memory skill in the first set of data and medium correlation in the second set of data. A possible explanation behind the low and medium correlation is the effect of computer-based game intervention in enhancing the working memory skill in the experiment group players. Most of these players are able to increase their theta band power after

the intervention, over the period of the study. The psychological results for the working memory skill show low correlation between the pre-test and post-test results in the first set of data and high correlation in the second set of data. The reason behind this can be the improvement in the Trail Making Test Part B test performance of the players over time.

Furthermore, the psychological results for the mental toughness skill show low correlation for the first set of pre-test and post-test data and high correlation for the second set of data. The possible reason is the effect of the interventions for the mental toughness skill on the experiment group players. The internal consistency of the Mental Toughness Questionnaire's overall score is evaluated by calculating the Cronbach's alpha coefficient. The Cronbach's alpha coefficient values (> 0.70) over the period of two sets of pre and post-test results show high internal consistency among the 30 questions of the questionnaire, measuring the overall mental toughness score, as depicted in Table 17.

Here, three cognitive skills have been taken for enhancement in the basketball players. Future studies can incorporate other cognitive skills required to be enhanced in the subjects. The present work includes the university basketball players. The future studies can include the state, national and international level athletes of different sports, to investigate their cognitive skills level and psychological needs, in order to improve their performance. Moreover, future investigations should include a large sample of subjects for better analysis and understanding of the cognitive skills. Another suggestion for future studies is to investigate the enhancement of cognitive skills in old persons and individuals with learning and developmental disabilities. In this way, these individuals can be helped to lead a fulfilling life.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

There is a need to incorporate the mental skills training in the training schedule of the athletes, along with the physical skills training. The cognitive skills such as selective attention, working memory and mental toughness have been psycho-physiologically examined in the university basketball players. Afterwards, the interventions for each of the above mentioned cognitive skills are provided to the experiment group players, while no interventions are provided to the control group players. It can be seen from the psycho-physiological results that many players of the experiment group are able to enhance their cognitive skills. Furthermore, correlation analysis between the pre-test and post-test results of the cognitive skills shows that the interventions are effective in enhancing the above mentioned cognitive skills. Additionally, there is a high internal consistency of the overall score of the Mental Toughness Questionnaire, calculated by Cronbach's alpha coefficient. Further studies are needed to explore the cognitive skills and interventions used in the present study, in different sports and in individuals with learning and developmental disorders.

In future studies, the sample size should be more. When there is a large sample, more information can be extracted and better analysis can be done. In the present study, university level athletes are considered. Higher skill level players such as state, national and international level players should be included in the future studies to understand the mental processes underlying their skilled performance. Here, three cognitive skills such as selective attention, working memory and mental toughness have been considered. Some other cognitive skills such as motor skill and reaction time can also be considered in future works along with the cognitive skills considered in the present study. Interventions can be developed according to the individuals' needs and provided to them for their skill enhancement. More emphasis should be laid on mental toughness of individuals and accordingly, the interventions sessions should be provided for a long duration such as 12-15 sessions. The future studies should be done for a long duration of time like 2 years or 3 years, so as to extract more information. The procedure considered in this study can be applied for the improvement of the cognitive functioning in old people and persons with mental and developmental disorders.

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