EVALUATION OF PHYSICAL FITNESS AFTER ATTACHMENT OF NEUROPRIMING DEVICE AMONG ADOLESCENT FOOTBALL PLAYERS

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by

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LIST OF SYMBOLS

cm	centimeter
kg	kilogram
mm	millimeter
N	Newton
s	seconds

LIST OF ABBREVIATIONS

ANCOVA	Analysis Of Covariance
ANOVA	Analysis Of Variance
BMI	Body Mass Index
CI	Confidence interval
df	Degree of Freedom
FAM	Football Association of Malaysia
FFM	Fat Free Mass
FIFA	Federation International de Football Association
GABA	Gamma-Aminobutyric Acid
IQR	Interquartile Range
KAFA	Kelantan Football Association
NFDP	National Football Development Programme
PLD	Pusat Latihan Daerah
SD	Standard Deviation
SEA	Southeast Asian Games
SMK	Sekolah Menengah Kebangsaan
tCDS	Transcranial Direct Stimulation
tVFS	Transcranial Variable Frequency Stimulation
TRW	The Red Warriors
US	United State
USM	Universiti Sains Malaysia

PENILAIAN KECERGASAN FIZIKAL SELEPAS PENGGUNAAN ALAT NEUROPRIMING DI KALANGAN PEMAIN BOLA SEPAK REMAJA

ABSTRAK

Teknik rangsangan arus terus transkranial (*t*DCS) yang tidak invasif dapat memberikan gambaran mengenai hubungan antara fungsi otak dan prestasi senaman. Tujuan kajian ini dijalankan adalah untuk mengkaji kesan *t*DCS terhadap ujian kecergasan berkaitan kesihatan dan ujian kecergasan berkaitan kemahiran pada pemain bola sepak remaja Malaysia dengan kumpulan umur yang berbeza. Kajian ini menggunakan percubaan terkawal, rawak terkawal secara rawak, antara teknik rangsangan non-invasif dan rangsangan palsu (sham). Enam puluh satu pemain bola sepak lelaki yang sihat, berusia antara 13 hingga 17 tahun, di bawah Program Pembangunan Bola Sepak Nasional Malaysia (PPBSN), dengan sekurang-kurangnya dua tahun pengalaman kompetitif mewakili negeri dan mengambil bahagian secara sukarela dalam kajian ini. Penilaian antropometri peserta, termasuk berat badan, tinggi dan indeks jisim badan (IJB) diukur. Para peserta ditugaskan secara rawak untuk menerima 20 minit *t*DCS atau rangsangan palsu, dengan jarak 14 hari. Penilaian kecergasan berkaitan kesihatan termasuk ujian bip untuk VO_2 max, komposisi badan, kekuatan belakang dan kaki, kekuatan genggaman tangan, ujian ringkuk tubi dan tekan tubi selama satu minit dan jankauan melunjur untuk kelenturan. Penilaian kecergasan berkaitan kemahiran terdiri daripada ujian ketangkasan, lompat jauh berdiri, lompat menegak, ujian daya pelantar dan pecut 30-meter diukur selepas rangsangan, dengan 10 hingga 15 minit berehat di antara ujian. Keputusan daripada ujian-t berpasangan menunjukkan bahawa pemain bola sepak yang menerima rangsangan *t*DCS bertambah baik dalam ujian kekuatan belakang dan kaki, satu minit duduk, ujian kekuatan

pegangan tangan kanan, ujian lompat menegak dan platform daya jika dibandingkan dengan keadaan palsu. Walau bagaimanapun, hanya VO_2 max, ujian kekuatan genggaman tangan kanan dan ujian pecut 30-meter menunjukkan peningkatan yang ketara menggunakan rangsangan *t*DCS, dengan masing-masing $p = 0.021$, $p = 0.004$ dan $p = 0.044$. Analisis ukuran varians berulang (ANOVA) dalam kumpulan menunjukkan peningkatan yang signifikan menggunakan rangsangan *t*DCS dalam VO_2 maks untuk kumpulan bawah 13 tahun, ujian kekuatan genggaman tangan untuk kumpulan bawah 15, dan ujian lompatan menegak dan ketangkasan untuk kumpulan bawah 17. Penambahbaikan ujian telah ditunjukkan untuk ujian kekuatan belakang dan kaki, ringkuk tubi satu minit, tekan tubi satu minit, ujian ketangkasan dan lompat menegak untuk kumpulan bawah 13 tahun; ujian genggaman tangan, lompat jauh berdiri, lompat menegak, ringkuk tubi satu minit dan ujian daya pelantar untuk kumpulan bawah 15 tahun; VO_2 max, ujian genggaman tangan kanan, fleksibiliti, ringkuk tubi satu minit, lompat menegak dan ujian daya pelantar untuk kumpulan bawah 17 tahun. Keputusan menunjukkan bahawa *t*DCS meningkatkan beberapa pengukuran kecergasan berkaitan kesihatan dan kecergasan berkaitan kemahiran dalam pemain bola sepak remaja Malaysia. Kajian itu menambah kepada literatur bahawa teknologi neurostimulasi mempunyai hubungan positif antara otak dan prestasi fizikal. Penemuan ini diharap dapat diguna pakai dan membantu dalam pembangunan program latihan khusus untuk pemain bola sepak Malaysia untuk mencapai prestasi terbaik. Walau bagaimanapun, lebih banyak kajian diperlukan untuk menentukan kesan jangka panjang intervensi Halo Sports ini terhadap latihan serta mekanismenya yang lebih terperinci.

Kata kunci: Rangsangan arus terus transkranial, pemain bola sepak, kemahiran fizikal, kecergasan fizikal

EVALUATION OF PHYSICAL FITNESS AFTER ATTACHMENT OF NEUROPRIMING DEVICE AMONG ADOLESCENT FOOTBALL PLAYERS

ABSTRACT

Transcranial direct current stimulation (*t*DCS) is a newly developed, non-invasive technique that can help researchers understand the relationship between brain processes and exercise performance. The purpose of this study was to examine the effect of *t*DCS on health-related fitness and skill-related fitness tests among adolescent Malaysian football players of various age groups. The study employed a blinded cross-over, randomised controlled trial, to compare the non-invasive approach to a sham-condition. Sixty-one healthy male football players from the Malaysian National Football Development Programme (NFDP), aged between 13 to 17 years old, with at least two years of competitive experience representing their state, volunteered to take part in this study. The participants' anthropometric assessments were measured, including their weight, height, and body mass index (BMI). The participants were randomised to either receive *t*DCS or sham stimulation conditions, with 14 days apart. The health-related fitness assessment included of bleep test for VO_2 max, body composition, back and leg strength, hand grip strength, one-minute sit-up and push up tests and sit and reach for flexibility. Skill-related fitness assessments consisted of agility test, standing long jump, vertical jump, force platform and 30-meter sprint were measured, with 10 to 15 minutes of rest in-between testing. The results from the paired *t*-test showed that the football players who received *t*DCS stimulation improved in their back and leg strength test, one-minute sit up, right handgrip strength test, vertical jump test and force platform when compared to sham condition. However, only VO_2 max, right handgrip strength test and 30-meter sprint test showed a significant improvement using the *t*DCS stimulation, with $p = 0.021$, $p = 0.004$ and $p = 0.044$

respectively. Repeated measure analysis of variance (ANOVA) within groups analysis showed significance improvement using the *t*DCS stimulation in VO_2 max for group under 13, handgrip strength test for group under 15, and vertical jump and agility test for group under 17. Improvement of test were shown for back and leg strength test, one-min sit up, one-min push up, agility test and vertical jump for group under 13; handgrip test, standing long jump, vertical jump, one-min sit up and force platform for group under 15; VO_2 max, right handgrip test, flexibility, one-min sit up, vertical jump and force platform for group under 17. The results demonstrated that *t*DCS improved some health-related fitness and skill-related fitness measurements in the Malaysian adolescents' football players. The study added to the literature that neurostimulation technology has a positive relationship between the brain and physical performance. The findings are hoped to be applied and aid in the development of specific training programmes for Malaysian football players to achieve peak performance. However, more research is needed to determine the long-term effects of this intervention on training as well as the precise mechanism through Halo Sports.

Keywords: Transcranial direct current stimulation; skill-related fitness; physical fitness; football player.

CHAPTER 1

INTRODUCTION

1.1 Mission of Malaysian Football

The National Football Development Programme (NFDP) was launched by the Prime Minister, Dato' Sri Haji Mohammad Najib bin Tun Haji Abdul Razak on April 10, 2014, along with Dato' Mokhtar Dahari at the National Football Academy in Cherating, Pahang. It is an attempt to restore the glory of football in the country and to become a force to be reckoned with the international stage ("Khairy: Football development programme will remain under govt," 2017). The project covers not only the Youth and Sports Ministry, but also the Education Ministry and the Football Association of Malaysia (FAM).

Children as young as seven to 17 years old will be taught the fundamentals of football and the styles of play known as the footballing DNA, which was supervised by NFDP director Lim Teong Kim, who was a former youth coach at Bayern Munich, Germany's most successful club ("Khairy: Football development programme will remain under govt," 2017). The NFDP will have about 50,000 football trainees, in over 300 training centres nationwide ("Khairy: Football development programme will remain under govt," 2017). Within three years, the programme has already trained 23,000 trainees in 123 regional training centres or 'tunas' academies across the country, which is a tremendous accomplishment ("Khairy: Football development programme will remain under govt," 2017).

Sekolah Menengah Kampong Chengal, Kota Bharu, Kelantan is also one of the district training centres in the programme which has 125 pupils consisting of form 1 to form 5 students. Each of the centres has six qualified coaches who are responsible for forming and training the players to the national level.

1.2 Performance of Football

The national football team of Malaysia is a football team representing Malaysia and fully administered by the FAM. The Malaysian football team is recognised by the Federation International de Football Association (FIFA). The team was respected in the 1950s to the 1980s but fell sharply in the 1990s and early 2000s ("Pasukan bola sepak kebangsaan Malaysia," 2017). But in December 2009, the team bounced back after winning the gold medal at the Southeast Asian Games (SEA) in Vientiane, Laos and AFF Cup champion ASEAN after defeating Indonesia 4-2 in aggregate in December 2010 ("Pasukan bola sepak kebangsaan Malaysia," 2017). The team also created the second best record when titled AFF Suzuki Cup runner-up in 2014 when losing 3-4 aggregates to Thailand ("Pasukan bola sepak kebangsaan Malaysia," 2017).

The Kelantan Football Association (KAFA) was founded in 1946 as the Kelantan Amateur Football Association ("LAMAN RASMI THE RED WARRIORS ", 2016). By 2005, Kelantan was the only state team that played in the third-tier football league in Malaysia ("LAMAN RASMI THE RED WARRIORS ", 2016). The team ended the season at the bottom of the second-tier Malaysia Premier League and was then relegated to the FAM League ("Laman Rasmi The Red Warriors, 2016).

Tan Sri Hj Annuar bin Hj Musa took over Kelantan FA in 2007 (Laman Rasmi The Red Warriors, 2016). He started a revolution and changed the way the team was run by implementing modifications similar to those seen in overseas. Local players were given exposure, while national players were brought in to provide a solid balance of experience and finesse. With sponsorship deals signed with various companies, and with a good cash flow going into the first few years of his leadership, Kelantan, now re-branded as The Red Warriors (TRW), was ready to take the pitch by storm (Laman Rasmi The Red Warriors, 2016).

The team succeeded in improving its position in the Malaysia Premier League during the 2007-2008 season and ended in third place during the season (Laman Rasmi The Red Warriors, 2016). 2009 marked the team's debut season in the Malaysia Super League (Laman Rasmi The Red Warriors, 2016). That year, the team also competed in the FA Cup and the Malaysia Cup finals. Since then, Kelantan has been consistently been in at least one of the cup finals every year since 2009 until today (Laman Rasmi The Red Warriors, 2016).

The KAFA Football Academy is explaining the idea of KAFA President Tan Sri Hj Annuar Bin Hj Musa in order to rebuild Kelantan football in such a situation, there must be an institution responsible for finding, developing and supplying quality and highly skilled players. Sekolah Menengah Kebangsaan Kampong Chengal opened in 2006 at a cost of 17 million with various facilities available such as a playground, boarding house, hall was selected as the KAFA Football Academy Center in collaboration with KAFA and Kelantan State Education Department.

The committee was given the responsibility of selecting players for the selection session in all 7 districts at that time involving more than 850 Form 1 students. The assessed aspect was the skill and size of players. 17 players have been selected in the first entry. They are promised professional training, scholarships, tuition classes, free hostel facilities and game equipment. The opening ceremony was held on March 3, 2008 by Tan Sri Hj Annuar bin Hj Musa, President of KAFA. Two instructors were appointed: Azman Ismail (later replaced by Mr. Abdullah bin Muhammad) and Hashim Bin Ismail. In 2012, with the inclusion of Hj. Redzuan Daud (Head Coach until now) many changed the Kijang Emas football team shortage thanks to the support and assistance of the Department and Administrator. Various victories have been sketched by this team either at the state or national level. One of the most memorable successes is the National Champion for the Super Cup 100 Under 17 on 2015. In year of 2016, our team had Champions NFDP National League Under 17 and got a bronze medal under 15 years old.

1.3 Factors Related to Performance of Football Player

A variety of things must come together and interact properly for success to occur. A football player's effective performance is influenced by a number of physical and mental factors. Fitness is one of the determinants, and it has a significant impact on success. There are also psychological aspects, which are followed by a variety of minor factors, such as the availability of equipment, the chance for training, expertise in coaching and skill teaching, nutritional status, a strong support network, and funding.

1.4 Physical Fitness

Fitness is the ability to meet the demands of a physical task. Physical fitness is the sum of total five motor abilities namely strength, speed, endurance, flexibility and cooperative abilities. The improvement and maintenance of physical fitness is perhaps the most important aim of sports training.

Based on American College of Sports Medicine (2013), physical fitness can be divided into health-related fitness and skills-related fitness. Health-related fitness include cardiorespiratory endurance, body composition, muscular strength, muscular endurance and flexibility. While skills-related fitness include agility, coordination, balance, power, reaction time and speed.

1.5 Problem Statement

Football is one of the world's most popular sports. It is, in fact, the only sport that is popular all over the world. It has a fan base that appears to cross all boundaries, including ethnicity, language, age, and gender. As a result, it is truly a universal sport. Apart from that, football has grown to be a significant contributor to global economics and business. Nowadays, the popularity of this sport is growing due to national media, which allows the community to keep up with the sport's progress. This rapidly growing popularity of football necessitates a high standard of excellent performance. This encouraging development has aroused the interest of numerous researchers in performing studies aimed at improving football player performance. These efforts involve improving football players' physical fitness, physiological, psychological, biomechanical, and nutritional state.

Football is classified as a high intensity intermittent team sport. Team sports, such as football, necessitate a combination of individual abilities, team plays, tactics and methods, and motivating factors. Regardless of these intricacies, a player's physical health is critical for both individual and team effectiveness. They incorporate a variety of fitness components that have been identified as essential for the team to be successful.

The attributes of football could be developed through systematic methods of preparation and application of scientific method of training. Non-invasive electrical brain stimulation is one technology that claims to improve training benefits and boost exercise performance. This notion was developed lately and is simply applied to athletes who use Halo Neuroscience or the Halo neuropriming device.

Neuropriming, which involves brain stimulation and neural entrainment using noninvasive techniques, may improve brain activity in healthy athletes in order to improve their physical performance. Several research have already used this stimulation approach to improve physical and mental performance, either during athletic training or in separate sessions.

The Halo Neuroscience provides many studies as supporting testimonies on this technology, which took part in various sports organisations. However, as previously stated, independent peer-reviewed research and more studies are needed for making any conclusive claims about the device's effect on the physical fitness among the football players. The purpose of this study was to investigate the influence of neuropriming on health-related and skill-related fitness in Malaysian youth football players.

1.6 Rationale / Justification of the Study

The purpose of this study is to investigate the effect of 20 minutes of neuropriming using transcranial direct-current stimulation (*t*DCS) on the physical fitness among the State football players. Our aim is to demonstrate that the neuropriming device intervention improves health-related fitness and skill-related fitness performance among the football players. Hence, this technique will be needed in future to improve both the health-related fitness and skill-related fitness performance among the football players. The study may shed light on the health-related fitness and skill-related fitness of the football players participating under the NFDP programme. The finding of this study will be added to the new knowledge in the area of physical fitness, which will benefit the players. The study may provide coaches with guidance on how to train the football players more effectively. The information obtained from this study may be beneficial to coaches that are responsible for the team tournament preparation.

1.7 Objectives, Research Questions, Research Hypotheses

1.7.1 Research Questions

1. Is there any difference of the level of health-related fitness with and without using the neuropriming among the adolescents' football players?
2. Is there any difference of the level of skill-related fitness with and without using the neuropriming among the adolescents' football players?
3. Is there any difference of the level of health-related fitness with and without using the neuropriming among three different age groups among the adolescents' football players?
4. Is there any difference of the level of skill-related fitness with and without using the neuropriming among three different age groups among the adolescents' football players?

1.7.2 General Objective

To examine the physical fitness with and without using neuropriming among the adolescents' football players.

1.7.3 Specific Objectives

1. To examine the level of health-related fitness with and without using neuropriming among the football players.
2. To examine the level of skill-related fitness with and without using neuropriming among the adolescents'football players.

3. To examine the level of health-related fitness with and without using neuropriming between the three different age groups of the adolescents' football players.
4. To examine the level of skill-related fitness with and without using neuropriming between the three different age groups of the adolescents' football players.

1.7.4 Research Hypotheses

1. There is a difference of the level of health-related fitness with and without using neuropriming among the adolescents' football players.
2. There is a difference of the level of skill-related fitness with and without using neuropriming among the adolescents' football players.
3. There is a difference of the level of health-related fitness with and without using neuropriming between the three different age groups of the adolescents' football players.
4. There is a difference of the level of skill-related fitness with and without neuropriming between the three different age groups of the adolescents' football players.

CHAPTER 2

LITERATURE REVIEW

2.1 Football

2.1.1 Introduction to Football

Football is the most popular sport on the planet. According to the International Federation of Association Football, there are around 265 million active players, as well as five million referees and officials. This equates to roughly 4% of the world's population. It is distinguished by a continuous sequence of exercises with varying degrees of intensity throughout the game. It requires a wide range of motor skills, such as sprinting, dribbling, kicking, jumping, and tackling (Haugen, Tønnessen, Hisdal, & Seiler, 2014). Players are rarely able to play the game with proper technique unless they are physically fit (Chapman, Derse, & Hansen, 2007). To achieve top results in this sport, players must have an excellent degree of technical and tactical skills, as well as significant physical fitness (Svensson & Drust, 2005).

In the context of football, fitness refers to a set of individual traits that are a synthesis of numerous abilities and competencies. Physical, physiological, and psychomotor variables all contribute to such competency (Reilly & Williams, 2003). Physically superior players were less fatigued during the same-intensity game, and as a result, those players saw less deterioration in technical performance (Sporis, Vucetic, Jovanovic, Jukic, & Omrcen, 2011). Competitive football players must have a lot of force, speed, and agility to do things like heading, shooting, sprinting, and dribbling (Stølen, Chamari, Castagna, & Wisløff, 2005).

2.1.2 The Structure of Football

Football is a high-intensity, intermittent sport in which players must repeatedly conduct striding, turning, sprinting, and jumping, putting significant strain on the neuromuscular system (Stølen et al., 2005). As a result, the capacity of the lower limb muscles to generate power is a critical fitness component for football players. Performance is determined by a number of individual skills, as well as their interaction and integration among team members. Technical and tactical ability are regarded as the most important qualities, but physical abilities must also be properly developed in order to be a successful player (Haugen et al., 2014).

During a 90-minute football game, professional football players do several explosive bursts such as kicking, tackling, jumping, turning, sprinting, and changing speed (Little and Williams, 2005). Speed strength, often known as power, is essential for performance in sports that require quick changes of direction, accelerations, and jumps. As a result, leg muscle strength and power are vital for professional football players. Physical training is an important element of preparing to play football (football) at any level, but putting up a truly effective training programme involves both a comprehension of the physiological principles at work and a practical understanding of the game's demands (Reilly & Williams, 2003).

Anaerobic training has a variety of consequences, the most important of which are increased neural activation of muscles and increased activity of creatine kinase and glycolytic enzymes. Anaerobic training can also increase the amount of glycogen stored in active muscles and improve their ability to neutralise the effects of hydrogen ions, postponing or offsetting fatigue. Generally, football is the combination of both aerobic and an aerobic exercise that have a significant effect on the overall performance of a player (Reilly, 2007).

2.2 Neuropriming

2.2.1 Concept of Neuropriming in Halo Sport

The Halo Neuroscience or Halo Sport device used the concept of *t*DCS. Neuropriming is also central to theories of memory and learning that attribute memory and learning to experience-induced changes in synaptic structure and function. *t*DCS is a neuromodulatory technique in which a small and constant direct current is delivered through the skull in order to inhibit or excite neurons in the brain, altering their firing threshold. As a result, it does not directly create new neural activity but rather influences the existing activity. They also provide transcranial variable frequency stimulation (*t*VFS) in addition to *t*DCS. Both of these techniques are referred as neuropriming.

The neurostimulation occur at the frontal area. It affects at T1-T2 and T9. Cathodal stimulation has been shown to foster implicit motor learning when stimulating the dorsolateral prefrontal cortex by suppressing working memory activity (Zhu et al., 2015).

2.2.2 Neuropriming Device or Halo-Sport

Halo Sport is head mounted device, which was developed by Halo Neuroscience. Halo Sport is standalone fully enclosed device. The headset is equipped with three electrodes, ear-pads, a USB charging cable, a USB wall adapter and a spray bottle. Two or three electrodes could be placed in the headset. The electrodes are placed on the left, directly above the ear, halfway to the centre of the head, and directly above the centre of the head. Electrodes can be removed, but not repositioned to any other location on scalp.

The whole device is controlled by the application in smartphone or tablet. The application also allows for specification of the requisite output of the training and neuropriming. The headset could be plugged into a phone and used as a standard headphone to listen to music. The phone and Halo Sport have to be connected via the included 3.5 mm audio cable. The device is powered by a rechargeable lithium-ion battery. The battery should be recharged approximately every eight sessions, depending on the use of the device. The use of headphones for listening to music does not affect the battery life.

The electrodes are made up of foam spikes and they must be replaced after three months of use. Each session must begin with wet electrodes. Before beginning a session, the researchers must spray the electrodes with water until they turn dark grey colour. The results are improved by removing the electrodes during this procedure. After watering, they can then be placed on the headset, the headset placed on the skull, and the session can begin. The user votes for the start of the process and the precise configuration of the session in device's application. Each session last between 20 to 30 minutes and be accompanied by certified practitioners.

2.2.3 Application or Usage of Neuropriming Device

*t*DCS is a neuromodulatory technique in which a small and constant direct current is delivered through the skull to inhibit or excite neurons in the brain, that is to change the threshold at which the neurons will fire. Therefore, it does not directly create new neural activity but influences the existing activity. *t*DCS probably helps patients suffering from major depression and relieves pain (especially in fibromyalgia) and symptoms of craving in addiction. *t*DCS could also help patients with neurodegenerative diseases or enhance human cognition.

*t*DCS is done by putting two or more electrodes on the scalp and running the weak direct current between them, so the current passes through the brain. Different areas of the brain can be affected based on the position of the electrodes. Depending on whether the stimulation is anodal or cathodal, the neuronal resting membrane potential is either depolarised or hyperpolarised, respectively. Anodal stimulation enhances excitability, while cathodal stimulation produces opposite results. The efficacy of the technique closely depends on the strength of the generated electrical field.

The proponents of the method argue that prolonged sessions of *t*DCS result in long-lasting after-effects that may last for hours. The mechanism of *t*DCS outlasting effect is predominantly caused by the induction of synaptic changes, especially in glutamatergic and gamma-aminobutyric acid (GABA) neurons. tDCS also alters resting membrane potential along the entire axon; this may result in a non-synaptic mechanism, which may contribute to tDCS's long-lasting effect in intracortical and corticospinal neurons. tDSC may also cause alterations in non-neuronal brain structures such as arteries and connective tissues.

2.2.4 Application of Neuropriming Device on Physical Fitness

According to one of the founders, Mr. Daniel Chao, Halo Sport increases the neuropriming of its users, hence they benefit from their training more than those who train their physical skills without the device. However, in order to enhance physical abilities, the use of Halo Sport has to be paired with training of these abilities. The main purpose of the device is to enhance physical abilities of its user through neuropriming. The device stimulates motor cortex. If it is used during a training, it is supposed to enhance motor abilities of its users, which could make the training more effective. The improvement of user's skill is based on neuropriming of the brain. It is the function of the brain, which allows learning a foreign language or a new skill. This feature was appraised by several sport organizations including the US Ski and Snowboard Association, Michael Johnson Performance, or Invictus that take a part in Halo Sport's testing (Linthorne, 2001). Halo Sport is also used by U.S. Department of Defense for improving skills of special operations forces.

The *t*DCS approach has demonstrated the utility of its application in sports. According to a review article, there is promise for using *t*DCS to improve motor abilities in sports (Sharma & Jain, 2019). Athletes nowadays employ cranial nerve stimulation to improve their coordination, attention, and even the indicators of the body's functioning state prior to sporting events. There is certainly promise for using *t*DCS to influence motor abilities linked to sporting performance, either by assisting motor or perceptual learning and/or the effectiveness of sports training (Sharma & Jain, 2019).

Sustained excellence in a variety of factors leads to successful sporting performance. Most sports involve great levels of physical fitness as well as excellent motor coordination. However, depending on the nature of the sport, a range of extra abilities may also contribute to success. *t*DCS is a non-invasive technology that affects brain excitability by applying low-amplitude direct current via electrodes put on the head. The excitability of the region of cortex directly beneath the electrode is modulated by this stimulation. The polarity of the electrode over the region being stimulated determines the direction of the generated change in excitability, with anodal stimulation being excitatory and cathodal stimulation being inhibitory.

Initial investigations with *t*DCS modified motor cortex excitability, demonstrating that the modulated cortical excitability can continue after stimulation is stopped and that this effect is controlled by both intensity and duration of delivery (Nitsche & Paulus, 2001). Neuromuscular fatigue is caused by both central and peripheral causes (Gandevia, 2001). Muscle tiredness is a type of peripheral fatigue. Central weariness may also play an important part in sports training. This is defined by the central nervous system's inability to drive muscles fully during exercise (Taylor et al., 2006), and is associated with alterations in spinal motor neurons and decreased supraspinal drive.

Previous research discovered that anodal stimulation, which increases cortical excitability, has results consistent with tiredness reduction when compared to both no stimulation and cathodal stimulation (Nitsche & Paulus, 2001). The magnitude of the effect was not insignificant, with anodal stimulation resulting in a 15% increase in endurance time. The findings were argued to be consistent with cortical function playing a role in task failure, and numerous possible explanations, such as regulation of supraspinal fatigue or modulation of feedback inhibitory systems, were presented. The precise method is definitely crucial when seeking to maximise the advantages of stimulation while limiting any potential negatives, but the key fact remains that *t*DCS stimulation may be used to manage fatigue to a great extent. While the effects are observed in minutes rather than hours after stimulation, it is easy to understand how this could be useful in training for a variety of sports where reduced weariness during training would be desirable.

*t*DCS has also been studied for its impact on motor strength. Tanaka et al. (2009) discovered that anodal *t*DCS resulted in a temporary increase in maximal leg pinch force in healthy participants, lasting approximately 30 minutes. They discovered that knee extension force could be controlled in a similar way, however the duration of the effect was shorter. However, not all of them require *t*DCS, which enhances motor strength. Cogiamanian et al. (2007) discovered no alteration of motor strength after *t*DCS. In this context, employing *t*DCS as a tool to control motor strength may have some potential utility, but further research is needed to determine the particular parameters that mediate this effect. Much of this research has focused on potential applications in stroke rehabilitation in people who have had a stroke.

*t*DCS during the learning of an explicit motor sequence resulted in polarity-specific performance modification. Anodal stimulation enhanced performance whereas cathodal stimulation slowed learning. Regardless of the polarity, delivering stimulation prior to the task resulted in poor performance. This demonstrates the apparent significance of *t*DCS stimulation timing in regulating task performance, acquisition, and consolidation. Kuo et al. (2008) discovered disruption to motor learning with anodal *t*DCS applied before task execution, similar to the findings of Stagg et al. (2011), although stimulation after training has been reported to result in augmentation (Tecchio et al., 2010). This implies that if the goal is to improve performance, stimulation prior to task presentation should be avoided.

Retention of such advantages for a sufficiently extended period of time beyond the stimulation window is also critical, and there is evidence that this occurs. Anodal *t*DCS over the motor cortex increased skill development on a challenging motor task, according to Reis et al. (2009), and skill rates remained higher for the stimulation group after 3 months. Finally, there is an emerging body of evidence that persons participating in high levels of athletic performance exhibit altered (usually enhanced) patterns of behaviour that extend beyond the domains of motor skill and exhaustion. As a result, it is plausible that these may also be sensitive to beneficial modulation by *t*DCS, but there is presently little research to assess the feasibility of such an approach or how advantageous it may be for sporting performance. There are multiple examples of increased behavioural performance with *t*DCS stimulation across a variety of cognitive and perceptual domains (e.g., Cohen et al., 2010; Santiesteban et al., 2012; Tseng et al., 2012). Tseng et al. (2012), for example, used *t*DCS to boost performance on a working memory task.

2.2.5 Application of Neuropriming in Football

There has been little research on the application of neuropriming in football. One study looked at the "Influence of Transcranial Direct Current Stimulation on Lower Limb Muscle Activation and Balance Ability in Football Players" (Yang, Park, & Uhm, 2018). The purpose of this study was to look into the effect of *t*DCS on lower limb muscle activity and balancing abilities in football players. It was done with 15 subjects in the *t*DCS group and 15 in the action observation training group for 20 minutes, 5 times a week for 8 weeks. Before the major activity, all football players completed 30 minutes of plyometric training.

Lower limb muscle activation, rectus femoris, and biceps femoris were examined using a surface electromyogram system, while bio-rescue was used to measure balancing ability, surface area, entire path length, and stability limitations. The results showed that the *t*DCS group improved more than the action observation training group in terms of total path length, limited stability, and muscle activation in the rectus femoris and biceps femoris. As a result, the authors conclude that *t*DCS intervention is more successful than action observation training in enhancing lower limb muscle activation and balance ability (Yang et al., 2018).

2.2.6 Ethical and Health Issues of Using Neuropriming Device

The application of *t*DCS has grown in popularity in sports science since the term "neurodoping" was coined (Davis, 2013). If brain activity influences exercise to some extent, then activating brain areas associated to exercise should increase physical and sporting performance. Companies like as Halo Sport claim that their "do-it-yourself" *t*DCS gadget has ergogenic benefits and can improve sport and exercise performance (Reardon, 2016).

In a recent review published at the Frontiers in Physiology, Angius et al. (2017) suggested that *t*DCS might have a positive effect on exercise capacity, although the mechanisms of that potential benefit were unknown. However, the expectations derived from those initial studies showing *t*DCS as an effective technique to increase exercise performance or reduce rate of perceived exertion (RPE), have left room for many others that do not seem to support the effectiveness of *t*DCS in the sports science.

Indeed, recent meta-analyses have called into question the notion that *t*DCS can improve exercise performance or reduce RPE, mood, or discomfort associated with exercise (Holgado et al., 2018; Lattari et al., 2018a; Machado et al., 2018). Holgado et al. (2018), for example, found that the effect of *t*DCS on exercise performance is small ($g = 0.34$) and may be increased by methodological errors and selective publication based on a study of 36 effect sizes. Similarly, the results of Machado et al. (2018) support the conclusion that *t*DCS has no effect on measures of muscle strength, although it may have a positive effect on cycling exercise. However, even this positive result seems to be entirely dependent on a single, low-quality study. Therefore, both Holgado et al. (2018) and Machado et al. (2018) reached the same conclusion: *t*DCS has little or no-effect on exercise performance. So far, only one meta-analysis (Lattari et al., 2018a) has concluded that *t*DCS may be useful to increase performance. However, upon closer inspection, these results also seem to be grossly influenced by individual studies with unusually large effect sizes ($g = 3.56$ for Cogiamanian et al., 2007 and $g = 1.94$ for Lattari et al., 2018b).'

Recent research have hypothesised that, due to the considerable inter-individual heterogeneity in participants' electric fields, the most efficient strategy to inducing specific cortical changes would be to administer a tailored current intensity for each person (Esmaeilpour et al., 2018; Laakso et al., 2019). Indeed, during rest or during activity, the normal stimulation intensity does not appear to generate oscillatory brain electrical changes (e.g., Holgado et al., 2019; Vöröslakos et al., 2018). Finally, the sham reliability of these effects. procedure may give an additional source of variability, because sham stimulation may have biological effects without the right technique (Fonteneau et al., 2019).

The available research does not support the efficacy of *t*DCS devices in sports. As a result, making claims about the ergogenic effects of *t*DCS and/or its prospective use as a novel doping method is premature. However, if researchers support strong scientific standards to address issues such as the function of stimulation intensity, stimulation site, and interindividual variability, this area of scientific inquiry could give significant insights. The most common difficulties associated with *t*DCS include headache, scalp pain, or impairment of motor or cognitive skills, although no significant differences were observed before and after using Halo-Sport.

2.3 Health-related Fitness

Health-related fitness include cardiorespiratory endurance (VO_2 max), body composition, muscular strength, muscular endurance and flexibility. Cardiorespiratory endurance (VO_2 max) involves bleep test. Muscular strength includes back and leg strength test and handgrip strength test. While muscular endurance includes 1-min sit up and 1-min push up.

2.3.1 VO_2 max

The bleep is a commonly used field tests of physical endurance, maximal running aerobic fitness test designed to estimate $\dot{V}O_2$ max. It is also known as the 20m multistage fitness test, 20-meter shuttle run test or beep test (Wood, 2008a). It is used in sports which have a high aerobic demand football, basketball, rugby and hockey.

Scores can be presented in three ways; $\dot{V}O_2$max, total distance (meters) or level achieved. Formula for predicting $\dot{V}O_2$max in children is predicted using the maximum 20m shuttle speed (km/h–1)* and age (years – rounded to the nearest integer): $\dot{V}O_2$max= 31.025 + 3.238 (speed) – 3.248 (years) + 0.1536 (speed) (years). Formula for predicting $\dot{V}O_2$max in adults is predicted using the maximum 20m shuttle speed (km/h–1)*: $\dot{V}O_2$max= –23.4 + 5.8 (speed) (Leger, Mercier, Gadoury, & Lambert, 1988).

Total distance is the most reliable method of reporting multistage fitness test performance. The simplest method is to record the total number of shuttles completed by the athlete and then multiply that number by 20 (20 = 1 x 20m shuttle: the run from cone A to cone B = 20m). If an athlete performs 30 shuttles, this number can then be multiplied by 20 to calculate their total distance (30 x 20 = 600m).

Last way is to calculate level achieved. An individual’s score is determined by two factors; level reached and number of shuttles within that level. If an athlete reaches level 17 and fails on the 8th shuttle within that level, then their score is registered as ‘Level 17, Shuttle 8’. This even applies if the individual is less than halfway to the end shuttle-line before the next beep sounds (1/3 of the 8th shuttle run completed). Reliability of the test will depend upon how strict the test is conducted and the individual's level of motivation to perform the test.

2.3.2 Body Composition

Body fat percentage and free fat mass are associated with performance in youth soccer players, with stronger relationships reported in the former metric (Esco et al., 2018). The findings highlight the need for accurate body composition measurements as part of an assessment battery in young athletes.

2.3.3 Back and Leg Strength Test

Back and leg strength test is used to measure the maximum isometric strength of the back and leg muscles. It able to track improvements of an individual's strength training and/or rehabilitation progress. An isometric muscle contraction is when force is applied to a muscle and no movement is seen at the joint. Strength dynamometers can be used to measure the maximum force applied through an isometric contraction. Strength dynamometers are usually composed of a cable tensiometer. They have been known as valid and reliable devices in order to estimate strength.

Procedure considerations may have an impact on the outcomes of the back and leg strength tests. A prior study found significant disparities in leg strength scores between similar groups. This condition shows that a violation of testing procedures happened throughout the testing process. A study was carried out on 127 healthy people. The participants' leg strength was measured using a back and leg dynamometer. The participants drew up the dynamometer's grab handle with and without using their upper leg. There were statistically significant differences between touched and non-contact pull trials. (Eyuboğlu, Aslan, Karakulak, & Şahin, 2019). It was discovered that if the dynamometer's grab-handle made touch with a participant's upper leg during the pulling phase, the strength measurement's score increased significantly (Eyuboğlu et al., 2019).

In this case, the leg strength test scores are influenced by a poor pulling technique in the back and leg dynamometers. For this reason, while performing a leg strength test with a dynamometer, researchers should be careful that the grab-handle should not come into contact with the subject's upper leg during the pulling phase.

2.3.4 Handgrip Strength Test

A hand dynamometer (JAMAR, USA) was used to measure the participant's handgrip strength (kg). This JAMAR hydraulic dynamometer is considered as the apparent gold standard to measure handgrip strength. However, the researchers need to maintain calibration standards. Dynamometer calibration should be done every 4 to 6 months to ensure longitudinal validity is maintained (Schreuders et al., 2003). Table 2.2 showed normative values for handgrip strength.

Table 2.1: Normative value for handgrip

Boys Percentile	**12 Years (n=127)**	**13 Years (n=57)**	**14 Years (n=57)**	**15 Years (n=69)**	**16 Years (n=89)**	**17 Years (n=91)**	**18 Years (n=53)**
5th	11.0	14.1	17.2	20.2	22.9	25.2	27.0
10th	13.1	15.0	18.0	21.6	25.3	28.6	31.0
20th	16.4	18.0	21.0	24.8	28.7	32.0	34.0
30th	18.3	20.0	23.4	27.6	32.0	35.7	38.0
40th	20.0	22.7	27.1	32.2	36.6	39.3	39.1
50th	21.7	25.0	30.0	35.4	40.0	42.6	42.0
60th	24.1	27.8	32.9	38.3	42.7	45.0	44.0
70th	26.0	30.1	35.3	40.6	45.0	47.4	46.9
80th	28.3	33.3	39.2	45.0	49.4	51.3	49.6
90th	32.9	38.9	45.0	50.5	54.5	56.3	55.0
95th	36.0	42.0	47.6	52.6	56.8	60.0	62.0

(Saint-Maurice, Laurson, Karsai, Kaj, & Csányi, 2015)

2.3.5 1-min Sit Up

This test assesses the endurance of the abdominal muscles. The result is analysed by comparing it to the findings of prior testing. The analysis is intended to show an improvement with sufficient training between each test. Normative statistics for the sit-ups test for 16–19-year-olds (Table 2.3). This test is appropriate for active individuals but not for those for whom the test is contraindicated.

Table 2.2: National norms for 16 to 19 years old

Gender	Excellent	Above Average	Average	Below Average	Poor
Male	>30	26-30	20-25	17-19	<17
Female	>25	21-25	15-20	9-14	<9

(Davis, Bull, Roscoe, Roscoe, & Saiz, 2000)

2.3.6 1-min Push Up

This test measures the muscular endurance of the upper body (anterior deltoid, pectoralis major, and triceps).

2.3.7 Flexibility

The sit and reach test is the most common flexibility test used to assess lower back and hamstring flexibility. Wells and Dillon (1952) were the first to describe this test, which is now widely used as a general flexibility test. There are several ways to conduct the test. However, there is a difference in the level of the feet. The most logical measurement is to start from zero and work your way up, so that any measurement that does not reach the toes is negative and any measurement that goes past the toes is positive (such as for PRT Sit and Reach for the Navy). Negative values, on the other hand, make statistical analysis and comparison more difficult. The Presidents Challenge version specifies that the box be 9 inches (23 cm) at the level of the feet, so reaching two inches past the toes is reported as 11 inches. The Eurofit manual recommends 15cm at the level of the feet, but 10 inches has also been used (NHL combine testing).

Participants with long arms and/or short legs would outperform those with short arms and/or long legs using the traditional sit and reach method, whereas those with short arms and/or long legs would be at a disadvantage. The modified sit and reach test compensate for this by adjusting the zero mark for each individual dependent on their sitting position. Flexibility tests can track the progress of participants' lower back and hamstring flexibility. Football players with low flexibility were more likely to sustain muscular injuries (Witvrouw, Danneels, Asselman, D'Have, & Cambier, 2003). This area's tightness has been connected to lumbar lordosis, forward pelvic tilt, and lower back pain. This test is appropriate for active individuals but not for those for whom the test is contraindicated.

It is critical to try many warm-ups first and record the best score. The result is analysed by comparing it to the findings of prior testing. The analysis is intended to show an improvement with sufficient training between each test. The degree of reliability would be determined by how stringent the exam is administered and the individual's level of motivation to complete the test. The normative statistics for the sit and reach test for 16- to 19-year-olds were shown in Table 2.3.

Table 2.3: Score of flexibility for male 10 to 17 years old

Age	**Score**				
	5	**4**	**3**	**2**	**1**
10	≥ 37	32 - 36	25 - 31	19 - 24	≤ 18
11	≥ 38	32 - 37	25 - 31	17 - 24	≤ 16
12	≥ 39	33 - 38	25 - 32	19 - 24	≤ 18
13	≥ 42	33 - 41	23 - 32	14 - 22	≤ 13
14	≥ 44	35 - 43	25 - 34	15 - 24	≤ 14
15	≥ 45	36 - 44	25 - 35	19 - 24	≤ 18
16	≥ 46	36 - 45	25 - 35	15 - 24	≤ 14
17	≥ 47	37 - 46	26 - 36	17 - 25	≤ 16

(Ishak, Hashim, Ahmad, & Jarwis, 2012)